

Building Consensus using a Collaborative Spatial Multi-Criteria Analysis System

by

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AUTHOR'S DECLARATION

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

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Abstract

This thesis studies the use of a collaborative spatial Multi-Criteria Analysis tool in site evaluation with multiple participants. The approach is situated within the context of three concepts of space, choice and participation, and is informed by fields as diverse as Decision-Making, Participatory Planning, Geographical Information Systems, Decision Support Systems, Voting, and Group Collaboration. A collaborative spatial Multi-Criteria Analysis software tool called MapChoice was designed for this thesis, built upon open source components and featuring easy-to-use decision support functionality in both single-user and collaborative modes. MapChoice was then evaluated in a real-world site selection situation with a case study on the location of much-needed affordable housing in the Town of Collingwood, Ontario. Based on previous discussions and workshops on the project, a workshop was held with a group of community housing advocates to compare a set of possible sites for an affordable housing project according to a set of spatial and aspatial criteria. The study indicates that a collaborative spatial MCA approach can be used in dealing with complex planning problems, and that it has the potential to contribute to improved consensus between participants.

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Chapter 1 - Introduction

1.1 Problem Statement

... the work that steers the course of society and its economic and governmental organizations is largely work of making decisions and solving problems. It is work of choosing issues that require attention, setting goals, finding or designing suitable courses of action, and evaluating and choosing among alternative actions. (Simon et al, 1987, p. 11)

It is the latter that Herbert Simon termed *decision making*, the process of evaluating and choosing alternatives. Decision making occurs frequently in planning, especially around problems relating to management of land resources or site selection. These problems are made difficult because they involve multiple objectives and stakeholders, a variety of possible approaches to finding a solution, and the potential to impact large segments of the public. For this reason, it becomes essential for multiple objectives and perspectives to be considered in spatial decision-making, and planning has recognized this need through efforts to involve many participants in the process of formulating public decisions.

In his excellent treatise on decision-making, Bryan Massam argues that planning processes aim for consensus in their actions and decisions (Massam, 1993). In the real world, however, the public's involvement in decision-making processes is less fully realized, and a diversity of conflicting objectives and interests makes consensus an elusive goal. In many instances, the choice of, and between, decision alternatives has mostly been left to planning professionals, who act on behalf of the public interest, and a minority of powerful stakeholders. Some encouraging progress has been made in the past decades towards increasing the opportunity for public input, particularly early in the consultation stages of projects. Community outreach meetings, town hall sessions, and design charrettes have all been used with success, but there are limitations to such methods:

Common practice in traditional methods of public participation involves the public, or at least those with a particular interest, in attending planning meetings that quite often take place in an atmosphere of confrontation. ... The restricted time and also

the actual location of public meetings can further restrict the possibility of widespread attendance. (Kingston et al, 2000, p. 111).

This kind of participation is not very interactive, provides few opportunities for contributing complex and detailed input, and involves little actual decision-making (Arnstein, 1969). The planners typically gather input from the public, then either make decisions alone or present recommendations to politicians, and finally display the decision to the public and get their reaction (Innes, 1998). Ideally a decision is made which satisfies as many interests as possible and falls within the constraints of the project. Furthermore, involving large numbers of the public directly in decision-making has not often been attempted due to the logistical difficulty of such an undertaking and the uncertainty regarding whether such collaboration can indeed provide for broader consensus than traditional decision-making modes.

This thesis presents a digital map-based approach that assists community members, planners and other interested persons in evaluating the suitability of different spatial features (*e.g.* sites, locations, etc.) relative to their own objectives and priorities. Moreover, it explores the potential for collaboration between stakeholders to bring about a better, more agreeable consensus decision, and it assesses whether such an approach is viable for handling the complex spatial problems encountered in planning.

1.2 Context

Geographical Information Systems (GIS) can be defined as computer-based tools for managing, analysing and visualizing spatial geographical data (Goodchild and Kemp, 1990). Traditional GIS have been adopted in many fields, such as land management, planning, and environmental engineering. While not strictly a GIS, popular tools like Google Maps have introduced a whole generation to easily available mapping and navigation.

A recent development in GIS has been the emergence of the concept of Public Participation Geographical Information Systems (PPGIS) which aim in part to provide broad public accessibility to

basic GIS mapping and data manipulation functionality. PPGIS tools and approaches have become more common in recent years as a mechanism for the greater public to learn about and be involved in planning projects. These tools may be as simple as a publicly-available mapping application or may involve some additional analysis or communication functionality. Independent citizen groups have begun to adopt GIS and PPGIS as a way of exploring and representing their perspectives on land use and other issues with significant spatial scope.

Most of the current PPGIS applications described in the literature offer little option for collaboration between users, presenting challenges to integrating the perspectives of diverse interests and stakeholders. Collaboration has the potential to greatly improve the decisions made using PPGIS, particularly when applied to planning-related issues, by allowing participants to interact and share information among each other. As shown by Lam and Shaubroeck (2000), having users perform analysis together and share their differing views on a planning problem, even briefly, provides the opportunity users' perspectives, knowledge and ideas to inform and enter into the conversation. Even if all users do not agree with the decision made by the group, consensus can be improved if participants understand (if not appreciate) the positions of the other users.

In recent years, multi-user interaction and collaboration has become an active area of research, linking elements of PPGIS, group theory, decision support and visualisation approaches (Feick and Hall, 2001; Hendriks and Vriens, 2000; Jankowski and Nyerges, 2001; Malczewski, 2006 and many others). Even so, there is only a modest understanding of how collaboration can be harnessed in PPGIS to deal with the contentious problems frequently encountered in planning, and more research is needed in the area.

A family of techniques widely used in other fields to support decision making processes is Multi-Criteria Analysis (MCA). By scoring a set of decision alternatives MCA generates as its output a ranking of the site alternatives under consideration. The relative importance of each criterion to the final result is determined by the input of the decision-making participants according to their objectives

and priorities. MCA has not experienced widespread acceptance in planning, partly due to its perceived “black box” nature, the relative lack of computer software (particularly collaborative software) geared towards the spatial decision problems encountered in planning, and practical problems of integrating the views of many stakeholders in an orderly, meaningful manner. Recent research has begun to explore the implications – theoretical and real-world – of combining the GIS tools used extensively in planning with spatial MCA to create a more planning-friendly set of tools. The idea of using linking MCA methods with GIS is not new as Carver (1991) and Jankowski (1995) demonstrate. More recently, there has been academic interest in extending GIS-MCA approaches to support collaborative or group-based forms of spatial problem solving and citizen participation (Feick and Hall, 1999; Jankowski and Nyerges, 2001). This approach will henceforth be termed *collaborative spatial MCA* in the remainder of this thesis. Recent work on the subject focuses on the ways that collaborative spatial MCA can be integrated within a planning context, but more research is needed to develop a better understanding of optimal software design, the types of planning issues where collaborative spatial MCA is most suitable, and whether it is preferable to other types of decision support in given scenarios. These issues have likely contributed to the limited acceptance of PPGIS and computer-aided decision-making by planning professionals and community groups. This study addresses these issues and the gap in existing research by evaluating a new collaborative spatial MCA with a group of participants evaluating a planning-related spatial decision problem.

A new collaborative spatial MCA tool was created for this thesis called *MapChoice*. It has been implemented within a multi-participant tool called *MapChat* that links multi-user online chat with map locations. Together these tools provide a customizable research framework for individuals and small groups to explore spatial and planning-related problems, and when integrated within a planning process, to provide input to planning or land management issues.

1.3 Case Study: Affordable Housing in Collingwood

The Town of Collingwood, Ontario has seen a dramatic growth of its tourism industry in the past decade led by the Blue Mountain ski resort (Curto, 2006; Pullen, 2005). A recent influx of wealthy retirees and vacation-home owners has led to a substantial rise in property values and rental costs and has made it difficult for many residents to find affordable housing (Statistics Canada, 2008). The situation has deteriorated to the point where a local housing assistance organisation has received close to a thousand requests for affordable housing in the area, but there are only 300 units available (Georgian Triangle Housing Resource Centre, 2008; Simcoe County Housing Corporation, 2008). With further expansion at the Blue Mountain resort and continued growth of the tourism service industry there is an increasing need for affordable housing in the region, as high housing costs continue to squeeze lower-income tourism service workers. Local planning officials and a task force of citizens are making efforts to increase the quantity of affordable housing units available in Collingwood, but to date they have made little progress due in part to community opposition. Finding locations for affordable housing is a difficult undertaking, as different stakeholder groups have divergent and often conflicting priorities. The location of affordable housing in a community both impacts and is impacted by the surrounding neighbourhood. Many of the criteria discussed when choosing sites have a spatial component which makes siting affordable housing projects an appropriate issue to test collaborative spatial MCA tools.

1.4 Research Objectives

To answer the research question, this thesis has four main objectives:

1. Develop a conceptual foundation by reviewing the literature on the key subjects, including MCA, spatial decision-making, PPGIS, decision support systems, collaboration and consensus. Corresponding linkages and relationships between these concepts will be emphasised.

2. Design and develop a software tool for collaborative spatial MCA.
3. Apply the software to explore a real-world planning problem, with a small group of participants.
4. Assess the potential of tools and approaches of this type to contribute to consensus (comparing single-user and collaborative modes), to impact participants' understanding of the decision problem, and to generate meaningful results in a planning context.

1.5 Organisation of Thesis

The thesis is structured as follows. Chapter 2 reviews the relevant literature, ranging from decision-making theory, spatial information technology and public participation to multi-criteria decision analysis. In Chapter 3, the design of the software created for the study is described. Chapter 4 introduces the issue of affordable housing in the broader Ontario context and specifically in the study site of Collingwood, Ontario. The design of a workshop undertaken in Collingwood to test the MapChoice tools is also described. Chapter 5 presents an analysis of the quantitative and qualitative results of the workshop. Finally, Chapter 6 summarises the findings of the study, discusses some caveats, recommendations for future work, and examines how the study contributes to the broader literature.

Chapter 2 - Literature Review

This chapter describes and links the many concepts and academic fields pertinent to this study.

Section 2.1 provides a broad overview of how the key concepts of space, participation and choice relate with respect to collaborative spatial MCA. Section 2.2 outlines decision-making theory in general and indicates how this theoretical base informs public participation in planning. The field of geographical information systems (GIS) is introduced briefly in Section 2.3, particularly as it applies to planning decision-making. The concept of Public Participation GIS, which combines participatory planning and GIS, is covered in Section 2.4. Section 2.5 introduces Multi-Criteria Analysis (MCA) as a specific approach for supporting decision processes. Decision support systems, the computer-based tools for aiding decision-makers, are outlined in Section 2.6. The use of voting and collaboration to achieve consensus are discussed in Section 2.7. The chapter concludes by discussing how the various fields introduced earlier can inform a computer-based approach to participatory planning, using a combination of GIS and MCA.

2.1 Key Concepts

This thesis draws upon a number of fields with long and rich academic histories, many of which developed independently but now overlap to produce sub-fields of research. Although there is partial sharing of ideas across the fields, some tend to have unique (and occasionally confusing) terminologies for common concepts or technologies. To structure this chapter, this section will clarify the position of the study at the intersection of three main concepts: *space*, *participation*, and *choice* (Figure 2.1). The concepts are described briefly below.

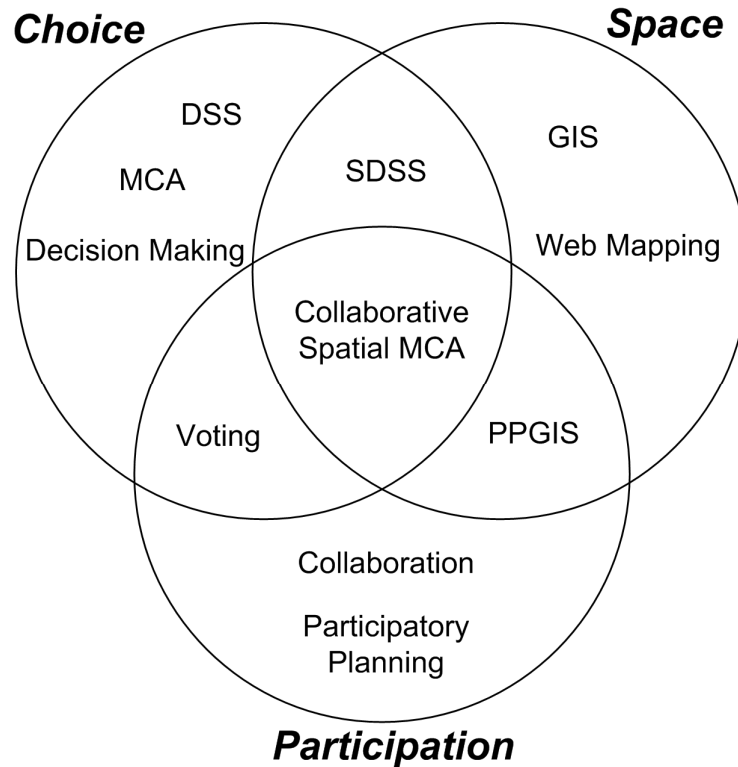


Figure 2.1 – Key concepts in the thesis

Space is the fundamental language of geography and informs much of planning as well. Geographical information systems (GIS) are tools for analysing spatial data and relationships. The recent surge in popularity of Web mapping tools like Google Maps and Mapquest among the wider public illustrate the increased recognition of the importance of location.

Participation is a theme that is centred on the involvement of people in decision processes that affect their lives or phenomena they value. Participation has been prominent in planning practice and theory as well as in the studies of politics and governance for some decades. Collaboration is a somewhat related idea that focuses not only on involving people but also having them interact and communicate with each other.

Finally, choice relates to the concept of decision making and specifically the task of choosing between alternatives (planning scenarios, business models, sites, etc.). Multi-Criteria Analysis (MCA) is just

one of many approaches to making choices using numeric information. Decision Support Systems are computer aids for problem structuring and decision making involving numeric and other kinds of data.

Some of the topics more closely aligned with this study fit within the overlap between these three main concepts. Public-Participation GIS (PPGIS) combines the spatial aspect of GIS with the open, non-elite and public-centric ideas of participation. Similarly, Spatial Decision Support Systems (SDSS) combine the analytical capabilities and decision structuring of DSS with the spatial component of GIS. Voting combines choice with participation of multiple people.

This study makes use of two pieces of software, MapChat and MapChoice, both of which are described in Chapter 3. MapChat combines a Web map environment with multi-user discussion and interaction. MapChoice builds upon MapChat by adding collaborative decision-making and analysis capabilities using an MCA technique. This thesis, and MapChoice in particular, sits at the intersection of the three concepts of space, choice and participation and builds upon ideas developed in the fields mentioned above. The next section explores the field of decision-making theory.

2.2 Decision-Making Theory

2.2.1 Classical Decision-Making

In his classical examination of decision-making, Simon (1960) postulated that many decisions are reached in a predictable, repeatable manner, regardless of the context or individuals involved. Since the publication of Simon's theory, a great deal of research has gone into understanding and formalising the process of decision-making, and especially in ways to improve or facilitate it.

A decision must be reached whenever there are multiple courses of action, choices or alternatives that are available to a decision-maker. Normally an individual is interested in what *outcomes* the alternatives entail, and how to ascertain knowledge of their properties or *criteria* for the decision.

Sometimes a decision can be made with reference to a single criterion (*e.g.* cost). In other situations,

decision making may require *multiple criteria* that may have varying degrees of importance to be considered when choosing the best alternative.

A decision-making process can be distilled into some fundamentally distinct stages (Arrow, 1957; Hwang and Yoon, 1981; Hwang and Lin, 1987; Simon, 1960), shown in Figure 2.2. Before any decision can be made, the decision maker(s) must gather information related to the decision in the *intelligence* stage. This can include background research on the decision problem, data on the alternatives, information on what criteria are most important to the decision, and whatever other information is necessary to the development of a sound decision. A thoroughly-researched decision is ultimately more defensible and thorough.

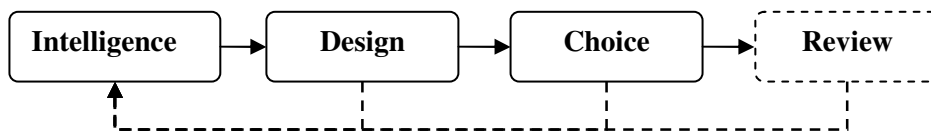


Figure 2.2 - The stages of decision-making

This information is then used in the *design* stage to set the groundwork for the decision establishing a structure for comparing a set of criteria and choosing between alternatives. This can be done on an *ad hoc* basis, or as is common in modern governmental or planning decisions, the structure can be explicitly and formally laid out.

Finally, the decision-maker(s) uses the previously-designed structure to come to a *choice* of the best course of action, that is, the best decision alternative. If the MCA decision-making approach is used (explained further in Section 2.5), the choice is achieved by assigning weights to criteria, and combining criteria values to a decision via a decision rule.

A fourth stage is *review* of the results and any or all preceding stages of the process. At all stages, and especially after a decision has been reached, it is possible to incorporate lessons learned during the

process to revisit the decision, including new information and insights in a fresh iteration of the stages of decision making. Note that it is often useful to iterate through this process several times prior to actually implementing the choice in order to gain a better understanding of the decision problem.

There is evidence that the human mind itself may be hard-wired to subconsciously structure external stimuli instinctively into a rudimentary decision-making approach, in a natural and intuitive way (Miller, 1956; Saaty, 1980). However, formal and comprehensive decision making processes as shown in Figure 2.2 are unlikely to be the norm in day-to-day decision making. Instead of pursuing the best or optimal choices, information resources or decision making procedures, people typically settle for options that are considered “good enough” for our needs. Simon (1957) referred to this behaviour as *satisficing*. For example, when purchasing a car, few buyers undertake a formalized decision process, drawing a spreadsheet of all available models and every possible criterion. Instead, most have an idea of the important criteria to them (number of doors, price, size), guesses on other criteria (*e.g.* reputation) and make a “good enough” evaluation.

Public decision issues that are encountered in land use planning and management are substantially more complex than those addressed in daily life. Decision-makers must choose between alternatives impacting potentially thousands of citizens and involving millions of dollars. In planning, decisions are carefully researched and justified in reports, analyses and assessments. Typically, many non-complementary objectives and interests need to be considered, which in turn complicates the process of delimiting the study and finding an appropriate decision framework. Many stakeholders may have an interest in the decision, and their views may change as the process wears on. Due to these factors, public decision making processes often undergo iterations of the stages of intelligence, design, and choice, as the boundaries and relationships of the decision problem become clarified and participants learn about the decision problem over time. With decisions of this kind, it becomes especially critical for citizens to be able to voice concerns and participate throughout the decision process.

2.2.2 Public participation in decision-making

In the past, planners enjoyed a privileged position as decision-makers on acting for the “greater good” of society as epitomized by the city plans of the 19th century that boldly tore down and reconstructed portions of major cities like Paris and Washington, D.C. This technocratic model of top-down, regulatory planning changed in the 1960s when well-publicised failures of planning such as “Urban Renewal” projects in large American centres contributed to public dissatisfaction with both the process of planning and its outcomes (Hall, 2002; Jacobs, 1961). The movement toward *participatory planning* became widespread as citizens demanded to have a say in planning decisions that would impact their communities (Arnstein, 1969). Public participation in planning gained traction in the late 1960s as a dialogue between city planners and concerned citizens (particularly minorities and disadvantaged groups). It infused government planning objectives with the local knowledge and concerns of the affected public, while empowering the people and increasing their trust in and respect for the decisions made (Davidoff, 1965; Innes, 1998).

The decades since participatory planning was introduced have seen large strides taken in involving the public in planning. Modern planning practice has embraced methods for public input, such as town hall meetings, design charrettes, and public consultations, and some see this as the public regaining its role in planning (Wondolleck et al, 1996). Many planning decisions, and ultimate approval of short-term and strategic plans, are handled by elected representatives who are ultimately responsible to voters. Public participation is mandated by law in the Ontario Planning Act and similar legislation exists throughout the world (Illsley, 2003). Virtually all local governments hold public hearings on issues of land use change and the right to object to decisions through legal means is becoming more available (Adams, 2004; Pløger, 2001) . While public confidence in planning decisions has gradually improved through increased public participation, some argue that public input is participatory in name only (Jackson, 2001). Arnstein (1969) used the concept of a “ladder of citizen participation” to rank public involvement against how much power is afforded to citizens (Figure 2.3). The lowest rung on

Arnstein's ladder represents a total lack of participation, where decision-makers impose their will on the public. In contrast, the topmost rung represents full citizen control over decisions. Typical planning participation, as discussed earlier, rates somewhere between the two extremes as "tokenism." Consultation through the form of public meetings, she argues, grants citizens a chance to be heard while conferring legitimacy to the decisions made by those in power.

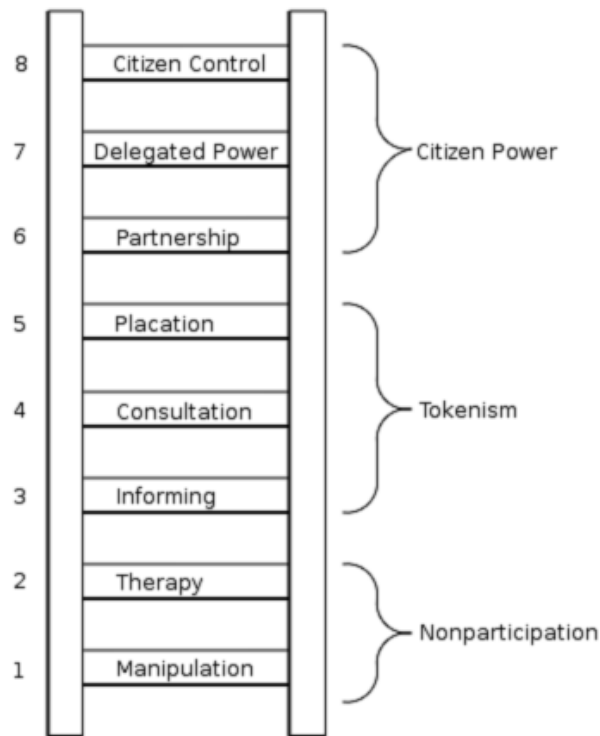


Figure 2.3 – The “Ladder of Citizen Participation” (adapted from Arnstein, 1969).

Rowe and Frewer (2005) note that communication and information often flows in a unidirectional manner from government officials to citizens, as in the typology of Figure 2.4. Planners take input from the public through consultation, and separately send prepared and packaged information back to the public, but these are not truly bi-directional, participatory communication modes. Uni-directional input in the forms of public meetings, town halls, surveys, and question-and-answer sessions can leave the public feeling left out of decision-making when their concerns are aired but clearly not valued (Jackson, 2001). Moreover, often the public is consulted only at the intelligence-gathering stage of a decision-making process, while planners act as proxies for the public interest during the design and

decision-making stages (Adams, 2004; Halseth and Booth, 2003). Also, while there is a legitimate role for public education on planning issues, this can be construed as the government trying to “show and tell” its position after the important decision-making has already been completed (Illsley, 2003, p. 270).

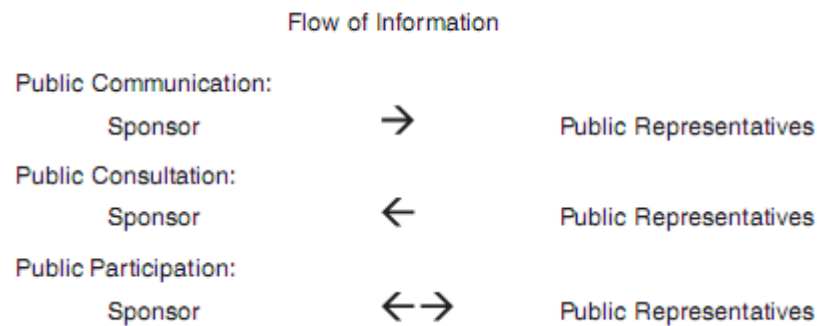


Figure 2.4 – Degrees of public communication (adapted from Rowe and Frewer, 2005).

Part of the reason why public participation appears to have stalled in planning is the reluctance of planners, politicians and other decision-makers to relinquish control over the decisions they make. A positive outlook sees this as a consequence of the pressures of policymaking that results not out of antipathy towards stakeholders, but in a desire to make decisions free of outside interference (Connelly, 2006). The public may not have the expertise or the information required to consider a public decision issue adequately (Hurley and Walker, 2004). Bedford et al (2002) note that planners have long complained of staunchly anti-development activists scuttling even responsibly designed and well-intentioned proposals. It continues to be challenging to improve participation rates as only those stakeholders personally affected by issues tend to show up to meetings, which in turn leads planners to question whether their concerns are representative of the community as a whole (Halseth and Booth, 2003; Pennington, 2000).

Another interpretation of the inequalities inherent to the planning process harkens back to Arnstein’s complaints from the 1960s where the presence of the public does not overcome inequalities in

entrenched institutional power structures (Connelly, 2006; McCann, 2001). Calls for increased public participation are seen as futile owing to the structural inequalities still present:

... responses of active publics interviewed in this study reveal that they are all too aware of the power of economics and institutionalised politics on the outcomes of public participation, and with this understanding comes a scepticism about what 'more' and 'novel' participation practice can achieve. (Bedford et al, 2002)

A pessimistic view sees participation as a cover for institutional control over decisions, and institutional planning practice as no more than a "spatial arm of state policies" (Pløger, 2001)

Aside from philosophical doubts over participation, there are practical and technical obstacles as well. Existing practices and frameworks in planning decision-making are not naturally suited to intensive public participation. Planning has been slow to adopt computer-based approaches and decision-making aids, let alone integrating innovative computer solutions for public participation into planning workflows (Alshuwaikhat and Nkwenti, 2002; Fadeeva, 2005; Geertman and Stillwell, 2004). Public participation can also be difficult and add costs and delays to projects. Meetings require organisation and attendance, focus groups must have qualified moderators and an appropriate venue, and surveys and questionnaires are expensive (Irvin and Stansbury, 2004). Allowing the public too much control also can be counterproductive by igniting long-dormant debates (particularly with contentious projects), simplifying complex problems to political sound-bite levels of discourse, and favouring well-organised and powerful "public" interest groups. These problems can lead to additional impediments such as stalling of important projects and other delays (Bishop and Davis, 2002).

While there are clear challenges to implementing public participation in planning, the benefits of participation are still considerable and planning literature appears to overwhelmingly support public participation. Research suggests public participation in decision-making generally promotes conflict resolution, improves legitimacy of decisions, and leads to better decisions across many metrics such as cost effectiveness, citizen satisfaction and trust in government responsiveness. (Arnstein, 1969;

Beierle, 2002; Bishop and Davis, 2002; Gregory et al, 2001; Halvorsen, 2003; Healy, 1998; Innes, 1998; Irvin and Stansbury, 2004; Susskind et al, 2003) Public participation has served to open up government to citizen influence, and is a powerful tool in promoting transparency, community cooperation, building social capital, and even at encouraging public involvement in the implementation of decisions (Brody et al, 2006; Gunton et al, 2006; Rydin and Holman, 2004).

Recently, there has been an increased push in planning towards more inclusive forms of participation (Fadeeva, 2005). Under this model, stakeholders are involved in the decision-making process throughout the duration of the project. This collaborative model has been tried sparingly throughout the world. In Canada, the province of British Columbia has used collaborative planning in defining environmental land use plans with mixed results (Gunton et al, 2006). Positive outcomes of collaborative planning include improved understanding of decision problems, building stronger relationships between participants, and participants preferring it over other planning methods. Challenges still remain in successfully overcoming disagreements between stakeholders, which indicates that more research is needed to produce best practice guidelines for collaborative planning.

Public interest in planning issues is often linked to specific locations, regions or neighbourhoods and the potential impacts of spillover effects from one locale to another. Moving from participation to the concept of space, the next section introduces Geographical Information Systems (GIS) as a widespread technological solution to the analysis and manipulation of spatial information in planning.

2.3 Geographical Information Systems

The kinds of decisions encountered in planning often require the consideration of many criteria that can have different effects from one place to another. Making well-informed planning decisions entails synthesizing a large amount of information, much of which is managed these days in computer systems. Geographical Information Systems (GIS) have emerged as a core technology to manage, analyse and visualize large volumes of geographically referenced data.

GIS began in the late 1960s as a related development of the earliest computer database research. An impressive variety of systems have been called GIS through the years, from systems for land inventory management (Tomlinson, 1988) and spatial data analysis (Chrisman, 1988) to workstation-based mapping and applications of the 1990s and today's lightweight Web mapping tools such as Google Maps. Today the term also incorporates the human organisational structures that have evolved to support and exploit the technology, such as data collection, information standards, and best practices guidelines.

GIS are used extensively in many fields, ranging from environmental management and forestry (Kangas et al, 2000), cultural and social analysis (Robbins, 2003), ecosystem ecology research (L. B. Johnson and Gage, 1997), botany (Lehmann and Lachavanne, 1997), military, health studies (Rinner and Taranu, 2006), agriculture, transportation, and planning and decision-making (Parent and Church, 1989).

More background on GIS can be found in any number of textbooks (Burrough, 2001; Lo and Yeung, 2002). A few basic concepts of GIS are illustrated below as they provide the basis of the system developed for this study.

GIS represent spatial phenomena using a few major conceptual models. In the vector model, features are represented as discrete points, lines, polygons, or curves. Common examples of vector features are cities, road and railways, and water features. These features can have various associated non-spatial attributes, such as area, names, cost, or population. The raster model, most recognizably used in aerial photography and satellite imaging, subdivides space into a grid of equally-sized cells, each having an approximately continuous (within the limits of the technology) data value. In a computer, spatial data can be stored in individual files (such as the ubiquitous vector .shp "shapefile", or raster images like the common .jpeg or .tiff format), or in powerful databases like the common "geodatabase" and the computer industry standard relational database.

Many GIS systems handle both kinds of data, displaying them through charts, graphs, and other visualization aids. The most common display paradigm is the map, where multiple feature layers (vector and raster) can be overlaid upon one another, alongside other reference aids like a scale and legend. Moreover, since vector data can have many associated attributes, it is possible to simultaneously display multiple map layers, each corresponding to a single attribute, from a single feature set (such as property parcels).

Figure 2.5 shows the basic concepts of GIS, including the data management functionality, the physical and logical separation of data into layers and the combination of data to produce maps.

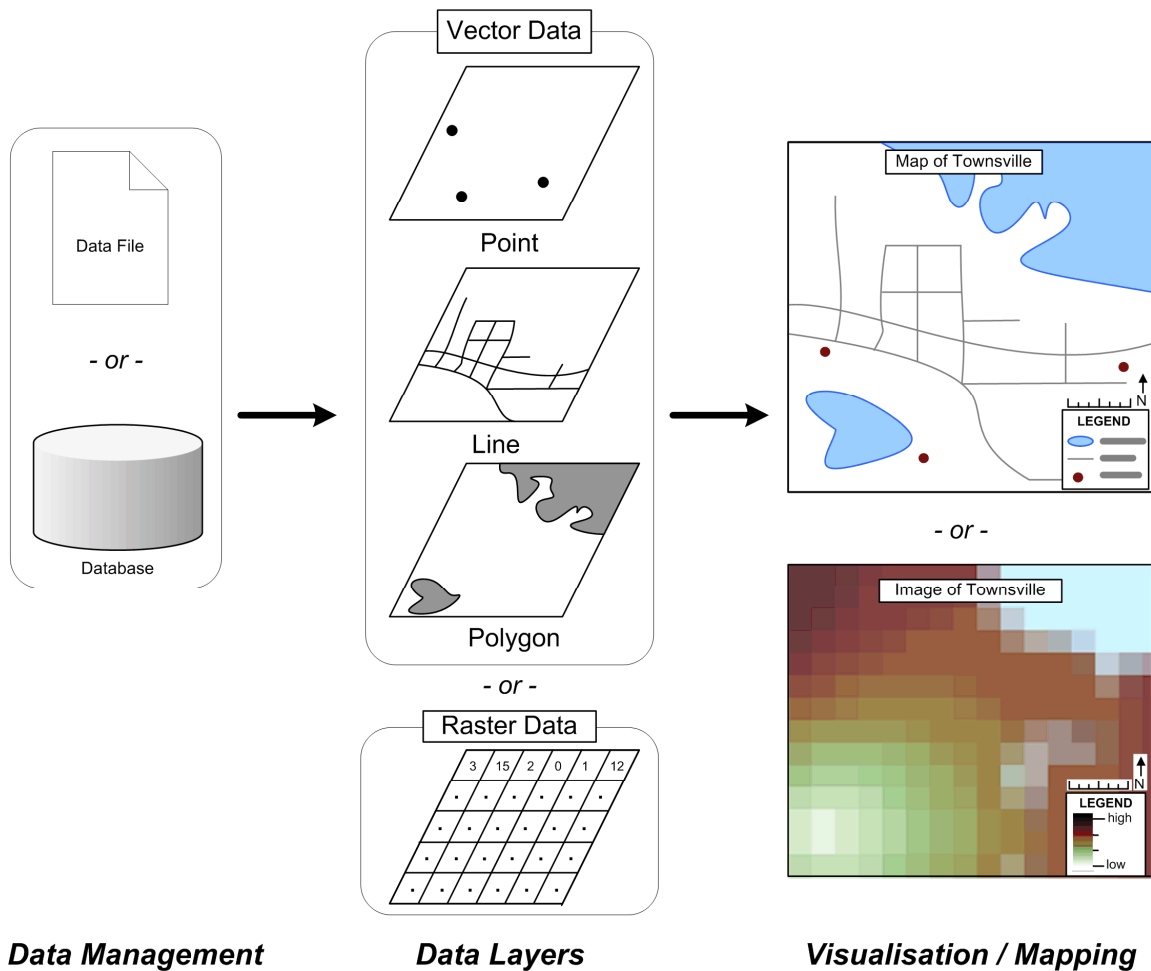


Figure 2.5 – Vector and raster data models

2.3.1 GIS Use in Land Planning

Location figures prominently in planning as evidenced by neighbourhood-specific plans, zones of intensification and protection, and even the traditional practice of circulating a notice of zoning by-law changes property owners within a certain radius. One of the most fundamental laws of geography is that land uses impact nearby households, businesses, and the broader well-being of a community (Tobler, 1970). Since GIS are ideal for handling spatial data, they have been used widely in planning and other land management fields where it is useful to integrate, analyse and visualize disparate data sets within a common spatial framework. For many non-experts, conceptualising planning problems through the cartographical perspective of GIS has proven to aid and enhance understanding of spatial issues, especially compared to traditional aspatial modes of discourse (Al-Kodmany, 2002).

The emergence of GIS use in planning was widely recognized even in the early 1990s (Harris and Elmes, 1993; Innes and Simpson, 1993). Over the past 15 years, improvements to GIS user interfaces and the development of planning-specific modeling, analysis and visualization functions have been fundamental to the widespread adoption of GIS in planning (Klosterman, 1997; Vonk et al, 2005). Today, many cities have reorganised their entire data resources, and indeed entire departments, around a GIS database framework. A ground-breaking example is Baltimore's innovative CitiStat program, which allows local decision-makers to use GIS in council meetings and to monitor various city indicators. Through the system citizens also have access to important local spatial information that permits them to submit requests online and view updated maps on everything from ongoing road repairs to recent crime incidents, and this accessibility is available from any Internet-connected location (City of Baltimore, 2008).

Another broad area of innovation in GIS has focused on the intersection of community participation and GIS as discussed in the following section, linking together the concepts of space and participation.

2.4 Participatory Planning and PPGIS

The widespread, almost unquestioned adoption of GIS was not without its criticisms, as debate over GIS as elitist and exclusionary technology raged in the 1990s (Monmonier, 1996; Pickles, 1995).

While the debate was effectively rendered moot by the universal acceptance of GIS (Carver, 2001), some of the points raised by the dissenters remain salient today.

Though early advocates argued for the evolution of GIS to a participatory, inclusionary technology, this aspect is still somewhat lacking in modern GIS. Few GIS provide frameworks to represent multiple perspectives although some specialized planning tools like CommunityViz do add scenario management capabilities to the generic workstation GIS platform (Placeways, 2008). However, collaborative GIS tools are not yet used on a routine basis by many planners because of limited experience or training, and a lack of awareness of the capabilities of such tools within the discipline (Vonk et al, 2005). It has been argued that even GIS, although in widespread use, have not been used up to their potential (Geertman, 2002; Nedovic-Budic, 1998).

Another roadblock to widespread use of GIS is the cost and difficulty of accessing data. Despite recent improvements, restrictive and often costly licensing agreements can limit access by small community groups to the local spatial data resources needed for GIS analysis (Sawicki and Craig, 1996; Sheppard et al, 1999). A public group with access to GIS may still find it impossible to do any meaningful analysis without high-quality local data.

A promising answer to the problems of traditional GIS has been the somewhat loosely-defined idea of Public Participation GIS, also called Participatory GIS or Collaborative GIS (Carver, 2001; Dragicevic and Balram, 2004; Sheppard et al, 1999). The PPGIS field focuses on more democratic forms and use of GIS technology that satisfy many of the criticisms of elitism that had been leveled against traditional GIS. PPGIS has the potential to facilitate more widespread access to information technology across interest groups and can also provide a way for planners to interact with and involve

the public in decision-making. A gradient of interactivity exists for PPGIS, ranging from merely viewing planning decisions spatially, to communicating with planners and other stakeholders, designing scenarios and performing spatial or multi-criteria analysis.

One way to classify PPGIS applications is to examine the degree of interactivity between the users and the system (

Figure 2.6). Single-user systems, like traditional GIS software, consist of one program running on a single workstation. Several people can congregate around it, but all participation is handled outside the tool. These systems can benefit the public simply by allowing people the ability to perform the same kind of analysis as planners would have access to, and possibly even work with the same kind of data, notwithstanding issues regarding the difficulty of acquiring useable data (Sawicki and Craig, 1996).

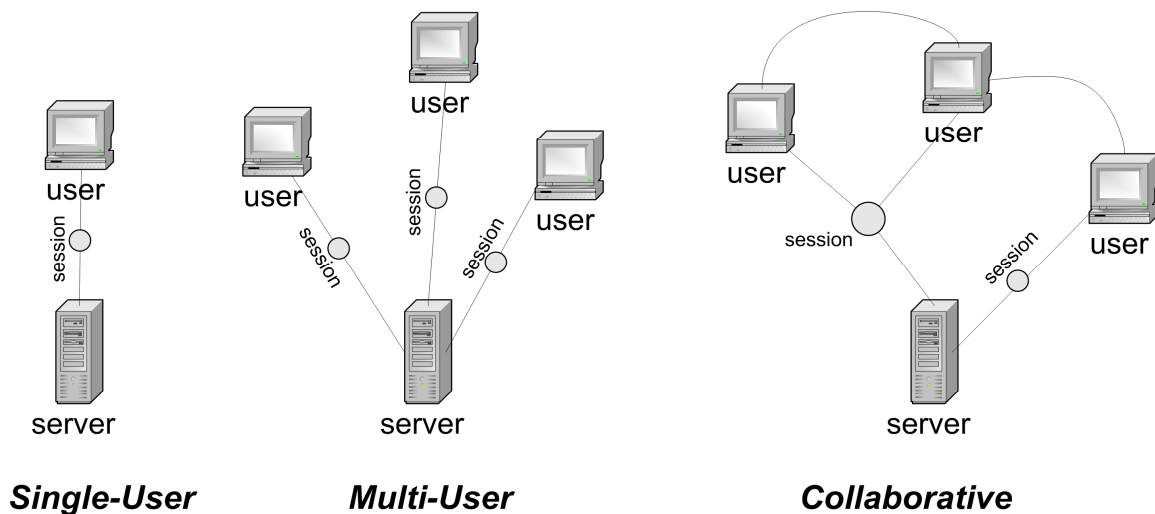


Figure 2.6 – Taxonomy of system interactivity

Multi-user tools are Web-based or arranged in a network that allow a number of participants to access the same data and functionality from one or more central servers. This is what is commonly called Internet GIS (Peng, 2001) or Web GIS. The greatly increased accessibility offered by these systems can lead to lower costs for interacting with the public (Carver, 2001; Zahir and Dobing, 2002).

Collaborative tools like PPGIS extend the multi-user model to allow participants to also communicate with each other and work together on collective tasks using physically separate workstations. Most research into such systems has been with relatively small user bases of 5-15 people, paralleling similar small group dynamics research (Jankowski and Nyerges, 2001). Large scale multi-user public planning is possible but this is on the edge of research. WikiMapia, while not planning-related, is an example of an Internet PPGIS project with hundreds of thousands of users (Wikimapia, 2008).

An idea from the education literature that is useful here is Coldeway’s typology of distance learning modes (referenced in Simonson, 2000), which can be extended to collaboration modes as well (Figure 2.7). Most workstation GIS are in the first quadrant, same place and same time, and can also be used over time (quadrant 3 - same place, different time). Internet-accessible GIS, and even those on a network, add the dimension of “different place” to user interaction (quadrants 3 and 4).

Same Time	Different Time
Same Place (1)	Same Place (2)
(3)	(4)
Same Time	Different Time
Different Place	Different Place

Figure 2.7 – A typology of user interaction modes, originally developed by D. Coldeway (from Simonson, 2000)

Collaboration adds considerable complexity to GIS software, particularly with issues of timing and interaction. It is relatively easy for users to collaborate through the Internet if they are using a common system at the same time (quadrant 3). It is also simple to leave multi-user Web-based applications open for later use (quadrant 4), so that long after a workshop is finished participants can log in, view the results, and even interact with the system to create new analyses (Mustajoki et al, 2007). However, introducing between-user collaboration to long-term asynchronous tasks (quadrant 4) is relatively unexplored, and is more intricate to implement (Zahir and Dobing, 2002).

The previous section discussed the use of space, collaboration and participation in PPGIS. In the next section, the concept of choice is examined through a discussion of MCA, a family of mathematical methods for comparing decision objectives.

2.5 Multi-Criteria Analysis

Multi-Criteria Analysis (MCA), also called Multi-Criteria Decision Making, Multi-Attribute Decision Analysis and other combinations of similar terms, refers to an approach of structuring and evaluating complex decision-making tasks. MCA has been formally discussed in the literature since before the 20th century, and the roots of modern MCA begin with the concentration on operations research and optimisation during the Second World War, followed by rigorous studies of management science in the ensuing decades (Mousseau, 2008). More recently there has been new interest in combining MCA and GIS to answer spatial questions such as facility siting, risk assessment, and exploratory data analysis (Massam, 1993; Pereira and Duckstein, 1993; Voogd, 1983). Malczewski (2006) found over 300 research papers combining MCA and GIS in the period from 1990 to 2004. It should be noted that although decision-making literature uses a variety of terms for the basic elements of MCA, this thesis uses the terminology laid out by Eastman et al (1998).

An emphasis on *human* understanding and preferences sets MCA apart from more mathematically-oriented decision-making approaches such as optimisation models (Voogd, 1983). The basic approach of MCA is to compare alternatives using various attributes or criteria, and then to assign a *priority* or *weight* to each criterion that represents a user's assessment of its relative importance to the problem at hand. These weights will vary based on the experiences, perspectives, and goals of the decision-maker(s). The end result of an MCA process is an ordered *ranking* of alternatives, calculated using some combination of the criteria priorities and data values associated with each of the alternatives.

MCA follows the *intelligence*, *design* and *choice* stages of decision-making described earlier in Section 2.2. First the relevant literature and background information on the decision problem is studied in the intelligence stage. Then in the design stage the decision-makers identify candidate *alternatives* to be compared, determine the *objectives* they are aiming to achieve for the decision problem, and find relevant *criteria* to measure the alternatives on achieving the chosen objectives. This stage is where the decision is structured under the MCA framework. Finally, in the *choice* stage, the decision-makers weight each criterion according to their preferences and a *decision rule* is used to combine the weights and the data values and determine a ranking of the alternatives. The decision process can be repeated through several iterations of intelligence-design-choice, a process made easier by computer-based MCA tools that give instantaneous feedback and where the decision framework can be modified on-the-fly (Rinner and Taranu, 2006).

Figure 2.8 illustrates the fundamental flow of an MCA decision process. In this diagram the process commences with five spatial alternatives, which have their associated criteria (the raw values r). In a typical GIS the matrix of criteria and alternatives would be stored in a single data table, and it is this same table of five alternatives and Criteria A to C that is used as a basis for MCA.

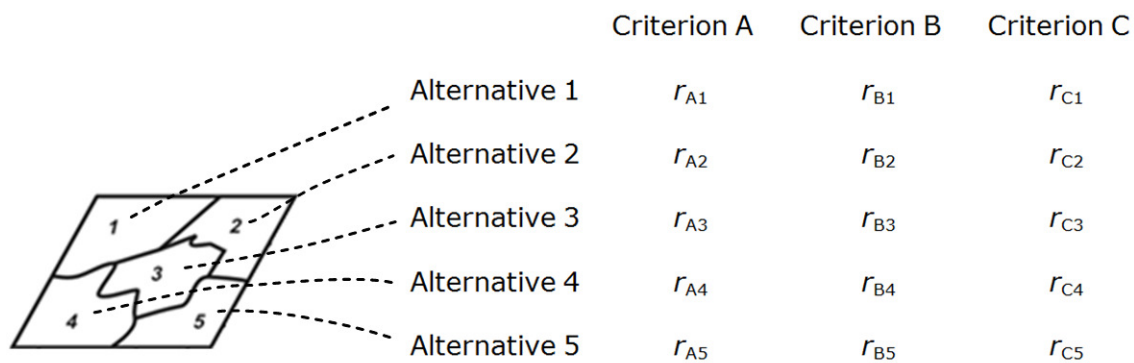


Figure 2.8 – Relation between spatial features and MCA alternatives and criteria

The table of values requires some processing before it can be useful for MCA. Often criteria data values are measured in different units (*e.g.* hectares, dollars, etc.). To permit tradeoffs between criteria, their original data values are standardised to a common scale that typically ranges from 0 to 1.

The standardisation function is shown in Equation 2.1, giving the standardised values x (this example uses Alternative 1 and criteria A to C):

$$\begin{pmatrix} x_{A1} \\ x_{B1} \\ x_{C1} \end{pmatrix} = \textit{standardisation} \begin{pmatrix} r_{A1} \\ r_{B1} \\ r_{C1} \end{pmatrix} \quad (2.1)$$

The decision makers then enter their preference weights (w) for each criterion and any other preference settings (p) that the chosen decision rule requires. Based on the preferences entered, the decision rule generates a single score value for that alternative. For example,

$$\textit{score}_1 = \textit{decision rule} \left(\begin{pmatrix} x_{A1} \\ x_{B1} \\ x_{C1} \end{pmatrix}, \begin{pmatrix} w_A \\ w_B \\ w_C \end{pmatrix}, p \right) \quad (2.2)$$

Decision rules and preference weights are discussed further in Sections 2.5.5 and 2.5.4. Finally, the calculated scores then determine a ranking of the decision alternatives, as shown in Table 2.1:

	Criterion A	Criterion B	Criterion C	Score	Rank
Alternative 1	r_{A1}	r_{B1}	r_{C1}	\textit{score}_1	\textit{rank}_1
Alternative 2	r_{A2}	r_{B2}	r_{C2}	\textit{score}_2	\textit{rank}_2
Alternative 3	r_{A3}	r_{B3}	r_{C3}	\textit{score}_3	\textit{rank}_3
Alternative 4	r_{A4}	r_{B4}	r_{C4}	\textit{score}_4	\textit{rank}_4
Alternative 5	r_{A5}	r_{B5}	r_{C5}	\textit{score}_5	\textit{rank}_5

Table 2.1– Calculated scores and ranks after MCA is performed

Aside from its role as a tool to aid decision-making, MCA has an intrinsic value that may go unrecognized until the end of the decision-making process. Gathering data, investigating the alternatives, specifying criteria that are relevant to higher-level objectives and iterating through this process can help participants understand the problem and the implications of choosing different weights, criteria or alternatives more completely (Zeleny, 1982).

The next subsection discusses in detail the framework used for MCA decision-making.

2.5.1 MCA Decision Problem Structuring

Two of the first steps in an MCA analysis are to articulate the objectives of the decision issue and identify criteria that can measure how well different alternatives meet these objectives. This stage alone is a powerful cognitive aid, as “when examining real life decision making, one frequently finds that a rough structure of options and objectives is sufficient to solve a problem without further numerical analysis” (Islei and Lockett, 1991, p. 69). For the more sophisticated problems in the MCA literature, this usually involves the creation of an objective hierarchy that begins with the high-level *objectives* and is progressively decomposed into sub-objectives, and finally *criteria* on the bottom (Figure 2.9). The idea is to decompose a complex problem into its constituent components, ending with the criteria being directly measurable properties of the decision alternatives (Saaty 1980, Zeleny 1982, Keeney and Raiffa 1976). There are disagreements between researchers over what distinguishes an objective from a criterion. Performance indices and proxy variables, for example, can be considered criteria since they directly measure an alternative, and objectives if they can be further broken down into constituent criteria. Generating a meaningful objective hierarchy is not trivial and for the purposes of expediency and simplicity a flat list of criteria was used for the case study discussed later in the thesis. In these situations, objectives are still considered in this process, but they are not explicitly entered into the hierarchy.

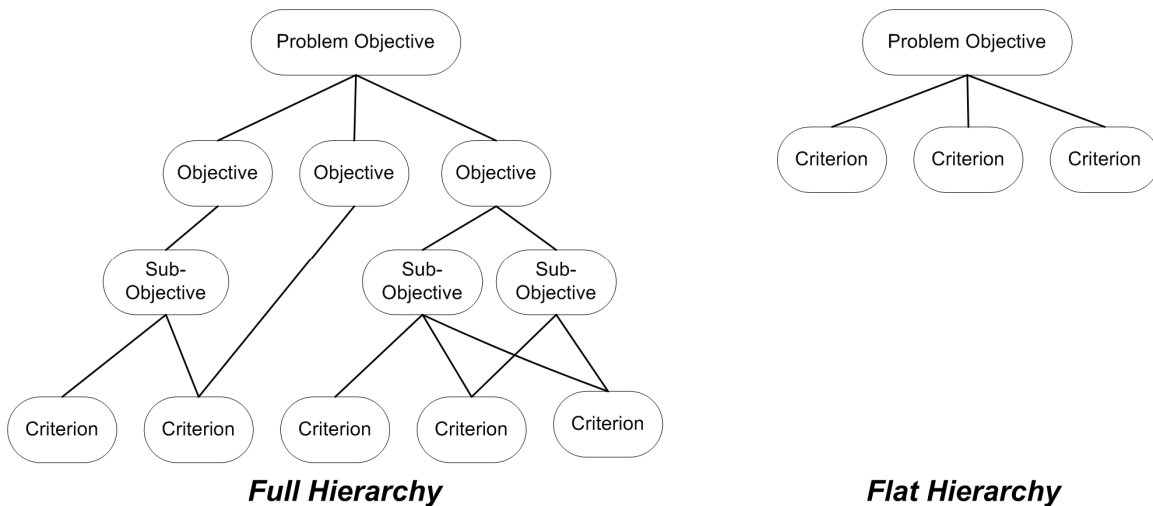


Figure 2.9 – Objective hierarchies

Care must also be exercised in the choice of criteria. For example, some criteria may not be able to be assessed due to incomplete, poor quality or unavailable data. In such cases, the decision-maker(s) must either use proxy variables that capture at least some aspects of an objective in a less direct manner or exclude these criteria from the analysis. There are many other factors to consider when selecting criteria. Keeney and Raiffa (1976) and Malczewski (2000) provide guidelines to criterion selection, in that the final set of criteria should be:

- *Comprehensive* – each criterion fully describes its related objective;
- *Complete* – the criteria encompass all the important aspects of the decision problem;
- *Operational* – the criteria can be used in the analysis;
- *Nonredundant* – criteria are independent, correlated as little as possible; and
- *Minimal* – the smallest set possible is used.

Unfortunately, fulfilling these guidelines in the context of spatial decision-making can be difficult, particularly in terms of criterion independence. It is difficult to choose a complete set of criteria that are not inter-correlated, especially if those criteria have a spatial component. Making a reasonable effort to satisfy as many of these requirements as possible may be the best possible course of action.

2.5.2 Choosing Alternatives

In MCA terminology, an alternative is any feasible solution to the decision-making problem. In the planning context, an alternative can be a proposed course of action or a spatial location (such as a site, neighbourhood, lot or district). Alternatives are typically generated externally to the MCA process by screening the entire set of possible alternatives using *constraints* that eliminate unworkable alternatives. This can be done by simply comparing alternative criterion values, or through spatial analysis in GIS using methods like spatial overlay or buffering. To trim the set of alternatives further, those alternatives that perform poorly across all criteria relative to other alternatives, called the

dominated alternatives, can be removed. This eliminates the criteria that would not be able to achieve a superior ranking under any possible combination of weighting parameters.

2.5.3 Standardisation and Criterion Utility

When working with real-world data sources, criteria are rarely *commensurate*, or directly comparable with each other. Criteria may have different measurement units (such as distance, particulate concentration, zoning categories, or monetary value), or else they may differ by orders of magnitude. To compare criteria in MCA directly, the raw data values must be transformed to comparable, unitless *standardised* numbers in the range of [0,1]. Standardisation is similar to the concept of monetary utility used in economics, where all aspects of a decision problem are translated to their monetary value and optimisation is performed on the single variable of “cost.”

There are a few standardisation methods used in MCA. The traditional method, from classical economics, is by determining a criterion’s *utility function* (also called a *value function*), which is a linear function relating a criterion’s data value to an abstract standardised score (Keeney and Raiffa, 1976).

Generating arbitrary utility functions is challenging, so a special case of the utility function called *score range transformation* (SRT) is commonly used in MCA. In SRT, the value function varies linearly between the minimum and maximum data values for the criterion. Since the function is fixed, the only input a decision-maker has is choosing whether a criterion is a *benefit* (where higher data values are desirable) or a *cost* (where lower data values are desirable). The following are the utility functions for SRT on the raw values for an alternative *i* and criterion *j*, using the maximum and minimum values for the criterion over the decision alternatives:

score range transformation, benefit:

$$\text{standardised value } x_{i,j} = \frac{\text{raw value}_{i,j} - \text{min}_j}{\text{max}_j - \text{min}_j} \quad (2.3)$$

score range transformation, cost:

$$\text{standardised value } x_{i,j} = \frac{\max_j - \text{raw value}_{i,j}}{\max_j - \min_j} \quad (2.4)$$

Figure 2.10 shows the utility functions for SRT as benefit or cost. SRT can be used with criteria having positive as well as negative values, and produces standardised values ranging from 0 to 1.

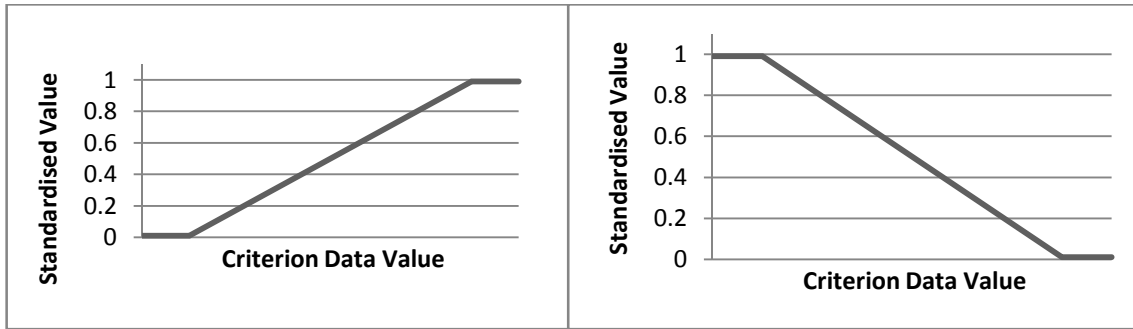


Figure 2.10 – Utility functions for: (a) SRT, benefit; (b) SRT, cost

Using SRT is a simplification on the part of the decision-maker, and there is a risk this “automated” value function does not accurately capture the complexity of a criterion’s utility. Malczewski (2000) further suggests that decision-makers must be judicious about their use of simplified standardisation functions, because the transformations rely on the range of values specific to the alternatives of the decision problem, whereas explicitly formulating a value function can be performed independently of knowing any alternatives. For example, when the alternatives in a given problem have a small variation in data values, SRT can exaggerate the effect of a criterion. This may only be desirable when criterion suitability is sensitive to small fluctuations in the data value.

The next subsection discusses how MCA lets users take these standardized values and assign them weights in accordance with their preferences and objectives.

2.5.4 Preference Weighting

MCA methods incorporate user preferences in the form of *criterion weights*. Almost all methods produce numeric weights that range between 0.0 and 1.0, subject to the constraint that all weights sum to 1.0. Some of the most common techniques for generating criteria weights are outlined below.

With the *accounting method*, each user distributes a fixed budget of “weighting points” (*e.g.* 100) across the criteria under consideration. Criteria that are deemed to be most important to a user’s objectives and priorities are assigned more points than criteria of less importance. The MCA functions in CommonGIS use a variant of this simple method that expresses weights in percentages, where weights are scaled proportionally to maintain a sum of 100%. After weighting, in both approaches the point or percentage allocations submitted by a user are scaled to a 0 to 1.0 range. While the accounting method has the practical advantage of being easy for non-experts to understand, it has been criticized for a lack of a theoretical base.

The *rating method* will be familiar to anyone who has ever filled out a multiple-choice survey or questionnaire. With this technique, decision-makers rate each criterion with a numeric value that may range between 1 (least importance) to 10 (most importance), or another scale (such as a 1-5 or 1-7 scale). Alternatively, users indicate the relative importance of criteria based on linguistic qualifiers (*e.g.* “somewhat important”, “important”, “extremely important” etc.) that are linked to numeric values. In both cases, the numeric values are normalized to a range of 0 to 1.0 (Herrera and Herrera-Viedma, 1997).

An interesting concern in preference weighting is that of preference resolution. It has been found that humans have a capacity to distinguish, on average, about seven levels of intensity on a one-dimensional scale. Miller (1956, p. 86) noted that this is a “limitation built into us either by learning or by the design of our nervous systems.” This means that when comparing criteria in MCA, decision-makers can only quantify ratings to a certain degree of accuracy. For that reason, when rating criteria, the number levels available for the rating method should be 7 ± 2 (Saaty and Ozdemir, 2003).

To this end, Saaty (1980) introduces another preference weighting method called *pairwise comparison*. Since it is difficult for people to compare many criteria concurrently, pairwise comparison breaks this task down so that only two criteria are compared at a time. This comparison is

repeated for every possible pair of criteria. With n criteria, $\frac{n(n-1)}{2}$ comparisons are needed, so this comparison can become very time-consuming with a large number of criteria ($n=8$ requires 28 comparisons; $n=10$ requires 45).

Weighting the criteria facilitates scoring of the alternatives, after which decision-makers may decide to try another iteration, or make a decision about the problem itself based on a type of decision rule. This procedure is discussed in the following section.

2.5.5 Decision Rules and Aggregation of Scores

The process of moving from the problem structure (objectives, criteria, alternatives and their data values) to a decision comprises the *decision rule*. There are many such rules to choose from and although only one is used in this thesis, a few of the major rules deserve some discussion because of their contribution to the development of MCA principles. Only additive decision rules are discussed here. Other methods, such as Ideal Point Analysis and outranking methods like ELECTRE and PROMETHEE, are quite different in nature but are beyond the scope of this thesis.

A decision rule combines the criterion values for each decision alternative with criterion weights assigned to the criteria by a decision-maker to calculate a numeric score for each alternative. The *Weighted Linear Combination (WLC)* rule, also known as simple additive weighting, is similar to the weighted overlay that is often performed in GIS analysis. For a decision with m criteria and n alternatives, let $x_{m,n}$ be the standardised data value of criterion m on alternative n . The decision-maker(s) then produce preference weights w_i for each criterion i , with the stipulation that the weights sum to 1:

$$w_1 + w_2 + \dots + w_m = 1.0 \quad (2.5)$$

Then the score for each alternative j is simply the sum of the products of criterion values multiplied by their respective weights. This can be expressed numerically as:

$$score_j = \sum x_{i,j} w_i = x_{1,j}w_1 + \dots + x_{m,j}w_m \quad (2.6)$$

WLC allows *tradeoff* between criteria such that low performance of an alternative on one criterion can be offset by high values on another criterion.

Two other decision rules not used in this thesis but widely accepted in the MCA literature are *Ordered Weighted Analysis* (Yager, 1988) and the *Analytic Hierarchy Process* (Saaty, 1980). The former is an extension of the WLC where the decision-maker can assume a risk-averse strategy (avoiding alternatives with an extremely poor performance on any criterion) or a risk-sympathetic strategy (favouring alternatives with at least one extremely high criterion values, despite low values on other criteria). The *Analytic Hierarchy Process* extends WLC by using the full criterion hierarchy (Figure 2.9). Preference weighting is done at every level of the hierarchy, reducing the maximum number of criteria compared simultaneously at each level, with the downside of increasing the number of rounds of weightings.

Malczewski (2000) argues that many users often ignore or overlook limitations of the WLC rule when applying it to their studies. Most crucially, he notes that many practitioners fail to consider the ranges and distributions of criterion data values when assigning weights to criteria. This is important because criterion values, standardization methods, and criterion weights are all inextricably linked together.

Criterion weights cannot be set without knowing the range of values in the alternatives under consideration, because weighting acts on differences in values.

Despite its apparent abstract mathematical nature, MCA is usually performed on real decision problems using the help of computer software tools called decision support systems. These are explained further in the next section.

2.6 Decision Support Systems

A decision support system (DSS) broadly refers to any computer system built to facilitate decision-making, whether using MCA or other techniques. DSS are particularly well suited for situations where there is uncertainty about the problem itself, providing problem structuring and decision facilitating functionality to analyse different aspects and strategies of a decision problem.

In fact, GIS can even be considered a DSS of sorts, though the decision-making aspect may not be readily evident. The term spatial decision support system (SDSS) is sometimes used to describe GIS systems that emphasise the decision aspect of their features (as opposed to data warehousing or visualization), usually with additional decision-structuring functionality and explicit decision-making tools like MCA.

Early DSS did not explicitly involve multiple participants in the evaluation of a decision problem. As interest in public participation in evaluating decision problems grew, the need to incorporate the preferences of multiple stakeholders in ranking alternatives became an increasing focus of research efforts. Group decision-support systems (GDSS), which allow multiple participants to work together as a group to weigh options and determine strategies, were developed to meet this need, and these are explained in the next section. Just as PPGIS brought participation to the spatial capabilities of single-user GIS, so too has participation been brought to the single-user choice functionality of DSS in the form of Group DSS.

2.6.1 Group Decision Support Systems

Business and planning decision-making is rarely done by a single person, often because of the myriad ways these decisions impact other people. Multiple stakeholders are involved in many decisions, whether in choosing a production strategy for a manufacturing firm or making siting choices for schools, landfills or health centres. In many cases these decisions are made with the stakeholders working together in a group setting. Group dynamics researchers have studied these groups and their

decisions for decades (Fisher, 1974). More recently, the advent of computer technology has given rise to automated group decision-making facilitating programs, called Group Decision Support Systems (GDSS). These systems are described by Huber (1984) as follows:

Just as the purpose of decision support systems is to increase the effectiveness of individual decision makers by facilitating the interactive exchange and use of information between the individual and the computer, the purpose of group decision support systems is to increase the effectiveness of decision groups by facilitating the interactive sharing and use of information among group members and also between the group and the computer. (Huber, 1984, p. 196)

Islei and Lockett (1991) note that a GDSS must not only be able to perform all the functions of a single-user DSS (problem decomposition, evaluation, aggregation, sensitivity analysis) but must also allow user preferences to develop through interaction. A good GDSS will manage controversy between participants and structure a group's decision-making process. Islei and Lockett (1991) remark in this context that, "A team, in general, requires a more clearly defined framework than does an individual in order to complete a given task" (p. 71).

A wide variety of GDSS have been developed offering multiple functionalities for use in a wide variety of decision situations. Eom and Kim (2006) have done three comprehensive surveys of GDSS literature finding that hundreds of GDSS have been developed with applications as varied as operations management, logistics, government planning, and environmental assessment (Eom, 1996; Eom et al, 1998; Eom and Kim, 2006). Despite this, GDSS use is still far more widespread in the business world than elsewhere and it has made relatively few inroads to non-corporate contexts (Eom and Kim, 2006). GDSS need not even use MCA methods. For instance, the Delphi method, originally developed by the military think-tank RAND Corporation, is a popular decision-making technique in the business world that eschews numeric values altogether, instead using expert opinion to develop consensus among individuals familiar with the problem (B. B. Brown, 1968). Poole et al argue that "GDSSs do not directly determine conflict interaction or outcomes. Rather, group use of the technology mediates its impact" (1991, p. 948). Similarly, the GDSS system must be appropriate for

the situation and especially the characteristics of groups involved, including its size, consensus level, and the ways it handles conflict. The design of the GDSS influences how the group uses it and the ultimate outcome depends on the appropriateness of the GDSS to its environment.

Many GDSS implementations use complex optimisation and simulation methods. Only 7.6% of the papers surveyed by Eom and Kim used the relatively simple AHP and 4.7% used Multi-Attribute Decision Making methods (another term for MCA). Even so, using a GDSS as the environment for an organisation's decision making positive impacts:

DSS helped organizations increase profits, on-time delivery rates, and annual throughput, and that DSS decrease inventories, the cycle times, and costs. (Eom and Kim, 2006, p. 1274)

It remains a challenge to adapt GDSS from the professional environment, which can afford to train its users and establish a culture of DSS use, to the general public which does not have such luxuries. Because of their sophistication and complexity, planning-related DSS remain better suited to use among planning professionals than with the public (Hwang and Lin, 1987).

GDSS are typically well adapted to dealing with conflict between participants, and usually encourage building consensus between participants. However, these terms have not yet been fully defined. The next section explores them in more detail, along with two major techniques for coming to consensus, namely voting and collaboration.

2.7 Conflict and Consensus-Building through Online Public Participation

Massam (1993) notes that modern planning practice, especially involving facility siting, strives for consensus between stakeholders. Even if this consensus is not reached, others agree that it remains an important goal of many decision-making contexts:

Consensus has become the preferred method for resolving problems, issues, and policy questions among American decision-making groups, public and private. (Casper, 1988, in Massam, 1993, p. 191)

The literature defines consensus variously, from unanimity to “united will” (Massam, 1993, p. 190) but there is a great deal of variation between these terms. Unanimity is very difficult to achieve when participants start with diverging values and ideas. On the other hand a majority consensus is less restrictive, but it is often unclear at what point a simple majority becomes true consensus.

Two particularly interesting definitions of consensus appear in the context of this thesis. Zahir and Dobing (2002) make a distinction between *criterion consensus* and *alternative consensus*. Alternative consensus is an agreement of various groups towards common solutions, even if the groups may approach the problem from entirely different value systems. This kind of consensus is somewhat fragile, as changes in circumstances can lead to a breakup of the agreement. Criterion consensus, also known as “shared values”, means that a group can agree on the importance of the criteria and objectives in a problem, but disagree on their preferences towards solutions or implementation.

Zahir and Dobing (2002) also identify three different types of groups: those with full consensus among their members, where GDSS are not particularly useful except for identifying solutions; those with “clusters of consensus” which can use voting tools to determine the nature of consensus and where conflict exists; and groups with no consensus, where DSS tools are generally unhelpful except to understand the structure of the conflict. Other approaches to consensus-building, such as mediation or discussion, are preferable for the last type of group. Similarly, Poole and Roth (1989) developed three types of consensus categories: *low conflict*, where the group can focus on work; *moderate conflict*, where there is discussion on disagreements, and *high conflict*, where groups split into sides and progress is more difficult.

There are two fundamental routes towards dealing with consensus in decision-making. The first is *social choice theory* which includes voting and related choice mechanisms and works by selecting a “median” solution somewhere between the opinions of the stakeholders (Figure 2.11). The second route is *collaboration*, which instead has participants deal with their conflict in a constructive manner.

By discussing their concerns and aiming for agreement in their decision, collaboration aims to change individual positions closer to consensus (Figure 2.12).

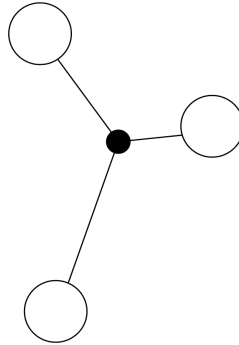


Figure 2.11 – Voting (Social Choice)

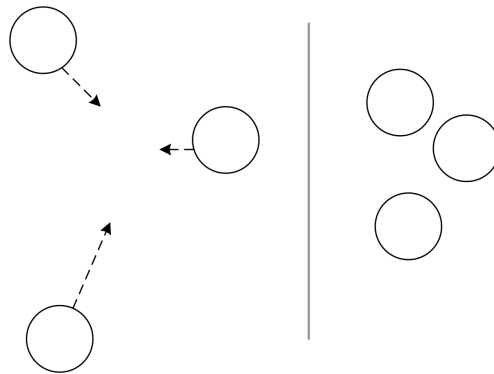


Figure 2.12 – Collaboration, before (a) and after (b)

Voting is examined in more detail in the next section, followed by a review of several social choice methods and a detailed analysis of collaboration.

2.7.1 Voting and Social Choice Theory

Though voting has been used since the days of the ancient Greeks, the modern study of voting theory began in the 18th century in France with the pioneering work of Condorcet and Borda (Borda, 1781; Condorcet, 1785). More recently, the field has fallen under the rubric of social choice theory, which is the study of how large groups of people (or society at large) come to decisions. What separates social choice theory from group decision-making theory is scope and scale. The kind of intensive decision-making tools that work in small group settings are unworkable when the decisions are undertaken across cities or even entire nations, so voting theory must, out of necessity, be simple, quick and

inexpensive. Voting is less a “consensus management” tool than a method for majority choice, so while it falls within both the choice and participation circles of Figure 2.1, it is considerably less participatory than collaboration.

Voting takes individual input in the form of a *vote* on *candidates*, also known as alternatives in decision-making theory (Arrow, 1951). Votes can be as simple as a single vote for the most desirable candidate or party, or can gather more information as a full ordered ranking of candidates. A *social choice function* aggregates the many submitted votes into a ranking of alternatives, where the top-ranked candidate is the *winner*.

Unfortunately, despite years of research, there is no one single ideal social choice function. Different functions have strengths and weaknesses, and many can be exploited by manipulative voting strategies. In fact, Arrow’s Impossibility Theorem famously proves that given five reasonable axioms (monotonicity, universality, independence of irrelevant alternatives, citizen sovereignty, and non-dictatorship), a social choice function that satisfies all five simultaneously cannot exist (Arrow, 1951). The choice of a voting method must therefore be carefully tailored to the circumstances of the choice problem.

Voting has the advantages of being reasonably simple to understand, and it can be made open, accountable, and transparent. Users can know precisely why a given candidate won or lost, and the conflict within a group can be studied and even measured by analysing vote results. Voting is used in political elections because it is quick and more efficient than direct public consultation. In groups with high conflict, voting can be used to push the group tasks forward out of deadlock, and a basic “consensus” decision can be used as a starting point for further discussion. Stam and Gardiner (1992) found that voting improves the overall efficiency and effectiveness of group decision-making. Voting is good for quickly coming to a decision, wrapping up discussion and moving on to another step.

Voting also has disadvantages and flaws. Voting assumes each user's input to be equal, ignoring the fact that some users may be affected by a decision more than others (Massam, 1993). The majority's choice can be seen as the "common good," which can lead to marginalization of the needy or disadvantaged, especially as voting presents a barrier of abstraction or indifference between stakeholders. However, increasing the voting power of some groups over others can be seen as impractical and unethical (Hwang and Lin, 1987). Most importantly, voting does not change positions, it does not allow for any negotiation or compromise, and it does not educate participants. In this respect voting is not collaboration, but participation.

Specific voting methods and social choice functions will not be described here, but it is important to note that different methods usually come up with different results. Choosing a method is somewhat arbitrary, and participants can complain that any method disadvantages their preferred candidate. A debate over candidates or alternatives can devolve into a debate over electoral methods. However, although many (or even all) voters may not get their ideal choice, the voting process chooses the "majority choice" candidate that represents a "satisfactory" solution. Further, participation in the process gives it validity; by voting, participants are bound to accept the result and whatever consequences follow. Multiple voting methods can also be used to analyse the behaviour of the submitted votes, and to better comprehend the nature of the disagreement or consensus among participants.

The next section describes collaboration as a counterpart to voting.

2.7.2 Collaboration

Small group environments are fundamentally based upon collaboration. Stakeholders interact with each other to negotiate, argue, learn, bargain, discuss, educate, and possibly change their values to come to a consensus decision. Group theory, a sub-discipline of psychology, has studied the mechanics of how groups function (Fisher, 1974).

Participants enter any interactive discussion with two kinds of knowledge, namely values, which are deeply ingrained and difficult to change, and views, which are constructed upon their values but which can fluctuate more readily (Kyem, 2004). The group meeting is a brief window of interaction during which the participants share pieces of information with the rest of the group, possibly resulting in their own views changing or compelling others to change theirs. The format used (focus group, DSS, or town hall) governs how information is divulged in the discussion (Hopfer and Maceachren, 2007). If individuals in a group do not share information or challenge each others' assumptions, they can easily devolve to "groupthink" (Postmes and Spears, 1998).

The group's purpose even has influence on how much information is shared, and the quality of decision results. For example, groups can have two overarching *norms*, which comprise the underlying objectives of a group's dynamics. Groups working with a *consensus norm* focus on building consensus and are focused on coming to a more agreeable and popular decision using shared information. In contrast, groups working with *critical norms* aim to examine more unshared information, leading to a better-informed decision (Postmes et al, 2001). It is a challenge to balance the group's need to complete its task with dealing with group conflict and trying to maintain group unity (DeSanctis and Gallupe, 1987).

DSS tools can help group consensus-building by streamlining interaction and allowing for the consideration of more alternatives, depersonalisation of group conflict (leading participants to approach a problem more objectively), equalising participation by giving an equal voice to all members (even shy participants), and keeping the group focused on its agenda (DeSanctis and Gallupe, 1987; Poole et al, 1991). Collaborative tools have been proven to have better performance (more information brought up, discussed, etc.) in this context than non-collaborative or even traditional face-to-face tools (Lam and Shaubroeck, 2000).

With voting and collaboration explained more fully, the next section discusses how the consensus between participants can be measured, as the goal for both techniques is come to some kind of consensus position.

2.7.3 Measuring Consensus

Both collaboration and voting are considered means for achieving consensus, but it must be emphasised that neither guarantee full consensus as their end result. There is a difference between “group choice” and consensus – a solution can be considered the group’s common decision, achieved either through a social choice function or by collaborative interaction, but there may still remain considerable disagreement between participants. It is therefore important to try to define or quantify the degree of consensus.

It is often difficult to measure the degree of consensus among group members, particularly when each individual may have different reasons for casting even a simple yes or no vote. Poole et al (1991) find that the degree of consensus in a group influences how the group handles conflict within a multi-participant DSS, and ultimately this influences the decision outcome.

A variety of methods for measuring consensus have been developed, as reviewed by Conway and Schaller (1998), including the classical Pearson r and Spearman’s r_s coefficients. This study uses the method developed by Cook and Seiford (1978), which is described in more detail in Chapter 5. It quantifies the psychological *distance* between voters, and can be used over criteria or alternatives (Eckert et al, 2006).

As stakeholder preferences vary over space, it is possible to have broad agreement on the suitability of certain areas on a map for some planning use, while other areas provoke more disagreement. This idea of spatial consensus has been studied somewhat in the past, such as the approach used by Feick and Hall (2001) and Jankowski and Nyerges (2001) to measure and map the degree of consensus across the alternatives under consideration. In another study, Brody et al (2006) overlaid multiple layers

simulating stakeholder interest to generate a map of estimated conflict over coastal water resources. A similar analysis can be done using real stakeholder preferences, such as the result rankings from a simple MCA, aggregated using voting techniques and quantified with consensus measures. This approach is carried out in Chapter 5.

2.8 Synthesis of Literature Fields into MapChoice

In this chapter, a whole number of literature concepts have been introduced that overlap and intersect in various ways. This thesis combines the ideas from all these fields in MapChoice, a collaborative spatial MCA tool which is described in more detail in Chapter 3. This section describes how MapChoice ties together ideas from the preceding chapter.

Involving the public in planning decisions has long been a goal for many theorists, and PPGIS may just be the technology that finally brings large-scale participation from a broad segment of the public. In this thesis, that means designing a PPGIS for small groups of community users to be able to explore a planning problem, evaluate potential locations, determine relationships between criteria and alternatives by considering multiple permutations of decision parameters, and collaborate on a group consensus decision. The workshop (as described in Chapter 4) was performed independently of the official planning establishment, but ultimately such an approach can be extended to fully integrate community participants in decision-making at any point in the planning process. Depending on the importance given to the results of such a process by the existing power structures and degree of involvement of planners or political interests, it can fall within the highest rungs on Arnstein's ladder of participation. At the very least, MapChoice can give participants an opportunity to explore the decision problem, and the system can represent different viewpoints in a spatial environment.

The thesis approaches planning decisions from a spatially-informed, map-based perspective where local problem-specific data is displayed on a map, and the decision alternatives (sites in a community) are compared in their spatial context. Only vector data is used for decision-making in MapChoice, but

a similar process can be extended to raster data. MapChoice combines GIS and MCA, but unlike other past research, this is done through a web-based GIS system that can be accessed from any location with Internet access. The system is collaborative, having multiple users connected and able to interact with each other, as well as having provisions for collaborative input into the decision-making. The MCA technique also works well with planning decision-making for another reason: planning decisions require the comparison and weighing of tradeoffs on a whole series of considerations, which is precisely the approach taken by MCA through its comparison of criteria.

Any collaborative spatial MCA tool using group decision-making should have some mechanism for allowing the multiple participants to come to a single choice. Voting, in that regard, is a well-developed and accepted method for a group of people to be able to come to a single decision quickly and reliably. Being based on ranks of candidates, voting techniques easily integrate with MCA. Most MCA methods involve users creating single-user preference rankings, and these can be used as input to a preference-based voting method to generate an aggregate group ranking. Voting can also be used throughout the MCA process, not just at the final ranking. Quick votes could be taken anywhere from deciding what information to use in making a decision (such as data layers), minor group decisions on specific MCA parameters (such as standardization or benefit-cost settings), or how much time to dedicate to specific tasks. In MapChoice, voting is used in the process of collaborative decision-making by having participants submit their preferences for each criterion under consideration (this is described more fully in Chapter 3).

As discussed earlier, however, different voting methods can yield different results, so the choice of a voting method that is relevant to the decision problem and type of participants is important. In Chapter 5, several voting methods are used in the analysis to examine different versions of what may be defined as “group consensus”. Similarly, techniques from social choice theory have been developed to quantify disagreement between participants, and these are used in Chapter 5 to examine how consensus evolves over the course of participants’ involvement with MapChoice.

The thrust towards decision-making at the early stages of a planning project has mostly been concentrated on providing data visualisation, communication, and rudimentary analysis functions. Collaborative spatial MCA can be the enabling technology for public choice in such decision-making contexts. Participants can create their own scenarios for consideration, and then vote for scenarios they prefer.

Collaborative methods can enhance PPGIS by managing and encouraging consensus-finding within the decision-making software. Collaboration results in far more information exchange than voting, but is much less frequently used in planning decision-making. This may be because traditional methods of collaboration, like group meetings or GDSS, have the disadvantage of complexity and cost, and because the progress of the entire group depends on the participation of all members (Huber, 1984). The approach of this thesis through MapChoice has participants working in a single-user mode at the speed and complexity level they find most comfortable, and also collaboratively through an uncomplicated, moderated process.

2.9 Summary

This chapter has covered theories a number of diverse fields, including decision-making, participatory planning, Geographical Information Systems, Public Participation GIS, Multi-Criteria Analysis, voting, and collaboration. These fields and theories were circumscribed within the three concepts of choice, space, and participation.

In the next chapter, the MapChoice software package is introduced, combining the spatial mapping aspect of GIS, the open public accessibility of PPGIS, the analytic power of MCA, and the group management capacity of GDSS, all within a multi-user collaborative environment.

Chapter 3 - Software Design

To address the thesis objectives discussed in Chapter 1, a software program that allows a group of participants to evaluate a set of planning alternatives was created and used in a group workshop setting. Section 3.1 provides an outline of the architecture of a software tool called MapChoice that was written to facilitate this. MapChoice is introduced in its single-user mode in Section 3.2, followed by the collaborative group mode of MapChoice in Section 3.3. The database architecture of MapChoice is shown in Section 3.4. Finally, some of the more challenging aspects of the design of MapChoice are discussed in Section 3.5.

3.1 General Overview of the Software

MapChoice was built as an extension to another software tool called MapChat that was developed at the University of Waterloo. These software tools were developed through a project funded by Canada's GEOIDE (Geomatics for Informed Decisions) network. A central goal of this project ("Spatial decision support for sustainable communities") was to build and test a set of community-based spatial collaboration and decision support tools, with an overall goal of allowing non-expert community participants to interactively tackle planning-related problems.

The project's focus on public participation influenced the design of the tools in several important ways. Targeting the project to community activist groups necessitated different developmental paradigms than those applied in the construction of off-the-shelf commercial software or research-level tools. Volunteer organisations often work with small or non-existent budgets which precludes the use of expensive commercial software. Powerful servers, high-end software and conference rooms with fast, modern computers may be common in the private sector, but many community groups have to rely on school computer labs with older resources, slower Internet connections and other

technological bottlenecks. At least some community participants will not be experts at using computer technology, and unlike in the corporate world, expensive training seminars are unfeasible.

Another constraint for the project was the requirement that all software be comprised of *Open Source* (OS) components. Although precise definitions of OS vary, at its core it refers to software where the source code is freely available to the public for use and modification, as opposed to typical closed-source commercial software. OS software was chosen partly due to the cost considerations of community groups, but it also bypasses the problems of opaque, “black box” functionality and restrictive licenses of some commercial software.

Together, MapChat and MapChoice attempt to address the intelligence, design and choice stages of decision-making discussed in Chapter 2. The software can handle a variety of tasks useful for analyzing planning problems such as data analysis, exploration and visualization, site identification, and scenario evaluation in a collaborative, inclusionary, group-based environment.

3.1.1 Software Architecture

MapChat was developed by linking a number of OS software projects, including the University of Minnesota’s MapServer, the Apache Web server, the PostgreSQL database server, DM Solutions’ Chameleon MapServer template and Refraction Research’s PostGIS extension to PostgreSQL. Custom code was designed and implemented by the researchers to facilitate development of the software described below. This section only provides a rudimentary overview of the software architecture. More in-depth discussion of collaborative Web-based OS GIS design, as well as a more detailed description of the architecture of MapChat Version 1, is available from other sources (Hall and Leahy, 2006; Hall and Leahy, 2008; Yeung and Hall, 2007).

MapServer is an OS Web mapping system that was developed originally by the University of Minnesota and is maintained by a community of users. MapServer takes as input spatial data layers in a variety of formats (including the industry-standard .shp *shapefile* format) and renders a map image

according to the classification of layers, their geographic extents, and other configuration options specified in the .map *mapfile*. MapServer runs in conjunction with the Apache OS Web server, and also PostgreSQL, an OS relational database management system used for data storage and query handling using the standard Structured Query Language (SQL).

The version of MapChat used in this study was based on a significant customisation of the Chameleon user interface environment originally developed by DM Solutions Inc. Chameleon provides a Web-accessible presentation of the map images generated by MapServer. Chameleon is built from a number of components called “widgets”, which can be activated individually, creating a customized Web interface. Examples of these widgets include navigation tools for panning and zooming, map display features such as a legend, scale, and north arrows, and general-use tools such as saving maps.

MapChat extends Chameleon by providing user session management (so users can log in and out with personal user accounts), group management and permissions, and the ability for administrators to create new map configurations. The central feature of MapChat is the chat component. With this, users can select map features or locations on the map, add comments regarding those features, and view and respond to other users’ comments as well. In this way, MapChat combines the map navigation functions of Chameleon with the interactivity of a chat messaging service (Hall and Leahy, 2006; Hall and Leahy, 2008). Subsequent to the completion of this thesis the code base of MapChat has been completely overhauled such that newer versions no longer based on Chameleon.

MapChoice comprises another series of widgets within MapChat that add MCA-based decision support and analysis functionality to MapChat using the MCA methods introduced in Chapter 2. The standard MapChoice widget is used for single-user decision making, Group MapChoice is used for collaborative decision-making, and the Data Table widget is an informational tool for viewing data values and the output results of MapChoice.

The next two sections describe the architecture and the operation of MapChoice from the single-user and group use perspectives. MapChoice underwent several iterations of design and development before it was deployed. Some of the functionality that was developed was not required for the affordable housing case study in Collingwood and these functions are discussed only briefly.

Figure 3.1 shows a high-level view of the organisation of the MapChat and MapChoice software. It is designed as a two-tier client-server architecture where users access the application through a local Web browser while the core program functionality resides on a remote server. The client-server architecture provides for centralized data and software management which facilitates software administration. It also permits participant input and licensed spatial data to be secured through password protection. With this architecture, MapServer does not send any spatial data to the client computers, but functions as a Web Map Server (WMS) which renders the data on the server to a static map image (in GIF, JPEG or PNG format) for transmission to the client.

Another advantage of the client-server model is that MapChat and MapChoice can be accessed from any computer that is connected to the Internet through a contemporary Web browser. This allows participants to access the software from locations that are convenient to them and eliminates the need to install any software on the users' computers. The latter point is particularly relevant in community use settings since public computers in libraries or schools typically do not allow users to install software. Finally, since data processing occurs on the remote server, the client computers need only modest processing power.

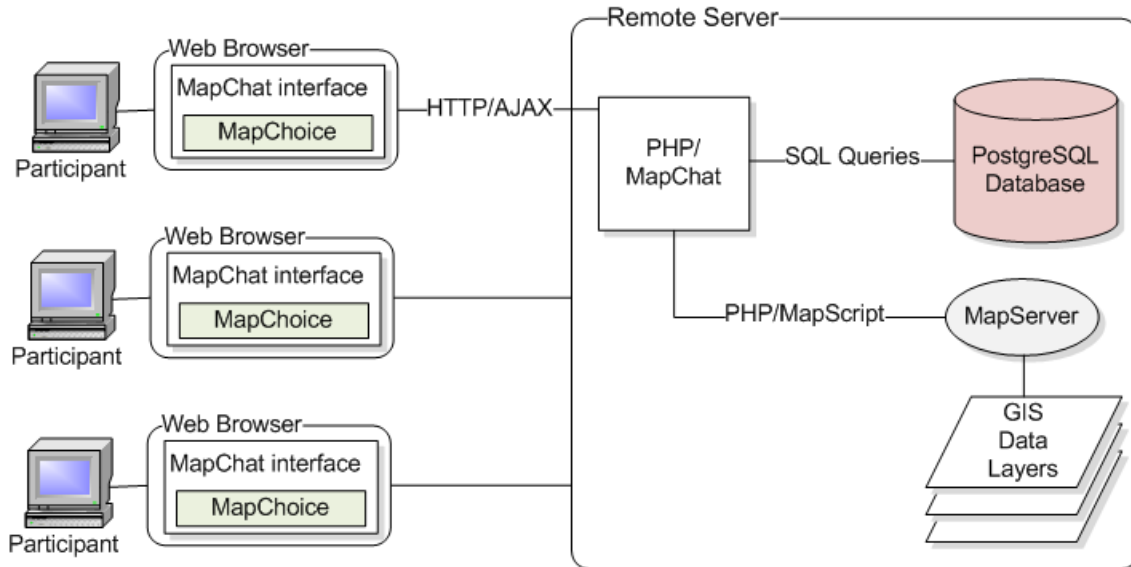


Figure 3.1 – Design of software system, including MapChat and MapChoice

In the Web-based architecture, server functions are accessed through HTTP requests, the Web communication protocol. Based on the parameters passed to the server through the request, the server responds by returning information in two ways. Simple, static Web pages are returned when the user navigates to a new Web page or reloads an existing page, and Asynchronous Javascript and XML (AJAX) responses are used to send updated information to an actively loaded page. AJAX avoids reloading the entire page whenever information is updated, instead only transmitting the newly updated information. In the case of MapChat, the entire application page is very large (taking some 5-10 seconds to load on a fast connection), so being able to transfer updated data as needed using AJAX instead of reloading the entire page is crucial to a smooth, efficient operation.

Requests to the server are handled by server-side portion of MapChat, which is written in the Hypertext PreProcessor (PHP) programming language. PHP is a relatively sophisticated Web programming language that generates the Web pages requested by the clients. Through associated libraries, PHP also communicates with the other components of the remote server including the PostgreSQL database (through SQL queries) and MapServer through the MapScript interface (which is accessed by PHP).

3.2 Administrator Side of MapChoice

MapChat and MapChoice require an administrator to complete several preparatory steps prior to the software being used by community members. First, all the data must be readied by collecting all relevant geographical data layers (in the common *shapefile* format), including the single layer of features that will be used as candidate sites for the MCA. This set of geographic features can be identified through a previous interactive MapChat session or can be produced by the administrator using external GIS software. The layer of alternatives must have criterion values in its associated attribute table in the format of numeric values. An appropriate *mapfile* must then be created that specifies map-related parameters such as layer symbology and display extents as well as which attributes of the alternatives map layer will be used in the MCA. It is possible to leave a larger number of attributes in the MCA layer, selecting only a subset as MCA criteria while leaving the remainder as informational attributes for the users' reference. All users are presented with the same set of alternatives to evaluate.

Finally, the administrator creates the “map discussion” in MapChat that specifies which user accounts can join the session. Simultaneously, the database tables are readied for use on the server.

3.3 Details of MapChoice

Figure 3.2 presents the flow of operations undertaken by an individual user when MapChoice is used in single-user mode. MapChoice essentially provides users with the ability to perform an MCA weighting on a given set of alternatives and criteria, resulting in a ranking of the alternatives. Once this is completed, users can map the spatial distribution of the ranks.

Weighted Linear Combination (WLC) is the only decision rule available in MapChoice, and it takes two sets of input preferences, namely criterion weight values and benefit/cost settings. Upon loading MapChoice, users are presented with a predefined set of criteria that are initially assigned equal

weights. The key tasks at this stage are: i) setting a weight for a criterion and, ii) determining whether high data values (designated as a “benefit” criterion) or low data values (designated as a “cost” criterion) are preferred for each criterion. Any changes to these two user preferences are sent to the server and saved in the database, and alternative ranks are calculated automatically. Simultaneously, the user’s map is updated to show the new calculated ranking. It is also possible to save the currently active weighting preferences for later retrieval, or to load a previously-saved weighting. At any time it is possible to proceed to the mapping stage using the current active weighting, where the user can change mapping options such as the colour scale and number of classes. It is also possible to return to the analysis stage at any time from the mapping stage.

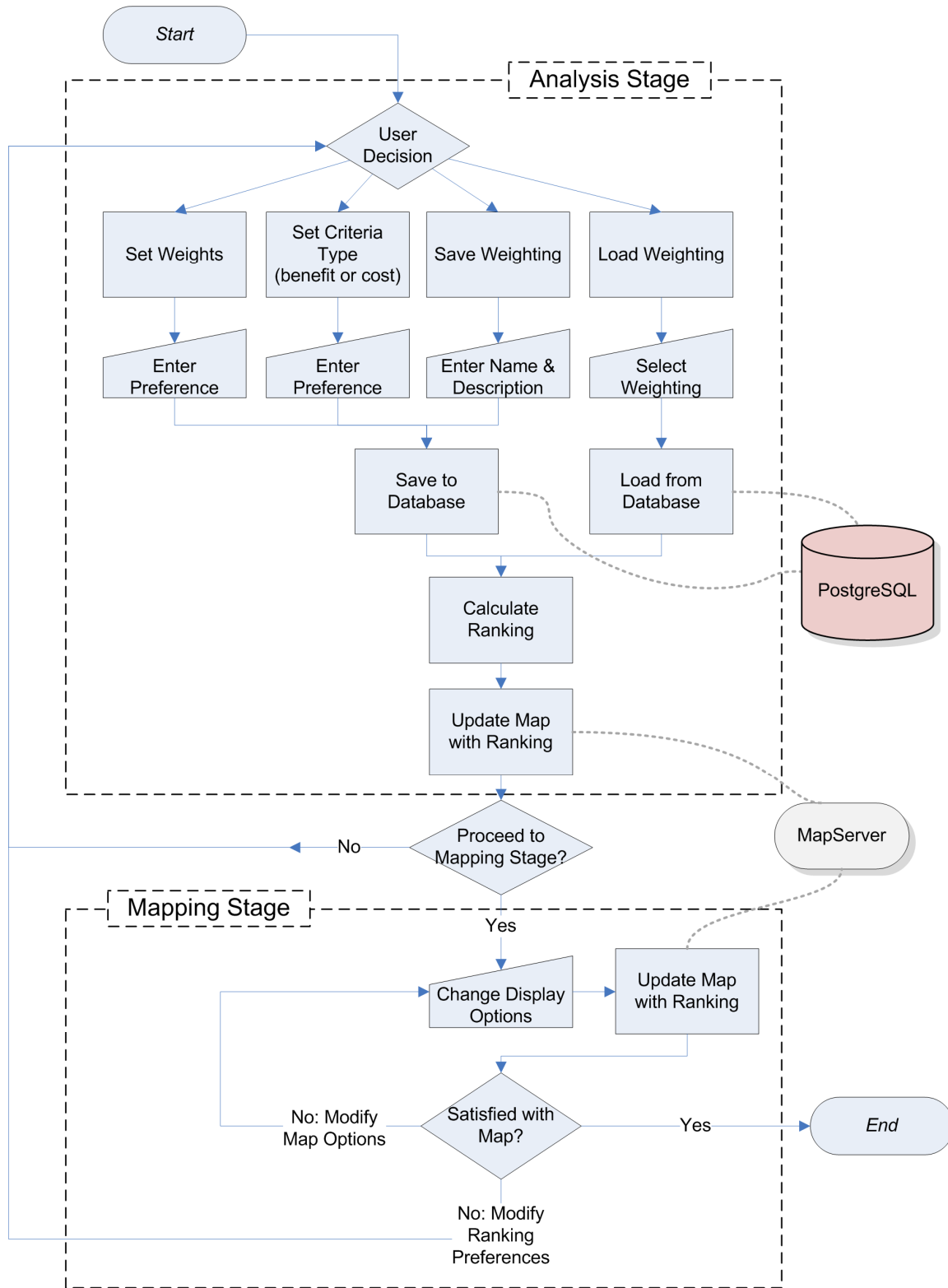


Figure 3.2 – MapChoice system flow

The Data Table widget is not included in Figure 3.2 because it can be activated and hidden independently of MapChoice. It typically displays the criterion values for the decision alternatives in a table, and also displays the updated scores and rankings whenever MapChoice is active. This shows users the relationship between criterion values and alternative scores, as well as displaying the direct results of their weighting preferences.

The first screen the user sees when loading MapChoice is the Analysis stage, shown in Figure 3.3. This screen presents the user with opportunities to choose criteria weights, criteria type (benefit/cost) assignments, and to record a rationale for their weighting preferences. For simplicity, only four criteria are shown in Figure 3.3 although eleven were ultimately involved in the case study.

Criterion weights are chosen from dropdown controls using a 1-7 scale of importance. The 7-point scale has a solid theoretical grounding as described in Section 2.5.4. By default weights are set to 4, which constitutes “Average Importance” for each criterion.

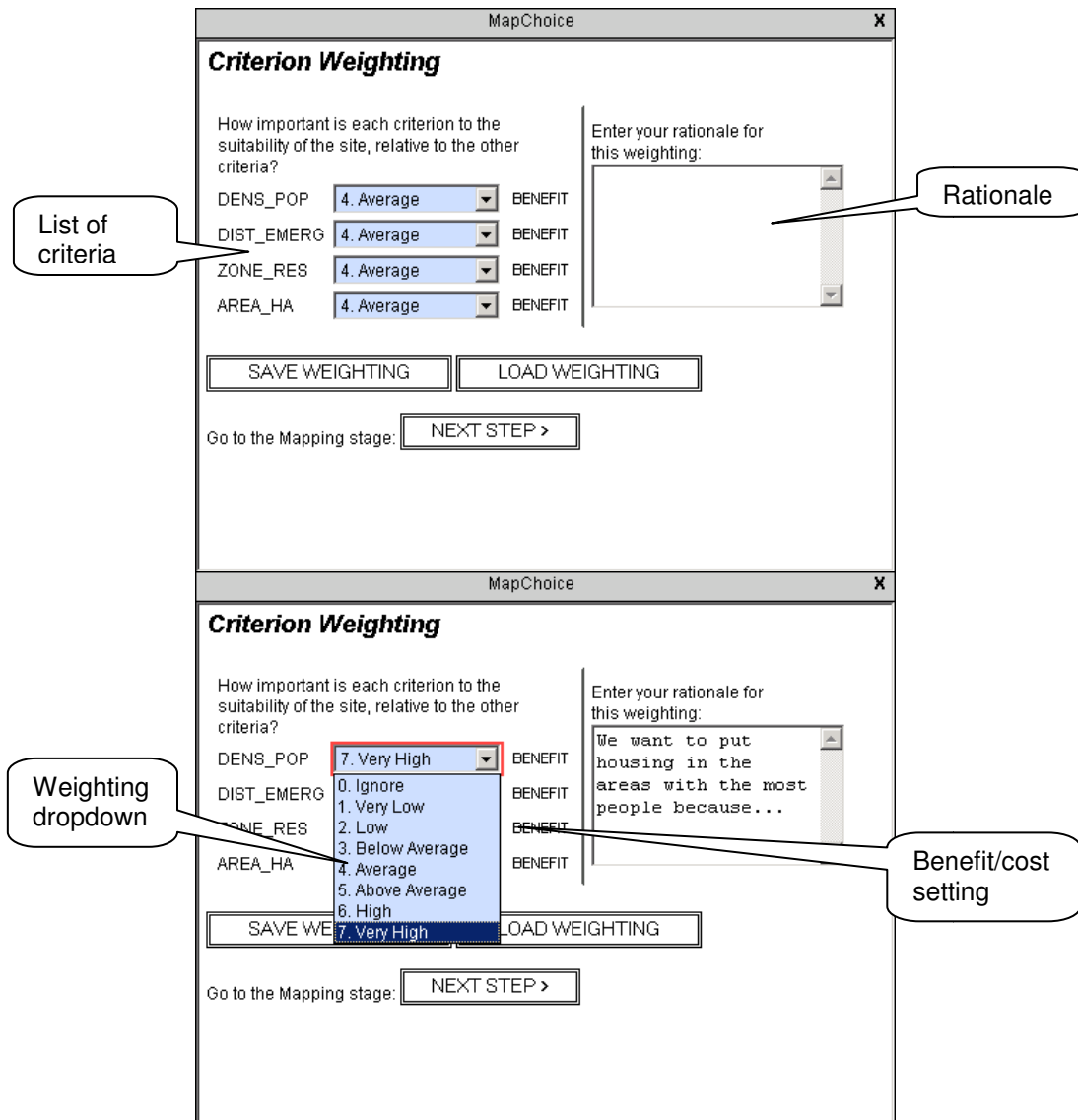


Figure 3.3 – (a) MapChoice weighting screen, (b) with weighting dropdown activated

Criteria that an individual judges to have no impact in the weighting can be given a weight of 0 to exclude it from the analysis. The software reminds users that the weights are not absolute, but rather weighted relative to each other. Users can also specify whether a criterion is a benefit or cost to them. The text box on the right of the MapChoice window is for users to enter their rationale for their preferences. This allows users to document their weight settings which could be particularly useful if they conduct several iterations of the evaluation.

Changing any weight or benefit/cost setting triggers an updated calculation of the ranking, which is saved in the database and reveals itself on the map. If the user intends to save the weighting for later use, it can be saved manually by selecting the “Save Weighting” button, where a name and a brief description can be given to the weighting. Saved weights can be loaded later by clicking the Load Weighting button.

At any point a user can move from the MCA step to the mapping step by clicking the “Next Step” button, which brings up a new window where the mapping options can be changed. By default five symbology classes are used to split the alternatives on the map, and this value can be adjusted from 2 to 10 classes. Users can also change the start and end colours for the classification.

Updated rankings are displayed in the data table whenever a ranking is calculated (Figure 3.4). Each row represents a decision alternative (these are land parcels in the scenario used in this thesis), while the columns show the non-standardised criteria values. The data table also shows several extra data attributes that were not included in the MCA calculations, but are present in the attribute information for the parcels layer (the attributes used in the workshop are described in Chapter 4). These are only included for the information purposes. The final two columns show the calculated scores and ranks.

Parcel Table							
DRESS	DENS_POP	DIST_EMERG	ZONE_RES	AREA_HA	MSID	SCORE	RANK
SLAN	1195.5	235	1	1.649	0	67.53	2
SLAN	1037.7	663	1	0.163	1	78.95	1
RON	1546.9	494	0	1.403	2	30.31	3

Display parcels in:

Figure 3.4 – Data Table widget screen

From a software architecture standpoint, Figure 3.5 shows the components and transactions involved in the tasks performed during the analysis stage. The left side shows the MapChat web interface on the user’s computer, including the Analysis stage component of MapChoice, and the right side shows the functionality residing on the remote server. Any change in settings by the user (changing a weight or benefit/cost preference, or performing a save or load) triggers an AJAX request to the calculation functions on the server. In turn, the server performs the appropriate read and write queries to the database, finally sending an updated ranking of the decision alternatives to the client. The Data Table widget, if active, loads the new ranking. Simultaneously, if a client’s request was a preference change or loading a weighting (but not saving a weighting), a new map image is generated and sent to the main MapChat window on the user’s web browser.

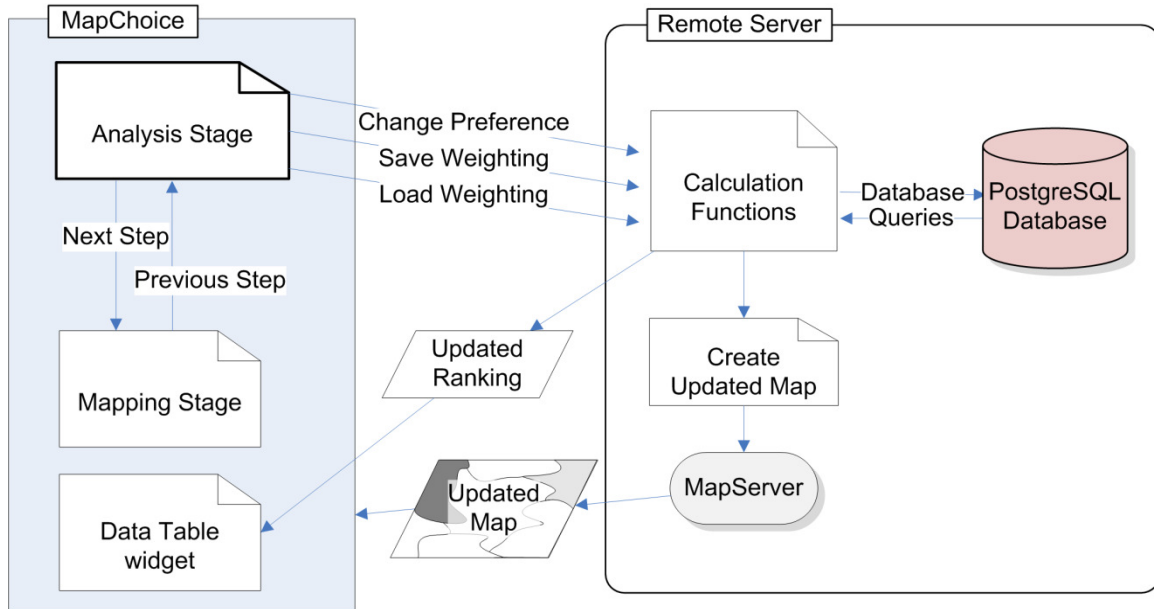


Figure 3.5 – Analysis stage in MapChoice

The single user mode of MapChoice allows individuals to independently evaluate a set of alternatives and to determine a preferred ranking that reflects their priorities and objectives. Group MapChoice is based on the same foundation, however it is designed to assist several participants to work together to produce a group-wide ranking of alternatives. The design of Group MapChoice is described in the next section.

3.4 Details of Group MapChoice

The second component of MapChoice is the collaborative widget, Group MapChoice. The goal in this case is to have participants discuss the importance of criteria, interacting with each other if they are located in the same place at the same time, or through the chat interface of MapChat if they are dispersed spatially but able to log on at the same time. Unlike in the single-user mode, where users operate independently of others, the group mode encourages openness and participants are able to see the preferences chosen by the group. Ensuring discussion about a criterion requires a different approach to interactivity. Whereas MapChoice lets users set preferences to criteria in any order they

choose, in a group setting this approach would make the discussion unfocused and difficult to manage. Hence, in Group MapChoice only one criterion is considered by users at a time.

Figure 3.6 shows the process logic for an end-user in Group MapChoice. Not shown is the moderator or administrator's role of starting the collaborative session before users can begin the criterion weighting process. Like MapChoice, Group MapChoice is split into two separate stages. In the analysis stage the moderator steps through voting for one criterion at a time, and users anonymously submit their weight and benefit-cost preferences (these comprise a "vote"). Users can update their vote at any time while the criterion is active, but only their latest vote counts, giving them an opportunity to revise their votes. Note that Figure 3.6 shows the process only for a single user, and there are multiple users simultaneously undertaking the same criterion weighting flow while the session is active. The discussion moderator can see how many votes have been submitted. Once a discussion is over and a particular criterion is judged to be complete, only the moderator can step to the next criterion.

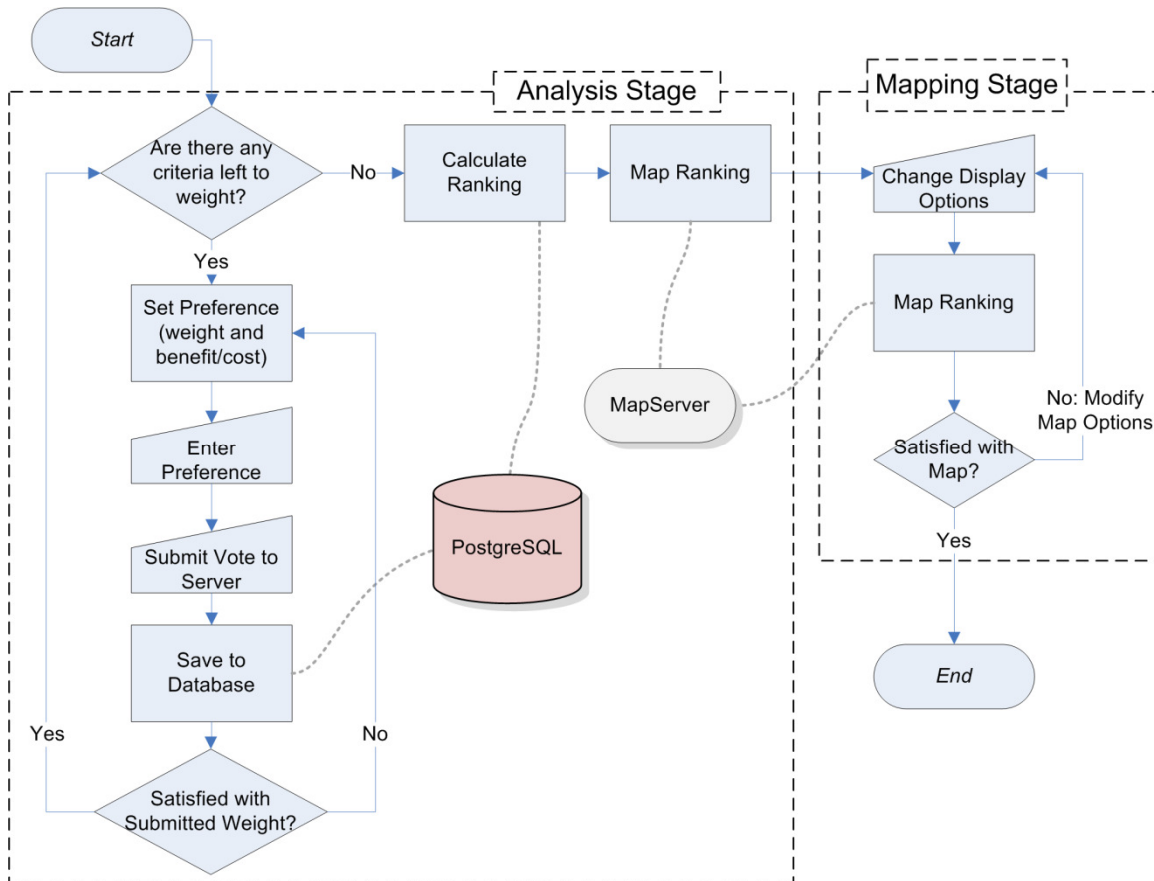


Figure 3.6 – Group MapChoice logical flow

The method of calculating the group weighting and benefit/cost values from the submitted votes occurs whenever a new vote is submitted. Submitted weights are averaged to a group weight, and a simple majority of the benefit/cost votes is taken as the group value. Further description of the vote calculation can be found in Section 3.6.

Only once all criteria have been discussed and voted on can a ranking be calculated for the decision alternatives. Group MapChoice performs the same kind of MCA calculation using WLC as the single-user variant. After this, the ranking results are calculated and are displayed in the mapping stage, which is identical to that for single-user MapChoice.

Despite differences in architecture, the interface for Group MapChoice is similar to single-user MapChoice. Figure 3.7 shows the interface to the analysis stage of Group MapChoice, with the first

criterion open for voting. The right side of the screen shows the updated voting results. Users choose a weight from the same 0-7 scale used in single-user MapChoice, select whether the criterion is a benefit or a cost, and when satisfied with their settings, click “Submit Vote” to send their vote to the server. The panel on the right side of the dialog shows updated group results, including the number of users who have submitted votes for the active criterion, the current average vote for the criterion, and the current group benefit/cost value.

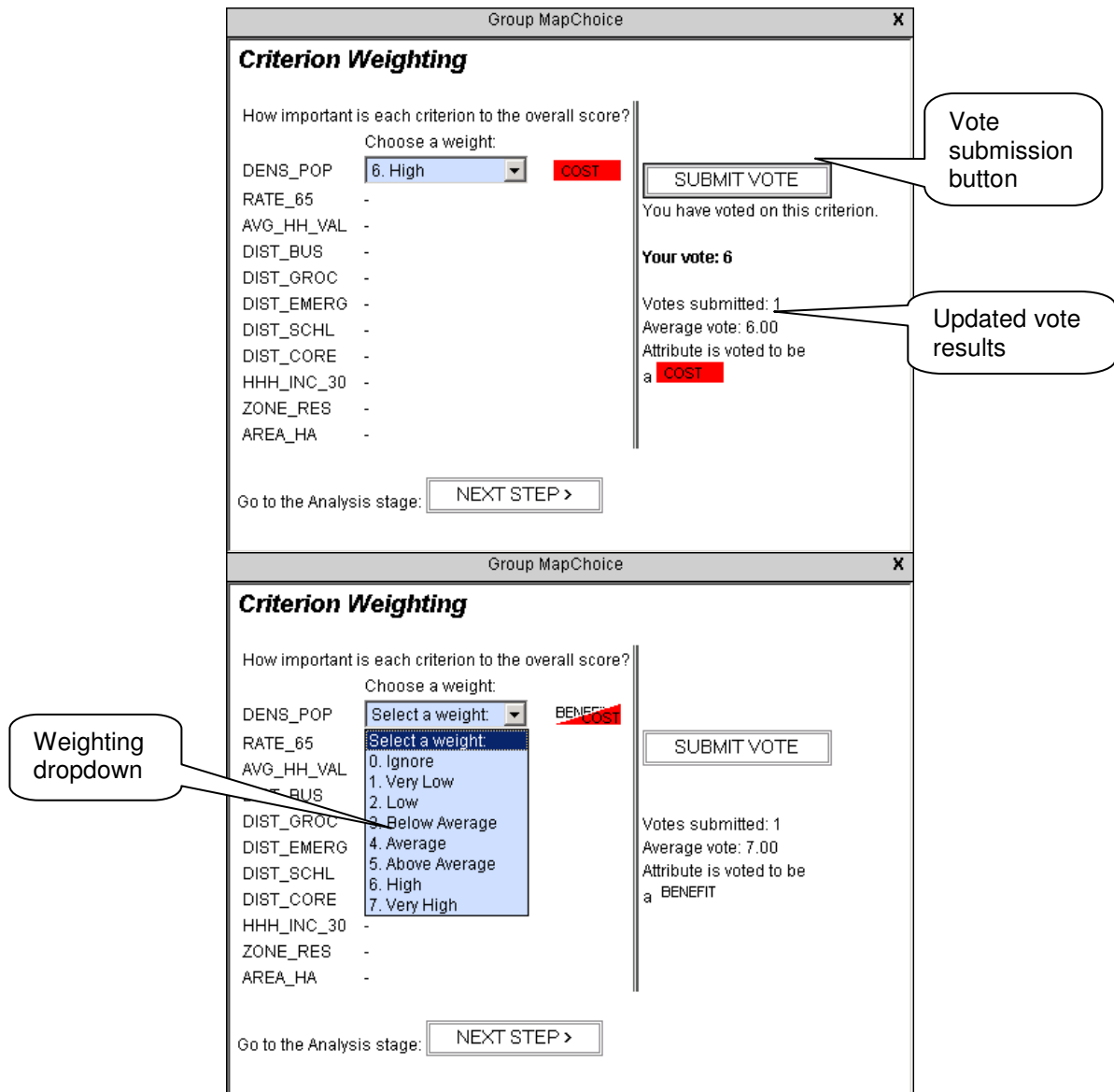


Figure 3.7 – (a) Group MapChoice screen, (b) with weighting dropdown selected

The collaborative architecture of Group MapChoice dictates a completely different software layout (shown in Figure 3.8) than single-user MapChoice. Votes submitted by the user (comprising of weight and benefit/cost preferences) are sent to the server, which saves the setting to the database and calculates the new group vote values. A user can refine or update their vote as many times as desired, until the moderator closes voting on the currently active criterion and moves to the next criterion (if any are still available). In the meantime, the user computers are constantly submitting AJAX requests in the background to the server, which returns the latest vote results and counts for the active criterion to all users. This way each user has an up-to-the-minute count of the group's votes for the active criterion.

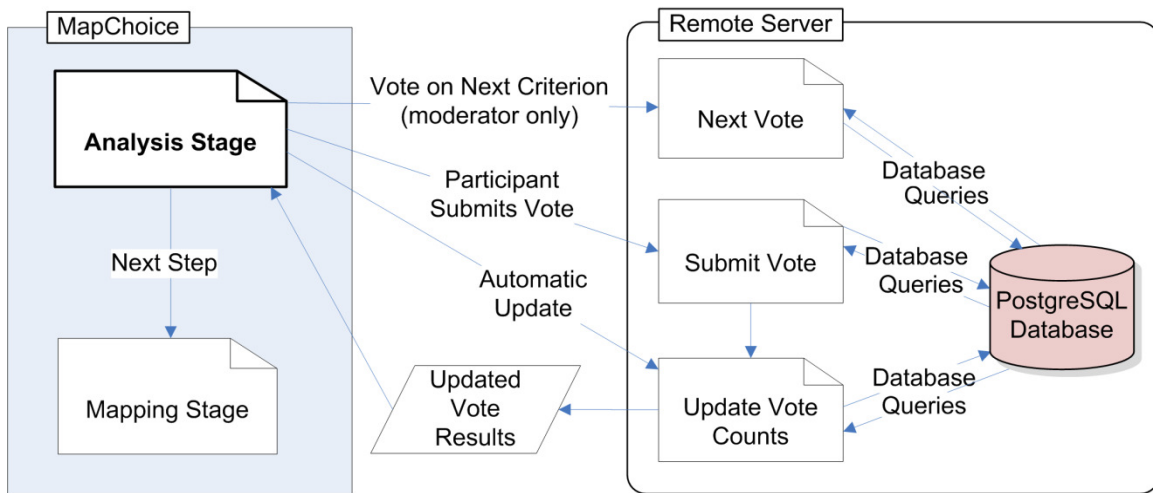


Figure 3.8 – Analysis stage in Group MapChoice

The database layout on the PostgreSQL server is discussed briefly in the next section.

3.5 Database Organisation

MapChoice requires a good deal of data to be stored in the database. The layout of the data in database tables is shown in Figure 3.9.

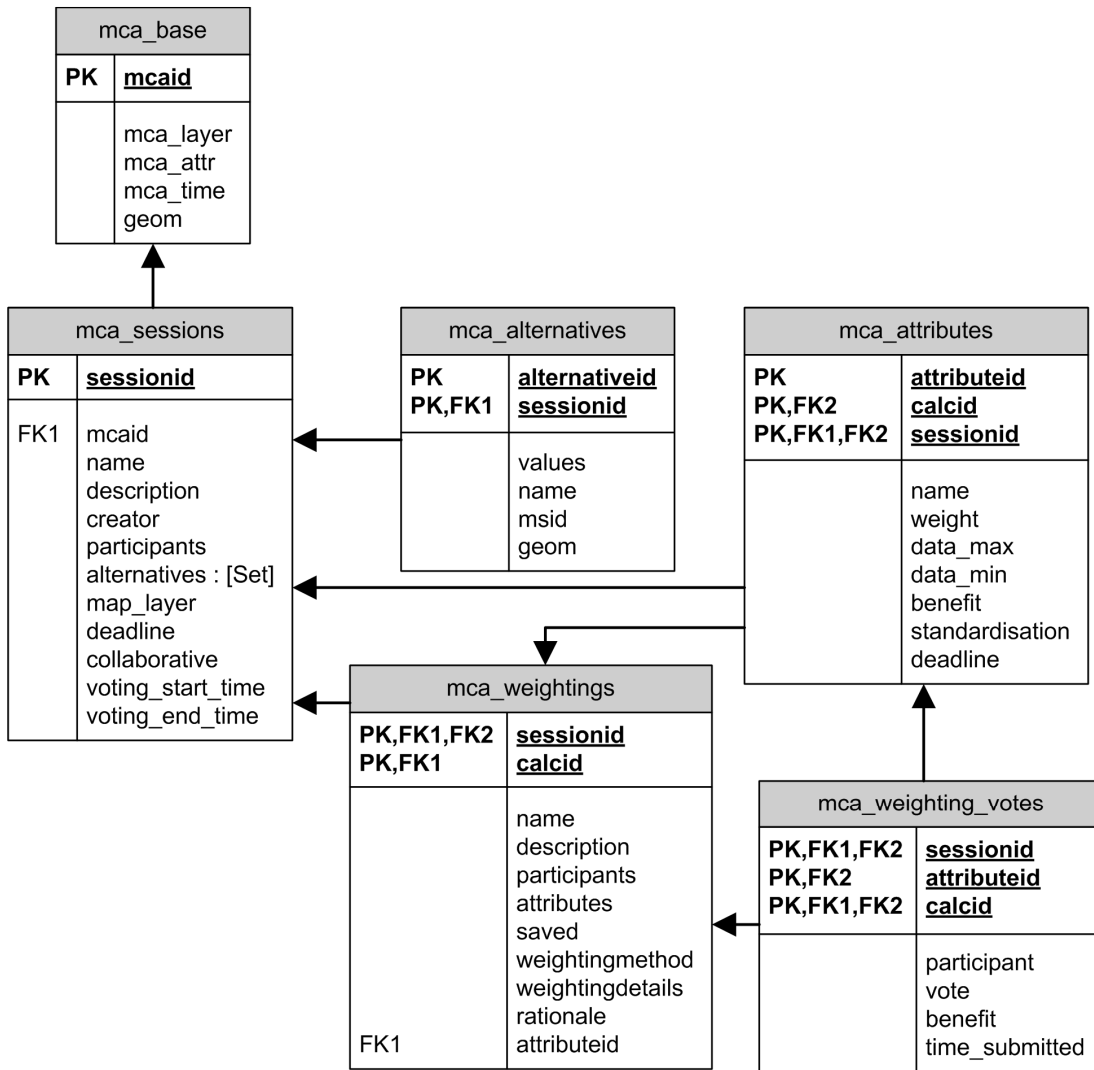


Figure 3.9 – MapChoice database schema

Altogether there are six tables used in MapChoice:

- mca_base
- mca_alternatives
- mca_attributes
- mca_sessions
- mca_weightings
- mca_weighting_votes

In MapChoice a session is defined as a collection of alternatives and criteria (optionally) generated by the users or moderator for a set of pre-established decision alternatives. In the databases *mca_sessions* contains information about the session, such as its creator, name, a description for the session, and the layer from which the alternatives are drawn. With the criteria and alternatives fixed during the

workshops, there is only one session for each participant with single-user MapChoice. Group MapChoice makes more use of this table, with a new session generated every time the moderator starts a collaborative weighting.

The *mca_base* table is a general repository for storing map features to be used in generating MCA sessions (by transferring them into *mca_alternatives* and *mca_attributes*). In earlier versions of the software it was possible for participants to select a custom subset of the set of decision alternatives using a separate MapChat widget. These features would then be written to *mca_base*, and sessions could be created based on the selected alternatives. However, the deployment version of the software left the alternatives fixed, with features loaded into *mca_base* only once by the moderator.

The *mca_alternatives* table stores alternatives along with the associated criterion values (for all criteria), and the spatial information associated with each alternatives. The *mca_attributes* table is where most of the MCA processing occurs. When a new session is created, default attributes are generated, containing some important information such as per-attribute maximum and minimum values across the alternatives in that session, and default weight and standardization settings. Then, when a new weighting is generated, all the criteria used in that weighting are saved to *mca_attributes* along with the updated weights and standardization values. Every weighting therefore has an associated set of attribute rows in the *mca_attributes* table, making it simple to load a saved weighting and calculate a ranking.

Each session may contain a number of weightings generated by the participant, stored at the user's explicit request when the weighting is saved or automatically when any weighting preference is changed. The *mca_weightings* table stores weighting-specific information such as the participant's name, the weighting's name and description, as well as what weighting method was used (MapChoice only used dropdowns in the final version, but other weighting models were available in earlier

versions), the weight values entered (used when later loading the weighting) and the rationale given to the weighting criteria. A weighting has a corresponding number of entries in the *mca_attributes* table.

Finally, the *mca_weighting_votes* table stores the per-criterion user votes in Group MapChoice.

Whenever a participant hits the “submit” button in Group MapChoice their choices of weight and benefit/cost settings are saved as an entry to this table, along with their name and time of submission.

Then when it comes to calculating the updated vote results for any criterion, only the latest votes from each participant are used.

Designing MapChoice necessitated some compromises, and the reasoning behind several of the most important development decisions is explained in the next section.

3.6 Issues Related to Design of MapChoice

Until now this chapter has been dedicated to presenting the software design and layout of MapChoice, and related components. This section discusses some of the design choices in more detail, particularly as they relate to decision-making concepts including weighting, standardisation, and combining the preferences of multiple users.

The biggest challenge in designing MapChoice was making it simple enough for users to learn quickly, but powerful enough to generate meaningful results. This was particularly crucial in the choice of an MCA decision rule and the method for choosing criterion weights. The goal, therefore, was to find the simplest MCA method that could still be considered rigorous. Weighted Linear Combination satisfied this requirement, particularly since it is the most popular MCA method in existing software packages (CommonGIS and ArcMap make heavy use of it), and it is used extensively in research (Malczewski, 2000; Malczewski, 2006). Its widespread acceptance suggests at least some degree of validity, and that people have fewer problems with it than with other more complex methods.

An important consideration in designing MapChoice was the method used to choose preference weights, as covered in Section 2.5.4. There is a good deal of diversity in these methods, including qualitative ratings, the accounting method and pairwise comparison.

Interestingly, research shows that different weighting methods yield about the same quality of results, and in fact the more complex methods such as pairwise comparison are not desirable because of the increased time requirements and higher degree of difficulty required for their use (Voogd 1983).

Complex methods can theoretically provide for more detailed or precise preferences, however such a degree of confidence can be hard to achieve when some criterion pairs are logically difficult to compare. It is simply not possible for participants to provide the kind of detailed responses that are best dealt with by these intensive methods, especially when the number of criteria is large. The accounting method is sufficiently simple and logical, but while it works well in single-user implementations, it cannot be readily adapted to group decision-making since it requires multiple “passes” of refinement until the weights have stabilized. In most implementations of the accounting method a change to one preference weight impacts the weights of all the other criteria, which would be confusing when sequentially stepping through criteria. Thus, the qualitative rating method using a seven-point scale was chosen for criterion weighting. It should be noted that pairwise comparison and the accounting method were coded into MapChoice, and an early version of the software allowed users to switch between the three weighting methods. However, these methods were subsequently removed from the interface in the interest of simplicity.

In the interest of simplicity, it was decided that MapChoice would use score range transformation (SRT) by default, and would not give participants the option to change the standardization function. Users can still choose whether a criterion is a benefit or a cost, and through this determine the direction of the SRT function, but intermediate points in the function are not modifiable. Performing a carefully-considered standardization on every criterion would consume a good deal of time in a

workshop – and risks alienating some participants - so removing the need for users to do this allows them to concentrate on the more important task of criterion weighting.

Malczewski makes a strong argument that users should be given full control over the standardization and weighting parameters in any MCA scenario, including value functions for standardization. MCA software should be transparent to the user and all settings should be customisable. Only this way could they perform a rigorous, “correct” weighting that reflects their own preferences for the alternatives under consideration. However, software designers must often make compromises when designing for non-experts, balancing sophistication with ease-of-use and simplicity. The intended audience for MapChoice is unlikely to have heard of MCA and less likely to understand fully its mechanics. Hence, complex details of MCA are not user-modifiable in MapChoice and are left at default settings instead.

On the other hand, relying on default values and methods runs the risk of making MapChoice seem like a “black box,” with the software design determining the end results without the knowledge of the participants. MapChoice does give some feedback to the user to help mitigate concerns over process transparency. The Data Table widget provides users with easy access to criterion values for the decision alternatives. The implemented SRT method depends on the maximum and minimum values for every criterion, and while users could not modify the standardization method, they could readily see the minimum and maximum values for each criterion. If the Data Table widget is insufficient, additional hardcopy documentation can be given to users, such as a handout with maximum, minimum, and average values for all the criteria, or even distribution graphs of criterion values.

Group MapChoice relies on a voting method to combine multiple participant votes into a single weight and benefit/cost rating. Many voting techniques can be found in the literature (Hwang and Lin, 1987) as discussed in Section 2.7.1. A simple method was chosen to implement in MapChoice: user votes are in the 0-7 scale, and the software calculates the average weight from the submitted votes. Determining a benefit/cost value is slightly more complex. If a majority votes “benefit”, the criterion

is a benefit. If a majority votes “cost”, the criterion is a cost. If there is a tie, the moderator’s vote is a tiebreaker. With this approach it is easier for users to consider one criterion at a time instead of many, so users are encouraged to discuss and find some level of compromise on each criterion as it comes up for voting. By averaging weights, this method also tends towards moderate scores while smoothing out extreme values.

This method can be highly sensitive when dealing with benefits and costs. If a similar proportion of users vote a criterion to be a benefit as a cost, only a small change in votes towards one direction could “flip” the criterion. Accurately and fairly aggregating multiple weighting preferences into one weighting schema remains an open research question. In this thesis the question remains unanswered and several methods of producing a “group ranking” are considered in Chapter 5.

3.7 Summary

This chapter summarises the architecture and database design of MapChoice, its logical flow and the commonalities between single-user MapChoice and Group MapChoice. Finally, since the software straddles a fine line between user-friendliness and technical rigour, some of the more critical design decisions were justified in more detail.

MapChoice was designed as a generic tool, but for this thesis it was applied to a specific real-world problem in Collingwood, Ontario. The town has been facing a severe shortage of affordable housing, and a citizen group was contacted to participate in a workshop exploring the problem. The next chapter outlines the case study, the extent of the housing problem, and explains how the workshop was designed to permit several participants to use MapChoice to compare possible locations for affordable housing.

Chapter 4 - Case Study and Research Design

To examine the research question asked by this thesis, the software was applied to a real-world decision making problem in the Town of Collingwood, Ontario. A case study was undertaken in Collingwood with a group of volunteers affiliated with the Simcoe County Alliance to End Homelessness, a citizen group involved with the issue of affordable housing. The group participated in a workshop assessing proposed affordable housing sites using MapChoice.

This chapter describes the organisation of the case study, beginning with the background and circumstances of Collingwood in Section 4.1. The problem of siting affordable housing from a planning standpoint is then explored in more depth in Section 4.2, including a clarification of the term “affordable housing”. Next, the research design is outlined in Section 4.3, followed by the outline of the workshop in Section 4.4 and the exit survey given to the participants in Section 4.5.

4.1 Study Area

The Town of Collingwood is situated on the southern shore of Georgian Bay in central Ontario and is approximately a 2 hour drive from the major urban centre of Toronto and 15 minutes’ drive from the largest freshwater beach in the world at Wasaga Beach (Figure 4.1).

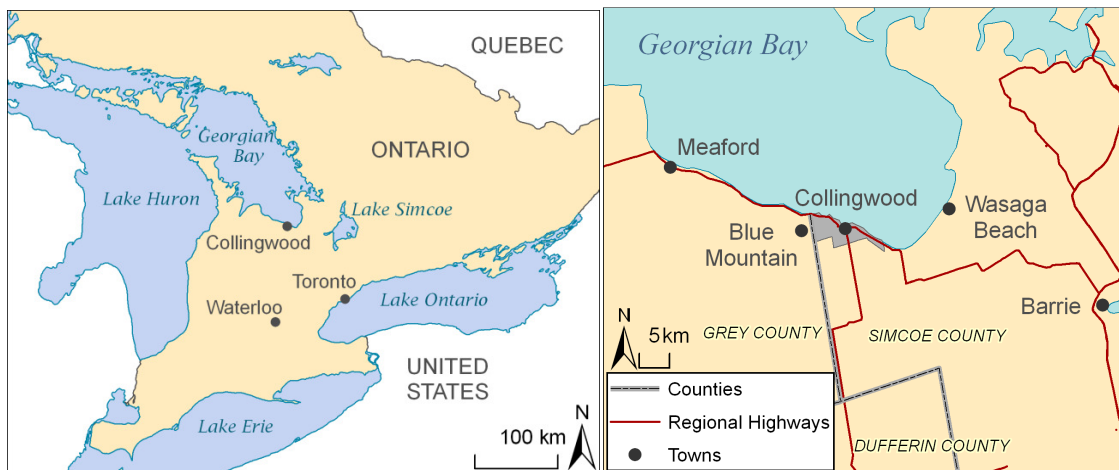


Figure 4.1 – (a) Collingwood in Ontario, (b) Collingwood and the surrounding region

Collingwood was incorporated in 1858 and in its first century it was a small, working-class town defined by its shipbuilding industry. In the last few decades the Town has experienced growth thanks to a tourism boom related to both waterfront recreation and development and the nearby Blue Mountain ski resort. Its population has burgeoned and an influx of wealthy residents has led to an increase in property values and a corresponding shortage of affordable housing (Doors Open Collingwood, 2008; Pullen, 2005; Town of Collingwood, 2005). Some of the residents employed in the growing tourism industry are having difficulty dealing with housing costs and the Town is beginning to take action to deal with the affordable housing problem.

4.1.1 Growth and Demographics

From 1991 to 2006, the Town’s permanent population increased nearly 30%, from 13,505 to 17,290 (Statistics Canada, 2008). These numbers do not include non-permanent residents, weekend-only visitors or second-home owners which swell the Town’s population by some 5,000 in the peak winter and summer seasons (Pullen, 2005; Town of Collingwood, 2005). Most of the population growth has been in the 45+ age range, while the younger working-age population has remained relatively stable (Figure 4.2). The Town is expecting growth to a permanent population of over 24,000 by the year 2021 (Town of Collingwood, 2005).

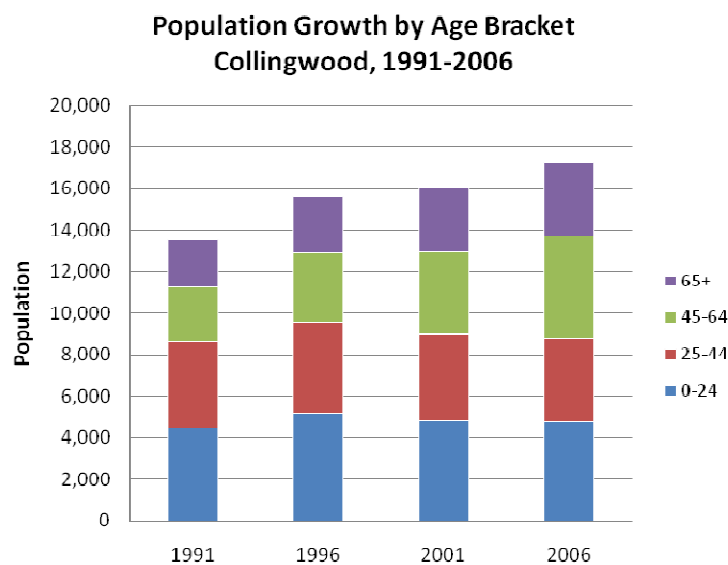


Figure 4.2 – Population growth, 1991-2006 (Source: Statistics Canada, 2008)

As is typical of other attractive tourist towns, the growth in Collingwood in the 45 and older age cohort is not due solely to a natural aging of the population, but rather an influx of seniors and near-retirement-age baby boomers moving to a quiet but active semi-rural lifestyle (Dahms and McComb, 1999). Many of the new residents have come from the nearby Toronto area, having visited and spent time in Collingwood in years past (Curto, 2006; Pullen, 2005). The new residents are mostly in the higher income brackets, and the one income group experiencing the most population growth is households with over \$100,000 in combined income (Figure 4.3). For this demographic group, the cost of living in Collingwood is comparatively much lower than in much of Toronto, with a better availability of lower-priced properties and a perceived higher quality of life (Dahms and McComb, 1999). The population with less than \$70,000 a year of household income barely changed in number over the 1991-2006 period.

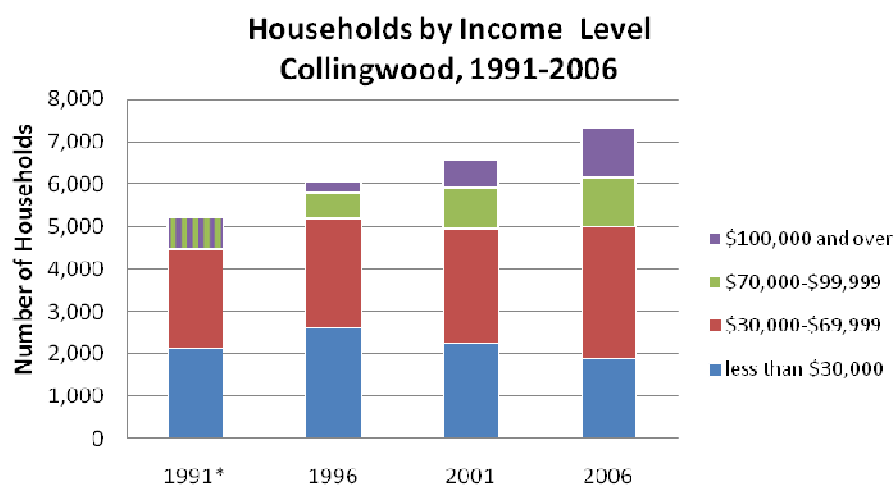


Figure 4.3 – Number of households by gross income (Source: Statistics Canada 2008)

*Note that in 1991 the \$70,000+ income group includes the \$100,000+ category

4.1.2 Economy

From 1883 to 1986, Collingwood’s industry was focused on the Collingwood Shipyards, the largest employer in the Town’s early years (Town of Collingwood, 2005). The shipyards are now closed and the site is the location of a new luxury condominium project. Other major industrial employers, such as an Alcoa wheel manufacturing plant and a Goodyear tire plant, have shuttered their Collingwood

operations recently. A handful of manufacturing and heavy industries remain active, including the Pilkington Glass works.

Tourism is now the dominant sector in Collingwood, driven by golf and boating in the summer and skiing in the winter. The Blue Mountain ski resort, located next to Collingwood in the Town of the Blue Mountains, was locally owned until 1999, when it was purchased by Intrawest Corp. It has since blossomed into an international attraction that employs over 2000 people, of which up to 1700 are seasonal employees. The popularity of the resort has had spill-over effects in the community, including spurring development of new leisure residences, marinas, golf courses, and other planned resorts (Pullen, 2005).

While tourism generates employment prospects and other economic benefits to the Collingwood economy, there are also downsides to the reliance on this sector. Whereas manufacturing provided stable full-time employment with benefits and unionised wages, many jobs in the tourism sector are part-time, seasonal, and offer relatively low pay. The susceptibility of the ski industry to changing weather conditions exacerbates these characteristics, as was the case in the winter of 2007 when unseasonably warm weather prompted Blue Mountain to temporarily lay off 1300 employees (McLaughlin, 2007). The loss of middle-class manufacturing jobs and replacement by service-industry employment is exemplified by Figure 4.4. As the recession of the mid-1990s came to an end, manufacturing grew substantially, but in the 2000s these jobs were replaced by service employment.

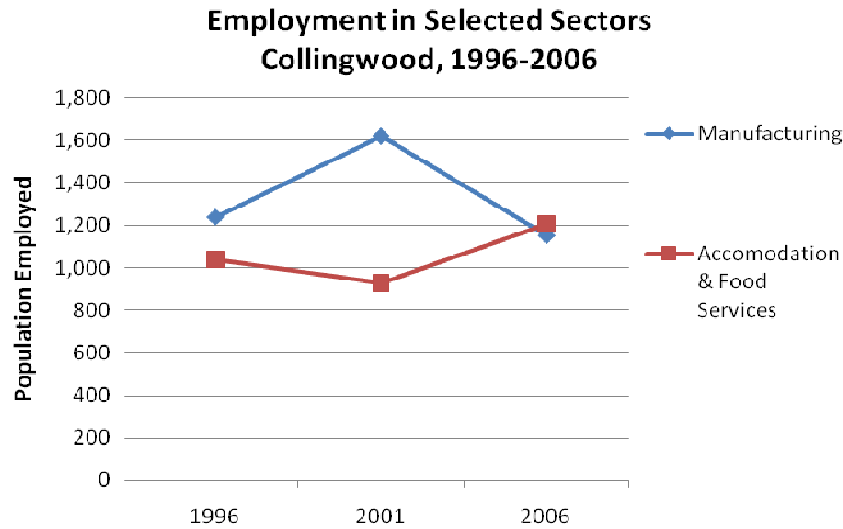


Figure 4.4 – Employment in selected sectors, 1996-2006 (Source: Statistics Canada)

A loss of blue-collar employment in manufacturing and resource industries is typical of many tourism towns and this effect has been studied in places as varied as Arizona, Idaho, and Rhode Island (Davis and Morais, 2004; Di Stefano, 2004; Krausse, 1995). While the overall economy prospers, a growing disparity between the lower and higher income classes can lead to increased friction and resentment and can be a barrier to dealing successfully with the problems facing these towns. The working class is strained by increases in the cost of living, from food, rent, and even property taxes. Further, the unstable nature of service industry employment can be especially harmful to the poorer residents with children. Workers with unstable incomes tend to spend a high proportion of their income on housing. Further, the seasonal nature of their incomes may force them to move frequently, which tends to depress their children’s quality of education and health (Mueller and Tighe, 2007). While some in these tourism communities may share a concern about the social well-being of their fellow citizens, it is not uncommon for the new residents to be unresponsive to such worries and for the local development councils to be more preoccupied with maintaining development and growth (Ryan and Montgomery, 1994).

Some tourism resorts have special plans for dealing with temporary service workers including on-site apartments or rooms for board rented out at reduced rate (Di Stefano, 2004; Gill and Williams, 1994).

Blue Mountain has not done this, and due to the high cost of living in Collingwood or the very small Town of the Blue Mountains, many employees are forced to commute from other distant, cheaper communities.

4.1.3 Real Estate

With a wave of wealthy newcomers to the Town, real estate prices have increased and Collingwood is experiencing a sharp upturn in property values. In 1996, the average home was valued at \$144,074, whereas the national average was \$147,877. By 2007, the average sale price had increased to \$246,500, compared to the Canadian average of \$231,595 (Georgian Triangle Housing Resource Centre, 2007; Statistics Canada, 2008).

The rental market is similarly affected. With a vacancy rate of only 2.6% compared to a national average of 3.7% (Canadian Mortgage Housing Corporation, 2007), the average rental price for a 1-bedroom apartment was \$688 per month. This is substantially higher than the national average of \$636. Even a single room cost \$425 per month (Georgian Triangle Housing Resource Centre, 2007).

4.1.4 The Affordable Housing Crunch

Together, the three forces of population growth, economic change and the brisk local real estate market have created an acute shortage of affordable housing for the lower income population of Collingwood (Avery, 2006). The Georgian Triangle Housing Research Centre (GTHRC) is a regional agency created to help people in their search for housing. It has compiled some disturbing statistics on the extent of the problem. In 2007, the Centre registered over 600 individuals searching for housing in Collingwood and an additional 400 registered in the smaller surrounding communities. With an average household income of only \$1,418 per month, these people are particularly vulnerable to high housing costs, as shown by the fact that 24% of the registered households are officially listed as homeless (Georgian Triangle Housing Resource Centre, 2008). The Simcoe County Housing

Corporation, which handles the region's subsidized housing, had a waiting list of over 460 persons by the end of 2007 and a wait time of 3 years for families (Simcoe County Housing Corporation, 2008).

The slow pace of affordable housing development in Collingwood contributes to the problem. At this time, few affordable units are available in the Town. Most of the existing supply was built decades ago (Noble, 2007) and there are perceptions the Town is more interested in luring new wealthy residents than dealing with the housing shortage and spiraling costs faced by local service workers (Pullen, 2005). Collingwood had only 235 units of county-operated subsidized housing in its housing stock as of 2008 (Simcoe County Housing Corporation, 2008). Community organisations and groups have attempted to meet the shortage, beginning with the foundation of the GTHRC with government help in 2001. In addition to maintaining a registry of affordable rental units, it advocates affordable housing issues (Access to Housing, 2008). The Town Council recognized the urgency of the issue by approving the creation of an Affordable Housing Task Force (AHTF) in 2007, which includes city planning advisors, community representatives, and affordable housing experts, that has a mandate to research pending proposals to the Council and actively seek out new sites (Town of Collingwood, 2007a). The Simcoe County Alliance to End Homelessness (SCATEH) is a related umbrella group that includes some members of the GTHRC and AHTF, and was created to bring more attention to the shortage of available housing in Collingwood and neighbouring communities.

In the last several years, a few attempts have been made to restart the debate over affordable housing and to search for new locations for a project. The first new affordable housing project of the new millennium was proposed in 2005 when a site that had been designated for a higher-density affordable development for years was approved for a new 54-unit complex. However, the site had lain dormant for years and the community had begun to use it for little-league soccer. When word of the project reached the public, a massive outcry (including petitions from over 1200 citizens) convinced Town Council to scuttle the proposal (Edwards, 2007a). In 2006, the site was rezoned to recreational (Town of Collingwood, 2006). Hence, while the problem is recognized in the Town as being important, there

are also local interests actively opposing affordable housing. In this respect, the issue is well suited to tools such as MapChat and MapChoice as there are divergent opinions that can be encapsulated through a multi-participant approach to assessing the problem.

Shortly after the research for this thesis was completed in Collingwood, another proposal for rehabilitating a vacant hotel near the downtown to 12 affordable housing units was similarly cancelled due to citizen concerns, particularly over increased traffic, parked cars, and “undesirable” residents. Even though it had even been awarded a grant of \$1.26 million from the Federal-Provincial housing agency (Ministry of Municipal Affairs and Housing, 2007), the site was leased for \$2 per year to a community theatre group by the Town Council (Edwards, 2007b; Town of Collingwood, 2007b). In October 2007, an 18-unit development in a vacant suburban lot was granted approval (Collingwood Living, 2007). As of writing, it appears to have passed the Planning Department, having been increased in size to 30 units (Town of Collingwood, 2008).

It seems some change is starting to take place. Thirty new units is an encouraging sign of commitment to relieving at least part of the affordable housing crisis, but it is far short of what is needed. The next section delves deeper into the meaning of affordable housing as a social welfare and planning problem.

4.2 Affordable Housing as a Multi-Participant Site Selection and Evaluation

Problem

4.2.1 What is Affordable Housing?

Affordable housing is an intuitively obvious but rather vague term that requires clarification. The literature commonly links the definition to a cut-off value of household income, namely “the generally accepted definition of affordability is for a household to pay no more than 30 percent of its annual

income on housing” (US Department of Housing and Urban Development, 2008). The Canadian and Ontario governments define it more specifically as:

“Affordable Housing” means housing which is modest in terms of floor area and amenities, based on household needs and community norms, and is priced at or below average market rents or selling prices for comparable housing in a community or area at levels affordable to agreed upon target groups who are on or are eligible to be on social housing waiting lists.” (Canadian Mortgage Housing Corporation, 2003, p. 2)

This definition demonstrates the breadth of the issue and suggests that strategies to deal with housing affordability potentially have many solutions. Supply-side programs include state-sponsored projects and housing developments, incentives for private developers to build affordable housing, and partnerships with groups dedicated to maintaining affordable housing (Carter, 1997). Resident-focused solutions range from tenant relocation, rent subsidies, and rent-g geared-to-income programs.

4.2.2 The Stakeholders in Affordable Housing

Concern with the provision of affordable housing for all members of society truly blossomed following World War II, with the rise of the social safety net. The early Canadian solution, like elsewhere around the world, was a combination of direct support for new housing construction, often in the form of fixed-rate subsidized mortgages for the construction of large-scale tenements, alongside rent assistance for challenged residents (Carter, 1997; Dreier and Hulchanski, 1993). Public resentment against such concentrated projects and budget cutbacks to public housing agencies have led to a diversification of strategies more recently.

Today the Federal, Provincial, and many Local governments maintain their existing stock of public housing, while retaining a diminished role in new construction. Instead, there are a variety of support programs through the Canadian Mortgage Housing Corporation meant to encourage private developers and particularly the non-profit/cooperative sector to build new affordable housing, with the government playing the part of regulator. Projects now come under many guises, from the provision of some affordable units within larger condominium or townhouse developments, mixed-use

developments combining live-work spaces and commercial ventures, and detached single-family homes (Canadian Mortgage Housing Corporation, 1999; Schwartz, 1999). Redevelopment of existing sites is being encouraged as well through subsidies for conversions and renovations of existing properties to accommodate more rental units (such as basement apartments), and preferential treatment for projects on brownfield sites or infill locations.

Additional government support goes to small-scale local non-profit developers building modest projects with the help of direct subsidies, fast-tracking of regulatory approval processes, and mortgage insurance and underwriting (Carter, 1997). Renter assistance still exists, particularly in the form of rent-geared-to-income housing, where the rent varies according to the earning capacity of the renter.

As a result of the decentralization and market focus of recent affordable housing programs, many parties have a stake in affordable housing, particularly compared to for-profit housing. The Federal and Provincial governments still retain their influence, but local and regional governments are now becoming involved too, handling site selection, zoning, and dealing with community concerns. In Toronto, a municipal agency oversees the operation of all public housing, providing homes for 160,000 tenants with a budget of over \$500 million (Toronto Community Housing, 2008). Planners and the local agencies entrusted with enforcing the regulatory framework have a role to play, streamlining the applications of affordable housing developments or stalling them endlessly. As direct representatives to their constituents, elected political representatives such as town councillors, mayors, and members of parliament also hold a key stake.

Non-profit and charitable organisations have emerged as critical players in housing supply and management, as they are involved in housing advocacy and political activism, and also in the construction and operation of housing (Dreier and Hulchanski, 1993). Many housing projects built since the 1970s are organised as co-operatives. Habitat for Humanity, a US-based non-profit organisation that builds homes for families in need using donated materials and volunteer labour

(Habitat for Humanity, 2007) has erected three houses in Collingwood for needy families (Habitat for Humanity South Georgian Bay, 2006). Another non-profit organisation, Options for Homes, has a business model closer to for-profit developers, selling low-cost no-frills units with special, protective financing for lower-income buyers (Options for Homes, 2008). They have attempted to join a project in Collingwood, but are still searching for a viable site (Town of Collingwood, 2007c). Other community groups, like the GTHRC, AHTF, and SCATEH, lobby on behalf of affordable housing, or provide support services for those residents searching for housing in a neighbourhood.

Another stakeholder group that should be mentioned is the public itself. Affordable housing policy must often pass scrutiny in the court of public opinion, and public opposition can easily scuttle housing initiatives. Public desires for more affordable housing can turn to opposition when faced with the prospect of locating projects in their neighbourhood, due to “Not In My Back Yard” (NIMBY) worries such as decreased property values, traffic congestion, perceived safety or crime problems, or an aversion to social undesirables (Martineau, 1998). Engaging the public helps in allaying community concerns, demonstrating to residents the government is not forcing through an undesirable development but responding to real community needs (Ontario Professional Planners Institute, 2001).

One group that can be overlooked in this discussion is the potential affordable housing residents. Their needs, desires and fears are easily ignored in the debate between politics and social conscience. Some studies have shown that fears of ostracism from the surrounding community can influence their decisions on where to move, and once affordable housing has been built in a neighbourhood, antipathy from existing residents can be a burden requiring ongoing support for successful integration into the community (Stauffer-Kuhn, 2006).

4.2.3 Spatial Dimension of Affordable Housing Site Selection and Evaluation

Building successful affordable housing requires much more than mere affordability. Other considerations include the size of the site, proximity to public transit, schools, grocery stores,

community centres, churches, and other urban services, and the likelihood that the development could become ghettoized. The spatial dimension can be as important as other issues such as building type and tenant mix. Location not only determines whether housing can be built at a particular site (*e.g.* whether zoning is appropriate or if a site is serviced with utilities) but location can be used in discriminating between proposed sites. For example, depending on the planners' set of criteria a well-planned affordable housing development could be located close to amenities required by the disadvantaged, such as public transit and inexpensive retail, or it could be placed within a quiet well-to-do suburb.

The spatial criteria for locating affordable housing can be further divided into residents' needs and the needs and concerns of the surrounding community. For example, residents might need a location near public transit with access to schools and grocery stores and well-served by emergency services. Planners may want to locate affordable housing in an area where the housing development would be successful, but also where the surrounding neighbourhood could accept the project. Clustering of poverty and crime in and around affordable housing remains a topic of discussion in the literature (Holloway et al, 1998). Although recent research shows that the "ghettoisation" of neighbourhoods as a result of an affordable housing development is largely a myth (Freeman, 2003), placing a development in a middle to upper income area can provoke backlash from established residents concerned about property values, especially if they have extensive legal or political resources at their disposal (Martineau, 1998). Alternatively, it may be desirable to locate a new project in a poor region to revitalize the area and spur community regeneration (Brown et al, 2004).

With these concerns in mind, the literature suggests several criteria to include in the Collingwood analysis (Cartwright, 2007; Freeman, 2003; Johnson, 2005; Johnson, 2006; Johnson, 2007; Mueller and Tighe, 2007; Schwartz, 1999). The next several paragraphs are dedicated to exploring some of the insights for this thesis that have been developed from their conclusions.

One common criterion is neighbourhood income, with the understanding that locating housing for low-income residents in an affluent neighbourhood greatly improves the quality of life of the housing residents. At the same time, this criterion can work in the opposite direction since an affluent neighbourhood association may be able to block the development as has happened before in Collingwood. A similar criterion is land cost which is most easily measured through property values. Agencies with limited resources for affordable housing may be more sensitive to property values as a component of overall project costs than to median neighbourhood socio-economic levels.

Population density can be important in several ways. From a planning standpoint, affordable housing is more economical when built as higher-density, and such buildings may fit better in neighbourhoods that already contain other medium- and high-density buildings than in others. As well, a higher population density can suggest more neighbourhood life, helping the residents integrate better, and better absorbing the impacts of a new project. Low-density neighbourhoods may be more likely to object to a large high-density building placed in their neighbourhood.

Education is also important to the success of affordable housing. The literature suggests that housing has more of an influence on the education outcomes of its residents, rather than the education levels in a neighbourhood having an influence on housing. Unfortunately education quality is complex to measure, requiring extensive data (such as school catchment boundaries) that are difficult to procure. However, education was included in this research because it can influence accessibility to schooling, particularly if residents without access to a car are located far away from schools (Timperio et al, 2006).

Affordable housing has been linked to its effect on neighbourhood crime rates. While crime statistics were unavailable in Collingwood, a proxy can be the distance from the police station, with the assumption that crime is lower near the police station. Similarly, there are links between affordable housing and health status, which can be quantified in terms of accessibility to health services.

Since affordable housing residents are less likely to own a car (Turcotte, 2006), the location of housing is especially important. It is useful to locate the housing within walking distance to amenities, such as grocery stores or retail centres, such as a town's business district or downtown core. If that is not possible, ready access to reliable public transportation can be a feasible if less convenient substitute.

Unemployment rates can also be considered as a criterion. Housing can be located in areas with low unemployment under the assumption that those neighbourhoods are healthy and can provide job opportunities. Conversely, housing could be located in areas with high unemployment, since those people would be in higher need of less expensive housing options, and since housing construction can be an additional source of employment.

Given the housing issues facing Collingwood, and considering the complex nature of locating affordable housing, two related workshops were held in the Town with a small community group interested in promoting more affordable housing development. The next section describes the workshops with particular attention being directed at the second workshop which focused on MapChoice.

4.3 Research Design

Collingwood already had a planning process to deal with the affordable housing problem, and this was progressing at its own pace. This research was conducted in parallel with the official planning process. It was designed to provide SCATEH members with an opportunity to apply their knowledge of the community's affordable housing situation in an experimental computer-based environment. Future work in this area could explore tighter coupling with existing participatory processes in planning, as discussed in Chapter 6.

An initial workshop was held on April 30th, 2007 in Collingwood, as detailed by Noble (2007) with a total of 10 participants from SCATEH, the Simcoe County Board of Education and from the surrounding community. Each participant was taught how to use the MapChat tool and then charged with identifying land parcels or user-defined areas that they believed to be potentially good sites for affordable housing in Collingwood. After the conclusion of the workshop, users were then given the opportunity to justify their comments or continue the discussion further by logging in to the discussion via the Internet. This different-time, different-place communication mode allowed them to contribute input at their leisure over the span of a week.

The second workshop, analysed in this study, was held on July 2nd 2007 with four members of SCATEH, although the entire group was invited to attend. In this workshop the sites identified in the first workshop were compared and evaluated using the MapChoice tool.

4.3.1 Selection of Participants

In the fall of 2006 contact was initiated with the SCATEH group and they agreed to participate in a project to identify and evaluate potential affordable housing sites using the software described in Chapter 3 (Noble, 2007). The SCATEH and AHTF groups had focused their efforts on advocating for affordable housing and managing projects as they came up. They were receptive to the idea of using collaborative GIS techniques to address their problem.

It was decided that having members from the SCATEH take part in the workshops would be the most viable option available. At the time they were already due to participate in the first workshop, and therefore would have a baseline level of experience with MapChat. The SCATEH members did not have the level of training of professional planners, and so more closely approximated the average citizen participant than an expert in the field. Moreover, members of SCATEH are all involved with the affordable housing debate within the community in various capacities, ranging from concerned citizens to employed positions in social housing agencies, making them knowledgeable about the

issue. The cost and additional time required to attract a qualified set of participants from the general population made that option less suitable than working in cooperation with an existing advocacy group with experience around affordable housing.

The SCATEH group members are from a variety of backgrounds, ranging from retirees to young professionals in their 30s. The group numbers between 12 and 15 regular members. Although they all share a goal of advancing the cause of affordable housing, their varied personal experiences and motivations meant that their approaches could be expected to differ somewhat. As well, members in the group have a basic knowledge of computers and some familiarity with simple mapping applications like Google Maps, along with an eagerness to learn the computer-based tools.

4.3.2 Choosing the Sites

The end result of the first workshop was a set of proposed affordable housing sites in the Town. Interestingly, the group had never considered searching the entire Town for suitable housing sites. Their approach was more involved in policy initiatives than an explicitly spatial, location-specific approach.

As can be seen in Figure 4.5, the set of all participant selections in the first workshop was extensive, including a good deal of spurious selections. This was reduced to a workable set for the second workshop.

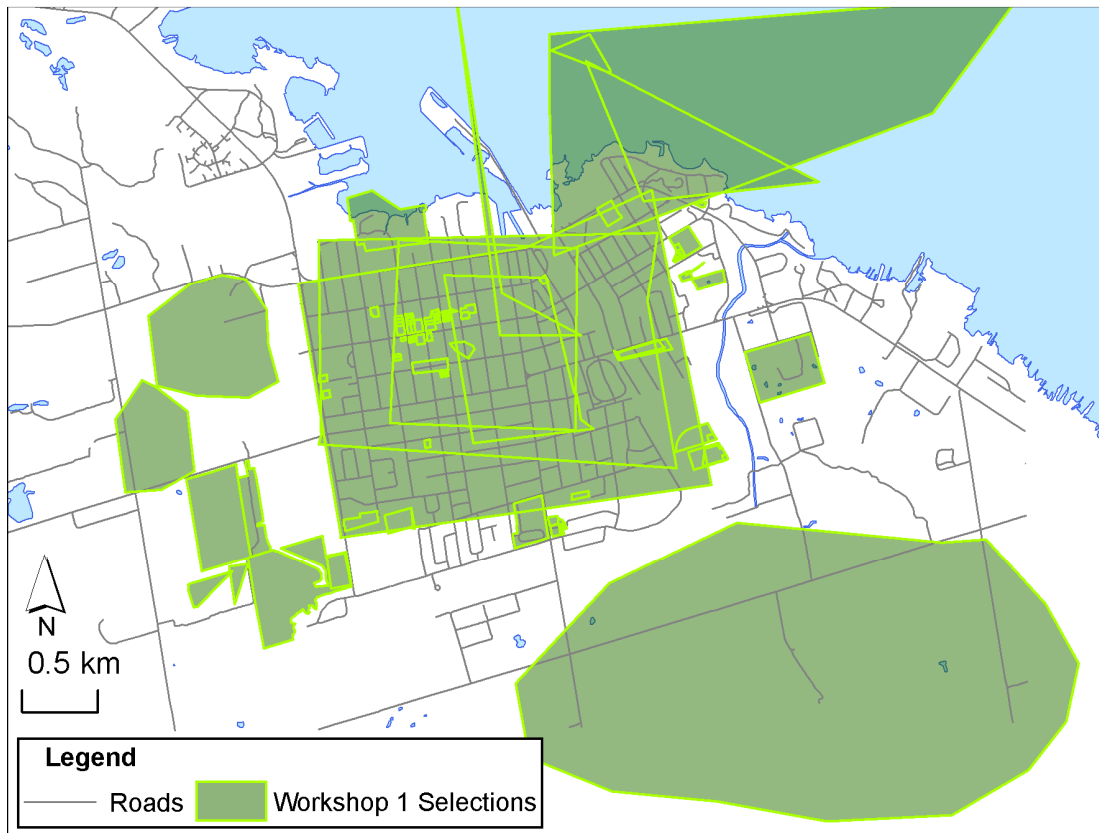


Figure 4.5 - All selections from first workshop

During the first workshop, users were asked to link comments to the sites they had selected, to give some explanation for why they felt those sites were useful or relevant (Noble, 2007). The majority of the sites with comments were considered as potential sites for evaluation in MapChoice. Some additional data processing was required to eliminate sites that did not have comments, to aggregate adjacent parcels that were considered a single site and to remove erroneous selections made in the first workshop.

The process of filtering out acceptable selections was partly subjective. In some cases, it was easy to recognize where a user had selected a number of sites without making any comments, especially when this was done in front of the researchers in the first workshop. In other cases, the non-commented parcels were specifically selected on their own, in which case they were retained as proposed sites. On another occasion the participant had selected directly adjacent residential parcels at the same time, so the three sites were merged to a single large parcel. The extremely large selections comprising

hundreds of property parcels were discounted as spurious. Some of the selections on the far western part of the Town were on the locations of established industrial or commercial enterprises, such as a Goodyear tire factory that was active at the time of the workshop and a regional shopping centre, and these sites were also removed.

One site in the south-west corner was comprised of a large property with road frontage that was separated from an active agricultural plot by a protected creek. Since the area surrounding the creek was assumed to be undevelopable the agricultural portion of the parcel was not used in the analysis. After the selection filtering process was completed, 24 parcels remained as potential sites (alternatives) in the MapChoice workshop (see Figure 4.6). These were the sites the users saw when starting MapChoice in the workshop.

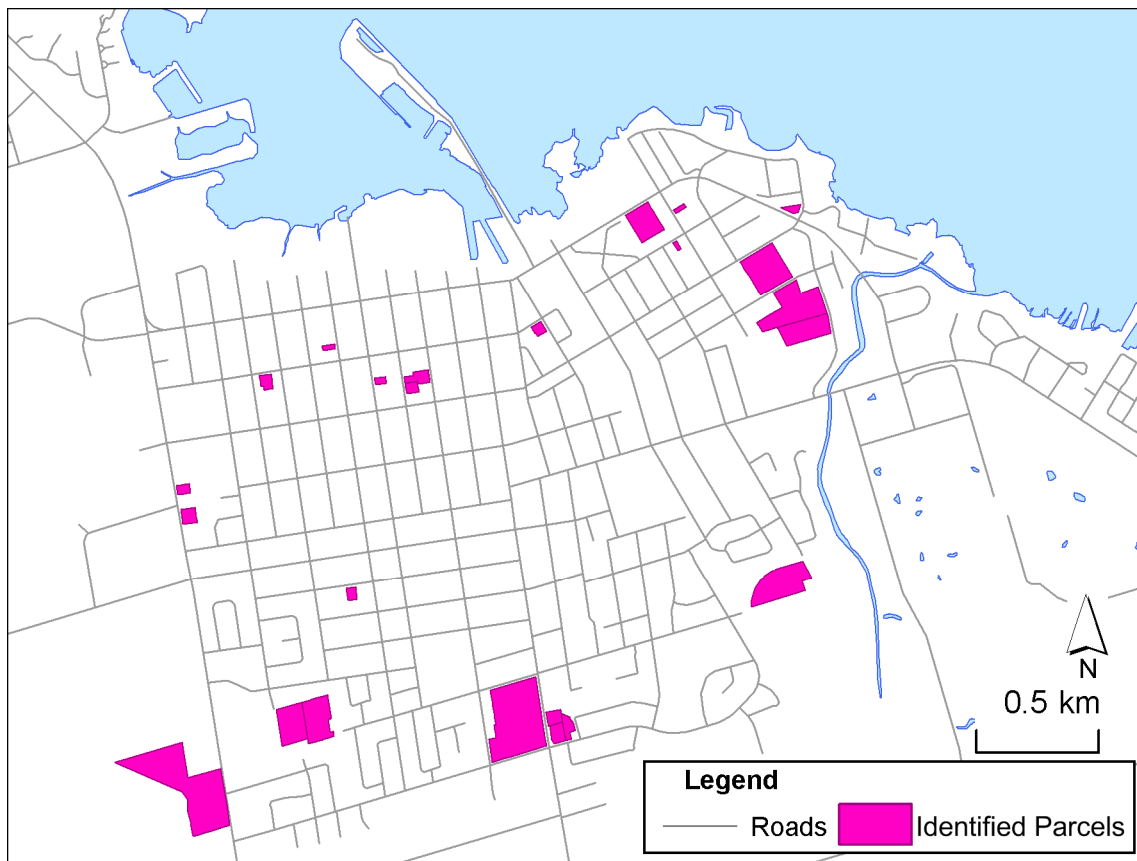


Figure 4.6 - Final set of proposed affordable housing sites

4.3.3 Criteria

To perform an MCA of the final selected parcels, the decision alternatives require associated criteria. During the first workshop, the researchers provided the participants with a list of suggested criteria that was compiled from the affordable housing literature and expectations of available data (Table 4.1). The participants suggested two additional criteria, namely site ownership (availability of parcels), and a list of open affordable housing applications. Most of these criteria were retained for the second workshop, while others could not be obtained or could only be included through proxy variables. The final criteria used are described in the next section, and some maps generated in ESRI ArcMap show the criterion distributions over the study area.

Site Characteristics	Neighbourhood Characteristics	Proximity
Size	Average property values	Grocery stores
Zoning	Demographic characteristics	Town core
Brownfield location (Ontario Brownfields Initiative)	Age	Schools
Number of units possible	Income	Churches
Estimated cost per unit	Employment	Bus routes
	Population density	

Table 4.1 – Criteria proposed by researchers

4.3.4 Selection of Criteria

A relatively extensive dataset supplied by the Town of Collingwood was used in tandem with the 2001 Canadian Census to calculate the criterion values for the proposed sites. At the time of the workshop, the 2006 Census results had not been made available which was unfortunate as many indicators such as property values had changed significantly in the intervening five years. In addition, a set of proximity-based criteria were generated from the Census and Town data sets.

Table 4.2 provides a summary of all of the criteria that were used in the second workshop. Not all criteria were used for the actual MCA analysis, owing to having too little variation in values between the proposed sites, or else just overall low importance in the analysis. Some criteria values were calculated at the site level, having location-specific information (for example, the distance to grocery

stores can be calculated precisely). Others were neighbourhood variables, calculated more generally by averaging aggregated statistics over entire neighbourhoods. The variable names were constrained to ten characters by the MapServer software, so a brief description is also included.

Name	Description	Type	Minimum	Maximum	Average	Data Source
Area_HA	The area of the parcel in hectares.	Site	0.064 ha	6.754 ha	1.268 ha	Collingwood
Ave_HH_Val	Estimated average dwelling value	Neighbourhood	\$127,895	\$180,363	\$151,372	2001 Census
Dens_Pop	Population density in persons per square kilometre.	Neighbourhood	621	2914	1459	2001 Census
Dist_Bus	Calculated straight line distance to the nearest bus line (not bus stops)	Proximity	30m	661m	122m	Collingwood
Dist_Core	Calculated straight line distance to the downtown core area as defined by the Collingwood Planning Dept.	Proximity	0m	1981m	785m	Collingwood
Dist_Emerg	Calculated straight line distance to the nearest police, fire or ambulance station	Proximity	195m	2600m	1062m	Collingwood
Dist_Groc	Calculated straight line distance to the nearest major grocery store	Proximity	315m	1951m	1013m	Collingwood
Dist_Schl	Calculated straight line distance to the nearest elementary school.	Proximity	106m	1032m	559m	Collingwood
HHH_Inc_30	Percentage of households spending over 30% of their income on rent or mortgage	Neighbourhood	18.7%	34%	29.4%	2001 Census
Rate_65	Percent of residents over 65 years of age.	Neighbourhood	12.7%	19.5%	16.6%	2001 Census
Rate_Unemp	Unemployment rate	Neighbourhood	4.3%	11.5%	6.5%	2001 Census
Zone_Res	Indicates if a parcel is zoned as a high- or medium-density residential. A value of 1 = Yes, 0 indicates No.	Site	1	0		Collingwood

Table 4.2 – Criteria used in MapChoice workshop

Nine criteria were calculated from the 2001 census including average dwelling value, population density, the proportion of households spending over 30% of their household income on housing, proportion of the population between the ages of 0 and 15 (also 65 and over, and between 0 and 18, because it had a different distribution from 0-15), proportion of residents moving or migrating in the previous five years, and the unemployment rate.

The values for all census-based criteria were based on Dissemination Area (DA) level variables since they are closer to “neighbourhoods” in size than census tracts. In Collingwood, DAs ranged from about 350 to 1100 people or approximately 250-400 households. For each DA the centroid was calculated as the geometric centre of the DA (Figure 4.7), except for one DA in the south-west part of the Town where the centroid was moved closer to the only area with any residential development.

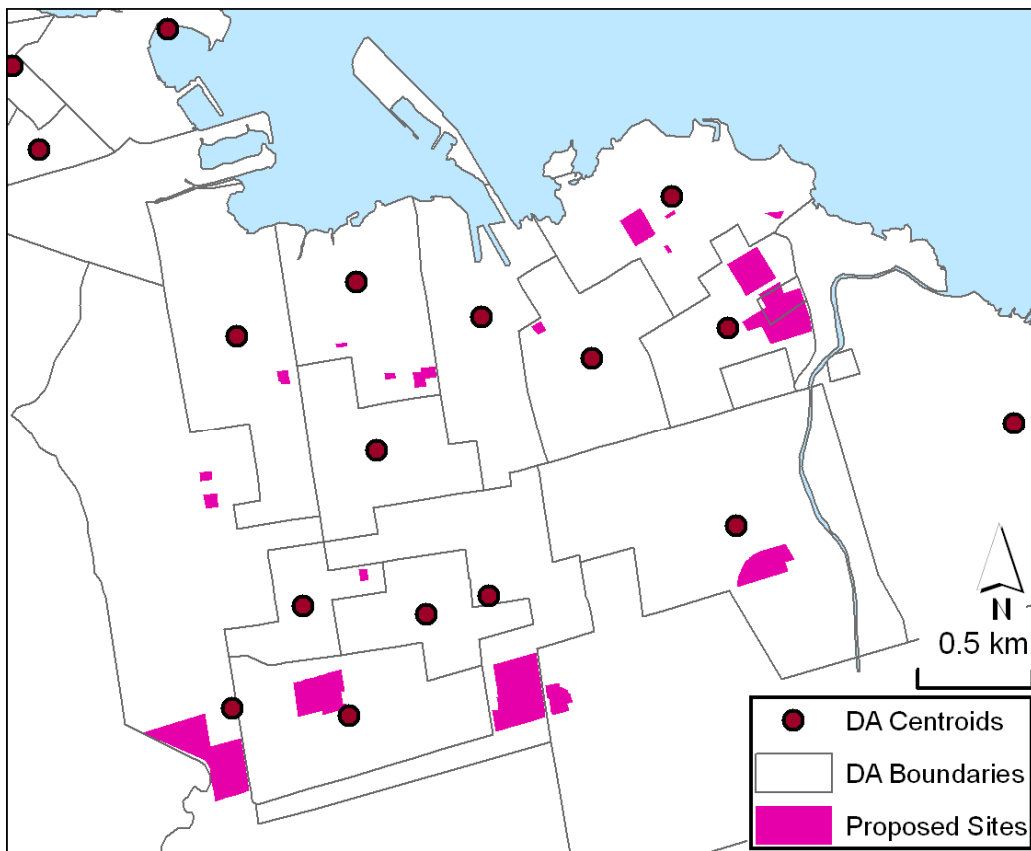


Figure 4.7 – Census dissemination area boundaries and centroids

*Note that some centroids are beyond the map extent

The centroids were used to generate a value surface using the census data values corresponding to the DA. Two types of surface were used in this analysis, namely weighted density, and Inverse Distance Weighting (IDW). Both create smooth surfaces of calculated values, but they are achieved in different ways. In the case that privacy concerns caused Statistics Canada to suppress a particular DA's data values, that DA was not used to generate the raster surfaces.

Population density was calculated as a weighted kernel density surface (ESRI, 2005). In this GIS process, a density surface takes counts of a phenomenon (in this case population) and assigns each count a "neighbourhood of influence". The density surface takes the population counts at each centroid and spreads the data out over the surrounding neighbourhood, showing areas with high and low concentrations of residents.

For the purposes of this study, a radius of 1000m was used as a reasonable estimate for a "neighbourhood," since it is accepted as equivalent to an easy 15 minute walk for most adolescents and adults (Colabianchi et al, 2007; Giles-Corti et al, 2006). As well, DAs were spaced about 500-1000m apart in the central part of Collingwood, so the 1000m radius was required to reach from one DA to another. Figure 4.8 shows the surface of population density.

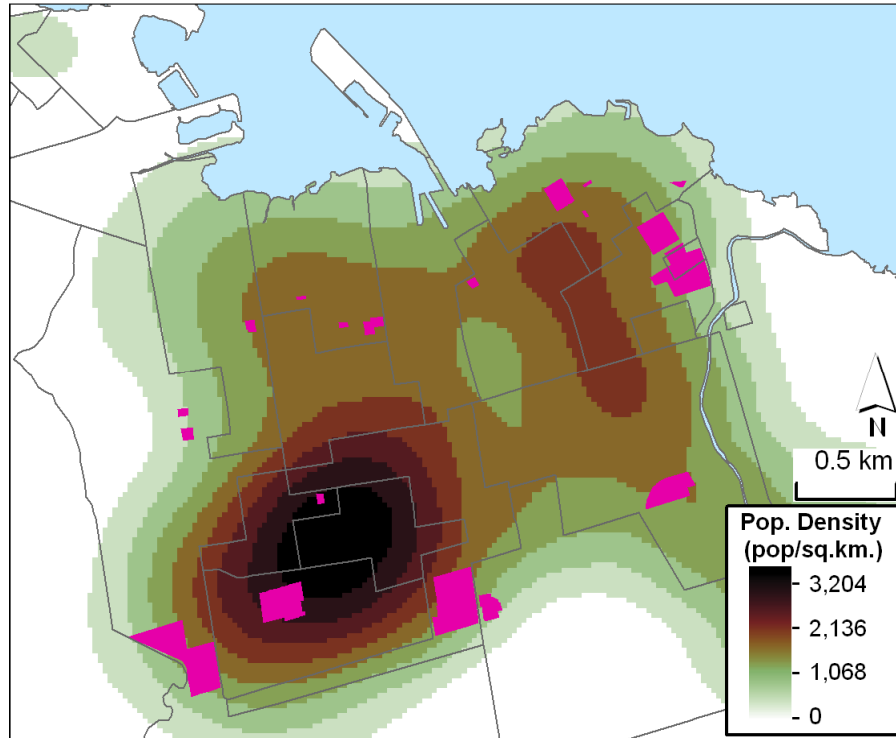


Figure 4.8 - Population density (Dens_Pop)

The other census criteria were calculated as interpolated surfaces using IDW (ESRI, 2005). Unlike the density surface, IDW interpolates the value of a variable at a given location based on a weighted average of the known data values at the sample points (centroids) found within a specified search radius. It averages the values of nearby centroids based on their relative distance away, with closer centroids having more influence than distant data points. Density functions and IDW generate useful surfaces, but they work on distinctly different data. Density is calculated from raw population counts and decays over distance. IDW is used on normalized rates (*e.g.* proportion of young people, unemployment rates) varying from 0% to 100%.

Some of the population variables, such as the counts of young people, seniors, and people who had recently moved, were calculated as rates instead of population density surfaces since they were so highly correlated to the overall population density. Three of the criteria exhibited enough variation to be used in the analysis: average dwelling value (Avg_HH_Val), the proportion of households spending over 30% of their income on housing (HHH_Inc_30), and the proportion of residents aged

65 and over (Rate_65). These surfaces are shown from Figure 4.9 to Figure 4.11. The other criteria (Rate_15, Rate_18, Rate_Mover, Rate_Migrt, and Rate_Unemp) did not have sufficient variation across the study area to be included in the MCA, although they were available for the participants' information in the data table.

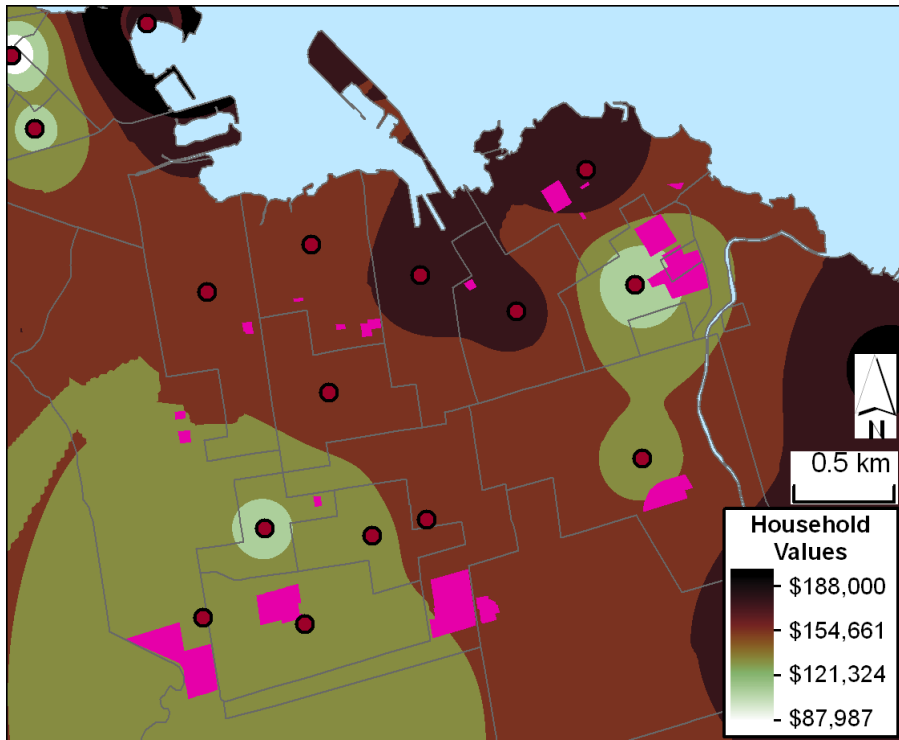


Figure 4.9 – Average dwelling value (Avg_HH_Val)

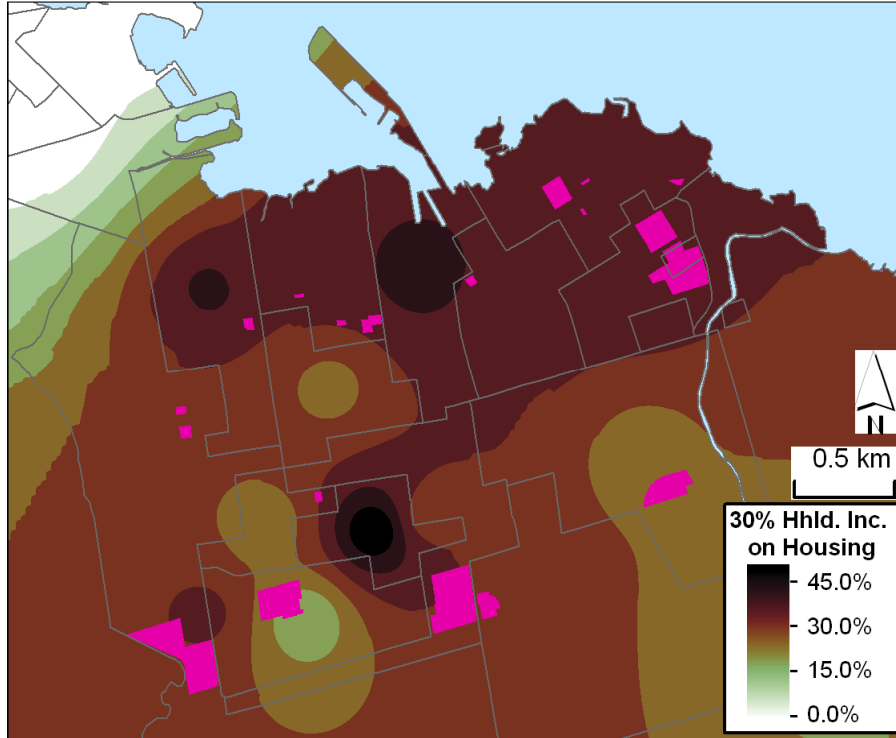


Figure 4.10 – Proportion of households spending over 30% of income on housing (HHH_Inc_30)

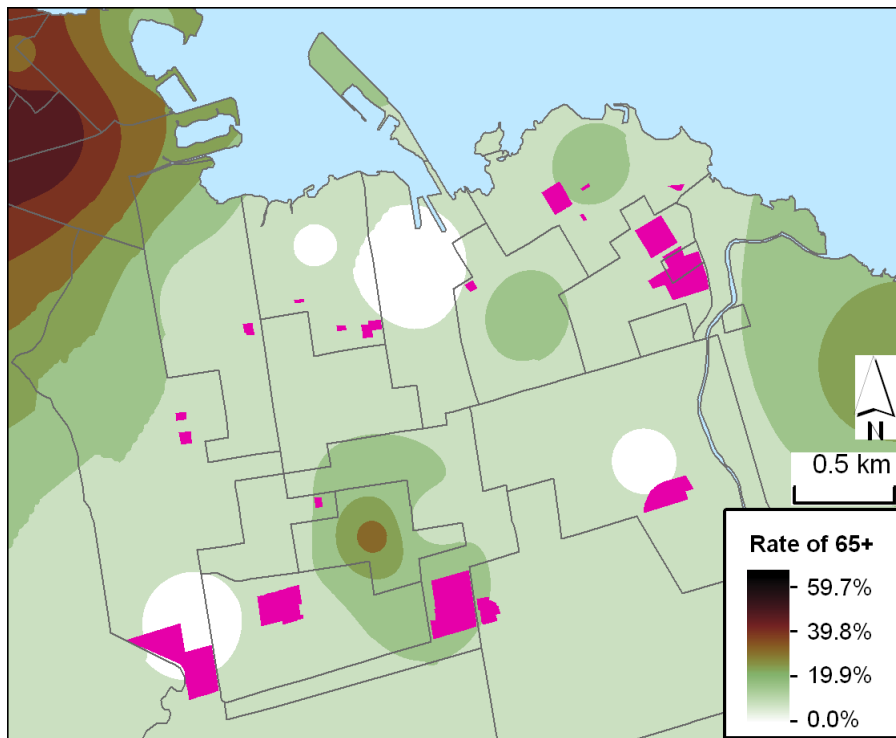


Figure 4.11 – Rate of residents aged 65 and over (Rate_65)

A number of the criteria involved measuring distances to amenities or services based on the data provided by the Town of Collingwood (Figure 4.12). The distance to bus lines used the existing bus routes in the Town, under the assumption that individual bus stops could easily be changed to accommodate resident demand. Distance to emergency services combined the location of the fire station, hospital, paramedic station, and police station, as they are all located within a small vicinity in the Town's north-east corner. Distance to grocery stores only considered large grocery stores, not convenience stores which are more expensive for affordable housing residents. Distance to schools used both elementary and secondary schools. Distance to places of worship used all the places of worship in Collingwood, regardless of size or community outreach involvement. All these distance criteria were calculated as grid cells of 20m resolution relative to the straight-line distance to the appropriate features.

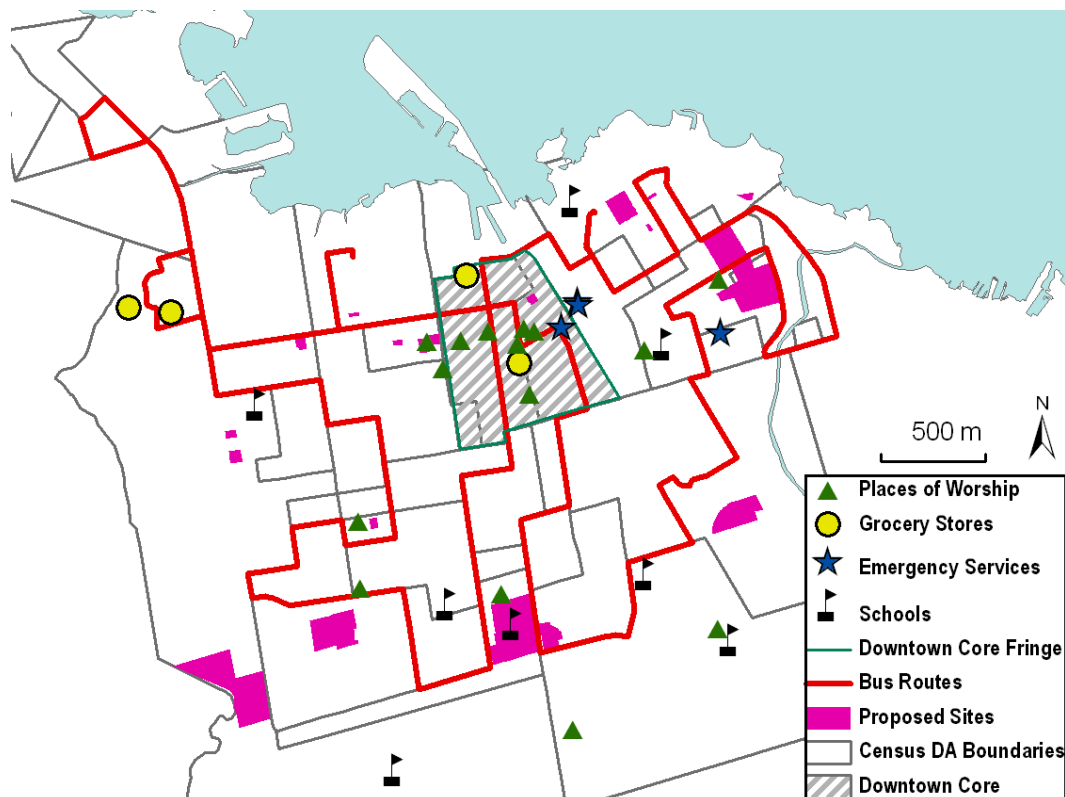


Figure 4.12 – Selected amenities

The distance surfaces used in the analysis are shown in Figure 4.13 to 4.17. Most of the distance criteria were used in the MCA analysis, except for the distance to places of worship which the participants decided was irrelevant to the analysis.

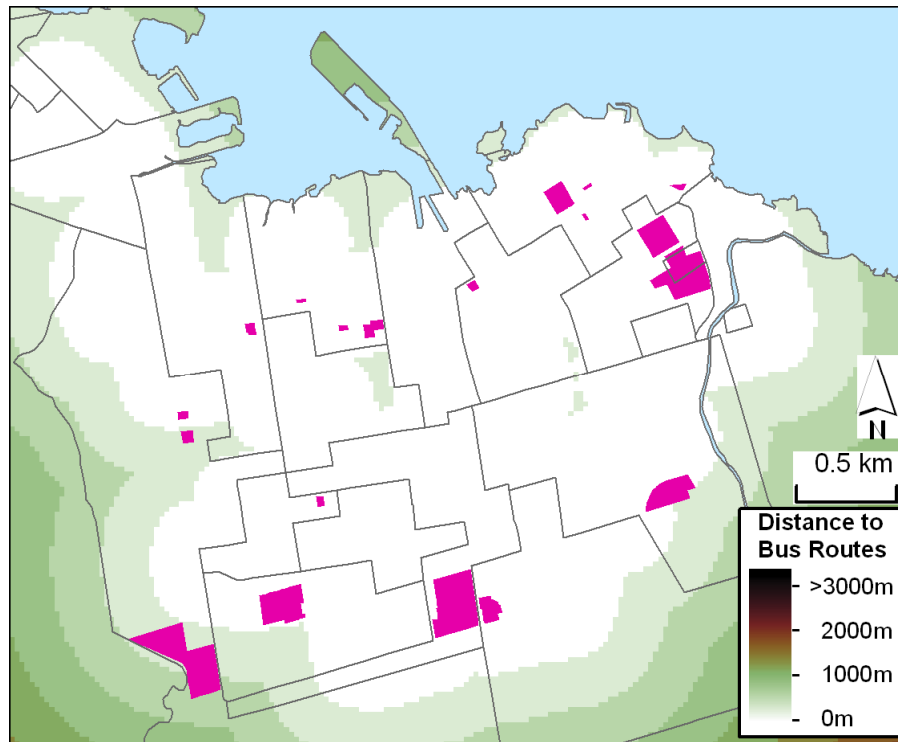


Figure 4.13 – Distance to bus transit routes (Dist_Bus)

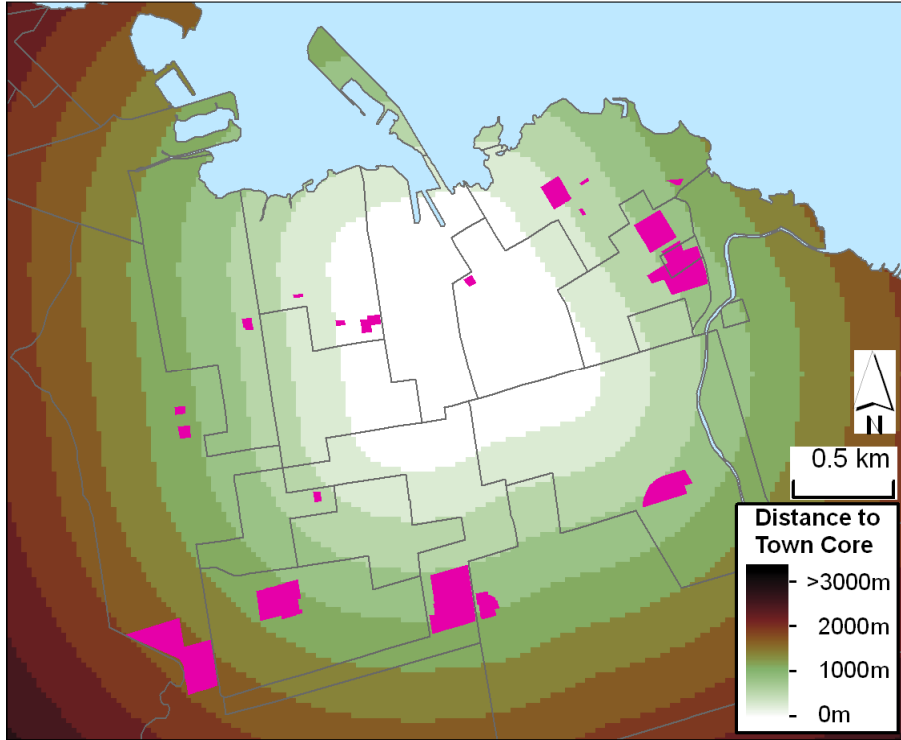


Figure 4.14 – Distance to downtown core (Dist_Core)

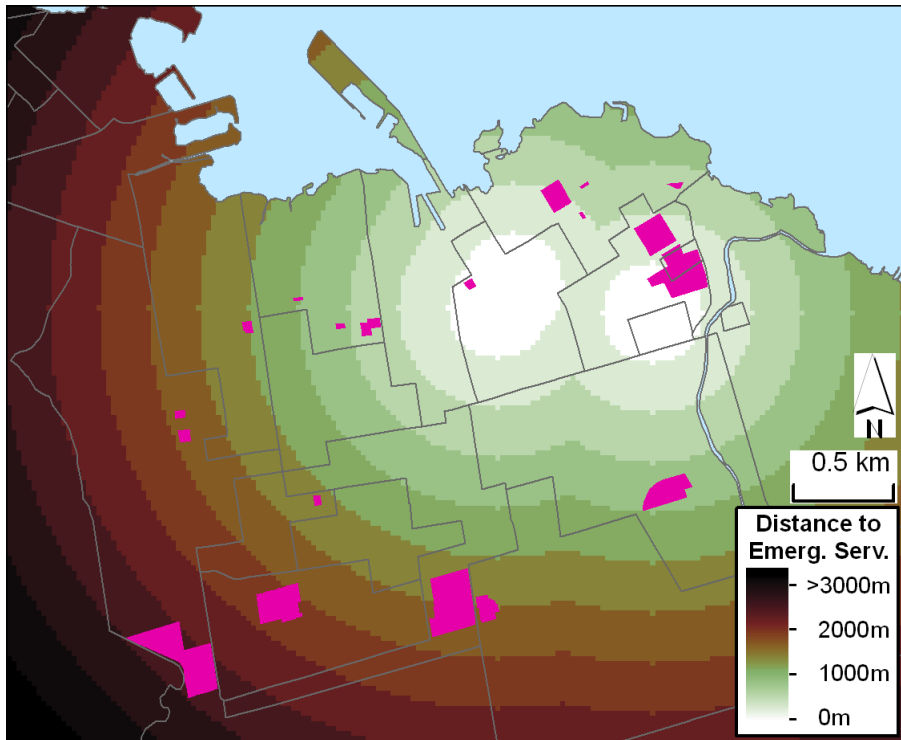


Figure 4.15 – Distance to emergency services facilities (Dist_Emerg)

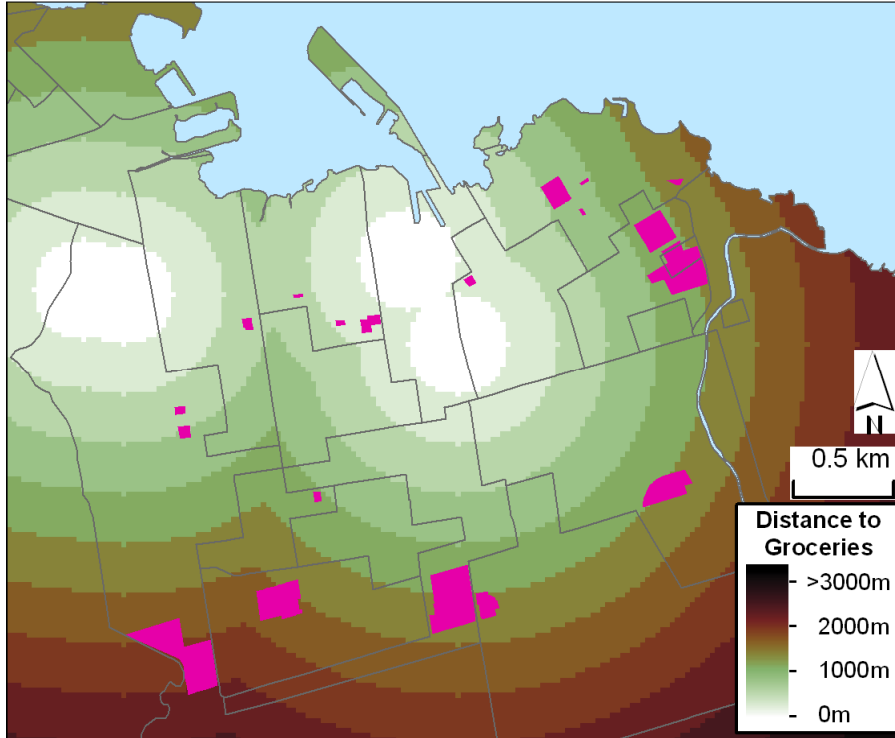


Figure 4.16 – Distance to grocery stores (Dist_Groc)

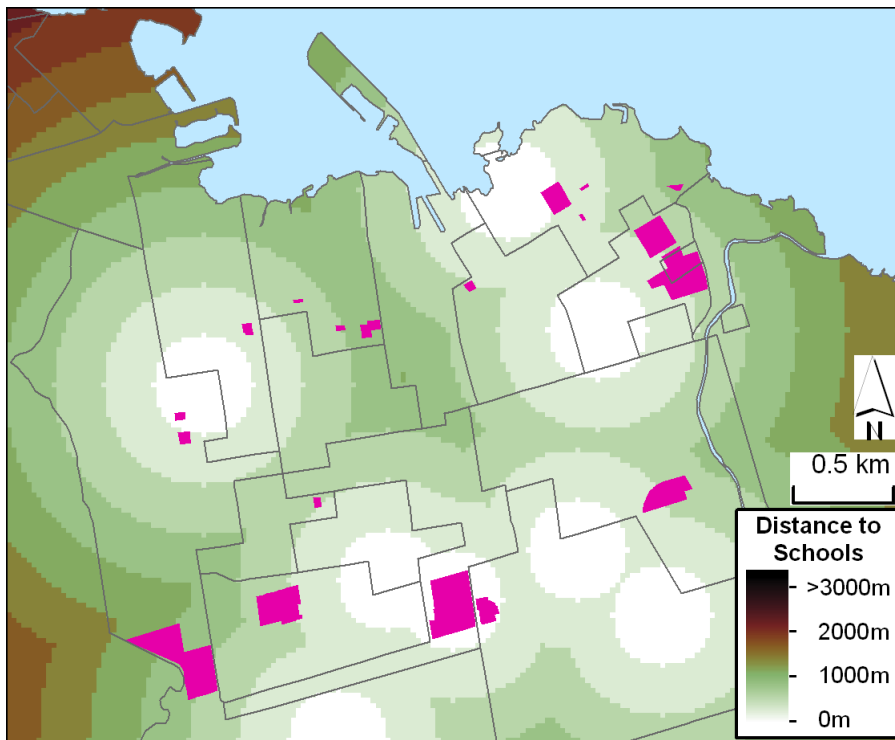


Figure 4.17 – Distance to schools (Dist_Schl)

For all the proximity and neighbourhood criteria, zonal averages of the raster cells falling within each affordable housing site polygon were used to assign criterion values to the sites.

The two remaining criteria (site area and zoning) were not calculated using interpolated surfaces, but instead they were site-specific values. Site zoning was taken from the Town of Collingwood's new Official Plan. The new proposed zoning was used in lieu of the existing zoning, representing the Town's intentions for the sites in question. An email conversation with planners at the Town indicated they would only look to locate housing in R3 or R4 (medium or high-density residential) zones. Sites were classified as either being in the appropriate zone (R3 or R4), receiving a score of "1," or were given a score of "0" if they were located in any other residential zoned land.

Together the calculated criterion values for the sites are shown in Appendix 2, and it was these values that were ultimately used in the MCA analysis during the user workshop.

Data for four criteria that were requested by the participants were not available. One such variable was the maximum number of housing units that a site could support. This could be calculated very roughly as a function of the developable area of a site (*i.e.* site area minus required setbacks and parking requirements as specified in the zoning bylaw), the maximum number of stories permissible and an estimated average size of an affordable housing unit. Unfortunately, since Collingwood's Official Plan was under revision at the time, these values were not available. Instead, a parcel's surface area was used as a rough proxy for the number of units it could likely support. Another proposed criterion that was not available was the estimated cost per unit. It would have been the site's estimated value plus construction costs divided by the estimated number of units, neither of which were available in our study. Finally, property values and site ownership data were not possible to obtain. This information is only available through the Municipal Property Assessment Corporation (MPAC) which charges a per-parcel fee for assessed property value reports. Even if these data had been available, site ownership information would not have been particularly useful, since the

participants were interested in the availability of proposed sites. This is a subjective notion, depending on the owner's willingness to sell the site, and could not be integrated within the MCA.

As noted earlier, the Collingwood workshop was done with volunteers from the SCATEH community group. The organisation of the workshop is discussed in the next section.

4.4 Workshop Organisation

4.4.1 Case Study Procedure

Introducing users to a new software tool like MapChoice is no easy matter. Much of the effort that went into the workshop was directed at making the process as straightforward as possible. From the outset, the workshop was designed so that most of the time would be spent teaching the users the software and the logic of the MCA process, so that they would be able to build upon their prior experience with MapChat and then move through the siting problem efficiently. The conceptual difficulty of the tasks assigned to the users would then increase along with their familiarity with the software and their comfort with MCA. Within the constraints of a single half-day workshop, it was hoped that participants would first contribute their individual preferences and justification for those preferences on affordable housing, then collaboratively work on a group analysis. The software would only gather their direct input to the siting problem. A post-workshop exit survey completed by the participants gathered their views and evaluations of the computer-based decision-making approach.

The workshop began with a brief presentation introducing MCA using a simple example, with a reduced set of three alternatives and four criteria. Users were shown how they could select different preference weightings, generating unique rankings of the decision alternatives. The distinction between benefit and cost was dedicated a good deal of time on its own, but in retrospect even this was not sufficient for participants to understand the concept clearly (this is discussed further in Chapter 5).

Once the fundamentals of MCA had been explained, the users were guided through the same limited MCA scenario used in the presentation. The researcher used a live demonstration of the software to guide participants through the steps of logging in, operating the basic navigation functions, then opening the MCA tool and entering their preferences for the weights and benefit/cost settings. Users learned how their preferences instantly updated the calculated ranking displayed on the map, how to read the data table, and how they could manipulate benefit/cost settings and criterion weights. Unfortunately the latter seemed to be difficult to understand for many of the users as some were not clear about the distinction between the weights and the criteria type (benefit/cost) settings.

When the participants were judged to have familiarized themselves sufficiently with the software, they proceeded to the full MCA analysis with all the alternatives and criteria. They were left to work on their own on the single-user MCA, with the researchers moving among them to assist as required. As described in Chapter 3, as users changed their weighting preferences, MapChoice provided feedback to the users in the form of a map that showed recalculated site rankings. Updated score and rank values were also displayed in the Data Table widget. Once they became familiar with the software, users were encouraged to interactively explore different weighting strategies and observe the impacts of weight changes on the housing site rankings. With the single-user version of MapChoice, users were able to save and load working versions of their rankings, but they could not see the work of the others. Near the end of the workshop, the participants saved their single-user weightings before moving on to the group MCA part of the exercise. The researchers verified that the users were satisfied with their ultimate preference weightings, since they had progressed through several iterations, and so these final saved weightings were used as their “definitive” single-user preferences.

The remainder of workshop focused on Group MapChoice. The researcher assumed the role of the session moderator and led the participants through a process where they would submit a “vote” that consisted of the weight they felt was appropriate for a specific criterion. This voting process was repeated for each criterion under consideration. To demarcate the start of each new round of voting,

the moderator announced the full name of each criterion to the participants (*e.g.* “distance to emergency services” was read out instead of “dist_emerg”). As well, the moderator explicitly restated what the benefit-cost value meant for each criterion in clear terms (*e.g.* “select ‘benefit’ if you feel higher distances to emergency services are desirable”). The participants were then given sufficient time to submit their preferences, and they were able to revise their vote as many times as needed if they were unsatisfied with their original choice. It is important to note that when a new vote was submitted, the software automatically updated the Group MapChoice screen (as shown in Figure 3.7) with a revised average vote value and a count of the number of participants who had submitted a weight for the criterion in question. Thus all the users could see the current average weight of their group’s submitted votes, and could even change their own votes in response. Once all users had cast a vote, the moderator asked if anyone still needed more time to change their preferences, then proceeded to the next criterion. Only once a full run through all the criteria was completed were users able to view the resulting ranking in the map and in the Data Table.

Upon the successful completion of the workshop, participants were given a survey to fill out, which is explained in detail in the next section.

4.5 Survey Design

The post-workshop survey asked participants both quantitative and qualitative questions about their background and experiences with MapChoice, and was prepared according to standard research design principles (Palys, 2003). A brief introductory section asked for participants’ demographic information, followed by a section determining their skill level with computer technology using a closed-format five-point rating scale. The remainder of the survey comprised of more open questions about the workshop, and two final open-ended questions asked for further suggestions to improve future workshops. The questions are explained in more detail here, and the full questionnaire is included in Appendix 1.

Questions 1 to 3 ask for demographic information. Answering them is optional if the participants have privacy concerns, since the small workshop size could make it possible to identify individuals based on these answers. Participants were asked their location of residence to see if proximity to the study area influenced their acceptance or opposition to affordable housing.

During the first workshop, they had generally succeeded in using MapChat, but the less tech-savvy participants experienced some difficulty with the software. Questions 4 to 7 were intended to see if a computer background helped any of the users in learning and navigating the software, and if those not familiar with computers struggled or became frustrated with the workshop. As well, some of the participants had been involved with planning decision-making, and thus may have been more comfortable with planning-centered MCA assessment using MapChoice.

The next set of questions (8 to 12) used the five-point rating scale along with a comments area for the users to add detailed answers. Questions 8 and 9 ask whether the workshop helped them better understand the multiple dimensions of the issue of affordable housing in Collingwood, and specifically how much the single-user and group modes of MapChoice contributed to this understanding. These questions can answer whether a collaborative SDSS can be an educational tool, facilitating information exchange to and between participants.

Question 10 again compared the single-user and group MapChoice, this time asking participants felt either mode helped towards improving the quality of the resulting decision.

Question 12 asked participants the extent to which the MapChoice tool represented an improvement over other planning methods the participants were familiar with. Separately, Question 13 asks if there are any disadvantages, instead of asking whether the software is a net benefit or cost.

Finally, Questions 14 and 15 ask for suggestions for further improvement, both in the software and in the preparation of the workshop, including the data used.

4.6 Summary

This chapter illustrated the extent of the affordable housing shortage facing the study area in the Town of Collingwood and the greater problem of locating affordable housing sites in general. It then described the workshop held with community members to explore this problem, including the research design, data gathering and preparation, workshop organisation, and survey design.

The affordable housing shortage in Collingwood was shown to be severe, fuelled by increased growth of the wealthier segments of the population, a transition from an industrial to a tourism-based economy, and sharply rising real estate costs. The Collingwood situation is by no means unique, as affordable housing has been studied extensively in other jurisdictions, and is described as a complex issue involving many interested stakeholders. There is a considerable spatial component in locating affordable housing and to this end the research design of the workshop involved comparing potential sites in MapChoice using a number of spatial criteria. Bringing together the three concepts of space, participation and choice discussed in Chapter 2, the workshop asked participants to evaluate sites individually (single-user) and collaboratively. After the workshop a survey was given to the participants, asking various qualitative questions including rating their experience with the software.

In Chapter 5, the results of the workshop are analysed, first by presenting the weightings and resulting rankings generated by the participants, followed by an examination of the evolution of consensus through the workshop. The results of the participant survey are also summarised.

Chapter 5 - Results

This chapter presents the results of the MapChoice workshop described in Chapter 4. The discussion focuses first on the single-user data in Section 5.1, including showing each user's preferences as well as mapping resulting rankings of the affordable housing sites, followed by a similar exposition of the results from the collaborative group session in Section 5.2. Section 5.3 examines the consensus between participants across the criteria in the single-user and collaborative stages, and Section 5.4 does the same for consensus across the decision alternatives. As noted in Chapter 4, participants were given a survey to complete asking qualitative questions about various aspects of the workshop, and this is covered in Section 5.5. This chapter concludes with a discussion of the results the workshop in Section 5.6.

It should be noted that the user preferences and rankings shown in this chapter were submitted using MapChoice. During the workshop, the users were able to view the rankings they generated with the Data Table widget and on the main map of MapChat as shown in Chapter 3. The maps and tables of rankings shown in this chapter, however, were generated externally from MapChoice using ESRI ArcMap and spreadsheet software because of their superior presentation-quality outputs and the ease that values for the consensus measures could be calculated.

5.1 Single-User Results

The subsections that follow describe the weighting and ranking results obtained by each participant during the single-user component of the workshop. Although it was for each participant to experiment with several possible weighting schemes, only one individual had enough time to complete two slightly different weight sets. Time constraints were also likely responsible for only one person making use of the capability to record supporting rationale for their weighting preferences, so the rationale was not used in this analysis. In this section user weight preferences are shown in two ways,

with the first column containing the weights in the 0-7 scale entered by users and the second column showing the weights normalized so they sum to 1.0.

Participants were also encouraged to save their work, and they saved from 4 to 22 such weightings-in-progress. As these intermediate weightings were just stepping stones to the final preference weighting, each participant's most recent weighting was taken as their ultimate personal set of preferences. Users could also enter a name and description when saving the weightings, but as with the rationale, they did not take advantage of this opportunity. Participants were guaranteed full anonymity when they agreed to participate in the workshop. Accordingly, they are represented by the names "User A", "User B", "User C" and "User D" to preserve their identities.

5.1.1 User A Results

User A favoured low distances to public transit (*dist_bus*, cost) and those sites which were zoned as higher-density residential (*zone_res*, benefit). Conversely, the proportion of seniors in a site's neighbourhood was deemed irrelevant (ignored) and the distance to emergency services (*dist_emerg*, cost) was considered to be of low importance (Table 5.1). This weighting favours sites with lower property values (*avg_hh_val*, cost), in areas with higher population density and lower poverty rates (*dens_pop*, benefit, and *hhh_inc_30*, cost). See Figure 4.8 to 4.17 for maps of the distributions of criterion values. Like the next two participants, this user did not record any rationale for their weights.

Criterion	Benefit/Cost	Weight	Normalized Weight
DIST_BUS	Cost	6 (High)	0.158
ZONE_RES	Benefit	6 (High)	0.158
DENS_POP	Benefit	4 (Average)	0.105
AVG_HH_VAL	Cost	4 (Average)	0.105
DIST_GROC	Cost	4 (Average)	0.105
DIST_CORE	Cost	4 (Average)	0.105
HHH_INC_30	Cost	4 (Average)	0.105
DIST_SCHL	Cost	3 (Below Average)	0.079
AREA_HA	Benefit	2 (Low)	0.053
DIST_EMERG	Cost	1 (Very Low)	0.026
RATE_65	Benefit	0 (Ignore)	0.000

Table 5.1 – Preferences for User A

This weighting by User A resulted in the site ranking shown in Figure 5.1. The two most favoured sites are in the south-west corner, beside the lowest-ranked site. They are located near a bus line, in an area with high population density, low housing costs and relatively healthy income indicators. The nearby site ranked 24 (very poor) was ranked low by MapChoice based on the supplied weightings as it was not zoned for high-density residential development.

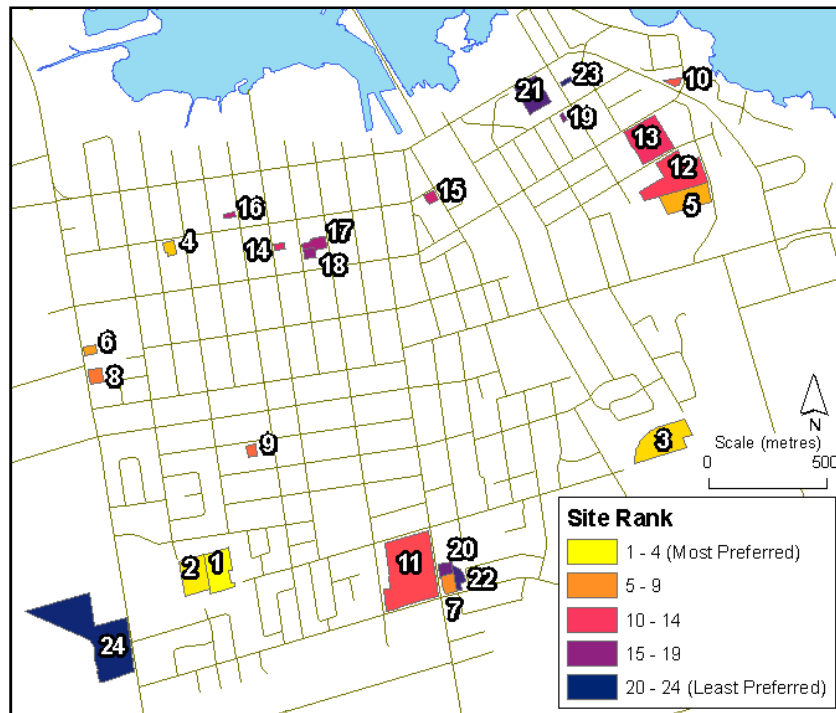


Figure 5.1 – User A site ranks

5.1.2 User B Results

User B gave a high priority to proximity to schools (dist_schl, cost) and public transit (dist_bus, cost) and favoured sites already zoned for medium- or high-density residential development (zone_res, benefit), while the proportion of seniors in a site’s neighbourhood was ignored (rate_65) (Table 5.2). Unlike User A, this user favoured sites in areas struggling with housing costs (hhh_inc_30, benefit) and favoured higher property values and property sizes (avg_hh_val, benefit and area_ha, benefit). While the user did not contribute his/her rationale for the preferences entered, this weighting emphasises the needs of young families (dist_schl, cost) instead of seniors, and would tend to favour sites where families may be having difficulties coping with high property values.

Criterion	Benefit/Cost	Weight	Normalized Weight
DIST_BUS	Cost	6 (High)	0.125
DIST_SCHL	Cost	6 (High)	0.125
ZONE_RES	Benefit	6 (High)	0.125
AVG_HH_VAL	Benefit	5 (Above Average)	0.104
AREA_HA	Benefit	5 (Above Average)	0.104
DIST_GROC	Cost	5 (Above Average)	0.104
DENS_POP	Benefit	4 (Average)	0.083
DIST_CORE	Cost	4 (Average)	0.083
HHH_INC_30	Benefit	4 (Average)	0.083
DIST_EMERG	Cost	3 (Below Average)	0.063
RATE_65	Benefit	0 (Ignore)	0.000

Table 5.2 – Preferences for User B

Since this weighting gave somewhat higher priorities for distances to amenities such as schools, transit, grocery stores, and the city core, the weighting does not disadvantage centrally located sites, as seen in Figure 5.2. Interestingly, even though smaller sites are not favoured in the weighting, it is mostly the smaller parcels that have good ratings, while the large parcels on the south-west corner of the city have low feasibility.

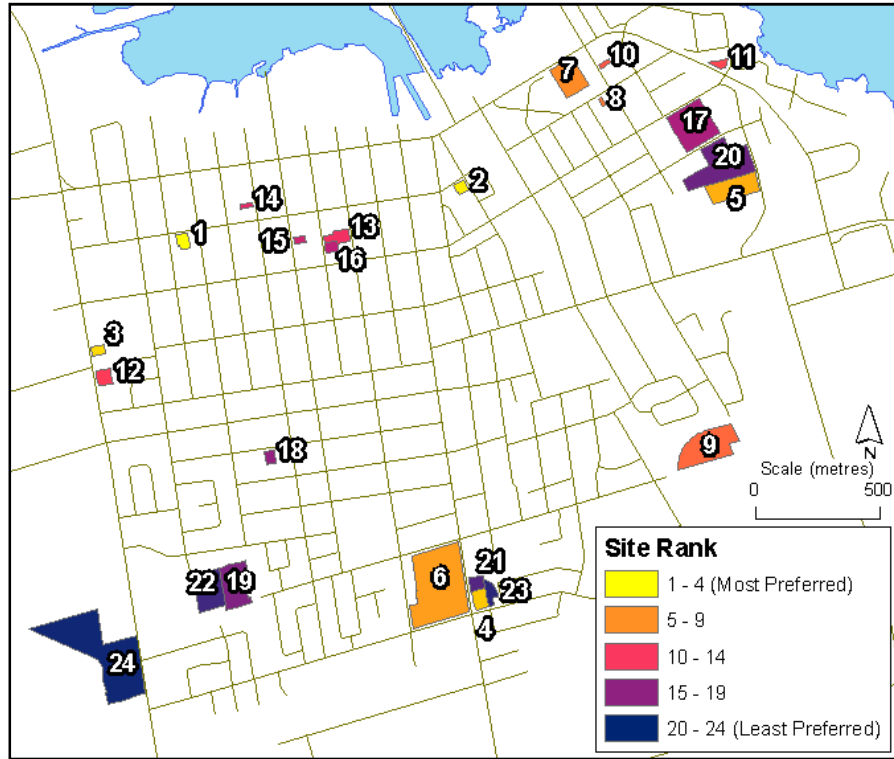


Figure 5.2 – User B site ranks

5.1.3 User C Results

User C gave high weights to low property values (avg_hh_val, cost) and favoured proximity to necessities like schooling, emergency services, and the downtown core (dist_emerg, dist_schl and dist_core, all cost) (T). This weighting also slightly favours larger sites not already zoned for high-density residential (area_ha, benefit and zone_res, cost), which may be sites that had not previously been considered by the affordable housing planners. The criteria of distance to public transit, grocery stores, and high population density are not weighted highly (dist_bus, dist_groc, dens_pop), possibly since the distance to the downtown core criterion is high instead.

Criterion	Benefit/Cost	Weight	Normalized Weight
AVG_HH_VAL	Cost	6 (High)	0.120
DIST_EMERG	Cost	6 (High)	0.120
DIST_SCHL	Cost	6 (High)	0.120
RATE_65	Benefit	5 (Above Average)	0.100
DIST_CORE	Cost	5 (Above Average)	0.100
HHH_INC_30	Benefit	5 (Above Average)	0.100
ZONE_RES	Cost	5 (Above Average)	0.100
AREA_HA	Benefit	5 (Above Average)	0.100
DIST_BUS	Cost	3 (Below Average)	0.060
DENS_POP	Benefit	2 (Low)	0.040
DIST_GROC	Cost	2 (Low)	0.040

Table 5.3 - Preferences for User C

Under this weighting, many of the highest ranks are found on the larger sites in the north-east corner, near the emergency services (Figure 5.3). The large site in the south-central region has a high score as well likely as a result of its proximity to a school. By comparison, the large sites on the south-west corner have low scores due to their large distance from major amenities.

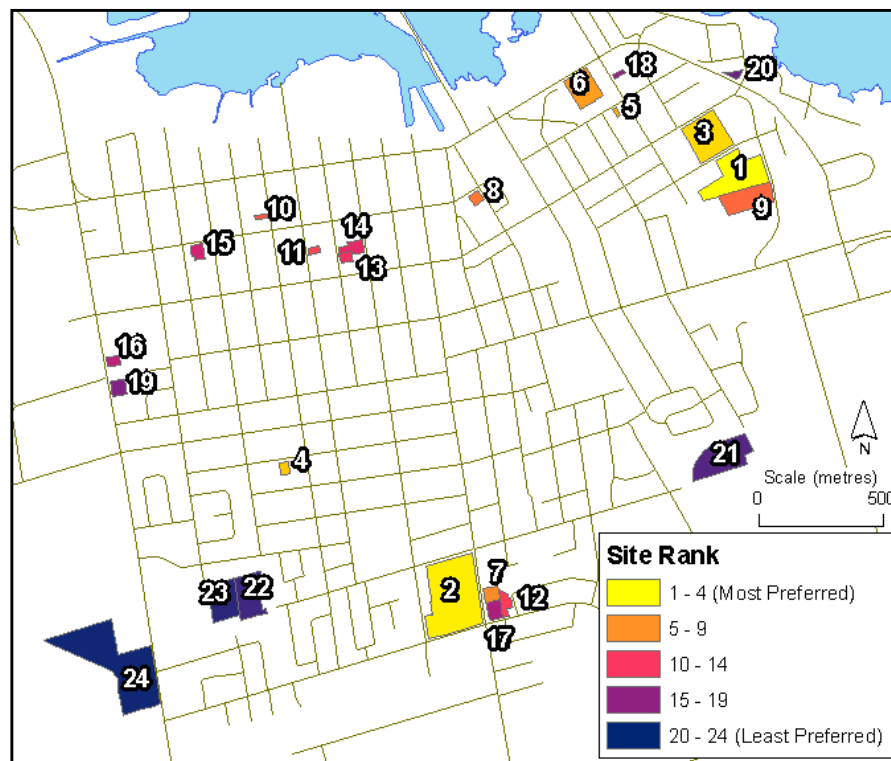


Figure 5.3 – User C site ranks

5.1.4 User D Results

Unlike the others, User D found the time to submit two different weightings, but did not indicate which one should take precedence. Both are shown here, but only the latter weighting was used in the subsequent sections. User D’s thought process behind the first weighting (shown in Table 5.4) can be understood better thanks to the detailed rationale given for most criteria. The user emphasised satisfying the zoning criterion (zone_res, benefit) as being more important over all others since it would make the task of approving an affordable housing project much easier. In comparison, population demographics are ignored (rate_65), as are property values or housing affordability rates linked to housing costs (avg_hh_val, hhh_inc_30). Since Collingwood is so expensive to live in, the user reasonably believed that most people would fall under the ascribed poverty level. All the distance-based criteria were given an above-average priority. The user indicated these criteria were important, but not quite as critical as the need for properly-zoned lots.

Criterion	Benefit / Cost	Weight	Normalized Weight	Rationale
ZONE_RES	Benefit	7 (Very High)	0.171	More easily expediated with correct zoning
DIST_BUS	Cost	5 (Above Average)	0.122	Due to many people in affordable housing with no cars
DIST_GROC	Cost	5 (Above Average)	0.122	People unlikely to have cars so better to be close to stores
DIST_EMERG	Cost	5 (Above Average)	0.122	Desire closeness to medical services
DIST_SCHL	Cost	5 (Above Average)	0.122	Proximity so children can walk
DIST_CORE	Cost	5 (Above Average)	0.122	Ease of walking to work, resources
DENS_POP	Benefit	4 (Average)	0.098	Areas for housing could be high or moderate density
AREA_HA	Benefit	4 (Average)	0.098	
RATE_65	Benefit	1 (Very Low)	0.024	Demographics are not a deterrent
AVG_HH_VAL	Benefit	0 (Ignore)	0.000	
HHH_INC_30	Benefit	0 (Ignore)	0.000	Most housing in Collingwood results in people spending over 30% on income

Table 5.4 – Preferences for User D, first weighting

This user's emphasis on zoning (a largely aspatial criterion for our candidate sites) and lack of emphasis on spatially-correlated population and property value criteria suggests that there would not be any obvious spatial pattern to the rankings. The most suitable site is located in the north-west corner (Figure 5.4), with nearby sites having rather poor values. Similarly, the lowest-rated site remains the large south-west lot, but it is near some relatively well-ranked sites.

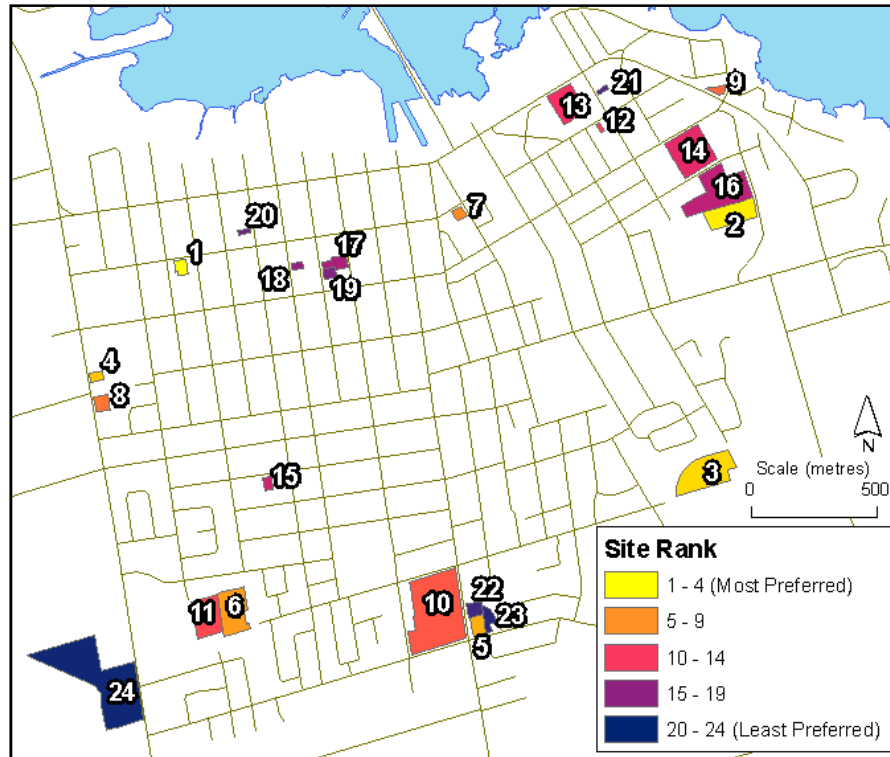


Figure 5.4 – User D site ranks – first weighting

This user's second weighting (Table 5.5) is interesting because it demonstrates to a limited degree how comparatively small changes in criteria weights can influence ranking results. Two of the distance measures are increased in priority (dist_groc and dist_schl), the poverty rate proxy is included (hhh_inc_30), and population density is slightly decreased in importance (dens_pop).

Criterion	Benefit/Cost	Weight	Normalized Weight
ZONE_RES	Benefit	7 (Very High)	0.159
DIST_GROC	Cost	6 (High)	0.136
DIST_SCHL	Cost	6 (High)	0.136
DIST_BUS	Cost	5 (Above Average)	0.114
DIST_EMERG	Cost	5 (Above Average)	0.114
DIST_CORE	Cost	5 (Above Average)	0.114
AREA_HA	Benefit	4 (Average)	0.091
DENS_POP	Benefit	3 (Below Average)	0.068
HHH_INC_30	Benefit	2 (Low)	0.045
RATE_65	Benefit	1 (Very Low)	0.023
AVG_HH_VAL	Benefit	0 (Ignore)	0.000

Table 5.5 – Preferences for User D, second weighting

The overall result of this ranking puts more priority on central and northern sites, while disadvantaging the sites in the south-west (Figure 5.5). Two of the sites (ranks 8 and 4) received a boost from their proximity to the local high school, while the four small sites in the town centre received a slight boost due to their proximity to a bus line and their location in a higher-income neighbourhood.

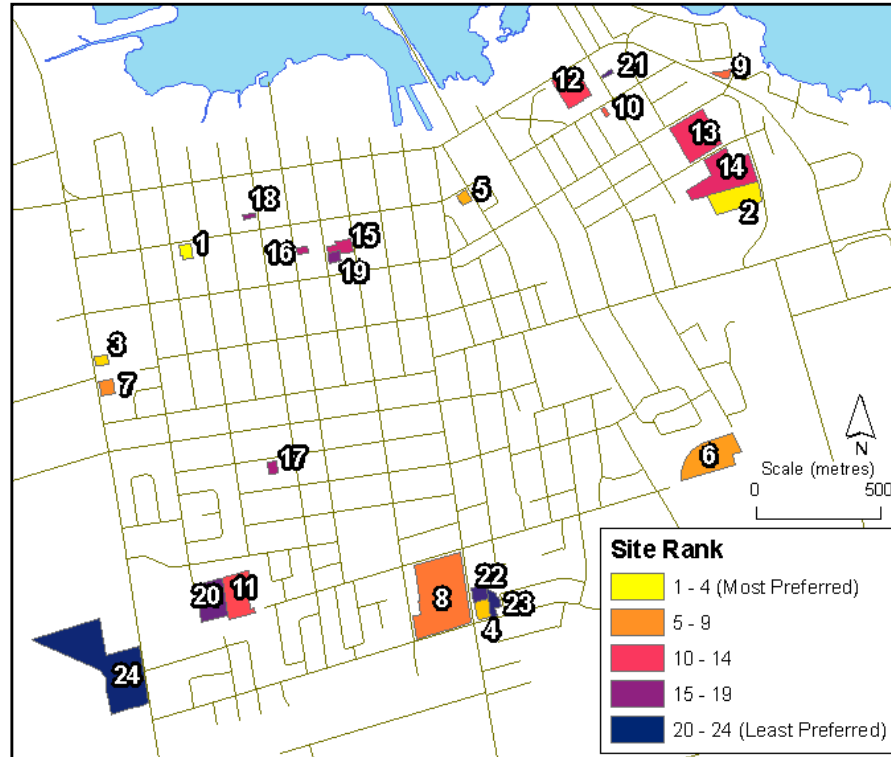


Figure 5.5 – User D site ranks - second weighting

Participants spent more of their time in the single-user stage, but it was the collaborative stage that provided the more interesting results.

5.2 Group MapChoice Results

As was described in Chapter 3, Group MapChoice follows a similar logic to single-user MapChoice but in a collaborative setting. Participant preferences were entered similarly to the single-user approach discussed in the previous section and in Section 3.4. In the collaborative case, the user-submitted weights were averaged together, and the majority of benefit or cost votes were used to produce the collaborative weight and benefit/cost ratings, respectively, as explained in Section 3.4.

The evolution of participant preferences from the single-user to group stages are compared later in this chapter, but for now the group result is analysed as this is the ultimate outcome of the MapChoice workshop (Table 5.6).

Criterion	Benefit/Cost	Weight	Normalized Weight
ZONE_RES	Benefit	6	0.121
DIST_BUS	Cost	5.5	0.111
DIST_SCHL	Cost	5.5	0.111
DENS_POP	Benefit	5	0.101
DIST_CORE	Cost	5	0.101
DIST_GROC	Cost	4.75	0.096
AVG_HH_VAL	Benefit	4	0.081
HHH_INC_30	Cost	3.75	0.076
AREA_HA	Cost	3.75	0.076
DIST_EMERG	Cost	3.5	0.071
RATE_65	Benefit	2.75	0.056

Table 5.6 – Collaborative weights from Group MapChoice

Relying on vote averaging to come up with a consensus group decision means that criterion weights would tend towards the mean weight value of 3.5 (where the maximum weight was 7), unless there is some commonality in users' views skewing in one direction. By looking at the group weights in Table 5.6, it is clear that users did differentiate between criterion priorities. For example, the zoning criterion has a very high score of 6 (zone_res, benefit), revealing that participants saw it as important to choose sites that would not have to be re-zoned. Distance to public transit and schools both had the second-highest weights of 5.5 (dist_bus, cost and dist_schl, cost). By comparison, the demographic criterion of proportion of seniors had a rather low overall weight (rate_65, benefit). The other criteria ranged from 3.5 to 5, at or slightly above the average value. Overall this weighting is rather balanced for most criteria, with few exceptionally highly or poorly weighted criteria, unlike some of the individual weightings.

The group weighting in Figure 5.6 looks similar to many of the user rankings discussed earlier. The high priorities given to proximity to amenities like bus routes, schools, and the downtown core favour central sites, while the high weight given to the population density criterion helps increase the ranks of sites in the south-west corner. The site in the north-west corner, selected as the best site by two users,

maintains its #1 ranking. The site ranked #1 by User A in the single-user stage is still ranked #4 in the group ranking. However, the top site for User C is ranked #23 in this group weighting, showing that even a “consensus” ranking may be against the wishes of some voters. The lowest-ranked site for most users retains its position of #24 in this ranking. Of course, given the small sample size in this workshop, even one divergent vote can swing a weight substantially.

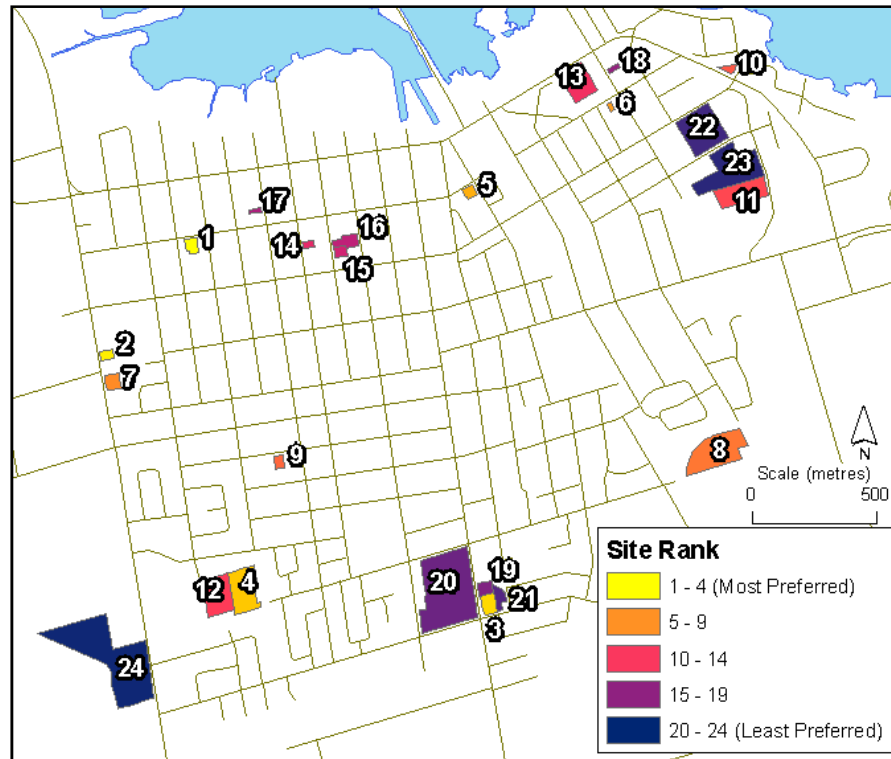


Figure 5.6 – Collaborative Session Site Ranks

Now that the participants’ rankings have been analysed, the next sections explore the evolution of consensus through the workshop.

5.3 Consensus Across Criteria

This section examines consensus both among participants and between different consensus ranking methods (*i.e.* social choice functions), beginning with single-user preferences and continuing with the collaborative results. The criterion preferences (weights and benefit/cost ratings) are the direct input of the participants, and by analysing the consensus over the criteria it is possible to see the disagreement


on the issue. In the next section a similar analysis of consensus is performed on the decision alternatives in place of the criteria.

The consensus measure developed by Cook and Seiford (1978; 1982; Cook et al, 1997) is used in this chapter to generate quantitative measures of the “consensus distance” or the degree of difference between participants’ views. Cook and Seiford’s method can also be used to measure the distance between individuals’ ranks and the consensus ranking, and this has clear parallels to the well-accepted Borda method for determining consensus rankings. Cook and Seiford note that consensus measures are not true statistical tests, as they depend on the number of voters and ranks. However, since these numbers were constant throughout the workshop, consensus can be compared and analysed using this method.

Cook and Seiford’s method takes votes as a ranking of candidates, such as the output of an MCA process. It then defines a “distance metric” between two rankings as the difference between the ranks for all alternatives. An optimal solution is calculated that minimizes the cumulative distance to all voters. This method is interesting because it is conceptually simple and mathematically straightforward, but also because it explicitly defines, then maximizes consensus (Lansdowne, 1996). It has been used to combine expert preferences (in the form of alternative rankings) to a consensus position, minimizing participant disagreement (Teng and Tzeng, 1994).

Consensus distance is defined as the sum of differences between the positions of the candidate ranks for two voters. Table 5.7 shows an example calculation of consensus distance given rankings of four candidates A to D by two voters. In this example, the distance for alternative A between the two voters is 3, since one voter ranks it 1st and another ranks it 4th. The distance for alternative C is 0, since both voters rank it equally in 3rd place.

Voter 1	Voter 2
A	B
B	D
C	C
D	A



Candidate	Distance
A	3
B	1
C	0
D	2
Total:	6

Table 5.7 – Example of Consensus Distance Calculation

It is possible to quantify the overall consensus in a decision by comparing the cumulative distance between all voters to its expected (statistically determined) value.

It is important to note that since consensus measures measure the distance between participants, a higher value means that participants are farther apart, indicating lower consensus. If the consensus value decreases, consensus has improved, and vice versa.

5.3.1 Single-User Consensus

In the single-user stage of the workshop, participants generated the weights shown in Table 5.7. The consensus score (the Cook-Seiford distance) indicates the amount of disagreement over a criterion, with higher values meaning lower consensus. The most disagreement was over the importance of property values, distance to emergency services and proportion of senior citizens. The way this disagreement is structured is interesting, as in the case of RATE_65 and AVG_HH_VAL, where one exceptional value from a lone participant (Users C and D respectively) differs greatly from the others. In the case of DIST_EMERG, it appears that the users have a variety of views. This could imply that, for RATE_65 and AVG_HH_VAL, the exceptional voter may have a novel or interesting idea that other participants had not considered or simply had a different opinion from the other participants. In the case of DIST_EMERG, the disagreement is more evenly distributed and could indicate a more difficult problem of disagreement. Conversely this could indicate that participants were unsure of the role of the criterion, and thus assigned arbitrary values. Other criteria did not engender any substantial

amount of disagreement. Participants were largely united in assigning high rating values to ZONE_RES and low values to DENS_POP.

Criterion	User A	User B	User C	User D	Cook-Seiford distance
DIST_CORE	4	4	5	5	4
ZONE_RES	6	6	5	7	6
DENS_POP	4	4	2	3	7
DIST_SCHL	3	6	6	6	9
HHH_INC_30	4	4	5	2	9
DIST_BUS	6	6	3	5	10
AREA_HA	2	5	5	4	10
DIST_GROC	4	5	2	6	13
RATE_65	0	0	5	1	16
DIST_EMERG	1	3	6	5	17
AVG_HH_VAL	4	5	6	0	19

Table 5.8 – Single-user criterion consensus

In determining criteria type, participants judged whether high levels of that criterion were desirable or undesirable, regardless of the importance of the criterion. Table 5.8 indicates that, overall, participants agree on the benefit/cost values. Only three criteria had any disagreement on benefit/cost.

HHH_INC_30 had three participants favouring sites in more impoverished neighbourhoods and one favouring less impoverished areas. With ZONE_RES, three participants favoured sites zoned for affordable housing development, while one preferred sites that were zoned differently (without giving any reason for this judgement). AVG_HH_VAL drew the most disagreement with two citing it as a benefit and two as a cost. This criterion also had disagreement as to its weights, and it is understandable that placing affordable housing in high- or low-value neighbourhoods is a contentious issue.

Criterion	User A	User B	User C	User D	differences
DENS_POP	BENEFIT	BENEFIT	BENEFIT	BENEFIT	0
RATE_65	BENEFIT	BENEFIT	BENEFIT	BENEFIT	0
DIST_BUS	COST	COST	COST	COST	0
DIST_GROC	COST	COST	COST	COST	0
DIST_EMERG	COST	COST	COST	COST	0
DIST_SCHL	COST	COST	COST	COST	0
DIST_CORE	COST	COST	COST	COST	0
AREA_HA	BENEFIT	BENEFIT	BENEFIT	BENEFIT	0
HHH_INC_30	COST	BENEFIT	BENEFIT	BENEFIT	1
ZONE_RES	BENEFIT	BENEFIT	COST	BENEFIT	1
AVG_HH_VAL	COST	BENEFIT	COST	BENEFIT	2

Table 5.9 – Single user consensus on benefit/cost values

5.3.2 Collaborative Consensus

A similar analysis of consensus can be done on the votes submitted in the collaborative component of the workshop. Table 5.9 shows that most criteria improved in consensus, particularly the distance-based ones (though DIST_EMERG remains contentious). Curiously, consensus worsened in this case (*i.e.* the consensus distance measure increases) for the criteria RATE_65 and HHH_INC_30. In the former case, User A increased his/her vote from 0 to 6, and with a small number of participants, the consensus measure was very sensitive to such a shift.

Criterion	User A	User B	User C	User D	Cook-Seiford distance
DIST_GROC	4	5	5	5	3
DIST_BUS	6	5	6	5	4
DIST_SCHL	5	6	6	5	4
DENS_POP	6	5	5	4	6
DIST_CORE	5	5	6	4	6
ZONE_RES	6	5	6	7	6
AVG_HH_VAL	5	4	5	2	10
AREA_HA	2	5	5	3	11
DIST_EMERG	5	2	2	5	12
HHH_INC_30	5	5	5	0	15
RATE_65	6	0	3	2	19

Table 5.10 – Collaborative criterion consensus

In terms of the benefit/cost values, the collaborative stage reduced the disagreement on the AVG_HH_VAL criterion, with two participants changing their preferences to indicate they preferred to locate affordable housing in areas with higher property values (see Table 5.11). MapChoice takes the majority of benefit/cost votes as its consensus choice. As noted in Chapter 4, when there is an even 2-2 split of benefit and cost votes the moderator acts as the tiebreaker. However, in the Collingwood workshop this situation did not occur. Three of the criteria with at least one benefit/cost dissenter (DIST_EMERG, HHH_INC_30, and AREA_HA) had some level of disagreement in their criterion distance values, indicating that these three criteria remain somewhat contentious. In particular, the AREA_HA criterion was seen as a benefit by all participants in the single-user stage, but three users changed their preferences to cost in the collaborative stage (as shown in the “changes” column), more than for any other criterion.

Criterion	User A	User B	User C	User D	differences	changes
DENS_POP	BENEFIT	BENEFIT	BENEFIT	BENEFIT	0	0
RATE_65	BENEFIT	BENEFIT	BENEFIT	BENEFIT	0	0
DIST_GROC	COST	COST	COST	COST	0	0
DIST_SCHL	COST	COST	COST	COST	0	0
DIST_CORE	COST	COST	COST	COST	0	0
ZONE_RES	BENEFIT	BENEFIT	BENEFIT	BENEFIT	0	1
DIST_BUS	BENEFIT	COST	COST	COST	1	1
DIST_EMERG	BENEFIT	COST	COST	COST	1	1
AVG_HH_VAL	BENEFIT	BENEFIT	BENEFIT	BENEFIT	0	2
HHH_INC_30	COST	COST	COST	BENEFIT	1	2
AREA_HA	COST	COST	COST	BENEFIT	1	3

Table 5.11 - Collaborative benefit/cost consensus

5.3.3 Change in Consensus

A key question addressed in this thesis is whether consensus changes from single-user to group participation in decision-making. Table 5.12 shows that the overall consensus distance measure (the sum of all criterion distance measures) decreased 20% during the collaborative part of the data collection, which corresponds to an improvement in consensus. This improved consensus was not uniform. Six criteria saw improved consensus (a decrease in the distance measure), while four had

poorer consensus after the collaborative session. Improvement in consensus can be attributed to any number of factors, including interaction with the other participants leading to a change in a user's preferences, more familiarity with the decision-making software, or a better understanding of the study problem. These are discussed in Section 5.6.2.

Criterion	Cook-Seiford distance		(change)
	single-user	collaborative	
DIST_GROC	13	3	-10
AVG_HH_VAL	19	10	-9
DIST_BUS	10	4	-6
DIST_EMERG	17	12	-5
DIST_SCHL	9	4	-5
DENS_POP	7	6	-1
ZONE_RES	6	6	0
AREA_HA	10	11	1
DIST_CORE	4	6	2
RATE_65	16	19	3
HHH_INC_30	9	15	6
Total	120	96	-24

Table 5.12 - Change in criterion consensus

5.4 Consensus Across Alternatives

Analysing consensus for the decision alternatives under review is more involved than for criteria, where each participant's preferences are only compared against each other. A ranking of the decision alternatives is the final outcome of the decision-making process, and it is necessary to use a voting technique to come to a consensus ranking of the alternatives.

A well-known issue with voting techniques is that different methods produce different results. To overcome this a sensitivity analysis can be performed by comparing the results of a number of voting methods (also known as social choice functions – see Chapter 2) and assessing how they would lead to different results for the consensus ranking. Three such methods are considered in this thesis, namely *score averaging*, *Borda ranking*, and the preference aggregation method of Group MapChoice (discussed in Section 2.7).

Score averaging, called *Cardinal Ranking* by some researchers (Hwang and Lin, 1987) takes an average of the fractional numeric scores (between 0.0 and 1.0) of each alternative for the four participants. The score values are shown in the “avg score” column of Table 5.12, and then a ranking is generated from the score values, shown in the “avg rank” column.

Borda’s voting method is quite simple and is currently employed to calculate college and university sports team rankings, among other uses. Voters rank candidates and the method assigns a point value to each ranking, ranging from the highest score ($n-1$) assigned to the top candidate to 0 for the bottom candidate. These scores are added for all voters, and candidates are ranked by their cumulative score – a kind of point system.

The MapChoice method, used only in the collaborative stage, averages the user votes for each criterion to a “collaborative weighting rating”, which is then used to calculate an overall ranking. This is different from score averaging because the averaging is performed at the criterion level, culminating in one set of (collaborative) weights and one ranking, whereas score averaging calculates a ranking for each participant, and averages the scores at the alternative level.

ADDRESS	Ranks				avg score	avg rank	Borda score	Borda rank
	User A	User B	User C	User D				
400 SECOND ST	4	1	15	1	0.6236	1	75	1.5
87 RAGLAN ST	5	5	9	2	0.6193	2	75	1.5
6 CAMERON ST	11	6	2	8	0.5972	3	69	3
115 HIGH ST	6	3	16	3	0.5845	4	68	4
80 SIMCOE ST	15	2	8	5	0.5786	5	66	5
1 LOCKHART RD	7	4	17	4	0.5730	6	64	6
(Riverside Subdivision)	3	9	21	6	0.5548	10	57	7
292 SIMCOE ST	19	8	5	10	0.5521	11	54	8
470 ONTARIO ST	13	17	3	13	0.5619	8	50	10
70 HURON ST	21	7	6	12	0.5443	13	50	10
135-145 HIGH ST (multi)	8	12	19	7	0.5442	14	50	10
49 RAGLAN ST	12	20	1	14	0.5630	7	49	12
302 SEVENTH ST	9	18	4	17	0.5587	9	48	13
19 RAGLAN ST	10	11	20	9	0.5248	15	46	14
WALNUT ST	1	19	22	11	0.5445	12	43	15
127-133 BIRCH ST (multi)	14	15	11	16	0.5227	16	40	16
70 OAK ST	16	14	10	18	0.5226	17	38	17
140 MAPLE ST	17	13	14	15	0.5193	18	37	18
131 BEECH ST	18	16	13	19	0.5127	20	30	19
CAMERON ST N/S	2	22	23	20	0.5130	19	29	20
649 HURONTARIO ST	20	21	7	22	0.5065	21	26	21
68 NIAGARA ST	23	10	18	21	0.4789	22	24	22
BRYAN CRT and LOCKHART RD (multi)	22	23	12	23	0.4703	23	16	23
420 HIGH ST	24	24	24	24	0.2959	24	0	24

Table 5.13 - Single-user consensus rankings

The consensus rankings at the single-user stage are shown in Table 5.14. A few points are interesting here. 420 High St., receives a very low ranking from all participants as its average score is much lower than any other site. Both rankings have the same top five and bottom four sites, and while there is some difference in the mid-ranked sites, this appears to be due more to closeness in scores than anything else, and therefore is an artifact of the voting method used.

A similar analysis can be undertaken on the collaborative session, using the user-submitted votes (Table 5.14). Again there is not a great difference between the rankings. The 420 High St. site is still ranked much lower than the next nearest site. However, User A ranks the 420 High St. site in 18th

place instead of 24th, so even if its average score is extremely low, its Borda score is the same as site at 49 Raglan St., which is rated 23rd by two of the participants. Hence, the Borda ranking can obscure differences in preference intensity, and can be sensitive to extreme votes (Hwang and Lin, 1987). It can also tend to “average out” alternatives in the middle, as is evident in terms of all the alternatives with a score between 40 and 50.

ADDRESS	Ranks				Single user	Collaborative				
	User A	User B	User C	User D	Borda rank	Map Choice	avg score	avg rank	Borda score	Borda rank
400 SECOND ST	6	1	1	1	1.5	1	0.6294	1	87	1
87 RAGLAN ST	14	18	14	2	1.5	11	0.5331	11	48	11.5
6 CAMERON ST	9	21	21	12	3	20	0.4859	19	33	15
115 HIGH ST	3	3	2	3	4	2	0.6134	2	85	2
80 SIMCOE ST	16	4	5	6	5	5	0.5501	8	65	7
1 LOCKHART RD	5	5	3	4	6	3	0.5964	4	79	4
(no address)	8	6	9	5	7	8	0.5628	6	68	6
292 SIMCOE ST	10	9	6	10	8	6	0.5433	9	61	9
470 ONTARIO ST	23	22	22	15	10	22	0.4362	22	14	21.5
70 HURON ST	11	16	12	11	10	13	0.5267	13	46	13
135-145 HIGH ST (multi)	2	8	7	9	10	7	0.5818	5	70	5
49 RAGLAN ST	24	23	23	20	12	23	0.4065	23	6	23.5
302 SEVENTH ST	7	10	8	14	13	9	0.5431	10	57	10
19 RAGLAN ST	13	17	11	7	14	10	0.5316	12	48	11.5
WALNUT ST	1	2	4	8	15	4	0.6064	3	81	3
127-133 BIRCH ST (multi)	15	11	13	16	16	14	0.5090	14	41	14
70 OAK ST	20	15	17	19	17	17	0.4921	18	25	19
140 MAPLE ST	21	14	18	17	18	16	0.4931	17	26	18
131 BEECH ST	17	13	16	18	19	15	0.4990	15	32	16
CAMERON ST N/S	4	7	10	13	20	12	0.5600	7	62	8
649 HURONTARIO ST	12	19	15	22	21	19	0.4951	16	28	17
68 NIAGARA ST	22	12	19	21	22	18	0.4800	20	22	20
BRYAN CRT and LOCKHART RD (multi)	19	20	20	23	23	21	0.4531	21	14	21.5
420 HIGH ST	18	24	24	24	24	24	0.2453	24	6	23.5

Table 5.14 - Collaborative consensus rankings

A well-known issue with the Borda ranking is its failure to satisfy the “Condorcet criterion”. That is, a majority of participants (Users A, B and C) rank the site at 70 Huron St. higher than 87 Raglan St., but the latter site still finishes with a higher overall ranking, thanks to the much greater preference intensity by User D. A similar issue occurs with the Cook-Seiford rule used in calculating the MapChoice collaborative ranking, seen between the site ranked 6th (292 Simcoe St.) and 7th (135-145 High St.).

The Cook-Seiford distance between the participant rankings and the consensus rankings allows examination of the influence of the different voting methods on overall consensus. Table 5.15 shows the distance between the individual user rankings and the group (consensus) ranking for each alternative. For the single-user mode, the distance uses the rankings generated by the participants, and for the collaborative mode, it takes the rankings calculated from their individual votes.

From this it is evident that in the single-user session there is a rather even amount of disagreement for all but two of the alternatives. Overall, the Borda ranking provides for slightly lower disagreement than the score-averaging method. In contrast, the disagreement is localized to a few sites in the collaborative session, and is low for most others. Some of the sites that had high disagreement in the single-user stage, such as Walnut St. and 49 Raglan St., have quite low disagreement in the collaborative ranking. For the former, two participants with very low scores changed their preferences in the collaborative stage such that the site was rated much higher. The latter was contentious in the single-user stage, with very high and low rankings. However, after the collaborative stage, all users’ rankings had the site near the bottom. While it is not always possible to generalize about individual alternatives, it does seem that improved consensus over attribute priorities softened the disagreement over this site.

To get an idea of the overall consensus, the distance from all sites is summed to a total distance score. The table indicates that in general disagreement was reduced from the single-user to the collaborative stage.

ADDRESS	Single User	Distance from Consensus Ranking				
		single-user		collaborative		
	Borda rank	avg score	Borda	MapChoice	avg score	Borda
400 SECOND ST	1.5	17	17	5	5	5
87 RAGLAN ST	1.5	13	15	22	22	21
6 CAMERON ST	3	17	17	21	21	21
115 HIGH ST	4	16	16	3	3	3
80 SIMCOE ST	5	16	16	13	17	15
1 LOCKHART RD	6	16	16	5	3	3
(no address)	7	23	21	6	6	6
292 SIMCOE ST	8	18	16	11	5	5
470 ONTARIO ST	10	24	20	8	8	9
70 HURON ST	10	22	20	8	8	8
135-145 HIGH ST (multi)	10	20	16	8	12	12
49 RAGLAN ST	12	31	21	4	4	5
302 SEVENTH ST	13	22	22	9	9	9
19 RAGLAN ST	14	20	18	14	12	12
WALNUT ST	15	29	29	9	9	9
127-133 BIRCH ST (multi)	16	8	8	7	7	7
70 OAK ST	17	12	12	7	7	7
140 MAPLE ST	18	13	13	10	8	8
131 BEECH ST	19	14	10	8	8	6
CAMERON ST N/S	20	25	23	16	12	12
649 HURONTARIO ST	21	16	16	14	14	14
68 NIAGARA ST	22	18	18	14	12	12
BRYAN CRT and LOCKHART RD (multi)	23	12	12	6	6	7
420 HIGH ST	24	0	0	6	6	7
Total		422	392	234	224	223

Table 5.15 – Distance between participant ranks and consensus rankings

5.4.1 Change in Consensus

Comparing the distances to a median consensus ranking can be useful in comparing voting methods, but to judge the change in consensus it is also possible to compare the distance measures between

participants, as shown in Table 5.16. The previous section showed that different consensus methods lead to different total consensus measure results. By comparing participants' rankings directly, the uncertainty introduced by the method used to calculate a consensus ranking is eliminated.

ADDRESS	Single user Borda rank	Consensus between participants		
		single-user	collaborative	change
400 SECOND ST	1.5	45	15	-30
87 RAGLAN ST	1.5	21	48	27
6 CAMERON ST	3	29	45	16
115 HIGH ST	4	42	3	-39
80 SIMCOE ST	5	42	37	-5
1 LOCKHART RD	6	42	7	-35
(no address)	7	57	14	-43
292 SIMCOE ST	8	44	13	-31
470 ONTARIO ST	10	42	24	-18
70 HURON ST	10	50	16	-34
135-145 HIGH ST (multi)	10	40	22	-18
49 RAGLAN ST	12	59	12	-47
302 SEVENTH ST	13	50	23	-27
19 RAGLAN ST	14	34	32	-2
WALNUT ST	15	71	23	-48
127-133 BIRCH ST (multi)	16	16	17	1
70 OAK ST	17	26	17	-9
140 MAPLE ST	18	13	22	9
131 BEECH ST	19	20	16	-4
CAMERON ST N/S	20	65	30	-35
649 HURONTARIO ST	21	46	34	-12
68 NIAGARA ST	22	42	32	-10
BRYAN CRT and LOCKHART RD (multi)	23	34	12	-22
420 HIGH ST	24	0	18	18
Total		930	532	-398

Table 5.16 - Change in alternative consensus between single-user and collaborative sessions

With the exception of four of the sites, there was a large decrease in the disagreement in ranks as the participants moved from the single-user to the group MapChoice session. Overall the distance from consensus dropped from 930 to 532, a decrease of nearly 43%. Even if the consensus measure does not have any indicator of statistical significance, this is a noticeable improvement in consensus. Two

of the sites experienced a slight increase in disagreement, and two others saw a much larger increase in disagreement. One of those sites, namely 420 High St., was rated last by all participants in the single-user stage, and by all but one participant in the collaborative stage. The participant who had the site ranked 18 instead of 24 was enough to increase the disagreement over the site from 0 to a higher value, but it was not enough to improve the site's rank under any consensus ranking.

The site at 87 Raglan St. was more complex. In the single-user stage it had relatively high ranks (5, 5, 9, 2). In the collaborative stage, three users dropped it down to 14, 18, and 14 respectively, while the last user still had it ranked second. This was enough more than to double the disagreement over the site. A few criteria accounted for most of the difference between participants. The site had the lowest data values of all alternatives for the property values criterion (AVG_HH_VAL). User D rated this criterion as being much less important than did the other participants, and this depressed the site's rank less for User D. Similarly, this site had a rather high value of household poverty rates (the HHH_INC_30 criterion). Three participants rated this as a cost criterion having above-average importance, lowering the site's ranking, while User D gave it a weight of 0, which did not disadvantage the site relative to the other locations. Disagreement over two particular criteria manifested in conflicting ways on different sites, and even if a "consensus" rating could have been found for the exercise, there remained disagreement (even increased disagreement) over particular alternatives.

Another perspective on consensus can be gained by exploring its spatial distribution of the rankings, since most criteria were spatial in nature. The consensus difference measure from the single-user session, using the Cook-Seiford distance measures of Table 5.16, is evident in Figure 5.7. High values (red) are sites for which there was high disagreement (and low consensus), and the opposite is true for blue sites. There was disagreement over most alternatives, with the exception of some of the central sites and the far south-western site (which received a universally low ranking). If nearby sites had similar values for the spatial criteria, it is reasonable to expect them to have similar rankings with any

weighting. If the weights or standardization values given to the spatial criteria were changed, the rankings for these sites would change as well, and so the disagreement measure would be higher. This was true for the spatial criteria in the single-user workshop, as the criteria RATE_65, AVG_HH_VAL, DIST_EMERG and HHH_INC_30 had high disagreement. Only the sites that had uniformly high or low ranks, such as the large site in the south-west corner, exhibited little disagreement between participants.

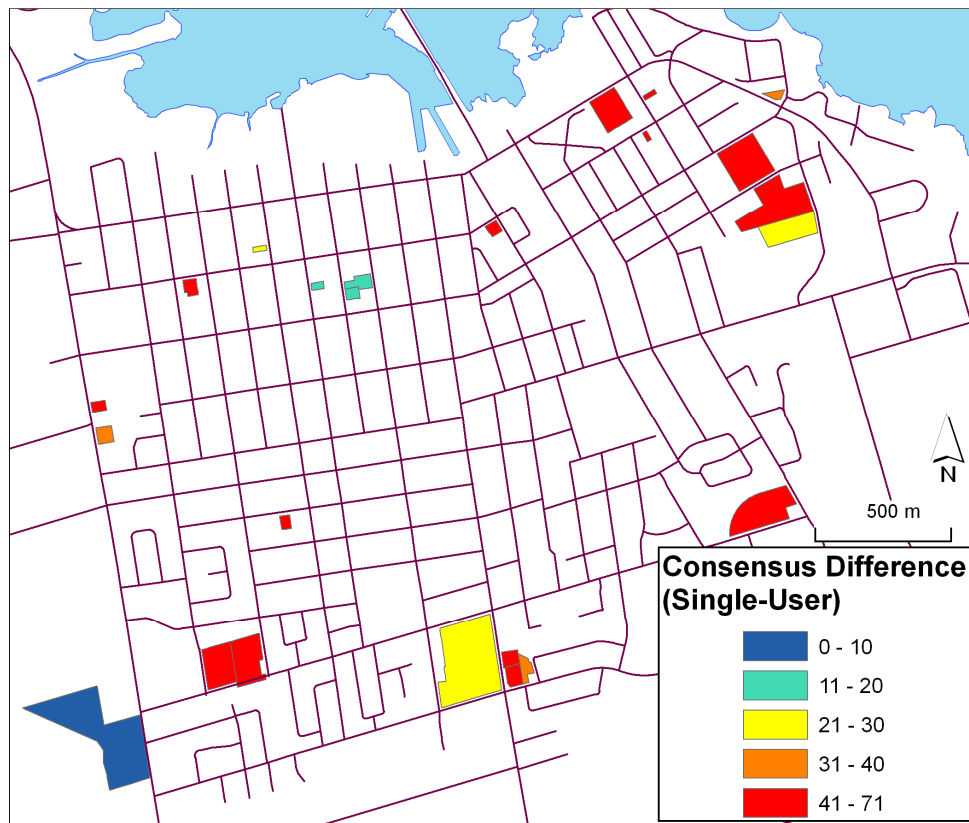


Figure 5.7 – Spatial distribution of consensus in after single-user session

In the collaborative session, the extent of disagreement is less than for the single-user session (Figure 5.8). The disagreement does not have any obvious spatial pattern, since some sites with high consensus are adjacent to other sites with low consensus in the north-east and south-central regions, yet in other regions (like the north-west part of the Town) most sites have low consensus.

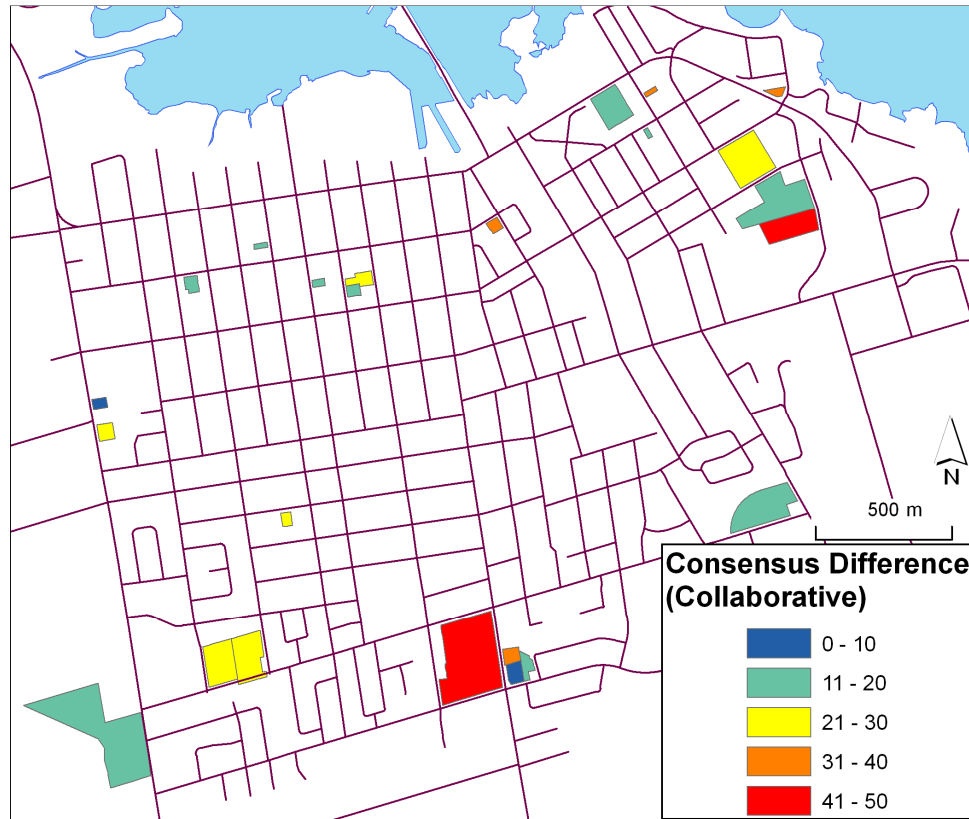


Figure 5.8 – Spatial distribution of consensus in after collaborative session

Mapping the change in consensus from the single-user to the collaborative sessions (Figure 5.9), it is clear that most sites experienced a sharp decrease in disagreement (a negative change in the Cook-Seiford consensus distance, mapped as green), while the three sites seeing a major worsening in consensus are mapped as red.

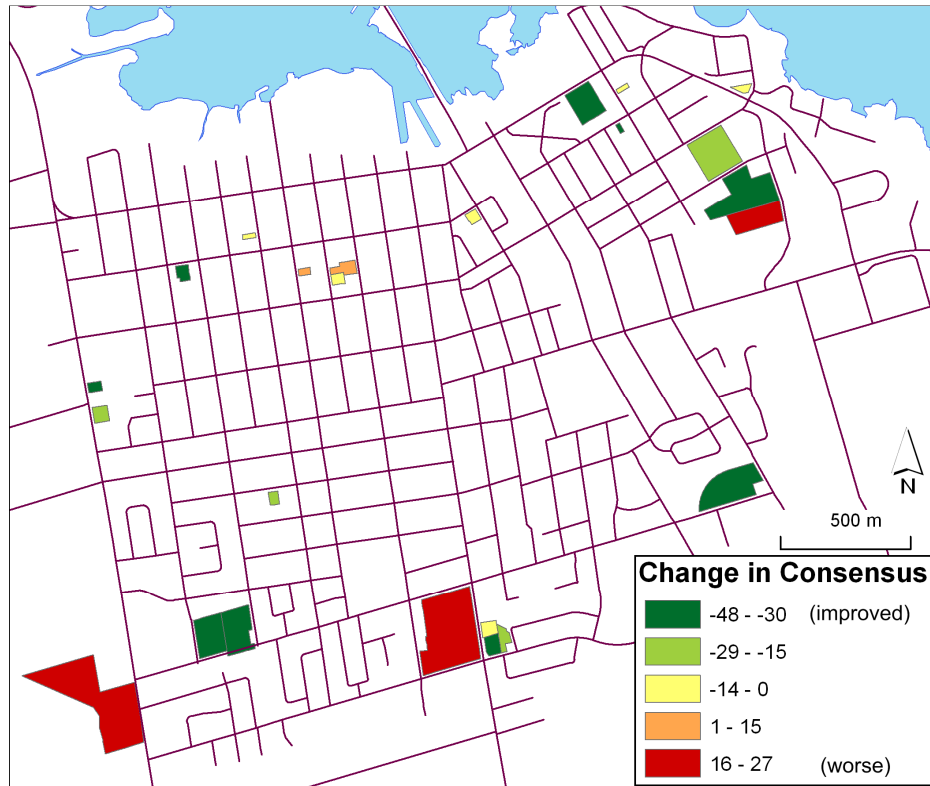


Figure 5.9 – Change in between-user consensus from single-user to collaborative stages

For the site with worst consensus in the north-east (87 Raglan Rd.), the decrease is caused by User D giving it an exceptionally high ranking compared to the other users. As discussed earlier, the criteria `avg_hh_val` and `hhh_inc_30` contributed to this, but so did the `dist_emerg` criterion, which is more explicitly spatial. This site is close to the local hospital, so it has a low data value for `dist_emerg`, a criterion for which there was some disagreement (Table 5.9). User D assigned it a weight of 5 and a “cost” rating, resulting in a high score for this alternative on the `dist_emerg` criterion. Users B and C assigned it a weight of 2, de-emphasising this criterion. User A gave it a weight of 5 but a “benefit” rating, meaning the site had a lower score on this criterion than most other sites, possibly due to misunderstanding the meaning of benefit/cost for this criterion, or to a different interpretation of the attractiveness of being located near several emergency stations. Accordingly, only for User D did this site have a good rating, with a lower ranking for the other participants contributing to its low consensus rating.

Although a recommendation on facility siting was not the purpose of this thesis, from the above analysis it is apparent that some sites are better suited to affordable housing than others. The site at 400 Second St. had overwhelmingly high rankings, and a correspondingly low degree of disagreement between participants. Other sites that had high scores but were slightly less stellar included 115 High St, 1 Lockhart Rd., and the site at Walnut St. The site at 420 High St. fared poorly under nearly all rankings, and its low disagreement ranking was a product of its strong unsuitability.

After the MapChoice portion of the workshop ended, participants were given a brief survey to fill out, and the results are described in the next section.

5.5 Exit Survey Results

Measuring consensus is not the only goal of this thesis. As noted in Chapters 1 and 3, it was also intended to get some qualitative feedback from the workshop participants on questions relating to whether they found use of MapChoice a positive experience, whether it helped them learn more about the affordable housing problem, and how intuitive they found the software. The survey conducted at the end of the workshop was used for this purpose, and the results are now discussed.

5.5.1 Demographic Spread

In terms of gender, the group had an even 2-2 male-female split. Two of the group members were aged between 45 and 54, and the two others were from 55 to 64, for a group makeup older than the Collingwood median age of 41 (Town of Collingwood, 2005). The SCATEH group is based in the larger Simcoe County, including communities outside of Collingwood, so three of the participants were residents of Collingwood while one was from elsewhere.

5.5.2 Familiarity with Software and Planning

	None	Some	Avg.	Above-avg.	Very
<i>Familiarity with general computer software</i>	-	-	3	1	-
<i>Familiarity with computer-based mapping (e.g. Google Maps, GIS software)</i>	1	1	2	-	-
<i>Familiarity with planning decision-making processes related with land-use change</i>	2	-	-	2	-

	Difficult	Somewhat Difficult	Neutral	Somewhat Easy	Easy
<i>Ease of use of MapChoice after initial tutorial</i>	1	1	-	1	1

The citizen group we were working with had some familiarity with computers in general, with all the participants using computers at least occasionally, and having participated in the first MapChat workshop. The two participants with a stronger computer background got up to speed faster with the software. Two participants that self-identified as unfamiliar with mapping software also mentioned they had difficulty learning to use MapChoice, even after the initial tutorial. Some of the group members had years of experience guiding planning decisions while others had limited planning experience and involvement. The more experienced group warmed more quickly to MapChoice than the latter. Figure 5.10 visually represents the strong relationship between the ease of use of MapChoice and the participants' previous experience with computer mapping technology and the concepts of planning decision-making.

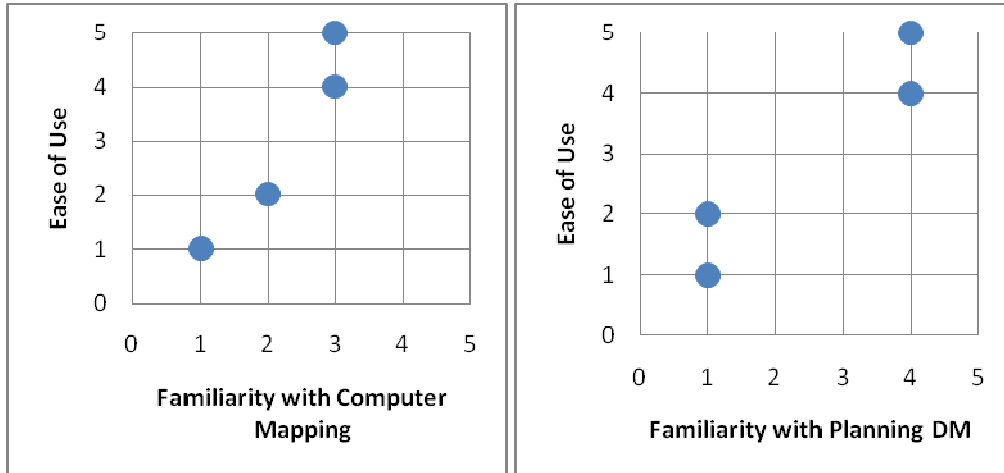


Figure 5.10 – Plot of ease of use of MapChoice vs. (a) familiarity with computer mapping, and (b) familiarity with planning decision-making

5.5.3 Impact of MapChoice on Understanding Issue of Affordable Housing

	Yes	Partly Yes	Neutral	Partly No	No
<i>Did MapChoice help in better understanding affordable housing?</i>	1	2	1	-	-
<i>Did single-user MCA help?</i>	-	3	-	1	-
<i>Did collaborative MCA help?</i>	2	1	1	-	-

The participants indicated that the MapChoice workshop was an informative experience, even if they were already familiar with the issue of affordable housing site selection and its assessment.

Participants generally seemed to prefer the group setting, stating: “I think the group discussion clarified some issues and brought up various points of view” and “both helped but understood it better when explained with group”.

5.5.4 Impact of MapChoice on Quality of Decision

	Yes	Partly Yes	Neutral	Partly No	No
<i>Did single-user MapChoice contribute to a better decision?</i>	-	1	-	1	-
<i>Did collaborative MapChoice contribute to a better decision?</i>	2	2	-	-	-

Participants felt the group MCA was more useful than the single-user mode, with comments such as “Preferred the group over single user method - would use it more. - could see results more quickly and could lead to discussion.” One user mentioned the order of the workshop tasks may have been reversed: “I liked thinking through the options + then sharing ideas in the group. However, I think doing it as a group to define the options might have been useful first.”

5.5.5 Advantages and Disadvantages of MapChoice vs. Other Planning Methods

	Yes	Partly Yes	Neutral	Partly No	No
<i>Did MapChoice provide any advantages compared to other planning methods (maps, presentations, etc)?</i>	3	-	-	1	-
<i>Any disadvantages to using MapChoice for comparing affordable housing sites?</i>	-	2	2	-	-

On this question, participants seemed to really like the benefits of MapChoice to planning decision-making. Some users liked the group mode, saying “Able to instantly see results of input. Especially liked the group aspect of the MCA.” Others liked the emphasis on objectivity: “By far superior to traditional (presentations) style Map Choice weights the factors more objectively for the group.”

The greatest challenge for the software was its learning curve, particularly on understanding the role of cost/benefit standardization in MCA. The users echoed this sentiment: “Difficult to understand cost/benefit part of software - for a larger group or for someone trying to navigate on own this would be difficult.” One user mentioned a disadvantage to MapChoice is “Just getting started + learning the software”

5.5.6 Suggestions for Improvement – MapChoice, Workshop Design, Data

Two final open-ended questions sought suggestions on how MapChoice and the workshop could be improved. The most common suggestion was to simplify and explain the concept of benefit/cost better. Users said “cost/benefit is very difficult to grasp” and suggested “change wording of

cost/benefit - not sure to what though.” Land ownership was also a concern, since there was no data on whether the proposed sites were in fact available, or even who the owners were. Participants mentioned that “... knowing who owns the land would be nice, especially government + private ownership” (although none of the candidate sites were located on government land). One participant asked for more information directly affecting affordable housing residents, such as proximity to daycare.

5.6 Discussion of Results

5.6.1 Sample Size

Even if some of the results in this chapter do show some definite patterns, the small sample size of four participants means the findings lack statistical significance. Variations in the preferences of even one participant can change the final results, so the quantitative conclusions of this study need to be interpreted with caution.

For technical reasons, a larger group would not have worked with the current configuration of MapChoice. At the time of the workshop, the prototype MapChoice software was not able to support more than six or seven concurrent users, bogging down or even becoming completely unresponsive. This bottleneck was not traced to any particular source, and it could have been caused by anything from a memory leak in the software, inefficient alpha-level code overloading the processors of the main server, or insufficient bandwidth. Even the computational strain of rendering raster images in MapServer could have been a problem, since one of the layers used in the workshop was a tiled mosaic of aerial imagery of Collingwood, which is much more processor-intensive to render than vector features.

Organising a successful collaborative workshop with more than 8 or 10 people would have introduced logistical challenges of its own, especially regarding teaching participants or managing group

interactions. Moreover, most statistical tests require even larger samples – at least 22 to 30 people – to achieve statistical significance and such a large group would have been unworkable using MapChoice (Palys, 2003). Running multiple small workshops could have mitigated this concern, but more research scrutiny and a greater organisational burden may be unwelcome for a community group.

5.6.2 Consensus Results

The small group sample prohibits definitive claims about the results, but the workshop did show signs that that collaboration may help improve consensus between participants. The mechanism by which this happens is not clear. Perhaps this is caused by the interaction and discussion over each criterion. However, during the collaborative stage, not all the criteria were fully discussed. Another explanation could be the average group vote, which was updated to reflect any newly submitted vote. This number could have been influencing participants to choose a weight closer to the consensus value.

The spatial analysis of consensus showed that in the single-user stage, there was high disagreement over site rankings across most parts of Collingwood. By comparison, during the collaborative stage some regions were not as contentious, while other regions had sites with low disagreement near sites with high disagreement.

These kinds of results could be useful to a community group attempting to convince neighbourhood associations and concerned residents of the viability of certain sites, or even of the MCA process. If certain regions are less contentious, those areas may be easier to justify or “sell” to the public and politicians, particularly if those sites have higher rankings. A high disagreement value in other sites or regions could signal that a battle is more likely over those sites, even if the sites may be ranked relatively well overall. If some citizens see a site as highly suitable, and others view it as undesirable, there could be conflict if that site were eventually placed on a shortlist, for example. Controversial sites might also be candidates for further debate, or may signal a need for gathering more information.

A workshop using MapChoice with a variety of participants can be used as a kind of focus group, exploring which areas are popular and which are contentious or unsatisfactory.

5.6.3 Running the Workshops – Issues and Difficulties

Ultimately the workshop was completed successfully, but there were some challenges that are worth noting. First, the time required for the participants to learn how to operate the software on their own was somewhat higher than had been anticipated. This could be due to a variety of issues including the user interface design of the software, the difficult nature of the affordable housing siting issue in general and the conceptual complexity of MCA.

The single most difficult point for the users to understand was the distinction between benefit/cost and criterion weight. It appeared that users understood the two preferences as somehow linked, as several asked whether a high weight and a “benefit” setting was equivalent to a low weight and a “cost” setting, somehow having the two balance out. Participants’ difficulties with the criteria type designation did decrease somewhat following the tutorial and was eased even more following a period of experimentation with the software.

MapChoice is a highly streamlined, simplified interpretation of MCA, with standardization abridged to merely choosing between benefit and cost, and with no sensitivity analysis or ability to build a criterion hierarchy. The academic literature on the subject calls for more mathematically rigorous and detailed analysis, however MapChoice necessitated compromises to be appropriate for participation by citizens with zero prior experience. Even in its simplified form, MapChoice still took some hours to learn, and advanced concepts like standardization functions, outranking, or dominated alternatives were not possible to cover during a half-day workshop. Despite its initial difficulties, the case study with SCATEH demonstrated that it is feasible to expect non-expert participants to learn the basics of MCA.

Many MCA approaches give participants the capability to specify a custom set of alternatives and criteria. This feature was designed in earlier versions of MapChoice, but it was disabled for the workshop due to time constraints. The full set of criteria and alternatives suggested by the participants in the previous workshop was sufficient for the workshop, and it was possible to ignore irrelevant criteria and alternatives.

As the workshop progressed, users began exploring the demographic data layers and experimenting with the effects of various rankings on certain, specific sites, and some even examined score and rank values in the data table. It appeared that users eventually understood the relationship between data values, weightings and rankings. By the time the collaborative MCA session had started, the participants were confident to enter their votes and discuss the criteria with the other participants. In this respect, it may have been possible that the highly positive reviews of the collaborative phase, and indeed the improved consensus level, were due to a better understanding of the software from the earlier single-user stage, rather than any superiority of the group process. Alternately, perhaps considering only one criterion at a time could reduce the cognitive load and produce a clearer understanding of the criterion's importance. More research exploring the impact of the order of tasks in a workshop on consensus may answer this question.

One comment heard repeatedly throughout the exercise was the wish to have a more diverse base of users doing the workshop. One participant even wrote: "We need to have the Town staff, councillors, real estate community, [and] developers involved if possible." Without any real stakes in the meeting, it was more of an interesting research exercise than a politically relevant vehicle for change. Involving users with more diverging viewpoints, rather than just the SCATEH volunteers, could have generated a more spirited, contentious discussion over the affordable housing issue.

Given the face-to-face workshop setting, there were no messages posted within the chat interface of MapChat. At one point, one of the participants who was having trouble with the software rolled out a

map of property parcels in Collingwood, and began a discussion about sites over the map instead of within MapChat. The communicative capabilities of the software were not used to build consensus, instead all the interaction occurred outside MapChat and MapChoice.

All in all, the participants claimed they learned a good deal from the workshop. This suggests that interactive decision-support software may be as useful not just as a decision-support tool, but also as an impetus for participants to thoroughly explore data and the multifaceted nature of the problem at hand.

The distribution of weight votes is shown in Figure 5.11. Two interesting patterns appear here. The single-user votes are close to a normal distribution, centred on the range of 4-6. It is possible the design of the software encouraged moderate positions, since the single-user mode started with a default weight of 4 for all criteria. Users may have been willing to change the weight within one or two points, but reluctant to choose weights of 0 or 7. Indeed, there were only two selections of a weight of 7 by one user during the entire workshop.

There was no default value in the collaborative weighting mode, with each weighting dropdown defaulting as “Choose a weight”, which may explain slightly greater variation in the distribution of weight selections, but even then the weight of 5 was by far the most popular. It is possible the software influenced the users’ weight selections, something that was considered only superficially in the study.

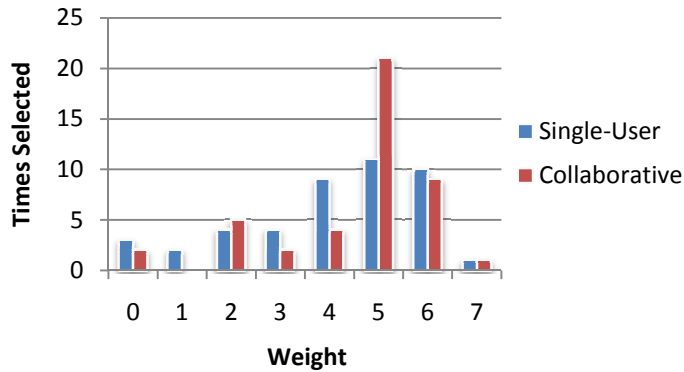


Figure 5.11 – Distribution of weight selections

Manipulation of technology has been discussed as a potential pitfall of collaborative tools (Carver, 2003), and also of voting (Hwang and Lin, 1987). One way users could potentially disrupt the group vote was by exaggerating their own vote to artificially move the group score closer to their desired level. During the workshop no manipulation was noticed by the moderators, and the database logs show the participants usually only voted once per criterion.

The group vote was designed to be anonymous. However, due to the very small size of the workshop, it was quite clear which user submitted which vote – the moderator’s view was visible on the main projector (with an updated tally of the averaged weight score), and when most users had voted they often would turn around in their chairs and look towards the front of the lab, indicating they were finished.

5.7 Summary

In this chapter the results of the MapChoice affordable housing workshop were presented and analysed, beginning with the results from the single-user stage, the collaborative stage results, analysis of the evolution of consensus through the workshop, and a summary of the participant survey. The implications of the research results were discussed in the final section. Despite the small sample size of participants, the major research findings of this chapter were that consensus did improve from the single-user stage to the collaborative session, both across alternatives and criteria, and that the

participants indicated they generally liked MapChoice, particularly the collaborative aspect of Group MapChoice, despite some effort in learning the software.

The next chapter brings the thesis to a close with a summary of the study's achievements, a description of how the thesis objectives were met, an examination of the study's contribution to the literature, limitations and caveats of the study, and directions for possible future research.

Chapter 6 - Conclusion

This chapter summarises the contributions of the thesis. First, the results are reviewed in relation to the goal and objectives stated in Chapter 1. The key findings of the research are stated and the limitations of the project are identified. The chapter also discusses how the research fits in within the broader academic literature, and proposes directions for future research.

6.1 Summary of Results and Thesis Objectives

This study has bridged a gap between the ideas of public participation, group decision-making, and participatory GIS, all with a focus on dealing with planning-related issues. As an intersection of several streams of current research, this project has shown that the participatory approach of MapChoice is feasible, it can provide tangible benefits to its users, and it even shows promise at managing consensus among stakeholders. The approach of this study has shown potential of a ripe new field for further experimentation and research.

Of the four primary objectives of the thesis, all were achieved to varying degrees. The first objective was to develop a conceptual foundation for the research by reviewing the literature on the key issues addressed by this thesis. Three primary concepts of *space*, *participation* and *choice* were shown to be the fundamental dimensions of the research, and within this framework were situated the many fields and sub-disciplines touched on by the study. Important ideas, terms and theories were introduced from the fields of decision-making, spatial decision-making and GIS, PPGIS, MCA, decision support systems, choice theory, collaboration and consensus. It was shown that the area of collaborative spatial MCA remains relatively under-studied and not fully understood, and the thesis was positioned to fill this research gap.

The other three research objectives related to contributions to the body of research were achieved by the study itself. The second major objective was to design and develop a software prototype for

collaborative spatial MCA. The software tool, called *MapChoice*, was designed as part of a larger environment of open-source software components providing web mapping, multi-user interaction and database functionality. MapChoice uses GIS data and map-based visualization as the base for an interactive, lightweight and simplified implementation of the common MCA method called Weighted Linear Combination. It allows users, both individually and in collaboration with other participants, to interactively compare candidate sites by evaluating a fixed set of criteria according to user-contributed weighting preferences. The software was designed to be simple and straightforward enough for non-expert participants to be able to learn in a short amount of time.

To satisfy the third objective of applying the software to exploring a real-world planning problem, MapChoice was used in a workshop in Collingwood, Ontario with a small group of participants who performed an exercise in site evaluation. Collingwood has recently experienced a dramatic increase in the cost of housing, driven by a shift in its economic base, population growth, and higher property values. As a result, affordable housing is in short supply. Recent efforts to find suitable locations for new affordable housing developments have seen mixed results and community opposition, so this workshop attempted a novel approach to finding housing sites using a city-wide spatial MCA investigation of potential locations. The workshop was organised with an extensive training period at first, followed by a single-user stage where participants performed the analysis independently, a shorter collaborative stage where the weighting was done as a group with interactions between participants, and finally ended with a brief participant survey. Ultimately the workshop was successful in educating the participants in the concepts of decision-making and involving them in the choice process of locating affordable housing, and although more time was required to explain certain concepts of MCA than had been expected, overall the participants had positive attitudes toward the workshop.

After the completion of the workshop, the results were tabulated and analysed to assess whether a collaborative spatial MCA tool like MapChoice could satisfy the fourth objective of contributing to

consensus between participants, impacting participants' understanding of the decision problem and generating meaningful results in a planning context. In this regard, despite the small and not statistically significant sample of four participants, the workshop results did show promise in successfully achieving these goals. There did appear to be some improvement in consensus when moving between the single-user and collaborative modes of the software, although this improvement was not uniform across all the proposed housing sites. The consensus improved more across alternatives than across criteria. Participants generally felt that their time spent with the tool did help them gain a better understanding of the various dimensions of the affordable housing problem within Collingwood, and felt the whole process was informational and educational. They also felt the decisions in the collaborative mode were better-informed and accounted for a variety of differing opinions compared to the single-user MCA. Finally, the workshop demonstrated that the MapChoice tool was able generate a useful ranking of the sites under consideration, and while this ranking did not see further use in the planning process in Collingwood, it did nonetheless reflect the positions and objectives of the study participants. Moreover, participants showed a good deal of enthusiasm for MapChoice over the formal meetings, presentations, and other planning exercises in which they had been involved previously.

6.2 Caveats and Limitations

Notwithstanding the successes in fulfilling the research objectives, this thesis has its limitations. Most importantly, the small sample size in the workshop precluded assessing consensus in a statistically meaningful way. The workshop participants' enthusiasm for MapChoice was not matched by a corresponding high rate of consensus, at least not at a conclusive level. A larger participant turnout would have been beneficial, but even a large group of 10 or more people would still have been theoretically insufficient, regardless of the logistical and technical challenges of running such a large workshop.

A likely reason for the low rate of participation (considering the first workshop attracted 10 people) may have been the lack of formal integration with the Town of Collingwood's formal planning process. It is entirely understandable that participants would be less likely to invest an afternoon of their time if the only rewards were stimulating one's own interests and contributing to academic research. If, on the other hand, the results of the workshop were to lead to further meetings, deliberation, or even consideration by the Town's planners, there would have been a stronger incentive for involvement. Other techniques that could have improved turnout include a greater involvement in the case study community, simultaneously running the workshop online for those participants who could not attend but were interested in participating, or even holding several workshops at different times and dates.

Planning-related assessments, particularly surrounding contentious topics like affordable housing, can generate conflict between stakeholders who have opposing viewpoints. In this study, the participants held relatively uniform views and goals, which proved to be helpful for an initial run of the software. A new dimension to results could be gathered by having more diversity in opinions and backgrounds of participants.

A limitation known by the researchers and pointed out by the participants was the incomplete nature of some of the underlying data. Several criteria requested by the group, such as assessed property values and land ownership, were not possible to obtain. Other data used, particularly the census data, had some gaps resulting from data suppression and were five years out of date.

The time constraints of a half-day workshop were a limit on how much could be covered and on the kind of data that could be used. Participants came in without a strong familiarity with decision-making, as would be typical of what would be encountered in a public setting. The time spent teaching the software and in one-on-one support, as the participants familiarized themselves with the tool, reduced the time left for exploring the data and attempting various scenarios.

Deciding on the Open Source software platform for MapChoice was borne out of necessity, as the existing MapChat project was a ready fit for MapChoice and the architecture was easily extensible and flexible. However, there are certainly limitations to the software. It is difficult from a programming perspective to create an attractive user interface in a Web-based environment, as the mechanics are less interactive than with desktop software. Transmitting data through the Internet from a remote server at the University of Waterloo led to longer loading times, particularly for the map images, which had to be reduced in size as not to overwhelm the computational capability of the server, resulting in less available screen area to work with. Communicating with the server introduced a delay in receiving interactive feedback and limited what could be done for data visualization.

6.3 Contributions to Research and Future Directions

Positioned as it is at the intersection of several avenues of current research, this thesis is a part of several emerging trends in the fields mentioned in the previous chapters, including participatory planning, PPGIS, spatial MCA, and collaboration. The thesis has identified a gap in the body of knowledge which MapChoice helps to address by combining decision support in the form of MCA with collaborative public participation and map-based visualization and analysis. As work in these fields evolves in new directions, some of the research questions and challenges encountered will be answered in due course, and some of the possible future directions are outlined in this section.

The importance of public participation in planning has been promoted for decades, but it seems that it is finally beginning to take hold in practice, meeting some of the calls made by advocates like Healy (1998) and Innes (1998) to bring citizens together to tackle planning problems through interaction and exchange of ideas. The trend is generally towards more participation, openness and transparency, but this is certainly not uniform throughout the world, and great care must be taken to ensure that recent progress continues. Some recent studies on fully collaborative, intensively participatory planning approaches have had mixed results, and more work must be done to refine the mechanisms of

collaboration and evaluate different collaborative techniques for participation (Fadeeva, 2005; Gunton et al, 2006).

GIS, and especially PPGIS, have been long touted as transformational technologies for improving participation in planning. In the past GIS had not been used to its potential in planning, but more recent studies (and anecdotal evidence) indicates this trend appears to be reversing (Geertman, 2002; Harris and Elmes, 1993; Klosterman, 1997; Vonk et al, 2005). New specialized tools are making inroads into planning decision-making, and departments have begun to use GIS technology as a structuring hub for spatial data management.

Similarly, the public is beginning to have access to GIS through the emerging field of PPGIS, which is just hitting its stride as an active field of research. PPGIS is quite different from the GIS tools used by experts because it is designed for a much more general audience, enabling collaboration between users, contribution of local knowledge, and direct control over the mechanisms of spatial information analysis (Carver, 2001; Carver, 2003; Carver et al, 2004; Jankowski and Nyerges, 2001; Sheppard et al, 1999). PPGIS has been suggested as bridging the gap between a technologically-active public and the information needed to participate in an active democracy. This thesis contributed to the PPGIS field by demonstrating the validity of the participatory spatial approach when dealing with real-world issues. Community participants found the process to be positive, educational and useful, and expressed enthusiasm for the technology even if they did not fully understand some of the finer nuances. Indeed the SCATEH group had not previously undertaken a spatial approach to decision-making, and they found the new spatial perspective to be enlightening.

Future research can explore in more detail how PPGIS tools can be used by community groups and interested citizens as a means for exploring, structuring, and better understanding planning issues from a spatial standpoint. It can be an empowering and democratising tool that encourages learning and contributes toward self-determination. However, to truly satisfy the need for broader public

involvement in planning, at some point the collaborative spatial MCA must be attempted in conjunction with an official, formal planning process. Existing planning participation methods like design charrettes are not too dissimilar from the same-place workshop accomplished by this thesis, but extending this kind of participation to potentially hundreds of interested citizens is an entirely different challenge altogether. Indeed, PPGIS software and even collaborative tools like MapChoice can relatively easily be extended to work in different-time, different-place environments, for example by having a group session spread out over a week with one criterion discussed and voted on every day. Users could then log in at any time, from any location, and contribute to the discussion. While this approach offers new opportunities for computer literate citizens to be involved in community planning, it also opens entirely new questions, such as how to deal with asynchronous input, the pros and cons of anonymous input the potential for abuse afforded by the Internet, and the challenge of training users without the benefit of a face-to-face workshop session. Many of these problems are common to all Internet-based multi-user tools, and these remain open questions in the academic and professional literature.

Challenges remain that inhibit the widespread adoption of PPGIS, such as the high cost of equipment and staff, the organisational and technical expertise required to maintain GIS systems, and the high cost and unavailability of spatial data (Sawicki and Craig, 1996). These costs are generally overwhelming for most community groups, and more research (and, realistically, more political support) is needed to determine better strategies for improving community access to technology. As demonstrated in the case study in Collingwood, the community group would never have had the resources to independently implement any GIS tools, and the study was only possible through the involvement of experienced researchers. If instead there were government agencies providing funding and assistance to commercialize research tools, expanding access to data, and assisting community organisations in the integrating technology within their operations, perhaps PPGIS could reach higher levels of penetration.

In the time since MapChoice was first designed nearly three years ago, new PPGIS and Web GIS software tools have evolved rapidly, including products supported by industry leaders like ESRI and Autodesk that are lightweight, compatible across many platforms, and easily extensible by software developers (ESRI, 2008; OSGeo, 2008). While none of these tools yet provide any kind of meaningful MCA or collaboration functionality, they can be used as an easily customized framework for further development of research tools. As well, the new generation of mapping tools are considerably more user-friendly, attractive in appearance and broader in their public appeal, which is necessary if these tools are to gain broad acceptance in society.

The challenge of developing rigorous but easy-to-use MCA techniques has already been discussed in this thesis, but much more work is needed on the specific mechanisms of gathering input into MCA methods, trying to find a balance between an acceptable cognitive load and meaningful results. To keep the software simple many of the finer points were decided upon by the researchers or left as pre-selected defaults (*e.g.* standardization, presumed neighbourhood size), and more research is needed into the validity of these kinds of assumptions, or else to come up with ways for participants to be able to easily and quickly modify these preferences to their liking.

As previous studies in the Town of Collingwood and elsewhere have demonstrated, affordable housing is a contentious, controversial subject, requiring careful consideration of many criteria to be successful. MapChoice, as applied here, showed that a collaborative PPGIS can be quite useful in dealing with such challenging planning land use problems, but more research is needed to see how such a PPGIS is used (or abused) in a situation with higher conflict. More work with participatory decision support tools similar to MapChoice should be repeated with larger, more diverse groups of participants. A more comprehensive understanding of group consensus can be gained by involving stakeholders holding different, even opposed viewpoints. A larger participant group can provide greater confidence in quantitative and qualitative tests, and running more workshops could better

control for variables like group size, demographics, and technological acuity. It would also be interesting to study if the order of the tasks in a workshop has any influence on the results.

MapChoice compared two instances of participant interaction, namely independent entry of preferences and voting-based collaboration. Both methods proved successful, but it appeared the collaboration yielded superior results in terms of quantitative consensus measures and participant satisfaction. This reinforces research findings from other studies to the same effect, and underscores the proven advantages of collaborative tools (Lam and Shaubroeck, 2000; Zahir and Dobing, 2002). As a simplified tool MapChoice worked well, but it is clear that in a group environment, handling collaboration successfully is challenging. Multi-user MCA or decision-support tools have been capable of handling individual user rankings, but MapChoice does collaboration at an earlier stage, while progressing through criteria. More research is needed on incorporating collaboration and choice in MCA, such as how to combine the two dimensions of user preferences (standardization and weights) concurrently for criteria. With larger numbers of participants it is possible that issues related to group choice become more pronounced (such as the simple majority needed to determine benefit/cost values), and the field of social choice theory may be able to develop a better compromise method for group choice while working under the constraints of Arrow's impossibility theorem (Arrow, 1951; Massam, 1993).

Measuring, displaying, and mapping consensus was considered but not implemented in MapChoice. This study analysed consensus only after the completion of the workshop, using external software. Further work could measure consensus within the MapChoice environment through an additional module, tracking inter-user consensus interactively during a workshop. For example, the criteria with the highest amount of disagreement could be singled out for discussion, or a miniature MCA session could be run on the sites with the best consensus if they are believed they could be more feasible politically. Actively monitoring consensus during a workshop plays into current research on group

decision norms, and could be a much more inclusionary and cooperative method of approaching planning decision-making than typically experienced by most citizens (Postmes et al, 2001).

Appendix 1 - Affordable Housing Workshop Handout

***SCATEH Workshop 2:
Comparing Affordable Housing Sites in
Collingwood***

June 3 ,2007

Username:

Password:

Welcome to our second workshop on using Web-based mapping tools for affordable housing planning in Collingwood! This package contains instructions on using the MapChoice software and some supplementary information to help you with the workshop.

In the previous workshop, a number of possible locations for new affordable housing projects in Collingwood were identified and commented on using the MapChat tool. Today's workshop will build upon that work by using a complementary module called MapChoice. MapChoice is a simple tool that will help (we hope!) you to compare and rank the sites in terms of their suitability for affordable housing.

Today's workshop consists of two stages. In Part 1, you will compare the sites on your own by: a) identifying the site characteristics, or criteria, that you want to use when comparing the different affordable housing sites, and b) setting the weight, or relative importance, of each criteria. In Part 2 of the workshop, the sites will be compared on a group-wide basis where each person "votes" on the criteria weight settings.

Finally, when the workshop is completed, we would appreciate if you could complete a brief survey. Thank you once again for your assistance with this research.

Part 1 – MapChoice training exercise and an introduction to Multi-Criteria Analysis

This stage is designed to get you familiarised with the MapChoice component of the MapChat software. We will run a short training exercise before proceeding to Part 2, where you will express your preferences for different affordable housing sites in Collingwood. At this stage, you will be working independently of others in the computer lab.

1. Login to MapChat with the username and password that have been provided to you on the first page of this handout. You are presented with the following screen:

MapChat (alpha)

Below is a list of available MapChat discussions:

- [SCATEH Training Discussion](#)
- [SCATEH MapChoice Discussion](#)

Administrative Options:

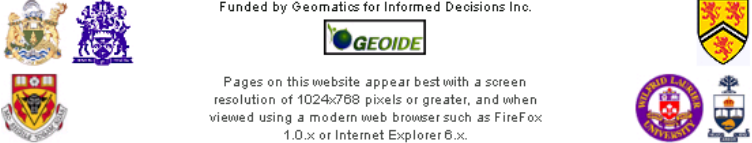
- [Create/Manage Users](#)
- [Create/Manage Groups](#)
- [Create/Manage Discussions](#)

Welcome to the MapChat website. The purpose of this project is to develop an online tool that supports argumentation in planning for spatial decision problems. The tool will incorporate elements of chat conversations embedded with mapping tools, enabling multiple users to interact and communicate with each other via an Internet-based interface.

This project will utilize of a series of Open Source projects including, but not limited to, MapServer, Chameleon, PostgreSQL, PostGIS, and PHP.

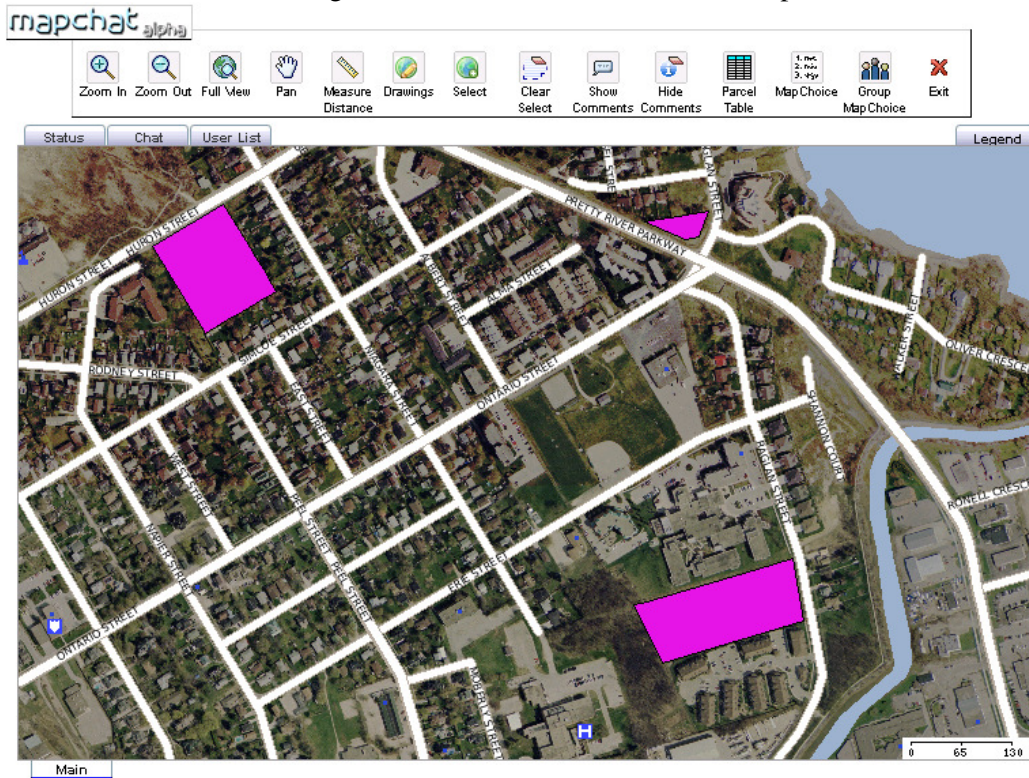
Current User:
jptaranu
[Edit Profile](#) | [Logout](#)






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Pages on this website appear best with a screen resolution of 1024x768 pixels or greater, and when viewed using a modern web browser such as FireFox 1.0.x or Internet Explorer 6.x.

- Click on “SCATEH Training Discussion”. You enter the main MapChat interface, as shown:



- We will review the processes of navigating the map interface through zooming in, zooming out and panning to new areas on the map. We will also run through a brief tutorial on MapChoice using this simplified example, using only three of the proposed sites and four of the site criteria.
- Briefly re-acquaint yourself with the MapChat navigation buttons.
 - The **Zoom In** tool () is used to zoom in to an area you select on the map. Click the Zoom In button, then click and drag on the map to select a rectangle for the zoom.
 - The **Zoom Out** tool () zooms out to view a larger area of the map. Click the Zoom In button, then click on a point on the map to zoom out from that point.
 - The **Zoom Extents** tool () returns to the original map extents, and is useful for quickly zooming out of the entire map or recovering your bearings if you ever become lost while navigating the map. Click the Zoom Extents button once and it automatically zooms to the original extents.
 - The **Pan** tool () is used to navigate horizontally on the map without zooming in or out. To pan, click the Pan button once, then click and hold down the mouse button, dragging the map to move it around.
 - The **Measure Distance** tool () is used to measure straight-line or more complex distances on the map. Click the Measure Distance button once to activate the tool, then click repeatedly on the map to draw a multi-segment ruler. The distance of this line is displayed on the bottom-right corner of the Internet Explorer window. Double-click to stop measuring.

- The next five icons, **Drawings** (🌐), **Select** (🌐), **Clear Select** (🗑️), **Show Comments** (💬), **Hide comments** (🔇), were introduced during the first workshop. They are not involved in this workshop, however they have been kept in case you would like to use them.
- The next three icons, **Parcel Table** (📊), **MapChoice** (🗺️), and **Group MapChoice** (👥), are the main tools we will be using in this workshop.
- Click the **Parcel Table** button (📊). This will open the Parcel Table window showing the site-specific criterion values for each proposed affordable housing site (as shown below). In the full MapChoice session we will run later, all of the sites and all the criteria will be shown; here, only the 3 training sites and their 4 criteria are displayed.

ADDRESS	DENS_POP	DIST_EMERG	ZONE_RES	AREA_HA	MSID
87 RAGLAN ST	1195.5	235	1	1.649	0
19 RAGLAN ST	1037.7	663	1	0.163	1
70 HURON ST	1546.9	484	0	1.403	2

Display parcels in: entire map

The selector on the bottom of the data table determines which parcels are shown in the table. If you choose “entire map”, all parcels are shown. If you have zoomed in a portion of the map to look at only a few parcels, you can select “current view” and only those visible parcels will be shown.

- Click the MapChoice icon (🗺️) to open the MapChoice tool.

Criterion Weighting

How important is each criterion to the suitability of the site, relative to the other criteria?

DENS_POP: 4. Average BENEFIT

DIST_EMERG: 4. Average BENEFIT

ZONE_RES: 4. Average BENEFIT

AREA_HA: 4. Average BENEFIT

Enter your rationale for this weighting:

SAVE WEIGHTING LOAD WEIGHTING

Go to the Mapping stage: NEXT STEP >

The first screen of MapChoice presents you with a list of criteria that can be used to compare the affordable housing sites identified in Workshop 1. These criteria reflect characteristics of the site

and its neighbourhood. A list that describes the criteria briefly is attached at the end of this handout, for your reference.

9. The dropdown boxes to the right of the criterion name can be adjusted to reflect how important that criterion is with respect to the suitability of affordable housing sites. Initially, all criteria are set to the same level of importance in determining the suitability of the sites. Any criterion you do not want to be considered as site comparison factors should be given a weight of “0 – Ignore”.

For all other criteria, choose a weight setting that represents its importance to the site rankings. There are 7 possible settings for the weights, ranging from “Slightly Important” to “Extremely Important”. Remember that the criteria are weighted relative to each other. In other words, the same ranking will result if all criteria are weighted “Extremely important” or if all criteria are weighted “Slightly important”.

For each weight you enter, please enter some notes in the text box to the right that explain why you chose that particular setting.

MapChoice

Criterion Weighting

How important is each criterion to the suitability of the site, relative to the other criteria?

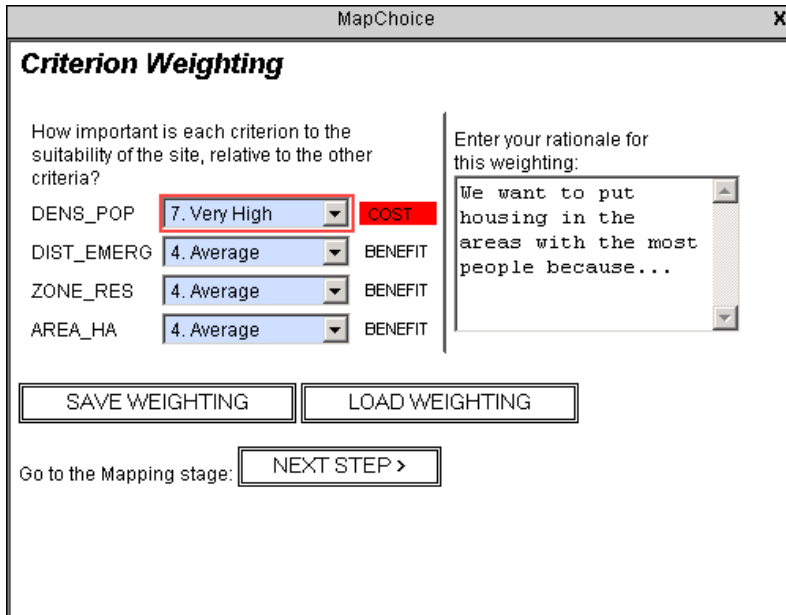
DENS_POP	7. Very High	BENEFIT
DIST_EMERG	0. Ignore	BENEFIT
ZONE_RES	1. Very Low	BENEFIT
AREA_HA	2. Low	BENEFIT
	3. Below Average	BENEFIT
	4. Average	
	5. Above Average	
	6. High	
	7. Very High	

Enter your rationale for this weighting:
We want to put housing in the areas with the most people because...

SAVE WEIGHTING LOAD WEIGHTING

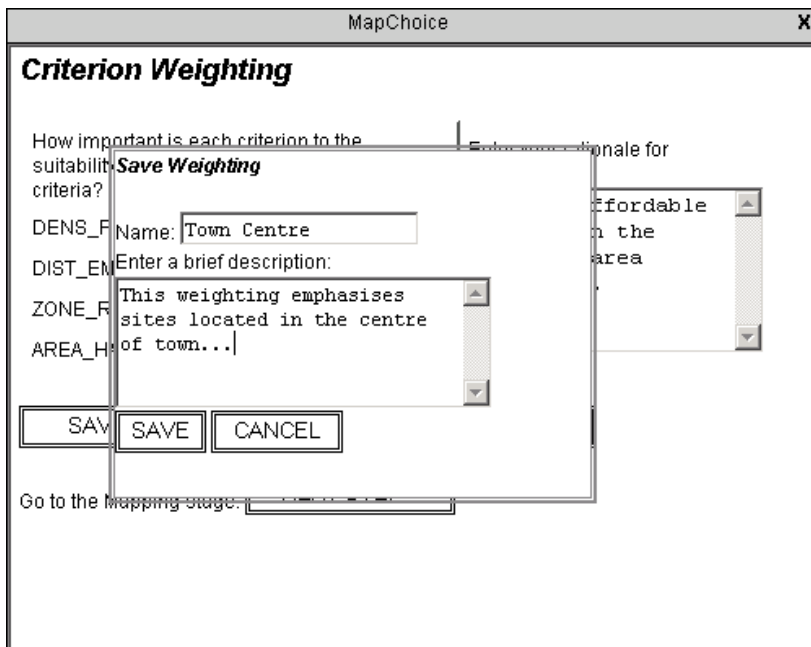
Go to the Mapping stage: NEXT STEP >


10. The final step required to set your weights is to indicate whether high values (“benefits”) or low values (“costs”) are preferred for each criterion. For example, if you want to favour larger sites which would permit projects that offer more housing units, “Area_HA” would be set as a “Benefit” criterion since larger parcels are preferred over smaller pieces of land. Similarly, if you prefer sites that are close to emergency services, you would set the “Dist_Emerg” criterion to “Cost” since short distances to first-responder stations would be preferred over longer distances.

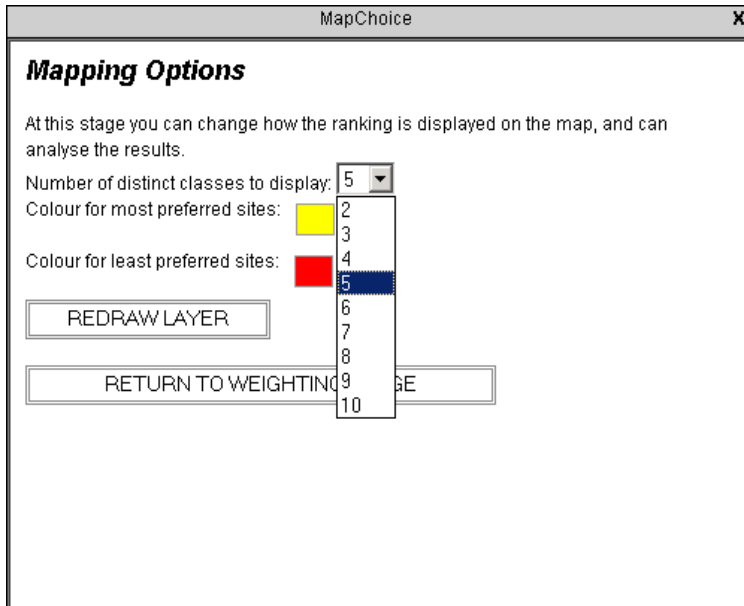



Initially, all criteria are set as “Benefit” criteria (high data values are preferred). To change a criterion to a “Cost”, simply click on the word “Benefit”. The word “Cost” is now displayed to the right of the criterion weight. You can change it back by clicking on the word “Cost”.

- When you are satisfied with your preferences, save your session by clicking the “Save” button. Enter a name and description for the weighting.




- You can now explore the mapped results. Click the “Next >” button to proceed to the map options stage. Here, you can change the colours in which the ranked parcels are displayed, and also how many classes (gradations of colour) will be displayed. When you are done exploring the mapped results, click the “Close” icon () on the MCA window.




13. Open the data table by clicking on the Data Table icon () again. There are now two new columns: “SCORE” and “RANK”, containing the calculated score (between 0.0 and 100.0) and rank (from 1 to 3) using the last weighting in MapChoice. You can use the Data Table tool to directly view the effects your weighting is having on the calculated scores for the proposed parcels, and examine how the criterion values for every potential affordable housing site rate to its score and rank.

ADDRESS	DENS_POP	DIST_EMERG	ZONE_RES	AREA_HA	MSID	SCORE	RANK
BLAN	1195.5	235	1	1.649	0	67.53	2
BLAN	1037.7	663	1	0.163	1	78.95	1
RON	1546.9	494	0	1.403	2	30.31	3

Display parcels in: entire map

14. If at this point you would like to change the preferences to your original weighting, you can load your weighting and edit it. Click the MCA icon () again. Your last set of preferences will be automatically loaded. Repeat steps 5 to 8 until you are satisfied with the results.

Part 2 – Individual comparison and ranking of affordable housing sites

Now that we have completed the training for MapChoice, we will proceed to using the full set of proposed housing parcels and all the site criteria. Click the “exit” button () on the main tool bar. You are now at the main MapChat login screen. Log in using your provided username, then click on “SCATEH MapChoice Discussion”.

Using the methods you learned in the previous exercise, enter your preferences for the weights assigned to the different criteria, specify whether they are benefits or costs, and also enter the rationale behind your weighting. When you are done, remember to hit “Save Weighting” to ensure your feedback is saved.

Part 3 – Group MCA

In this stage, you will be working with other group members to come to a group ranking of the proposed sites. Each person’s weight setting for a criterion is taken as a “vote” and then combined with the other participants’ votes to generate a group weight. This procedure is repeated for all criteria. When voting is complete, the resulting group weights are used to calculate a group ranking of the proposed affordable housing sites.

1. At the organiser’s signal, load the group weighting module by clicking on the Group MCA icon (👥). You are presented with the following screen:

Group MapChoice

Criterion Weighting

How important is each criterion to the overall score?

Choose a weight:

DENS_POP	Select a weight:	BENEFIT
RATE_65	Select a weight:	COST
AVG_HH_VAL	0. Ignore	
DIST_BUS	1. Very Low	
DIST_GROC	2. Low	
DIST_EMERG	3. Below Average	
DIST_SCHL	4. Average	
DIST_CORE	5. Above Average	
HHH_INC_30	6. High	
ZONE_RES	7. Very High	
AREA_HA	-	

Go to the Analysis stage:

Submit VOTE

Votes submitted: 1
Average vote: 7.00
Attribute is voted to be a BENEFIT

2. When the group session begins, the moderator will step through each criterion. You are encouraged to discuss the importance of this criterion with the other users, but ultimately the weight you enter should be your own preference. When you have determined an appropriate weight for the criterion, select it from the drop-down menu.
3. As in Part 1, also select whether you believe the criterion to be a benefit or a cost by clicking on the ~~BENEFIT~~ button.

4. Finally, submit your vote by clicking on “Submit Vote”. The screen will update to reflect your submitted vote.

Group MapChoice

Criterion Weighting

How important is each criterion to the overall score?

Choose a weight:

DENS_POP	6. High	COST
RATE_65	-	
AVG_HH_VAL	-	
DIST_BUS	-	
DIST_GROC	-	
DIST_EMERG	-	
DIST_SCHL	-	
DIST_CORE	-	
HHH_INC_30	-	
ZONE_RES	-	
AREA_HA	-	

Go to the Analysis stage: [NEXT STEP >](#)

SUBMIT VOTE

You have voted on this criterion.

Your vote: 6

Votes submitted: 1
Average vote: 6.00
Attribute is voted to be
a **COST**

5. When all criteria have been voted upon, the results will be displayed on the map as in Part 1.

<u>Name</u>	<u>Used in MCA?</u>	<u>Description</u>	<u>Type</u>	<u>Min.</u>	<u>Max.</u>	<u>Average</u>	<u>Source</u>
Area_HA	Yes	The area of the parcel in hectares.	Site	0.064 ha	6.754 ha	1.268 ha	Calculated
Ave_HH_Val	Yes	Estimated average household value	Neighbourhood	\$127,895	\$180,363	\$151,372	2001 Census
Dens_Pop	Yes	Population density in persons per square kilometre.	Neighbourhood	621	2914	1459	Calculated
Dist_Bus	Yes	Distance to the nearest <u>bus line</u> (not bus stops)	Site	30m	661m	122m	Calculated
Dist_Core	Yes	Distance to the downtown core area as defined by the Collingwood Planning Dept.	Site	0m	1981m	785m	Calculated
Dist_Emerg	Yes	Distance to the nearest police, fire or ambulance station	Site	195m	2600m	1062m	Calculated
Dist_Groc	Yes	Distance to the nearest major grocery store	Site	315m	1951m	1013m	Calculated
Dist_Schl	Yes	Distance to the nearest elementary school.	Site	106m	1032m	559m	Calculated
Dist_Wrshp		Distance to the nearest place of religious worship	Site	34m	1037m	354m	Calculated
HHH_Inc_30	Yes	Percentage of households spending over 30% of their income on rent or mortgage	Neighbourhood	18.7%	34%	29.4%	2001 Census
Rate_15		Percent of residents from 0 to 15 years of age.	Neighbourhood	19.6%	30.4%	23.5%	2001 Census
Rate_18		Percent of residents from 0 to 18 years of age.	Neighbourhood	33.6%	41.3%	37.7%	2001 Census
Rate_65	Yes	Percent of residents over 65 years of age.	Neighbourhood	12.7%	19.5%	16.6%	2001 Census
Rate_Mover		Percent of residents who moved within 1996-2001	Neighbourhood	35.4%	58.6%	44.8%	2001 Census
Rate_Migrt		Percent of residents who migrated from another region within 1996-2001	Neighbourhood	17.5%	29.0%	23.4%	2001 Census
Rate_Unemp		Unemployment rate	Neighbourhood	4.3%	11.5%	6.5%	2001 Census
Zone_Res	Yes	Indicates if a parcel is zoned as a high- or medium-density residential. A value of 1 = Yes, 0 indicates No.	Site	1	0		City of Collingwood
Zoning		Indicates if the parcel is zoned as a high- or medium-density residential, with the current zone in brackets	Site				City of Collingwood

Post-workshop questionnaire

1. What is your gender:

Male Female Prefer not to answer

2. What is your age:

18-24 25-34 35-44 45-54 55-64 65+ Prefer not to answer

3. Where do you live?

Collingwood Rest of Simcoe County Other: _____ Prefer not to answer

4. How would you rate your familiarity with computer software?

Not familiar Somewhat familiar Average familiarity Above-average familiarity Very familiar

5. How would you rate your familiarity with computer-based mapping (e.g. Google Maps, MapQuest, GIS Software)?

Not familiar Somewhat familiar Average familiarity Above-average familiarity Very familiar

6. How would you rate your familiarity with planning decision-making processes relating to land-use change?

Not familiar Somewhat familiar Average familiarity Above-average familiarity Very familiar

7. How easy was MapChoice to use after the initial tutorial?

Difficult Somewhat difficult Neutral Somewhat Easy Easy

8. Do you believe that you understand the issue of locating affordable housing because of using MapChoice in this workshop?

Strongly agree Somewhat agree Neutral Somewhat disagree Strongly disagree

Comments: _____

9. Did either of the two modes (single-user or group) help you better understand the issue of siting affordable housing in Collingwood?

Single-User MCA:

Definitely yes Yes, partly Neutral No, partly Definitely not

Group MCA:

Definitely yes Yes, partly Neutral No, partly Definitely not

Comments: _____

10. Did either of the two modes (single-user or group) contribute to achieving a better decision?

Single-User MCA:

Definitely yes Yes, partly Neutral No, partly Definitely not

Group MCA:

Definitely yes Yes, partly Neutral No, partly Definitely not

Comments: _____

12. Did MapChoice provide any advantages compared to other planning methods (maps, presentations, on-the-ground tours of the town, etc.) you are familiar with?

Definitely yes Yes, partly Neutral No, partly Definitely not

Comments: _____

13. Are there any disadvantages to using MapChoice to compare affordable housing sites?

Definitely yes Yes, partly Neutral No, partly Definitely not

Comments: _____

14. Can you identify any ways that MapChoice could be improved? Consider the ease-of-use of the program, responsiveness, features that need to be added, removed or changed, etc.

Comments: _____

15. Can you identify any ways that the data used in this workshop could be improved (e.g. additional map layers needed, existing map layers that were incomplete, any other attributes that need to be included) ?

Comments: _____

Appendix 2 - Proposed sites and criterion values (data table)

ADDRESS	DENS_POP	RATE_15	RATE_18	RATE_65	RATE_MOVER	RATE_MIGRT	RATE_UNEMP	AVG_HH_VAL	DIST_BUS	DIST_WRSHP	DIST_GROC	DIST_EMERG	DIST_SCHL	ZONING	DIST_CORE	HHH_INC_30	ZONE_RES	AREA_HA
87 RAGLAN ST	1195.5	29.84	40.85	17.73	49.48	26.25	11.23	\$129,843	102	215	1188	235	530	Yes (R3)	985	32.06	1	1.649
(no address)	1426.3	24.41	40.80	13.19	41.02	17.51	6.12	\$148,697	207	566	1274	889	440	Yes (R3)	974	23.15	1	2.540
302 SEVENTH ST	2913.7	20.91	37.33	19.47	46.26	20.98	4.53	\$138,647	76	76	1044	1312	541	No (R1)	704	29.90	0	0.188
115 HIGH ST	683.5	22.04	36.99	18.13	47.20	20.64	5.86	\$147,090	183	749	638	1673	106	Yes (R3)	1147	29.45	1	0.201
400 SECOND ST	1453.0	23.12	37.30	16.57	46.81	19.48	6.42	\$156,294	30	605	640	1257	457	Yes (R3)	736	32.81	1	0.279
131 BEECH ST	1570.5	23.13	36.43	14.75	53.63	27.82	5.99	\$161,448	145	34	392	663	919	No (R1)	143	31.05	0	0.206
140 MAPLE ST	1583.0	23.60	36.00	13.89	55.23	28.72	6.15	\$163,781	111	35	345	630	960	No (CS)	109	32.12	0	0.405
1 LOCKHART RD	886.9	20.48	36.12	18.60	41.60	20.41	5.74	\$150,664	32	316	1337	1511	268	Yes (R3)	969	28.79	1	0.416
80 SIMCOE ST	1500.4	24.14	33.61	14.31	58.65	28.96	5.92	\$172,830	87	148	315	195	655	No (C1)	0	33.98	0	0.205
6 CAMERON ST	1452.7	19.64	35.46	19.50	40.88	20.29	5.67	\$150,248	70	194	1284	1482	147	No (CS)	902	29.54	0	5.802
649 HURONTARIO ST	1062.4	20.16	35.99	18.76	41.12	20.25	5.82	\$151,305	38	264	1276	1452	220	No (C7)	907	29.02	0	0.330
BRYAN CRT and LOCKHART RD	821.8	20.58	36.25	16.54	41.59	20.36	5.79	\$151,066	58	330	1317	1485	287	No (R1)	959	28.70	0	0.341
127-133 BIRCH ST (multiple)	1611.3	23.19	37.14	15.23	52.46	27.25	5.93	\$158,479	101	131	449	784	817	No (R1)	263	30.42	0	0.124
19 RAGLAN ST	1037.7	24.64	38.27	18.16	43.89	24.79	7.84	\$156,906	64	424	1366	663	847	Yes (R3)	955	31.82	1	0.163
68 NIAGARA ST	1438.0	20.55	38.28	12.65	35.39	23.86	5.16	\$180,363	36	512	981	616	731	No (R1)	527	32.01	0	0.081
70 HURON ST	1546.9	21.97	37.78	18.40	40.32	24.63	5.90	\$173,165	95	580	825	494	697	No (REC)	377	32.18	0	1.403
292 SIMCOE ST	1760.3	23.26	38.20	18.32	42.05	24.80	6.65	\$166,261	52	419	902	485	577	No (R1)	452	32.20	0	0.064
70 OAK ST	1657.9	24.98	37.60	14.97	53.38	28.05	6.70	\$157,388	60	378	574	1007	718	No (R1)	465	32.73	0	0.093
49 RAGLAN ST	1291.0	30.36	41.29	17.72	49.92	26.64	11.51	\$127,895	73	151	1171	280	538	No (CS)	924	32.36	0	3.007
135-145 HIGH ST (multiple)	705.4	22.16	37.57	17.73	47.34	20.78	5.63	\$144,539	304	671	755	1696	187	Yes (R3)	1170	28.52	1	0.357
WALNUT ST	2741.3	24.20	36.82	16.26	43.90	20.38	4.26	\$133,706	149	217	1535	1797	534	Yes (R3)	1157	18.71	1	1.767
CAMERON ST N/S	2579.2	24.04	37.94	15.41	44.50	20.29	4.56	\$134,628	156	287	1611	1875	636	Yes (R3)	1240	21.31	1	1.623
470 ONTARIO ST	1485.1	28.87	40.61	17.82	48.42	26.30	10.45	\$136,158	46	157	1135	401	576	No (REC)	806	32.39	0	2.443
420 HIGH ST	620.9	23.34	39.24	13.57	45.43	21.10	5.50	\$141,542	661	1037	1951	2600	1032	Yes (HR3)	1981	28.42	1	6.754

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