Sustainability Indicators for Computer-based Tools in Community Design

FINAL REPORT

VOLUME_1 PROJECT SUMMARY

VOLUME_2 CASE STUDIES SUMMARY

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This report (Volume 1 of 2) fulfills reporting requirements for the External Research Program project **Sustainability Indicators for Computer-based Tools in Community Design**. Included are summaries of:

Interim Report #1 (September 2007): **Phase I: Secondary Research on Indicators, Phase II: Primary Research on Indicators** gathered and sorted existing sustainability indicators for potential application to charrette-based processes and GIS tools. Principal products included a preliminary roster of indicators.

Interim Report #2 (June, 2008): **Phase III: Tool Development** evaluated and refined indicators proposed in Interim Report #1 with depth and detail appropriate to technical requirements of GIS tools. Principal products included a revised and expanded roster of indicators, descriptions, metrics, methodologies and formats.

Phase IV: Application and Evaluation of Indicators adapted previously reported indicators for application in the **Plan|It** Calgary project (2006 – 2008). This effort established metrics, performance targets and comparative benchmarks for the Phase V case studies.

Phase V: Indicator Application and Evaluation / Research Products applied a subset of the proposed indicators in three community design case studies at three planning scales — regional-, district- and neighbourhood-scale. Charrette-generated alternatives were measured and compared against selected indicators, targets and benchmarks.

ABSTRACT **Sustainability Indicators for Computer-based Tools in Community Design** develops a set of design-centred sustainability indicators for GIS-based modeling and visualization tools in ways useful to, and supportive of, charrette-based community design processes. Selected indicators and metrics of those proposed were applied and tested at three community design scales — region, district and neighbourhood — in a three year long range planning case study, Plan | It Calgary. Project results include a framework and methodology for indicator definition and design and many indicator examples. The case studies demonstrate that GIS-based indicators are feasible and effective in charrette-based community design processes and could be more widely applied with modest additional research and refinement.

ACKNOWLEDGEMENTS

Many have contributed to the indicator concepts, definitions, metrics, methods and applications of this project. Keltie Craig and Max Goldstein contributed background research. Duncan Cavens and Nicole Miller contributed spatial modeling methods and metrics and measured most of the indicators in the case studies. The City of Calgary **Plan|It** team (2006 - 08) as well as colleagues and former colleagues in the Design Centre for Sustainability at the University of British Columbia — Jone Belausteguigoitia, Isabel Budke, Elisa Campbell, Sara Fryer and Kristi Tatebe — contributed to applications of indicator concepts in the case studies (see Appendices of Volume 2) or to subsequent projects.

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As the sophistication and accessibility of GIS tools have improved, it is now technically possible for charrette–generated planning alternatives to be efficiently measured, modeled and visualized. However, there remains a considerable knowledge and methods gap as current practice in sustainability indicators lags behind the demands of charrette-based community planning and design processes and the technical capabilities of the GIS-based tools available to measure them. As a result, sustainability goals and targets cannot be measured or considered with the same speed, rigour and confidence as other indicators of community planning and urban design performance.

Sustainability Indicators for Computer-based Tools in Community Design diminishes this gap with a set of design-centred sustainability indicators designed to be integrated with GIS-based modeling and visualization tools in ways useful to, and supportive of, charrette-based community design processes. This integration significantly increases the frequency, effectiveness and timeliness of measures and representations of sustainability that can be considered in community design.

Five types of design-oriented spatial indicators are defined:

- **indicators of intensity** — that reveal the relative density or concentration of something (people, dwellings or jobs, for example)
- **indicators of distribution** — that reveal the relative concentration or dispersal of something (parks, community centres or affordable housing, for example)
- **indicators of proximity** — that reveal the relative location of, and distance between something and something else (jobs to transit stops, or dwellings to services, for example)
- **indicators of connectivity** — that reveal the relative accessibility or spatial interconnectedness of a system or network (open space, habitat or streets, for example)
- **indicators of diversity** — that reveal the relative mix and variety of types of something in a given area (land use types or dwelling size, type or tenure, for example)

37 indicators and 52 metrics are proposed in 10 sustainability areas:

- **LAND** — 5 indicators and 7 metrics
- **MOBILITY** — 9 indicators and 17 metrics
- **WATER** — 2 indicators and 2 metrics
- **HABITAT** — 3 indicators and 3 metrics
- **ENERGY** — 3 indicators and 4 metrics
- **FOOD** — 2 indicators and 3 metrics
- **EQUITY** — 3 indicators and 3 metrics
- **ECONOMY** — 3 indicators and 4 metrics
- **CULTURE** / **WELL-BEING** — 6 indicators and 8 metrics
- **MATERIALS** / **WASTE** — 1 indicators and 1 metric

Of these, 21 indicators and 27 metrics were selected for further development and refinement and applied at three scales in case study charrettes of the long range planning project Plan | It Calgary in 2007 and 2008 (See Volume 2). These included:

- **A regional scale application** — three city-wide land use and mobility scenarios (dispersed, compact and hybrid) for a population of 2,000,000 (roughly double current population) in 2075. Design scale 1:40,000

- **A district scale application** — a land use and built form scenario for a transit-oriented district on a greenfield site in one of the regional scenarios above. Design scale 1:2,000.

- **A neighbourhood scale application** — a land use and built form scenario for an infill transit corridor (17^{th} Avenue SE) based in one of the regional scenarios above. Design scale 1:2,000

For each case study, sustainability indicators were used to engage stakeholders in defining a sustainability agenda, selecting appropriate indicators, setting performance targets and, establishing comparative benchmarks prior to design. Within and following the design process, alternatives were measured and compared using these same selected indicators and were used to guide stakeholder evaluation of results and inform discussion of preferred directions and alternatives.

From this research and case study application we conclude the following:

- **Indicators 'work':** It is feasible to design and apply GIS-based sustainability indicators to community design processes. In the case studies, GIS-based sustainability indicators concepts, methods and processes could be sufficiently developed that community design stakeholders were able to use indicators and timely results from their measurement to inform choice and decision-making.

- **Alignment of indicators with a sustainability decision support framework is crucial:** In order to make their purpose and logic transparent to all, indicators should be situated within a larger, overall decision making process and used throughout to guide and monitor progress.

- **Indicators** (fewer in number, broader applications, less variety and flexibility) **are not the same as metrics** (greater in number, narrower applications, more variety and flexibility): Indicators articulate desirable attributes to be measured; metrics are the specific methods (input data, calculation methods, output units, for example) by which desirable attributes are measured which can vary significantly from community to community.

- **'Relative' measures and values represented graphically are more useful:** With the exception of threshold measures (densities necessary to economically viable transit, for example), relative indicator values that can be communicated and benchmarked on a graphic scale (alternative A performs 50% higher than alternative B, for example) were more accessible and useful to stakeholders than those presented in absolute values and tabular formats.

- **Data availability and alignment** (too much, too little, wrong kind) **remains a challenge:** The availability, type and format of spatial data necessary to run some indicators can vary significantly from community to community.

- **Linking 'enabling'** (spatial sustainability attributes) **to 'behaving'** (non-spatial sustainability attributes) **is an ongoing challenge:** Crucial sustainability goals and objectives — many pertaining to economic, social and cultural goals and objectives, for example — are difficult to associate with the spatial attributes of community design. Some can be measured indirectly or by proxy — the diversity and distribution of dwelling types, size and tenures, for example, approximates housing affordability. Others, such as local economic opportunity or employment equity are more challenging and await further researchy. Some may not be measurable in community design.

INTRODUCTION

Many Canadians express a desire to live in sustainable cities and neighbourhoods. Aspirations to 'grow more sustainably' figure prominently in the planning vision and policy goals of many Canadian communities. Yet, despite this interest in sustainability and its associated gaols, there is often a substantial gap between intentions and practice. Even communities with the most progressive and clearly framed sustainability goals and policies are challenged to negotiate their implementation and continue to replicate familiar but less sustainable patterns of development. Vancouver, Seattle and Portland (the principal cities of 'Cascadia'), for example, are frequently cited as North American models for sustainability thinking and policy in urban planning and design. However, in several key sustainability areas — land, energy and habitat, for example — even these cities continue to sprawl, expand energy consumption and lose valuable habitat (see for example, Sightline Institute's Cascadia Scorecard at sightline.org).

Shifting prevailing planning and implementation practices toward more sustainable models and processes is no small challenge. Communities must be enabled to set goals for sustainability and measure progress towards them as a matter of course rather than exception in day to day planning and practice. The processes that could enable communities to do that demand different types of knowledge, methods and tools able to integrate consideration of the diverse issues, scales, voices and timeframes necessary to greater sustainability. While a critique of where and how prevailing planning processes have failed in this regard falls well beyond the scope of this project, direct engagement of stakeholders and the public in a comprehensive, collaborative planning and decision-making processes has been crucial to the more successful models. Among the most successful of these have been design charrettes (Condon, 2007 and Gindroz, 2003, for example).

Design charrettes are intensely collaborative events choreographed to productively engage diverse stakeholders in the issues, concepts and processes of urban design. Charrettes have been effective facilitators of the lively, holistic exchange of issues across scales, timeframes and perspectives that must be negotiated if communities are to learn to 'grow more sustainably'. They have been well suited to planning for sustainability not only for the opportunity they provide to consult with many but also for their capacity to integrate and act upon those considerations to rehearse the multiple 'what if' alternatives arising from that consultation.

While charrettes offer much promise to deliver more sustainable community planning and design, they are also limited by gaps in the methods and technologies used to define and, in particular, to evaluate alternatives. In current charrette practice, for example, methods of evaluation are by necessity more visual than empirical. As a result, are challenged to differentiate alternatives that look ‘more sustainable’ but may not perform ‘more sustainably’ from those that perform ‘more sustainably’ but perhaps look ‘less sustainable’. Another shortcoming has been the capability to logically and consistently track progress toward sustainability goals over time through many stages and layers of decision making associated with community planning and design. As a consequence, stakeholders are also challenged to track their progress toward sustainability through these iterative, spatial design-centred processes.

In order to plan and design for greater sustainability, communities need rigorous and convincing tools that ‘fit’ within these sustained design decision-making processes and, in particular, at those points where they can most effectively inform planning and design choices. Design indicators provide one opportunity. Indicators are conceptual tools that highlight key variables associated with desirable performance and provide a basis for comparing one alternative mean to achieve that performance relative to another. In urban planning and design, these typically include a variety of indicators related to issues of community, transportation, natural systems, infrastructure, housing, employment and participation. Each typically embodies an expression of a desired outcome and a measure with which to evaluate and compare achieved performance from measuring other instructive examples against the same target.

Indicators are important to charrette-based urban planning and design for the degree to which they establish the technical measures and dimensions of performance that bridge between the aspirations and intentions captured in words and the quantities and spatial relationships of physical planning and design. Effective indicators enable explicit, transparent continuity between ‘big picture’ vision and goals, 'place-specific' design strategies, evaluation metrics and the details of implementation and monitoring. However, in the sustainability arena, few existing indicators are well suited to that task. Most are defined and applied to measure results achieved post-planning and design than are directed to informing choice and decision making before or during planning and design processes. Those that are only measurable once planning and design decisions are implemented, after a community has been built and inhabited, afford little opportunity or incentive to revisit or remodel the planning or design decisions most closely related to, at times causal to, indicator results.

More useful to planning and design decision makers, particularly those engaged in a collaborative, charrette-based process, would be indicators that define desirable sustainability attributes and targets from the outset and facilitate regular feedback about them throughout a sustained planning process and, in particular, at times of opportunity to fine tune or re-direct decision making accordingly. These indicators would not only establish important goals for planning and design choices, but do so in ways explicitly linked to, and measurable in, the physical, spatial and visual language of urban planning and design choices — as they are being generated or considered. An effective set of these charrette-useful, design-centred sustainability indicators would necessarily shift the focus method and norms of indicator design toward those aspects of form and spatial organization with the greatest implications for sustainability at the earliest phases of consideration and decision-making. And, as contemporary planning and design processes, as well as issues of sustainability, demand data-intensive computer-based methods and tools, these indicators would also necessarily integrate with Geographic Information System (GIS)-based modeling and visualization tools.

As the sophistication and accessibility of GIS tools have improved significantly, it is now technically possible for charrette–generated planning alternatives to be efficiently measured, modeled and visualized. However, there remains a considerable knowledge and methods gap as current practice in sustainability indicators lags considerably behind both the demands of design-centred community planning and design processes and the technical capabilities of the GIS-based tools available to measure them. As a result, sustainability goals and targets cannot be measured or considered with the same speed, rigour and confidence as other indicators of community planning and urban design performance.

Sustainability Indicators for Computer-based Tools in Community Design sets out to diminish this gap by developing a set of design-centred sustainability indicators that can be integrated with GIS-based modeling and visualization tools in ways useful to, and supportive of, charrette-based community design processes. Achieving this integration will significantly increase the frequency, effectiveness and timeliness of measures and representations of sustainability that can be considered in community design. Specific project objectives include:

- gather and evaluate sustainability indicators for potential integration with GIS-based modeling and visualization tools
- refine the content and method of those indicators most suitable for such integration
- propose new indicators where necessary

- test these proposed indicators in a case study project and,
- evaluate the results for broader application.

A SUSTAINABILITY AGENDA FOR CHARRETTE-BASED COMMUNITY DESIGN

In the context of this project, sustainability refers to those dimensions of community capacity influenced by urban planning and design. Within this reference, more sustainable communities are those that have made planning and design choices to create a physical framework (of land, land use, infrastructure, built form, etc.) able to sustain their operation and growth with due consideration of environmental, social and economic needs, limits and opportunities. Planning and design for sustainability then, necessarily begins with an understanding of the issues or themes that a community might consider as it seeks to create a physical framework within which to live and grow more sustainably.

While specific sustainability issues can, and will, vary in detail and priority with the diverse needs, resources and circumstances of particular communities, consensus around the broader themes within which these issues fit is more widely shared. Sustainability-oriented organizations such as Bio-Regional and World Wildlife Federation's One Planet Living, Natural Resources Canada's Sustainable Urban Neighbourhoods, for example, outline topical themes that can be elaborated, or adapted to particular communities and applications. Table 1.01 illustrates one example of a roster of sustainability themes from the Design Centre for Sustainability at the University of British Columbia based in part on the work of these and other sustainability related organizations.

Table 1.01: A roster of sustainability themes for community design adapted from projects of the Design Centre for Sustainability at UBC

LAND	Land is a precious resource and using it with efficiency and sensitivity is a fundamental to sustainability. More sustainable communities use land efficiently and dynamically to accommodate the places of dwelling, work, education and play vital to a sustainable life. Less sustainable communities do not conserve land or arrange its uses as efficiently, increase the extent, cost and energy intensity of infrastructure and mobility networks.
MOBILITY	Mobility refers to the degree to which communities provide physical access to the places of dwelling, work, education and play vital to a sustainable life. More sustainable communities accommodate diverse, energy efficient modes and route options for people to move between these elements of their daily lives.
WATER	Water refers to the natural hydrologic cycle that links precipitation (rain, snow, hail) surface water (streams, wetlands, rivers, lakes) and groundwater as well as water extracted from or contributed to this cycle by people. More sustainable communities carefully protect and manage the water flows that make up this cycle as well as their demand for and treatment of potable and waste water and its impact on aquatic ecosystems.
HABITAT	Habitat refers to the network of places and ecological functions that support natural plant and animal populations. More sustainable communities protect, enhance or restore habitat of appropriate quality, quantity, location and connectivity to support locally significant species and species diversity.
ENERGY	Energy refers to the demand, supply and distribution of energy to power machines, buildings and vehicles. More sustainable communities reduce demand for energy and increase opportunities to meet demand from renewable, low emission sources efficiently distributed.
FOOD	Food refers to community capacity for, and access to, places of food production. More sustainable communities protect food growing capacity and resources, provide secure opportunities for local food production reduce dependence on imported food and transportation energy demand associated with food distribution.

EQUITY

Equity refers to a fair distribution of resources and amenities. More sustainable communities equitably accommodate and distribute resources and amenities such as dwellings, services or amenities of types, quantities, qualities and locations appropriate to community needs.

ECONOMY

Economy refers to the interaction of resources, people, jobs and commerce necessary to sustain a strong local economy. More sustainable communities support a mix of resilient business and employment types and opportunities of sufficient quantity, type and locations appropriate to community needs.

CULTURE and WELL-BEING

Culture and Well-being refers to the places of amenity and experience intended to meet the social, recreational and cultural needs of a community. More sustainable communities accommodate a mix of parks, sports, education, cultural and social or civic service types and opportunities of sufficient quantity, type and locations appropriate to community needs.

MATERIALS and WASTE

Materials and waste refers to the latent mass and potential value of the resources, materials and by-products used to create and sustain the buildings, infrastructure and processes of a community. More sustainable communities reduce demand for new resource- and energy-intensive structures and materials and increase opportunity to re-use and re-cycle those otherwise destined for landfills.

Effectively linking a broad sustainability vision to specific local action presents a significant process and methods challenge to community planning and design. Consideration of sustainability through a thematic framework such as the example above, enables communities to explore a broadly defined and widely shared aspiration for sustainability, in common with other communities, as well as to logically organize and define local goals, objectives and actions necessary to that aspiration at the same time. As this is a challenging logic and coordination task, some communities have applied relatively new tools such as a decision support frameworks to choreograph the complex, long term and multi-faceted decision-making to ensure that initial, broadly stated purposes and principles can be explicitly and directly linked to subsequent decisions and ultimately to actions. These decision support frameworks (process management strategies for logically and systematically organizing decision making processes from broadest vision to finest details) link high level themes and goals to local, context-sensitive objectives, targets and strategies to specific implementation actions actions. Figure 1.01 below illustrates one version of a decision support framework. This particular example articulates a process of seven sequential, incremental, steps that establish and then transform higher order vision and goals into more specific objectives, indicators and targets into design strategies and actions — in the end a logical, incremental transformation of ideas and words into physical form and spatial organization. See also, for example, Sheltair, South East False Creek: Vision, Tools and Targets (1998).

Figure 1.01: An example of a decision-making framework for considering sustainability in community design

Vision refers to a brief statement that captures in few powerful words the ultimate end state of a sustainable community. (Example: Community X will become a replicable model of urban development that supports a sustainable, attractive and affordable lifestyle for all.) ***Goals*** define direction toward that vision elaborating and articulating specific, but still ideal, qualities and attributes. (Example: Land will be considered a precious resource.) ***Objectives*** add greater specificity and detail to goals and increase their focus to specific areas of action (Example: All new development will be compact.) ***Indicators*** identify areas of evidence and measurement that reveal and monitor progress toward an objective (Example: Residential density). ***Targets*** define the expectations against which progress toward an objective can be evaluated. (Example: Average community residential density shall be no less than 20 dwellings per hectare). ***Strategies*** are the approaches deployed to achieve a set of goals-objectives-targets. In an urban design context these would be the specific concepts applied to achieve a goal or set of goals. (Example: Highest density dwelling types are located within 400m of transit stops and commercial services) ***Actions*** are the implementation mechanisms applied to realize a strategy (Example: Modify zoning standards to allow greater density within 400m of transit stops and commercial services).

Indicators play particularly significant roles in such a framework. They compress large amounts of information into an easily understood format able to facilitate monitoring of progress towards (or away from) an objective (Sheltair, 1998) and "stimulate vision, trigger insight, provoke discussion, draw criticism, challenge assumptions, and inspire action" (Sustainable Seattle, 1993). In these roles, indicators occupy a crucial point of connection and transformation, roughly in the middle of a design decision-making framework, between the words and numbers of politics and policy and the strategies of design and the actions of behaviour. As Figure 1.02 illustrates, above (preceding) indicators is a political realm, where policy gives bridges to vision and goals. Below (following) indicators is a design and action realm, where choices about physical form and spatial organization are made based in part on estimates of the degree to which the more sustainable performance or behaviour anticipated by policy is likely to be facilitated or enabled.

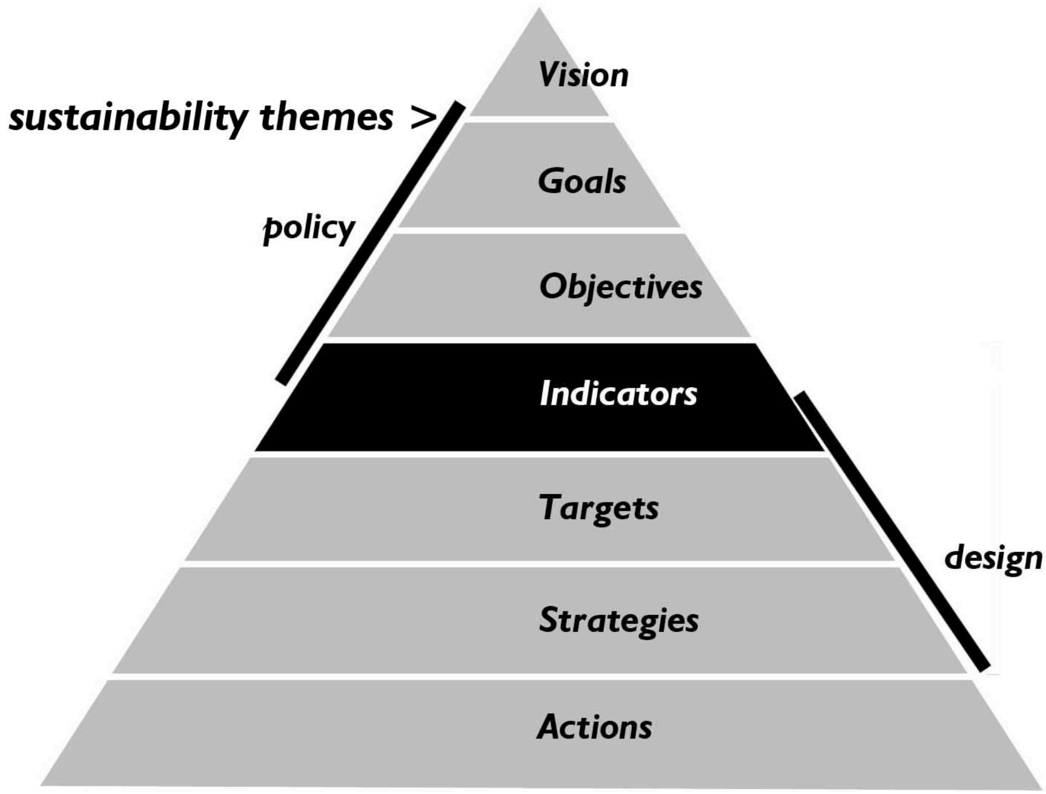

Figure 1.02: Indicators represent a crucial point of connection and transformation — linking policy to strategies and action through design — within a decision-making framework.

Implications for Charrette-based Community Design Charrette-based planning and design is a powerful collaborative model for shaping the physical form and spatial organization necessary to achieve sustainable communities. Among its strengths is a sequential but iterative decision making process. With each iteration, features and flaws become apparent and ideas get fine-tuned, elaborated, or thrown out. One idea can generate three more, with variable degrees of detail ranging from conceptual 'bubble diagrams' to specific design standards, represented by a sharp line on a map to a quick and loose character sketch.

Figure 1.03 illustrates a charrette-based design process as something in the 'middle' — between consultation and implementation. Goals and targets are defined for all relevant issues. Planning and design alternatives are generated, visualized, measured and evaluated. A preferred alternative is created from the results.

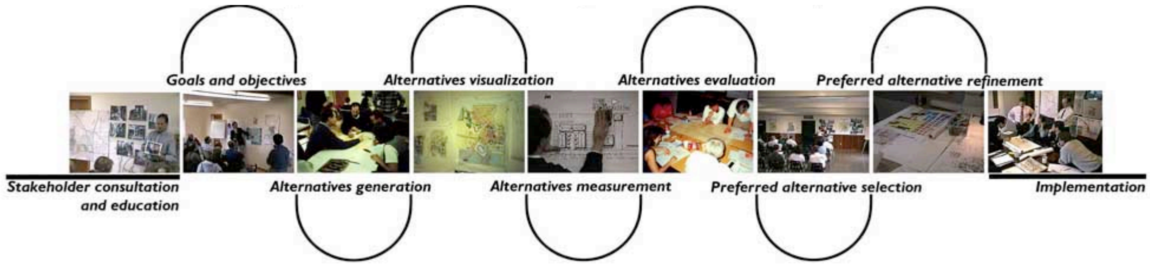

Figure 1.03: Decision-making stages in a typical charrette-based design process

A typical charrette convenes a representative group of stakeholders to collectively craft a negotiated solution to a planning and design problem. Information about goals and planning issues is gathered, cross-referenced and shared among all stakeholders. A design brief (prepared in consultation with stakeholders) defines the problems to be solved and establishes a schedule of task milestones toward that end. Stakeholders work closely together over the course of several days to immerse themselves in learning about the project and to negotiate the mutually acceptable arrangements of land, buildings and infrastructure that respond to the requirements of the design brief. Alternative plans are proposed, compared and evolve through iteration. Eventually, a preferred alternative emerges and is refined until it can be implemented. In this time, the main elements of a proposed solution must be determined and broad consensus amongst stakeholders attained. While there are typically many details that must be refined or resolved after a charrette, the main elements of a design solution are usually established by consensus.

Within this process (Figure 1.04), indicators and their associated targets are most effective when defined early, typically in conjunction with goals and objectives and applied, and re-applied, at multiple subsequent points — typically iteratively, at process points where design alternatives have been generated and evaluative decisions must be made about them. It is also typical that these iterations of alternative generation and evaluation afford opportunity to refine, or expand the range of, indicators and to revise or re-calibrate targets as more is learned about the efficacy or acceptability of particular design strategies and alternatives.

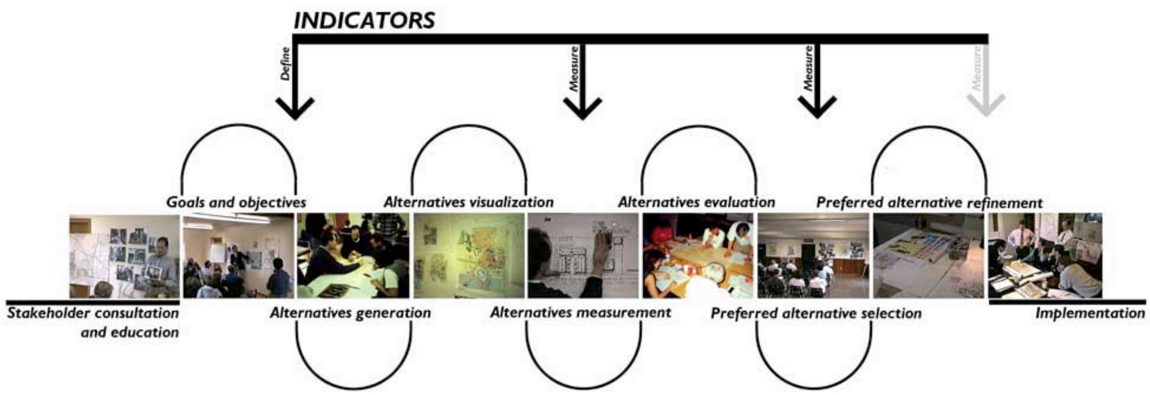

Figure 1.04: A typical charrette-based design process highlighting the role of indicators to define and measure progress toward goals and objectives.

TAILORING SUSTAINABILITY INDICATORS TO CHARRETTE-BASED DESIGN PROCESSES

Indicators have been developed for diverse issues, contexts and stakeholders from government, non-profit, professional and research institutions from buildings to neighbourhoods to regions to national and international scales. Throughout the 1970s, indicators frequently took the form of profiles and needs assessments such as state-of-the-city report cards, citizen surveys, based principally on socioeconomic data (Sawicki and Flynn, 1996). While Maclaren (1996) has suggested that the forbearers of sustainability indicators such as Quality of Life, Healthy City, and State of Environment made progress toward the more holistic view necessary to examine sustainability, it is only recently that these more narrowly defined and sourced examinations have given way to more broadly scoped issues based on more appropriately diverse types and forms of evidence. Indicators research now takes into account the environment, community and the economy has increased, and has begun to consider relationships between and among issues and evidence to the degree that it is now common to measure aspects of environmental quality, for example, and aspects of social and economic vitality at the same time.

However, largely missing from the body of research and action in this field are sustainability indicators that are sufficiently spatial and readily (with respect to time and cost) measurable to be effective in public planning and design processes — connecting words to numbers to spatial information and representations in ways that facilitate and inform the conversations that link community design to sustainability. Talen, for example, reports that “the biggest problem in city measurement is a lack of specificity about the ‘on the ground’ physical reality of cities…our understanding of cities weighs more heavily on the theoretical / generalized / socio-economic side of urban study, while empirical knowledge about physical urban form is weak" (Talen, 2002). Without that knowledge, connected to on-the-ground decision-making, we are unable to determine the degree to which physical design choices can promote and / or hinder the economic, environmental and social processes that underlie sustainability (Porta and Renne, 2005).

Hunting, gathering and sorting indicators for community design
Early phases of this project began with a global literature review of current and recent research on sustainability indicators. This review compiled background indicator knowledge and principles and established a baseline of 134 potential indicators. Each potential indicator was 'tagged' with the sustainability attributes to which it pertained and re-sorted to reference each to the sustainability theme or themes (of the 12 cited in Table 1.01) it seeks to support or enable — compactness, land use mix or housing diversity, for example.

Once sorted by sustainability theme, each indicator was referenced to its customary or potential metrics and methods of measurement. This exercise revealed the specific dimensions of 'what indicators measure' when applied — important distinctions that can be difficult to glean from indicator titles and narrative descriptions. As patterns of 'what indicators measure' began to emerge, each was assigned a spatial attribute type that in turn linked it to types of community planning and design choices and indirectly, suggested the means by which it could be measurable with Geographic Information Systems tools (as discussed later in this report). These types included:

> **Indicators of intensity:** Indicators of this type measure the relative density or concentration of something — typically people or jobs or land uses or services. For example, are residential and employment densities of sufficient intensity to support convenient transit or local shopping?
>
> **Indicators of distribution:** Indicators of this type measure the relative distribution of something. For example, are parks, community centres or affordable housing distributed, clustered or concentrated in a community?
>
> **Indicators of proximity:** Indicators of this type measure the relative location of, and distance between something and something else. For example, are transit stops proximate to

apppropriate concentrations of employment or residential development?

Indicators of connectivity: Indicators of this type measure degrees of spatial interconnection or access between and among something and something else — typically related to travel mode, open space or habitat. For example, to what extent do pedestrian routes in residential areas effectively connect households to daily services?

Indicators of diversity: Indicators of this type measure the relative mix and variety of types of something in an area. For example are commercial, housing or open space land uses sufficiently diverse to support community needs?

Table 1.02 illustrates this process. On the vertical axis are selected themes of a sustainability agenda. On the horizontal axis are urban design related spatial attributes. Within selected cells are examples of indicator types that might be found at the intersection of a sustainability theme and a spatial attribute.

SUSTAINABILITY THEMES	SPATIAL ATTRIBUTE THEMES				
	INTENSITY	**DISTRIBUTION**	**PROXIMITY**	**CONNECTIVITY**	**DIVERSITY**
LAND	Infill intensity		Daily destinations proximity		Land use diversity
MOBILITY	Street network intensity		Transity proxmity	External community connectivity	Mode diversity
WATER	Effective impervious surface intensity				
HABITAT	Urban forest intensity			Significant habitat connectivity	
ENERGY	Passive energy intensity				
FOOD	Food growing intensity		Food growing proximity		
EQUITY	Affordable dwelling intensity	Dwelling type distribution			Dwelling diversity
ECONOMY	Employment intensity		Employment proximity		Employment diversity
CULTURE	Civic amenity intensity	Civic amenity distribution	Civic amenity proximity	Open space connectivity	Open space diversity
MATERIALS	Existing building intensity				

Table 1.02: Indicators referenced to spatial attributes and sustainability themes. Illustrated is very small sample of a much larger set.

In addition to the evaluation criteria applied above, several other considerations informed indicator selection. One concerns scales of decision-making (Figure 1.05). While the themes and goals of sustainability may cross several scales, decision-making authority or influence resides at particular scales. For example, senior levels of government typically make decisions about natural resource, land and transportation policy, Municipalities typically make decisions about land use, infrastructure and community development. Residents and local organizations such as neighbourhood associations typically make decisions about which local values, aspirations and priorities. Developers and land owners tyically make market and economic decisions about when and how land is developed. In order to be efficient and effective informers, sustainability indicators must likewise consider, and be tailored to, the scale at which decisions are being made and the needs and priorities of the government, interest groups, professionals, developers, neighbours, and related audiences, who make or influence decisions at that scale.

This project has targeted ‘regions’ to 'neighbourhoods' as the logical and effective scales at which to direct community design related sustainability indicators. The reasons are several. These scales reside at an important interface between government, citizens and the development community and big enough to consider the larger scale infrastructure and systems necessary to sustainability yet small enough to consider the choices and actions of individuals and groups of individuals at the same time.

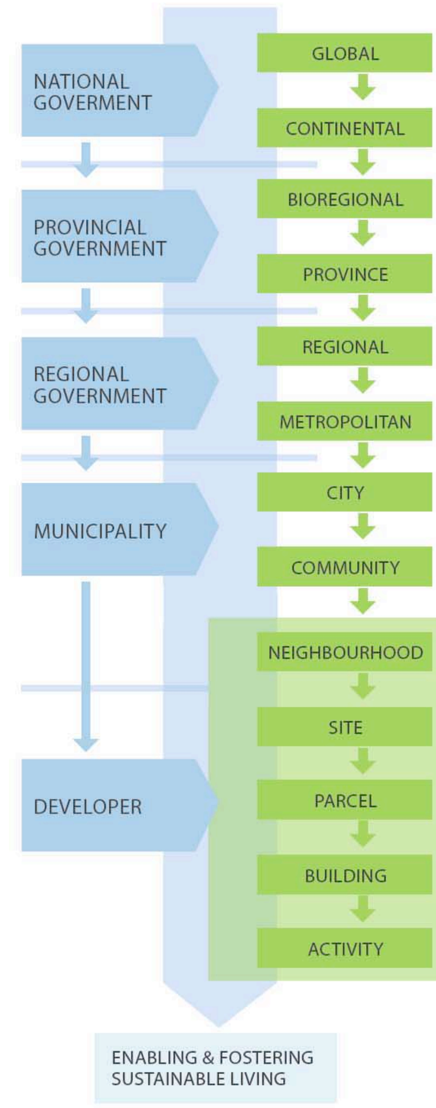

Figure 1.05: Scales of jurisdiction and decision-making in community planning and design. Adapted from Campbell and Mayhew, Emerald Hills Urban Village: Sustainable Urban Neighbourhood Guidelines, 2006.

Finally, there was both need and opportunity to expand the current breadth of design indicators. Throughout the research stage, certain themes frequently arose far more than others. The quality and quantity of indicators research and experience related to design for pedestrian networks and walkability, for example, is substantial. However, the design-related research necessary to generate quality indicators in other sustainability themes, social equity or well-being, for example, is conspicuously absent. While equal representation from all sustainability themes may not be possible or desirable as some are simply more influential than others in design decision making, a more thorough inventory and gap analysis is warranted but beyond the scope of this project.

TAILORING SUSTAINABILITY INDICATORS TO GEOGRAPHIC INFORMATION SYSTEM (GIS) TOOLS

Cities are complex systems shaped by diverse issues and agents. As urban planning and design processes have evolved to manage that complexity with greater sophistication, so too have the supporting methods and tools. Those who make decisions about cities — politicians, professionals, development stakeholders and the public, for example — expect to be informed, active participants in the planning and decision making that shape their communities. With that evolution, demand for accessible, technically rich and sophisticated information, analysis and visualization tools has increased in parallel. Chief among those has been a rapidly expanding suite of tools based on the technology and methodologies of Geographic Information Systems (GIS).

GIS refers to a class of computer-based spatial modeling and visualization tools. As the term implies, GIS is a 'system' of appropriately configured computer hardware, software and data that is informed by human knowledge and expertise to create a capacity to link various types of descriptive information about 'what things are like' to geographic information about 'where things are'. GIS systems integrate 2- and 3-D representations of physical form (geographic and spatial features) with database management tools to assign attributes to those features and, with modeling and analytical tools, to simulate the interaction of attributes and features. Inputs must be spatial (any data or attribute that can be described and located in space). Outputs are visual and spatial (maps and map-like illustrations, for example) and quantitative (tabular data, charts and graphs, for example). In between are automated data management, modeling and representational processes that facilitate combinations of data and other attributes in support of analysis, modeling and visualization tasks.

Many GIS-based applications have been developed (see the website of the Environmental Sciences Research Institute (ESRI) www.esri.com, for example) to support spatial data management, decision-making and visualization of many types at many spatial scales. However, within the scope and context of this report, the term is applied more narrowly to refer to GIS-based applications that spatially reference information about urban form (land + land use + transportation networks + infrastructure networks + buildings) to support urban planning and design decision making in general and, in references to issues of sustainability in particular.

Like any system, GIS depends on enabling concepts and norms in order to perform this role. Of particular significance to this project, GIS represents sustainability attributes via two types of conventions — spatially discrete points, lines or objects (a transit stop, street segment or building, for example) and continuous fields (population density or distribution, for example). In order to applicable in GIS, indicators must represent and model the sustainability attributes of urban form that can be represented and modeled within a language of discrete points or continuous fields and the spatial patterns and mathematical relationships between and among them. In addition, although GIS software is a licensed proprietary technology, the data and models that run in GIS are not necessarily either. In order to meet project expectations for applicability, charrette process suitability and replicability, proposed indicators must meet the following criteria summarized in Table 1.03.

GIS APPLICABILITY CRITERIA

Spatially definable	Indicator and associated metrics must be spatially definable (point, line, plane or continuous field).
Accessible data	Indicator and associated metrics must be based on broadly available source data (existing land uses, street and transit network, population distribution, for example) or 'mappable' from typical charrette-generated assumptions or products (proposed land use allocations, street and transit network plans, building type and density allocations, for example)
Open source	Indicator and associated metrics must be appliccable without proprietary license
Transparency	Indicator and associated metrics must be clearly and logically referenced to the sustainability attribute and design scale that they most effectively inform.
Modest complexity	Indicator and associated metrics must not require specialized extraordinary (beyond the usual training and experience of most urban design, planning and GIS professionals or GIS technicians) technical knowledge or expertise.

Table 1.03: GIS-related priorities informing indicator design

ROSTER OF SUSTAINABILITY INDICATORS FOR GIS TOOLS IN CHARRETTE-BASED COMMUNITY DESIGN PROCESSES

Effective design tools, whatever their purpose, must augment the human and social processes that underlie that exchange. Tools that will be most valuable are those that do not intrude on the conversation but help participants see, remember, analyze, measure, compare, collaborate, and communicate with each other – better, more clearly, faster, more accurately. If indicators are to support the fundamentally 'human', iterative processes of design charrette, they must be designed to bring the right content, in the right form, at the right time — when key decisions impacting sustainability are considered and made. However, in order to be effective and rigourous, indicators must also be designed to suit the extensive and complex analyses of spatial and numerical data associated with sustainability and GIS tools.

To that end, selection criteria or 'filters' based on the sustainability-, design charrette- and GIS tools- oriented issues and criteria described above were applied to a long list of potential indicators. Priority indicators were those that linked sustainability themes to the physical, spatial attributes of charrette-based community planning and design AND could be measured in GIS. For example, an indicator that used generally available GIS-suitable data and methods to measure the physical attributes of street networks that encouraged people to walk would be considered a high priority indicator. An indicator that measured preference for walking unassociated with spatial attributes would not. Six "lenses" were applied to filter and sort potential indicators to this end.

Extractive Lenses: Four 'extractive lenses eliminated potential indicators from consideration where certain threshold criteria were not met. These included:

> **Low Relationship to Sustainability:** Indicators not directly related to a sustainability theme or creation of a context that could lead other factors towards sustainability were eliminated. Within the remaining list, those directly impacted a core sustainability theme — land, water, mobility, for example or multiple sustainability themes were considered higher priority.
>
> **Low Relationship to Urban Form.** Indicators not directly related to spatial attributes of urban form — the type, quantity, dimensions and patterns of land, land use, networks or environmental assets, for example — were eliminated. Decisions affecting land use and transportation or the spatial dimensions of

land use and transportation were considered to have the greatest impact on urban form at a neighbourhood scale, for example.

Low GIS Utility: Indicators that could not be integrated with a GIS program were eliminated. These included indicators that could not be tied to spatial attributes or required difficult to acquire data types were eliminated

Redundancy: Numerous indicators directly or indirectly measured similar attributes. Indicators that measured the same or similar attributes as others were eliminated or, where appropriate, consolidated to with others.

Sorting lenses: Two 'sorting' criteria or lenses were applied to those remaining to categorize indicators based on their relevance to sustainability related decision-making in community planning and design using GIS-based tools. These included:

Scale: Indicators were evaluated according to the scale at which had most impact: Regional, Neighborhood, and/or Block scale. Some indicators are relevant at multiple scales. Impact at a neighbourhood scale was prerequisite. Impact at a regional scale or block scale only was considered too coarse- or fine-grained for further consideration.

Data Source: Indicators were evaluating for the degree to which data could be made spatial and generally available from a municipal data set, or could be derived from charrette-products.

After application of these lenses, at the conclusion of Phase III Tool Development, the following roster of 36 indicators and 51 metrics (see summary table 1.04 following) was proposed for consideration in a case study project in Phase IV: Application and Evaluation of Indicators (see Volume 2). Not all sustainability themes are equally represented. Some, such as Land and Mobility, for example, have many significant physical, spatial attributes and are readily adaptable to GIS-based tools, are represented by the greatest number of indicators. Other sustainability themes such as Economy and Equity, for example have fewer (or less clear) physical, spatial attributes and less adaptable to GIS-based tools are represented by fewer. These are (by theme):

Table 1.04: Roster of sustainability indicators considered for application to case studies on next 11 pages.

LAND
THEME INDICATORS

LAND 01 DEVELOPMENT INTENSITY
An indicator of land use efficiency

DEVELOPMENT INTENSITY METRICS

01 **Region • District • Neighbourhood scale**
Urban area expansion

02 **District • Neighbourhood scale**
Population and / or jobs per hectare

LAND 02 INFILL INTENSITY
An indicator of the degree to which new development utilizes urbanized land and existing infrastructure

INFILL INTENSITY METRICS

01 **Region • District • Neighbourhood scale**
Percentage of new development served by existing civil infrastructure

LAND 03 DWELLING INTENSITY
An indicator of residential land use efficiency

DWELLING INTENSITY METRICS

01 **Region • District • Neighbourhood scale**
Dwellings per gross and / or net hectare

LAND 04 LAND USE DIVERSITY
An indicator of the mix of service, employment, culture and recreation land uses

LAND USE DIVERSITY METRICS

01 **Region • District • Neighbourhood scale**
Simpson diversity for land uses

02 **District • Neighbourhood scale**
Mixed use parcel intensity

LAND 05 DAILY DESTINATIONS PROXIMITY
An indicator of household access to daily goods and services

SERVICES PROXIMITY METRICS

01 **Neighbourhood scale**
Percentage of population and / jobs within 400m of daily services

MOBILITY

THEME INDICATORS

MOBILITY **01**

STREET NETWORK INTENSITY

An indicator of mobility-related land use efficiency

STREET NETWORK INTENSITY METRICS

01 **Region • District • Neighbourhood scale**
Land allocated to street rights of way

02 **Region • District • Neighbourhood scale**
Ratio of freeway to arterial length and / or rights of way

MOBILITY **02**

MODE DIVERSITY

An indicator of potential transportation mode choice

MODE DIVERSITY METRICS

01 **Region • District • Neighbourhood scale**
Mode diversity index

MOBILITY **03**

EXTERNAL COMMUNITY CONNECTIVITY

An indicator of potential connectivity with adjacent land uses

EXTERNAL COMMUNITY CONNECTIVITY METRICS

01 **Region • District • Neighbourhood scale**
Connections per kilometer of boundary

MOBILITY **04**

STREET NETWORK CONNECTIVITY

An indicator of potential route and destination options within a street network

STREET NETWORK CONNECTIVITY METRICS

01 **District • Neighbourhood scale**
Local street intersections per hectare / km2 of development

02 **District • Neighbourhood scale**
% arterial street length with segments greater than 200m (or local alternate)

03 **District • Neighbourhood scale**
% collector street length with segments greater than 125m (or local alternate)

04 **District • Neighbourhood scale**

% local street length with segments greater than 80m (or local alternate)

MOBILITY **05** **TRANSIT SUPPORTIVE LAND USE INTENSITY**
An indicator of transit viability and potential

TRANSIT SUPPORTIVE LAND USE INTENSITY METRICS

01 **Region • District • Neighbourhood scale**
% development meeting local transit density threshold

MOBILITY **06** **TRANSIT PROXIMITY**
An indicator of transit accessibility and use potential

TRANSIT PROXIMITY METRICS

01 **Region • District**
Jobs within 600m of convenient transit

02 **Region • District**
Population within 600m of convenient transit

03 **District • Neighbourhood**
Dwellings within 400m of convenient transit stop

MOBILITY **07** **PEDESTRIAN ROUTE CONNECTIVITY**
An indicator of potential pedestrian route and destination flexibility

PEDESTRIAN ROUTE CONNECTIVITY METRICS

01 **District • Neighbourhood scale**
Pedestrian intersections per ha or km2 of development

02 **District • Neighbourhood scale**
Average pedestrian directness ratio

MOBILITY **08** **BICYCLE NETWORK INTENSITY**
An indicator of bicycle route potential

BICYCLE ROUTE INTENSITY METRICS

01 **Region • District**
Bicycle network length / 1000 population

02 **Region • District • Neighbourhood**
Population / jobs within 1000m of access to continuous cycle network

MOBILITY **09** **BICYCLE ROUTE CONNECTIVITY**
An indicator of potential bicycle route and destination flexibility

BICYCLE ROUTE CONNECTIVITY METRICS

01 **District • Neighbourhood scale**
Bicycle route intersections per ha or km2 of development

WATER

THEME INDICATORS

WATER 01 NATURAL HYDROLOGY INTENSITY

An indicator of natural hydrologic systems potential

NATURAL HYDROLOGY INTENSITY METRICS

01 **Region • District • Neighbourhood • Block • Parcel scale**
% natural hydrologic functions protected or restored

WATER 02 IMPERVIOUS SURFACE INTENSITY

An indicator of stormwater runoff (quantity and quality) potential

IMPERVIOUS SURFACE INTENSITY METRICS

01 **Region • District • Neighbourhood • Block • Parcel scale**
Effective impervious surface area

HABITAT

THEME INDICATORS

HABITAT 01 — HABITAT INTENSITY

An indicator of habitat potential

HABITAT INTENSITY METRICS

01 **Region • District scale**

% significant habitat function protected or restored

HABITAT 02 — HABITAT CONNECTIVITY

An indicator of habitat integration potential

HABITAT CONNECTIVITY METRICS

01 **Region • District • Neighbourhood scale**

% significant habitat function connective with others

HABITAT 03 — URBAN FOREST INTENSITY

An indicator high natural systems value tree coverage

URBAN FOREST INTENSITY METRICS

01 **Region • District • Neighbourhood scale**

Tree canopy density

ENERGY

THEME INDICATORS

ENERGY 01 COMMUNITY ENERGY SUPPORTIVE LAND USE INTENSITY

An indicator of community energy system potential

COMMUNITY ENERGY SUPPORTIVE LAND USE INTENSITY METRICS

01 **District • Neighbourhood scale**
% developed land meeting community energy threshold

ENERGY 02 PASSIVE ENERGY INTENSITY

An indicator of passive and heating or tempering potential

RESIDENTIAL SKIN AREA INTENSITY METRICS

01 **Neighbourhood • Block • Parcel scale**
% of parcels with significant passive solar potential

02 **Neighbourhood • Block • Parcel scale**
% of parcels with significant natural ventilation potential

ENERGY 03 RESIDENTIAL ENVELOPE INTENSITY

An indicator of heat gain or loss potential in residential buildings

SOLAR ORIENTATION INTENSITY METRICS

01 **Neighbourhood • Block scale**
Residential envelope to floor area ratio

FOOD
THEME INDICATORS

FOOD 01 FOOD GROWING INTENSITY
An indicator of food growing potential

FOOD GROWING INTENSITY METRICS

01 **Region • District • Neighbourhood scale**
% significant agricultural function protected or restored

02 **District • Neighbourhood scale**
% significant food growing area per population or household

FOOD 02 FOOD GROWING PROXIMITY
An indicator of access to food growing opportunities

FOOD GROWING DISTRIBUTION METRICS

01 **District • Neighbourhood scale**
% population or households within 400m (or local alternate) of significant food growing area

EQUITY
THEME INDICATORS

EQUITY **01**
DWELLING DIVERSITY
An indicator of the mix of dwelling types and price points

DWELLING DIVERSITY METRICS

01 **Neighbourhood scale**
Simpson diversity index for dwelling types

EQUITY **02**
DWELLING DIVERSITY DISTRIBUTION
An indicator of spatial distribution of dwelling types / price points

DWELLING DIVERSITY DISTRIBUTION METRICS

01 **Region • District scale**
Average dwelling type diversity

EQUITY **03**
AFFORDABLE DWELLING INTENSITY
An indicator of affordable housing availability

AFFORDABLE DWELLING INTENSITY METRICS

01 **Region • District • Neighbourhood scale**
% dwellings meeting local affordability criteria

ECONOMY

THEME INDICATORS

ECONOMY **01**

EMPLOYMENT INTENSITY

An indicator of potential employment opportunity

EMPLOYMENT INTENSITY METRICS

01 **Region • District • Neighbourhood scale**
Jobs per ha or km2 development

02 **Region • District • Neighbourhood scale**
Jobs per dwelling or household

ECONOMY **02**

EMPLOYMENT PROXIMITY

An indicator of potential local employment opportunity

EMPLOYMENT PROXIMITY METRICS

01 **District • Neighbourhood scale**
Jobs with 5km

ECONOMY **03**

EMPLOYMENT DIVERSITY

An indicator of potential employment opportunity options

EMPLOYMENT DIVERSITY METRICS

01 **Region • District scale**
Simpson diversity index for employment types

CULTURE and WELL-BEING

THEME INDICATORS

CULTURE 01 CIVIC AMENITY INTENSITY

An indicator of civic amenity and service potential

CIVIC AMENITY INTENSITY METRICS

01 **Region • District scale**
Land allocated to civic amenities and services per household or population

02 **District • Neighbourhood scale**
Land allocated to civic amenities and services per dwelling

CULTURE 02 CIVIC AMENITY PROXIMITY

An indicator of potential access to places of civic amenity and service

CIVIC AMENITY PROXIMITY METRICS

01 **Region • District scale**
Percentage of population or households or jobs within 400m of a civic amenity or service

CULTURE 03 CIVIC AMENITY DISTRIBUTION

An indicator of civic amenity and service concentration and convenience

CIVIC AMENITY DISTRIBUTION METRICS

01 **Region • District • Neighbourhood scale**
% civic amenities or services within local nodes or centers

CULTURE 04 OPEN SPACE INTENSITY

An indicator of public open space capacity

OPEN SPACE INTENSITY METRICS

01 **Region • District • Neighbourhood scale**
% land allocated to public open space

02 **Region • District scale**
Public open space per 1000 population

CULTURE 05 OPEN SPACE PROXIMITY

An indicator of potential access to public open space

OPEN SPACE PROXIMITY METRICS

01 **Region • District scale**

% population or households or jobs within 400m (or local alternate) of a significant open space

CULTURE **06**

OPEN SPACE CONNECTIVITY

An indicator of the degree to which open spaces functionally connect with others.

OPEN SPACE CONNECTIVITY METRICS

01 **Region • District scale**

% public open space connective with others

MATERIALS and WASTE

THEME INDICATORS

MATERIALS **01**

BUILDING RE-USE INTENSITY

An indicator of resource conservation and waste reduction

BUILDING RE-USE INTENSITY METRICS

01 **District • Neighbourhood scale**

% existing building stock protected, re-used or restored

“Good indicator” form In our opinion, a 'good indicator' should clearly and transparently articulate its purpose, metrics, inputs, methods, outputs and calibration sufficiently that those who use it are able to readily understand what it does, how it matters, how it is measured and what its results mean or imply for design decision-making. It is also one that is flexible and resilient — able to adjust to different scales and contexts as well as improve over time. See, for example, detailed descriptions of the indicators applied and tested in the case studies in Volume 2.

To that end, each proposed indicator was developed to a common nomenclature, structure and format that acknowledges its relationship to core sustainability themes and links those roots to its own particular purpose, methods and products. Each indicator, for example, has been associated with a particular sustainability theme. While the path to sustainability is necessarily achieved through a holistic integration of multiple themes and physical form attributes and, while many indicators can and do align with more than one — it is equally important, perhaps more important, to isolate, and thereby focus, community planning and design decision-making more selectively on, a smaller number of influential physical form variables with opportunity to enable greater performance in particular sustainability areas. The assumption being that more sustainable whole places are built from better performing constituent parts.

LAND
THEME INDICATOR

02 INFILL INTENSITY

Definition	**An indicator of the degree to which new development utilizes existing urban land and infrastructure.**
Related sustainability goals	**Compact communities** • Reduce rate of urban expansion • Increase utilization of existing urban land and infrastructure **Energy efficient / Low carbon Communities** • Increase extent of urban forms (districts, neighbourhoods, blocks, parcels, buildings) to reduce energy demand (travel, space conditioning, lighting, for example)
Significance	**Infill intensity** reveals the degree to which new development reuses or recycles existing urban land and infrastructure. Greater infill intensity reduces demand for new urbanized land and infrastructure. Lesser infill density increases that demand and rates of VKT growth.
Applicable scales	**REGIONAL, DISTRICT** and **NEIGHBOURHOOD** scale applications are common

METRIC

01 PERCENTAGE OF NEW DEVELOPMENT WITHIN EXISTING URBAN LAND AND INFRASTRUCTURE

Grain	Coarse
Scale	Region • District • Neighbourhood
Input data	Area of new development Area of new development served by existing civil infrastructure
Calculation method	Area of new development directed to existing urban areas and infrastructure divided by area of new development
Output data	%

Table 1.05: Proposed indicator format. Indicator concepts are defined above / Indicator metrics below.

Every indicator not only focuses on one theme but also one principal physical form or spatial attribute of that theme (intensity, proximity, connectivity, distribution or diversity) and embeds that attribute in its title. The body presents its content in two sections — concepts and metrics. The rationale being that the core concepts of a well designed indicator are likely to be fewer and more stable over time and application than the methods or metrics available or feasible to measure it. We anticipate that the number and sophistication of indicator metrics will expand and change at rates than greater indicator concepts. For example, while the indicator concept of pedestrian connectivity is relatively clear and stable, there are multiple methods to measure it. Research underway today will uncover more, different, perhaps better measurement methods in the future.

In addition, while indicator concepts are broadly applicable, the appropriateness of potential metrics varies with place and circumstance. While all may purport to measure the same attribute, they do so quite differently and some will inevitably be more suited to the needs and circumstances of one community or project than another. Some metrics are very simple and coarse-grained. Others are more sophisticated and fine-grained. Each would require different types and amounts of input data and potentially different methodological or technical fluency to apply.

As illustrated in the upper portion of Table 1.05 above, the introductory portion of an indicator articulates its broader concepts, attributes and purposes. These include statements of intention, related sustainability goals, significance and applicable scales as follows:

Intent states what knowledge one would hope to gain through application of the indicator.

Related sustainability goals situates indicators within a larger planning and decision framework of values and desired outcomes. Goals and objectives have been simplified to a few and are associated with more than one indicator (and vice versa). These particular goals and objectives are illustrative and not comprehensive or exclusive of others. These statements can and should be tailored to the communities in which they are applied.

Significance highlights the particular contribution that an indicator might make toward achieving these goals.

Applicable scales articulates the design decision-making scales (region, district, neighbourhood, block, parcel) at which the indicator is most commonly applied or instructive.

The second portion of each indicator (lower portion of Table 1.05) articulates alternative metrics — strategies and methods of measurement — associated with an indicator. These include statements of 'grain', scale, input data, calculation method, output data and visualization, illustrative scores and, where necessary and appropriate, citations or references as follows:

Grain refers to the 'fineness' or 'coarseness', the relative specificity and accuracy, of inputs and outputs associated with a metric. Coarse-grained metrics are approximate measures derived from more generalized inputs and calculation methods — averaged data or spatial relationships, for example. Fine-grained metrics are more precise measures derived from more specific or detailed inputs and calculation methods — site specific data or spatial relationships, for example. Grain is important to design-centred processes where decision-making tends to be incremental and iterative adding sophistication and detail with progress — bigger, coarser grain decisions made first at the outset, followed by the smaller, finer grain decisions within the context set by the first.

Scale defines the design scale (region, district, neighbourhood, block, parcel) at which a metric is most effectively or commonly applied. Some can be applied across scales with varying degrees of detail. Given the priorities of this project most can be measured at a neighbourhood scale, the decision making scale at which much community design takes place.

Input data identifies the types of data necessary to use a metric.

Calculation method outlines, in general terms, how input data is used to generate an intended result — anticipating that specific methods would be adapted to local data availability, priorities and technical capabilities.

Of the 37 indicators and 52 associated metrics contemplated above, all (and more like them) have been applied and tested in various forms in community-based planning and research projects in British Columbia and Alberta. Of these, the most extensive single application has been **Plan|It**, a sustained, comprehensive land use and transportation planning study undertaken by the City of Calgary. **Plan|It** was initiated in 2006 to develop an integrated land use and transportation plan that would accommodate projected growth of an additional 1.3 million people and 600,000 jobs over the next 50 to 60 years while meeting 11 recently adopted Sustainability Principles. Table 1.06 below summarizes those selected for application and testing.

The indicators-based evaluations and comparisons enabled by this project have been applied and tested in a series of case studies for **Plan|It** Calgary between 2006 and 2008. Selected indicators (See Table 1.07 below) from this project were used or adapted by **Plan|It** stakeholders to generate and discriminate among potential alternatives, establish preferred directions and link them to planning and design implementation strategies and actions at three scales of community design. This work and its results is summarized, elaborated and illustrated in considerable detail in Volume 2.

Table 1.06: Indicators selected for application and testing in Plan | It Calgary case studies on 2 pages following. See also Volume 2.

CASE STUDY APPLICATIONS

SUSTAINABILITY THEME	INDICATOR	METRICS	REGION	DISTRICT	NEIGHBHD
			PLAN-IT CALGARY		
			CITY-WIDE	GREENFLD TOD	17TH AVE CORR
LAND					
	01 DEVELOPMENT INTENSITY				
		01 URBAN AREA EXPANSION	●		
		02 JOBS / POP'N PER HA	●	●	●
	02 INFILL INTENSITY				
		01 % SERVED BY EXISTING INFRASTRUCTURE	●		●
	03 DWELLING INTENSITY				
		01 DWELLINGS PER HECTARE	●		
	04 LAND USE DIVERSITY				
		01 SIMPSON DIVERSITY INDEX FOR LAND USES	●	●	●
		02 MIXED USE PARCEL INTENSITY		●	●
	05 DAILY DESTINATIONS PROXIMITY				
		01 JOBS / POPN WITHIN 400m DAILY SERVICES	●	●	●
MOBILITY					
	01 STREET NETWORK INTENSITY				
		01 LAND ALLOCATED TO STREETS	●		
		02 RATIO OF FREEWAY TO ARTERIALS	●		
	02 MODE DIVERSITY				
		01 MODE DIVERSITY INDEX		●	●
	03 EXTERNAL COMMUNITY CONNECTIVITY				
		01 CONNECTIONS PER KM OF BOUNDARY		●	●
	04 STREET NETWORK CONNECTIVITY				
		01 LOCAL STREET INTERSECTIONS PER HA / KM2 DEVELOPMENT		●	●
		02 ARTERIAL STREET SEGMENTS > X			
		03 COLLECTOR STREET SEGMENTS > X			
		04 LOCAL STREET SEGMENTS > X			
	05 TRANSIT SUPPORTIVE LAND USE INTENSITY				
		01 % OF DEVELOPED LAND MEETING CONVENIENT TRANSIT THRESHOLD			
	06 TRANSIT PROXIMITY				
		01 JOBS WITHIN 600m of CONVENIENT TRANSIT CORRIDOR	●	●	●
		02 POPULATION WITHIN 600m of CONVENIENT TRANSIT CORRIDOR	●	●	●
		03 DWELLINGS WITHIN 400m of CONVENIENT STOP		●	●
	07 PEDESTRIAN ROUTE CONNECTIVITY				
		01 PEDESTRIAN INTERSECTIONS PER HA			
		02 AVERAGE PEDESTRIAN DIRECTNESS RATIO			
	08 BICYCLE NETWORK INTENSITY				
		01 BICYCLE NETWORK / 1000- POP		●	●
		02 JOBS / POPULATION WITHIN X OF CONTINUOUS CYCLE NETWORK	●		
	09 BICYCLE ROUTE CONNECTIVITY				
		01 BICYCLE ROUTE INTERSECTIONS PER HA / KM2			
WATER					
	01 NATURAL HYDROLOGY INTENSITY				
		01 % NATURAL HYDOLOGIC FUNCTION PROTECTED OR RESTORED			
	02 IMPERVIOUS SURFACE INTENSITY				
		01 EFFECTIVE IMPERVIOUS SURFACE AREA			
	03 GREEN INFRASTRUCTURE INTENSITY				
		01 % LAND ALLOCATED TO GREEN INFRASTR		●	●
HABITAT					
	01 HABITAT INTENSITY				
		01 % SIGNIFICANT HABITAT FUNCTION PROTECTED OR RESTORED			
	02 HABITAT CONNECTIVITY				
		01 % SIGNIFICANT HABITAT FUNCTION CONNECTIVE WITH OTHERS			

			PLAN-IT CALGARY CITY-WIDE	GREENFLD TOD	17TH AVE CORR
	03 URBAN FOREST INTENSITY				
		01 TREE CANOPY DENSITY			
ENERGY					
	01 COMMUNITY ENERGY SUPPORTIVE LAND USE INTENSITY				
		01 % OF DEVELOPED LAND MEETING COMMUNITY ENERGY THRESHOLD	•		
	02 PASSIVE ENERGY INTENSITY				
		01 % PARCELS WITH SIGNIFICANT SOLAR POTENTIAL		•	
		02 % PARCELS WITH SIGNIFICANT NATURAL VENTILATION POTENTIAL			
	03 RESIDENTIAL ENVELOPE INTENSITY				
		01 RESIDENTIAL ENVELOPE TO FLOOR AREA RATIO			
FOOD					
	01 FOOD GROWING INTENSITY				
		01 % SIGNIFICANT AGRICULTURAL FUNCTION PROTECTED OR RESTORED			
		02 DEDICATED FOOD GROWING AREA PER DWELLING			
	02 FOOD GROWING PROXIMITY				
		01 % DWELLINGS WITHIN 400m OF SIGNIFICANT FOOD GROWING AREA			
EQUITY					
	01 DWELLING DIVERSITY				
		01 SIMPSON DIVERSITY INDEX FOR DWELLING TYPES	•	•	•
	02 DWELLING DIVERSITY DISTRIBUTION				
		01 AVERAGE DWELLING TYPE DISTRIBUTION			
	03 AFFORDABLE DWELLING INTENSITY				
		01 % DWELLINGS MEETING LOCAL AFFORDABILITY CRITERIA			
ECONOMY					
	01 EMPLOYMENT INTENSITY				
		01 JOBS PER HA DEVELOPMENT	•		
		02 JOBS PER DWELLING			
	02 EMPLOYMENT PROXIMITY				
		01 JOBS WITHIN 5km			
	03 EMPLOYMENT DIVERSITY				
		01 SIMPSON DIVERSITY INDEX FOR EMPLOYMENT TYPES			
	04 COMMERCIAL DIVERSITY				
		01 AVERAGE COMMERCIAL STREET FRONTAGE TO FLOOR AREA			
CULTURE AND WELL-BEING					
	01 CIVIC AMENITY INTENSITY				
		01 % LAND ALLOCATED TO CIVIC AMENITIES AND SERVICES PER DWELLING			
	02 CIVIC AMENITY PROXIMITY				
		01 % JOBS / POPN WITHIN 400m OF A CIVIC AMENITY OR SERVICE		•	•
	03 CIVIC AMENITY DISTRIBUTION				
		01 % AMENITIES WITHIN LOCAL NODES / CTRS			•
	04 OPEN SPACE INTENSITY				
		01 % LAND ALLOCATED TO PUBLIC OPEN SPACE	•		
		02 PUBLIC OPEN SPACE PER 1000 POPULATION	•	•	•
	05 OPEN SPACE PROXIMITY				
		01 % JOBS / POPULATION WITHIN Xm OF A DEFINED PUBLIC OPEN SPACE	•	•	•
	06 OPEN SPACE CONNECTIVITY				
		01 % OPEN SPACE AREA CONNECTIVE WITH OTHERS			
MATERIALS AND WASTE					
	01 EXISTING BUILDING INTENSITY				
		01 % EXISTING FLOOR AREA PROTECTED OR RESTORED			

Sustainability Indicators for Computer-based Tools in Community Design set out to develop a set of design-centred sustainability indicators that can be integrated with GIS-based modeling and visualization tools in ways useful to, and supportive of, charrette-based community design processes. At this writing, the degree to which the proposed indicator concepts, metrics and methods of this project are replicable by others in other places remains untested. However, it has been an intent of the authors to define the foundation knowledge, methods and example by which most community, academic or professional planning audiences with intermediate or better GIS capabilities could define and measure a meaningful array of sustainability indicators in a charrette- or similarly design-driven community planning process.

To that end, the indicators explored and reported here have developed over several years of research, application and testing in diverse community design contexts. The core concepts, metrics and methods have been adapted and applied in over a dozen projects (including the **Plan | It** Calgary case studies of Volume 2) at scales from regions to neighbourhoods. While the process has been, and continues to be iterative, much knowledge and experience with GIS-based sustainability indicators in community design. Some of these include:

> **Indicators 'work':** While the indicators described in this project will continue to improve and refine, with further research, application and testing, as well as advances in modeling and visualization technology, they have already been effective decision support tools. Many small and large communities have been able to understand, measure and compare the spatial attributes of sustainability within alternative planning and urban design scenarios at reasonable time- and economic cost. The experience and the results, have afforded these communities the opportunity and knowledge to more informed consideration and choice about urban planning and design alternatives and directions. In all three of the **Plan | It** case studies, for example, indicators-based assessment and comparison of contemplated planning and design alternatives contributed information and evidence valuable to discussion and negotiation of preferred alternatives.
>
> **Aligning indicators to a sustainability decision support framework is crucial:** If it can be said that 'all measures serve a purpose', it would follow that sustainability indicators can and should be transparent to their purpose(s). In this purpose, that

purpose is ‘sustainability’ and the degree to which indicators can be made transparent to crucial dimensions of sustainability has tended to elevate their significance in community design decision-making. To achieve that transparency, the decision support framework and associated sustainability themes (see Figure 1.01), or something like it, has been crucial.

In the **Plan | It** case studies, for example, it was necessary to clearly demonstrate a relationship between the indicator instruments used to evaluate and compare potential alternatives to the City’s recently adopted Sustainability Principles. While these Principles were not the same as the sustainability themes around which the set of potential indicators had been generated, it was possible to cross-reference them so that **Plan | It** project stakeholders could at any time readily connect an indicator and its metrics to the presence or absence of the higher principles to which they had agreed.

Indicators (few in number, broadly applicable — less variety across instances) **are not the same as metrics** (greater in number, narrower applicability — greater variety across instances)**:** It has been useful in this work to differentiate indicators which, in this project, define attributes to be measured, from metrics which, in this project, define the particular means and methods (input data, calculation methods, output units etc.) through which attributes are measured. By this convention, an indicator articulates desirable attributes — the intensity of land uses, or the connectivity of streets, for example. Indicators would change little community to community, project to project, design phase to design phase, scale to scale.

Metrics, on the other hand, measure those attributes in ways appropriate to the particular scale, decision-making phase and data available in a community planning and design project. The metrics used to measure a single attribute could, would likely, vary community to community, project to project, design phase to design phase, scale to scale.

Within the experience of this project, it was occasionally necessary and valuable to tailor indicator specifics and details (but not concepts) to the priorities of projects and communities However, as the means and methods available to measure indicator concepts attributes tend to be more numerous, metrics were far more frequently tailored and tuned to suit more particular requirements and circumstances. Some of these include:

- Local norms and priorities — how an indicator might be named, framed or measured can be adapted to local priorities, nomenclature and performance thresholds.

  In the **Plan | It** case studies, for example, indicators were re-organized, re-titled in some cases, and re-framed to parallel the 11 Sustainability Principles of a formally adopted public policy document (see the regional case study, for example) rather than the sustainability themes outlined in Table 1.01 elsewhere in this report. Similarly, measurement units, performance thresholds and benchmarks were recalibrated to local conventions and expectations. However, the core principles and concepts of the original were maintained.

- The coarseness or fineness of data and design scale — what can and should be measurable (and how) at a regional scale is more coarse that what can and should be measurable (and how) at a neighbourhood scale. The nature of the question and the available data, are often quite different.

- Decision-making stage — what can and should be measurable (and how) in the initial phases of a particular community design process can be more coarse and less detailed that what can and should be measurable (and how) in latter phases.

  In the **Plan | It** case studies, for example, 'Proximity to Transit' was considered an important indicator of potential travel mode choice, a sustainability attribute measurable at multiple scales and decision-making points. At a coarser regional scale early in the process, 'Proximity to Transit' was measured from aggregated parcel data as job and population density within 600m of a transit corridor. At a finer neighbourhood scale later in the process, 'Proximity to Transit' could be measured with parcel scale data as places of employment and dwellings within 400m travel distance of transit stop.

'Relative' measures and values represented graphically are more useful: With the exception of threshold values — sufficient intensity and diversity of land use to support transit, for example, most measured indicator values tend to contribute more effectively to public discussion in 'relative' rather than 'absolute' terms. Like most measures of tasks as complex and comprehensive as community planning, indicators are necessarily estimates based on best available information. Understanding that alternative A is likely to perform twice as well as alternative B or within 20% of alternative C (rather than A=100, B = 50 and C = 120), for example, helps to simplify the potentially distracting technical and quantitative density of indicators and to focus stakeholders on clarity around important 'orders of magnitude' factors and issues. Similarly, it was also valuable to represent orders of magnitude variations in performance graphically. In all three of the **Plan | It** case studies, for example, most indicators results were expressed in simple, rounded values and represented graphically on an appropriately scaled line or bar, whenever possible accompanied by a familiar or instructive benchmark. See examples in the case studies Appendices C, D or E.

Data availability and alignment (too much, too little, wrong kind) **remains a challenge** (finding, assembling, filtering and creating the right data**):** Among the challenges to GIS applications in community design has been the complexity and cost of gathering and reconciling spatial data from multiple sources and organizing it into base models upon which alternative plans can be effectively modeled and indicators measured.

Currently there is much variation in the quantity, types and standards of the spatial data that communities collect and maintain in Geographic Information Systems. While the breadth and depth of that variation limits the ability to generalize, experience in this and related projects has more often been that too much, and infrequently too little, data available to apply these indicators. Rather communities with GIS systems tend to collect and manage large quantities of diverse information about themselves in GIS — much of it unrelated to core issues of sustainability or meaningful through a community planning and design lens.

Rather the data challenges have tended to be those associated with sorting and streamlining available data to the relatively simple, but often more explicitly physical form and pattern seeking lens of spatial indicators. In the **Plan | It** case studies, for example, much data about the city was collected at a either parcel scale or zoning area scale or transportation analysis zone (TAZ) scale. Parcel scale data are often too fine grained and detailed for neighbourhood scale and larger analyses and had to be simplified and streamlined.

On the other hand, zoning scale data are often too coarse and unreconciled with existing conditions. Both zoning and TAZ data are often aggregated to different spatial extents than study areas or not available in the case of new area and had to be created.

Very few communities maintain datasets that articulate future plans in scope and terms equivalent to those that articulate existing conditions. Much of that has to be created and codified from, charrette- or comparably design-generated plans. In the **Plan | It** case studies, for example, the project had to generate equivalent spatial data associated with proposed or contemplated land uses and systems considered in particular study areas. See for example the discussion of creating development pattern data in Appendix B.

Linking 'enabling' (spatial attributes) **to 'behaving'** (non-spatial attributes) **is an ongoing challenge:** Among the challenges to developing a meaningful and robust set of sustainability indicators for community planning processes has been finding a means to link the non-spatial attributes of sustainability to the spatial attributes that are the domain and focus of community planning and design. Crucial sustainability goals and objectives — many pertaining to economic, social and cultural goals and objectives, for example — are difficult to associate with spatial attributes measurable in community design. Some can be measured indirectly or by proxy — the diversity and distribution of dwelling types, size and tenures, for example, could approximate housing affordability. Others, such as local economic opportunity or employment equity are more challenging and await discovery of indirect measures or proxies. Some may not be measurable in a community design process.

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