

Measuring the Sustainability of Cities: An Analysis of the Use of Local Indicators for the Major Cities of Quebec¹

Juste Rajaonson, *Université du Québec à Montréal*

Georges Tanguay,² *Université du Québec à Montréal and CIRANO*

Abstract

Sustainable development indicators and indices are increasingly being recognized as essential tools for evaluation, implementation and follow-up of urban sustainable development. However, the necessarily multidisciplinary nature of urban studies and the will to bridge theory and practice have propelled researchers and practitioners to define common objectives and develop consensual approaches to the use of indicators. In this article we select, sort, classify and apply indicators to evaluate sustainable development in the 25 largest cities in Quebec. We thus create indices that group indicators and maximize the coverage of social, environmental and economic dimensions of sustainable development to facilitate the use and understanding of indicators without compromising scientific validity. An aggregation method is applied, weighting scenarios are presented and cities are ranked.

May 20th 2009

Keywords: Sustainable Development, City, Indicators, Indexes, Aggregation, Weighting.

¹ The authors thank the *CIRANO* for its financial support. Errors are the authors' responsibility.

² Corresponding author: UQAM, ESG DEUT, CP. 8888, Succ. Centre-ville, Montreal, QC, Canada, H3C 3P8. E-mail: tanguay.georges@uqam.ca; Fax: 514-987-7827.

1. INTRODUCTION

Sustainable development, first defined in the Bruntland report in 1987,³ implies objectives to attain, which reflect the interdependence of the environmental, social and economic domains, along with concern for the needs of current and future generations. Although these objectives were initially national in scope,⁴ experience in municipalities, cities and communities ensuing from article 28 of Agenda 21 demonstrated that it is at the local scale that issues are best identified and actors are most mobilized (Camagni, 2002). A growing number of public institutions have recognized the importance of developing evaluation and monitoring tools such as sustainable development indicators (SDI). Such tools serve to inform the public and the stakeholders involved, measure progress toward the attainment of sustainable environmental and socioeconomic objectives and support subsequent decision making processes (Bell & Morse 2008).

Despite this popularity, the use of SDI in Quebec is still in its infancy, and remains problematic. Although there have been several experiments with indicator charts in territories in Canada (MacLaren 1996, Fraser Basin Council 2000, TRNEE 2003, Sustainable Calgary 2004, Tomalty 2007, Corporate Knights, 2009), Quebec has just begun to explore this area (Centre Québécois de sustainable development 2003, Fondation Rues principales 2008, MDDEP 2009). Further, the general definition of sustainable development has given rise to multiple interpretations, and has particularly favoured an explosion of indicators for its implementation. Although researchers agree on the importance of defining selection criteria for indicators (Niemeijer & De Groot 2008), aggregation and weighting methods, consensus on this subject is lacking.

Given these findings, we propose to develop an SDI chart that covers the largest cities in Quebec, inspired by territorial practices and scientific findings. First we propose a parsimonious selection method for indicators that covers the main dimensions of sustainable development as broadly as possible by minimizing their number. Second, we propose a framework of analysis that we will use to create synthetic, composite indicators for communication and operation purposes, without reducing the scientific validity of the indicators. Third, we apply the SDI chart to the largest cities in Quebec to produce a tentative ranking of cities based on weighting scenarios of composite indicators.

³ The Bruntland report defines sustainable development as “a development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED 1987)

⁴ The Rio summit of 1992 brought together several nations and engendered Agenda 21, which states the guiding principles for sustainable development.

2. Review of Concepts Related to Urban Sustainable Development Indicators

Sustainable development of cities

The transposition to the local level of a concept that was originally formulated by international political authorities raises serious issues regarding the need to bridge thought and action, science and politics, and discourse and implementation. Hampered by a relatively blurry definition and a claim to cover several dimensions at a time, urban sustainable development is undoubtedly characterized by a large number of players, but has suffered the consequences, including an abundance of interpretations and indicators used in its implementation.

If some territorial practices associate sustainable development with the concept of quality of life (FCM 2004, Jacksonville Community Council 2004, Koller 2006), others tend to consider it simply another environmental issue (Ville de Montréal, 2006). In both cases, the definition of sustainable development is problematic.

By emphasizing quality of life, an entire aspect of sustainable development, i.e. negative externalities, is not taken into account in the formulation of indicators. Thus, a given city or municipality may indeed promote a good quality of life for its citizens, yet this lifestyle may not necessarily be viable for the environment or equitable for the society as a whole.

Further, specifically treating environmental issues from a sustainable development perspective amounts to reducing the factors that underlie development of a city to the sole needs and uses related to natural resources and the quality of the physical environment. Thus, a city or municipality may have the least impact on the environment, be the most energy efficient and the best equipped in terms of environmental sensitivity and education whereas it has a very low employment rate, negative growth of the work force and a very high crime rate, for example.

This is why sustainable development on the city level requires major coordination of research and territorial practices, along with the reconciliation of these two approaches. Not only does research and application into the concept of sustainable city require bridging and interdisciplinary, but there are also constraints involving research and action tools.

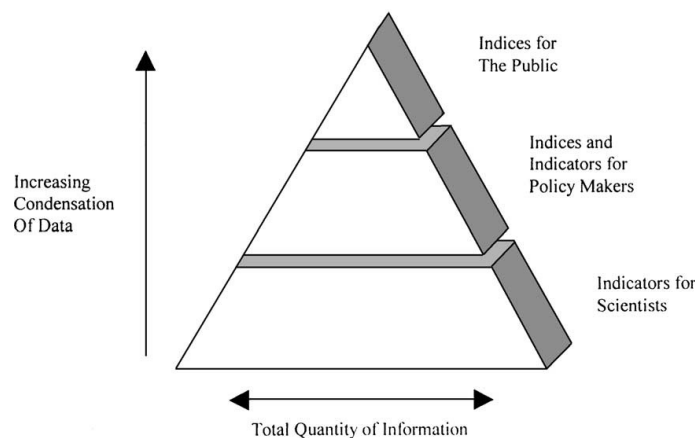
Accessibility and availability of data on the challenges of sustainable development are among the recurrent problems, particularly with respect to cities and municipalities. This reality sometimes necessitates the use of indicators that are not necessarily the most efficient at capturing urban sustainable development. For example, bus speed is often proposed as an indicator of the efficiency of mass transit (Basiago, 1999), whereas it has

been demonstrated that cities where buses travel the quickest have greater sprawl coupled with less efficient and less used mass transit (Newman & Kenworthy, 1988).

Research on Territorial Practices

Research on territorial practices diverges widely in terms of the choice, number of indicators and objectives. If practitioners tend to favour a less conceptual structure involving as few indicators as possible, along with simple and quantifiable objectives, scientists envision minimal aggregation and simplification in order to remain loyal to the concepts (Shields *et al.* 2002) and to ensure the scientific validity of results. This contrast is illustrated in Figure 1. Nonetheless, aggregation and simplification of information invariably decreases analytical power while reinforcing the subjective nature of indicators (Verry & Nicolas, 2005). Kahn (2006) argues that there are still no standard pertinent and universal methods or criteria for aggregating or weighting SDI.

Figure 1 Relation between Condensation of Indicators and the Audience



(Source: Shields *et al.* 2002)

Second, practitioners and researchers concur on the importance of developing robust and efficient indicators. However, researchers favour modeling, conceptualization and development of knowledge, whereas practitioners are compelled to realize policies by applying pertinent actions. The impenetrable barrier between thought and action and between science and politics must give way to greater complementarity based on more consensual objectives.

Objectives of an Urban Indicator Chart

These findings related to sustainable urban development and the application of SDI motivate a quest for more consensual and integrating approaches. A chart of urban sustainable development indicators should be able to:

- Inform the public;
- Orient future sustainable development objectives of all municipalities
- Evaluate progress in sustainable development between municipalities.

To do so, it must be scientifically valid, maximally cover the three dimensions of sustainable development and minimize the number of indicators used, to facilitate operationalization and communication.

3. Territory and Scale of Analysis

Regarding the methodology, we have chosen to apply the indicators to the 25 largest cities in Quebec, with a minimum of 40,000 inhabitants, for two main reasons. Most of the data analyzed are available only for urban centers with over 40,000 inhabitants. In addition, all these cities have adopted strategies or sustainable development plans that facilitate coordination and research into information and municipal data.

From a practical standpoint, sustainable development is a relatively recent domain in Quebec, few practices and territorial experiences exist (Centre Québécois du sustainable development 2003, MDDEP 2009) and very few research projects have been conducted to date (Barcelo 1999). Further, the largest cities are subject to particular attention because they host the majority of the Quebec population, and sustainable development issues are thus of greater concern there.

4. Collection of Municipal Data in Quebec Related to Indicators Retained

Table 1 presents the sources of data that we used to calculate the indicators. In general, the data are primary, and no additional calculations were made aside from the standardization required for the compilation of indices.

Table 1 Sources of Data Used to Calculate Indicators

Banque de données des statistiques officielles sur le Québec	Québec. 2009. "Auto-évaluation de l'état de santé, population de 12 ans et plus, Québec et régions sociosanitaires (4 avril 2008): période 2005-2006."
Environnement Canada	Municipal Water and Wastewater Survey. 2006. http://www.ec.gc.ca/water/MWWS/fr/report.cfm
Institut National de la Recherche Scientifique – Urbanisation, Culture et Société (INRS-UCS)	Sénécal, G. 2007. <i>L'état de l'environnement urbain au Québec: un coup de sonde auprès des municipalités</i> . INRS-Urbanisation, Culture et Société.
Ministère des Affaires municipales, des Régions et de l'Occupation du territoire du Québec.	Prévisions budgétaires des organismes municipaux – Exercice financier 2008. Participation rate in municipal elections
Ministère du développement durable, de l'environnement et des parcs du Québec	MDDEP. 2002. "Statistiques annuelles de l'IQA: 2007." In <i>Le portail du ministère du Développement durable, Environnement et Parcs du Québec</i> . Hébert, S. and M. Ouellet, 2005. <i>Le Réseau-rivières ou le suivi de la qualité de l'eau des rivières du Québec</i>
Société d'assurance automobile du Québec (SAAQ)	SAAQ, 2008. Répartition des automobiles et des camions légers promenade par municipalités, 2007 et 2008.
Canada Mortgage and Housing Corporation (CMHC)	Data related to the cost of housing (ordered)
Statistics Canada	Cumulative Profile, 2006 - Québec (Census Subdivisions) (table), 2006 Census of population (provinces, census divisions, municipalities) (database), E-STAT (distributed). Uniform Crime Reporting Survey , 2007- Statistics on Crime - Crime Statistics - All police services - 1977 – 2007.
Ville de Montréal	Bilan environnemental, Qualité des cours d'eau de Montréal. 2004. http://ville.montreal.qc.ca/portal/page?_pageid=3216,3787640&_dad=portal&_schema=PORTA

5. Theoretical Framework for Processes Ranging from Selection to Application of a Chart of Sustainable Development Indicators to the Largest Cities of Québec

Collection of Indicators

A survey-based analysis on the use of SDI conducted by Tanguay *et al.* (2009) extracted 188 SDI from a review of 17 studies on the creation of territorial indicators. These studies covered practices in Canada, the United States and Europe and were selected to ensure the compatibility with the socioeconomic context in Québec and accessibility of information and data. Scientific studies and articles were another source of indicators. These documents enabled the authors to determine which classification, weighting and aggregation methods were suitable for the treatment and analysis of indicators. Table 2 presents the 17 studies selected and the number of indicators they use.

Table 2 Sources of 188 Indicators Compiled

Reference	Territory covered	Number of indicators
Fraser Basin Council (2000)	Canada, British Columbia	40
Sustainable Calgary (2004)	Canada, Calgary	36
Federation of Canadian Municipalities (2004)	Canada	72
ToMLPty <i>et al.</i> (2007)	Canada, Ontario	33
Corporate Knights (2007)	Canada	35
Jacksonville Community Council (2004)	United States, Jacksonville	86
Sustainable Report (2006)	United States	15
Boston Foundation (2007)	United States, Boston	28
Ambiente Italia Research Institute (2003)	European Union	10
Planque, B. and Y., Lazzeri (2006)	European Union	74
Agence régionale pour l'environnement (2001)	France, Midi-Pyrénées	27
Cowley <i>et al.</i> (2007)	United Kingdom	13
Koller (2006)	Switzerland	30
Meier & Wachter (2005)	Switzerland	35
Brazzini-Mourier, S (2006)	Switzerland, Onex	39
ARCOLATINO.org (2004)	Arco Latino ⁵	21
Thomas <i>et al.</i> (2003)	Theoretical Indicators	22

Classification, Sorting and Selection of Indicators

Once the indicators were noted, they were grouped according to basic categories (Tanguay *et al.* 2009). For example, indicators related to transport were grouped, as were indicators related to air quality and those related to energy consumption. Tanguay *et al.* (2009) recommend an additional sort to identify the most frequently used indicators. Such indicators then appear in the indicator chart that we propose in this article. This classification is summarized in Table 3, which also indicates the frequency of use of indicators in the 17 studies analyzed.

⁵ Arco Latino is an association of regional and departmental communities corresponding to islands, coastal and inland regions in the Western Mediterranean (Portugal, Spain, France and Italy)

Tableau 3 Category and Frequency of Use of Indicators Compiled from 17 Studies

INDICATORS					
Category	Total	Number of Times Used			
		1 or 2	3	4	5 and +
Énergy (excluding transport)	8	7	1	0	0
Transport	25	20	2	2	1
Air quality	15	10	3	0	2
Noise	3	3	0	0	0
Drinking water	7	4	2	0	1
Green space, ecosystems and heritage	16	12	1	1	2
Waste	5	3	0	0	2
Demographics	10	7	2	1	1
Housing	18	15	1	1	1
Education	11	7	2	1	1
Security	5	4	0	0	1
Health	9	8	1	0	0
Well-being	3	3	0	0	0
Social and community services	11	8	1	2	0
Governance	4	1	1	0	2
Public expenses and administration	6	4	0	0	1
Household income and expenses	13	8	1	0	4
Employment	8	5	0	0	3
Businesses	5	3	1	0	1
Other indicators*	6	3	2	1	0
TOTAL	188	135	21	9	23

* Ecological footprints, natural catastrophes, level of exposure to natural and industrial risks, consumption of equitable products, urban intensification, and soil use.

Below, we will associate the syndicators with environmental, social or economic dimensions using a classification model that can be used to resolve problems raised by indicators' overlapping more than one dimension.

Lastly, although the most recent studies on sustainable development advocate the systematic use of selection criteria to obtain a refined list of indicators (Nieimeijer & De Groot 2008), we opt for a selection model of indicators based on frequency of use. Tanguay *et al.* (2009) maintain that the use of this model avoids the recurrent application of selection criteria to indicators whose pertinence and quality have been repeatedly demonstrated and justified by previous research or operationalizations. Accordingly, the model developed by Tanguay *et al.* (2009) specifies a strategy that subjects the categorization of 188 indicators derived from the 17 studies mentioned above to three criteria that allow the number of indicators to be reduced to an optimal level. These criteria are 1) frequency of use with an optimal threshold; 2) exhaustive coverage of the

components of sustainable development and their subcategories; and 3) operationalization that facilitates data collection, interpretation and dissemination

This optimal number thus results from the union between the most frequently used indicators and indicators that allow the broadest inclusion of the dimensions of sustainable development and their constituent categories (Tanguay *et al.* 2009). A total of 24 SDI were retained; they are shown in Table 4.

Table 4 The 24 Indicators Retained

Category	Indicator
Administration, public expenses	SD policies or strategies
Air	Air quality
Well being	Household spending allotted to housing
Housing conditions	Households spending 30% or more of income on housing
Demography	Density of urban population
Water	Residential water consumption
Ecosystem, heritage, green space	Area allotted to nature conservation
Ecosystem, heritage, green space	Quality of waterways
Education	Level of education of population aged 18 and over
Employment	Participation rate for all sectors
Employment	Unemployment rate
Energy	Annual residential energy consumption
Business	Companies with environmental certification
Governance	Participation rate in municipal elections
Waste	Quantity of waste recycled
Waste	Quantity of household waste sent to landfills
Income and expenses	Mean/median household income
Income and expenses	Ratio, population with high income-low income
Income and expenses	Low income households
Health	State of health reported by population
Security	Crime rate
Social and community services	Amount municipality spends on social assistance, community services, sports, recreation and culture
Transport	Use of mass transit (MT)
Transport	Automobile ownership per inhabitant

Aggregation of Indicators

Aggregation can be spatial (e.g. progression from a regional spatial scale to a provincial scale), temporal (e.g. from a monthly interval to an annual interval) and thematic (Geniaux, 2006). The aggregation method is crucial because it refers directly to the organization model that synthesizes the indicators into indices and that will serve for both communication and operation purposes. For example, indicators related to entropic pressure on the environment (level of pollution, energy consumption, quantity of waste sent to landfills, etc) can be grouped together and aggregated to form a “pressure index.” This index can determine the degree of pressure exerted by entropic activities on the environment of a given territory.

In this study, we apply thematic aggregation that is aggregation intended to group a set of indicators according to different themes that are used to construct indices.

We thus introduce an organization model that is faithful to the environmental, social and economic dimensions of sustainable development, and that can solve problems related to indicators that overlap two or three dimensions (Tanguay *et al.* 2009). This model has the advantage of expressing one indicator within new dimensions: it can be environmental and economic, economic and social or social and environmental. Such an initiative reflects the will to better integrate the multiple dimensions of sustainable development.

Thus, for a city to be sustainable it must be able to permanently offer favourable conditions for the maintenance and implementation of economic agents, and these agents must produce and consume responsibly. The city must therefore:

- Offer conditions that attract and retain a highly educated and skilled population;
- Offer conditions favourable to economic development;
- Monitor the viability of natural resources;
- Ensure good governance.

Based on these conditions, we can define intermediate indices that we will use to aggregate the 24 indicators retained. The first index refers to “quality of life,” and comprises environmental, social and economic indicators that favour attraction and retention of households (affordable housing, high income, health, public facilities, etc.). The second index refers to “economic development,” and comprises indicators associated with the social and economic dimensions governing economic transactions (level of education, participation rate, urban density, etc.). The third index refers to the “viability

of natural resources,” and includes indicators that overlap the environmental, social and economic dimensions (energy consumption, transport, spending on environmental awareness, etc.). The fourth point concerns “mobilization of local players,” around sustainable development issues. These formalized intermediate indices are presented in Table 5, and will serve to calculate the global index (GI)

Table 5 Indices and Dimensions of Sustainable Development

Index	Dimension		
	Environmental	Economic	Social
Quality of life (QL)	✓	✓	✓
Economic development (ED)		✓	✓
Viability of natural resources (VNR)	✓		✓
Mobilization of local players (MLP)	✓	✓	✓
GLOBAL INDEX (GI)	✓	✓	✓

To aggregate the 24 indicators, we first apply corresponding data standardization to each indicator. The objective is to perform calculations on data with different units and significant heterogeneity. For this transformation, each indicator will therefore have a mean of 0 and a standard deviation of 1 ($N(0,1)$), as expressed by the following formula:

$$Y_{in} = (x_{in} - \bar{x}_{in}) / \text{standard deviation } x_{in}$$

where \bar{x} is the mean.

We then group the indicators according to the intermediate indices identified in Table 5. This new organization of indicators into indices is presented in Table 6. Lastly, for each group of indicators we calculate the weighted average of the standardized data and present a preliminary classification of the 25 largest cities in Quebec based on sustainable development.

Table 6 Classification of Indicators into ED, MLP, QL and VNR Indices

Index	Indicator	Category
ED	ED1. Population aged 18 and over with at least a high school diploma	Education
	ED2. Participation rate for all sectors	Employment
	ED3. Unemployment rate	Employment
	ED4. Density of urban population	Demographics
MLP	MLP1. Participation in municipal elections	Governance
	MLP2. SD policies or strategies	Administration, public expenditures
QL	QL1. Household spending allotted to housing	Well being
	QL2. Households spending 30% or more of income on housing	Housing conditions
	QL3. Mean/median household income	Income and expenses
	QL4. Ratio, population with high income-low income	Income and expenses
	QL5. Low income households	Income and expenses
	QL6. State of health reported by population	Health
	QL7. Crime rate	Security
	QL8. Amount municipality spends on social assistance, community services, sports, recreation and culture	Social and community services
VNR	VNR1. Air quality	Air
	VNR2. Air quality	Water
	VNR3. Area allotted to nature conservation	Ecosystem, heritage, green space
	VNR4. Quality of waterways	Ecosystem, heritage, green space
	VNR5. Annual residential energy consumption	Energy
	VNR6. Companies with environmental certification	Businesses
	VNR7. Quantity of waste recycled	Waste
	VNR8. Quantity of household waste sent to landfills	Waste
	VNR9. Use of mass transit (MT)	Transport
	VNR10. Automobile ownership per inhabitant	Transport
GI		

Inter- and Intra-Index Weighting

After calculating the indicators and grouping them into intermediate indices, we apply different weighting scenarios to determine the extent that weighting can change the results and hence the ranking of cities. Weighting entails attributing a greater value or contribution to one indicator or index than another. This approach has drawn much criticism (Perret, 2002 and Martinez-Alier *et al.*, 1998) because it is an arbitrary process and no weighting structure can rationally justify the attribution of a greater weight to a given indicator. Nonetheless, Callon (2001) suggests that any attempt to weight

sustainable development indicators take public participation in decision-making processes into account. Thomas *et al.* (2003) contend that participating processes remove much of the scientific validity from the indicators while giving local players free rein to define their own sustainable development, which undermines the credibility of the indicators.

Weighting is crucial in when defining sustainable development indicators intended for several territories with the same legal status, because each indicator does not have the same explanatory power. Rather, it is influenced by the city's size and by its social, environmental and economic structure.

If applying an aggregation model when creating indices can allow a synthesis of SDI for communication and operationalization purposes, applying formal weighting to these indicators can eliminate the bias related to their synthesis while ensuring scientific validity.

Intra-Index Weighting

Two weighting scenarios appeared relevant. The first consists of intra-index weighting, where we add a weight or a value that to the indicators that make up each intermediate index. To do so, we define a weighting rule based on the contribution of each indicator to the intermediate index. The greater the contribution, the greater the weight attributed.

We then calculate the score for each intermediate index as follows:

$$CI_n = (w_1y_{1n} + w_2y_{2n} + \dots + w_p y_{pn}) = \sum_{i=1}^p (w_i y_{in})$$

CI_n corresponds to the score of the intermediate index in city n

Y_{in} corresponds to the indicators for attribute i in city n

W_i specifies the weight attached to attribute i

N is the number of indicators in the index.

We then sum the intermediate indices to create a global sustainable development score for each city and establish a ranking of cities.

$$IG = \text{sum} (QL; VNR; MLP; ED)$$

Inter-Index Weighting

The second weighting method is inter-index weighting, in which we add a weight or value to each intermediate index. We thus assign a discriminant explanatory power to

each of the indices depending on the size of the city (see Table 7). The weighting rule is based on three statements:

- The intermediate index VNR has the highest weight regardless of the size of the city.
- The intermediate index ED has a higher weight on the QL and MLP indices for cities with over 100,000 inhabitants that play a greater role on the regional economic level.
- The intermediate index QL has a higher weight on the ED and MLP indices for cities with fewer than 100,000 inhabitants, the majority of which have a more residential function.

Table 7 Inter-Index Weighting Rule

	Total	VNR	ED	QL	MLP
City with 100,000 inhabitants or more	100%	40 %	30 %	20 %	10 %
City with fewer than 100,000 inhabitants	100%	40 %	20 %	30 %	10 %

6. RESULTS

Table 8 presents the score of the intermediate indices of sustainable development for each city in Quebec with 40,000 inhabitants or more, without weighting. Brossard, Lévis and Dollard-des-Ormeaux top the list of sustainable cities with the highest global index (GI) scores. The strong performance of these three cities stems from the fact that they offer the most favourable conditions for attraction and retention of households, with a high QL score. In addition, Brossard and Dollard-des-Ormeaux best monitor the viability of natural resources, with high VNR scores, whereas Lévis has conditions conducive to economic development (ED = 3.95). Shawinigan, Saint-Jérôme and Trois-Rivières perform the worst among the cities studied, with relatively low global indices. Conditions favourable for household settlement mainly influenced these results, although these cities allow better mobilization of local players than most of the cities examined. As for Montréal, its ranking was largely affected by a very low QV, although it is by far the most efficient at monitoring the viability of natural resources (VNR=8.8). Cities such as Saint-Jean-sur-Richelieu and Repentigny stand out because they appear attractive in terms of quality of life despite scoring poorly on viability of natural resources. Lastly, Terrebonne, which is situated in the middle (12th place) of the ranking, offers particularly

favourable conditions for economic development, but must increase its effort to monitor the viability of natural resources.

We then produced another ranking by applying inter-index weighting (See Table 9). Overall, when we give more weight to indicators comprised in the intermediate indices, Brossard falls to 10th place, while Lévis and Dollard-des-Ormeaux remain among the top three cities. The quality of life component best explains these results, along with the favourable conditions for economic development. By attributing a greater weight to indicators such as household income, household spending on housing and level of education, cities whose function is mainly residential stand out. It is not surprising that cities such as Longueuil, Laval, Gatineau and Quebec fall slightly in this ranking because their population is more diversified in terms of income, and tends to spend more to live close to their workplace. Like Montréal, these cities are penalized in terms of socioeconomic conditions although they generally monitor the viability of natural resources

Tableau 8 Score for Intermediate Indexes without Weighting and Ranking of 25 Largest Cities in Quebec Relative to Sustainable Development

Municipality	Population 2008	ED	MLP	QL	VNR	IG	Rank
Montréal	1659962	1.22	-1.47	-5.21	8.8	3.34	9
Quebec	502119	2.14	0.82	-1.76	3.62	4.82	7
Laval	376425	1.73	-2.04	-1.47	-0.09	-1.87	15
Gatineau	247526	1.15	0.39	1.5	2.46	5.5	5
Longueuil	234352	0.53	-1.04	-2.92	1.37	-2.06	16
Sherbrooke	150751	-0.75	-0.04	-1.28	3.8	1.73	11
Saguenay	146641	-3.05	1.68	-2.43	0.04	-3.76	19
Lévis	132851	3.95	0.39	4.78	0.28	9.4	3
Trois-Rivières	128941	-1.98	0.68	-5.41	-0.31	-7.02	23
Terrebonne	96795	2.61	1.11	0.32	-3.58	0.46	12
Saint-Jean-sur-Richelieu	89388	0.17	-0.90	4.94	-2.31	1.9	10
Repentigny	77744	2.97	-0.61	4.97	-2.93	4.4	8
Brossard	72707	1.76	-1.33	5.7	5.14	11.27	1
Drummondville	68841	-2.33	0.00	-3.27	-0.47	-6.07	21
Saint-Jérôme	65048	-2.04	-1.04	-3.76	-3.42	-10.26	24
Granby	60617	-1.91	0.11	0.99	-2.63	-3.44	18
Shawinigan	52865	-6.2	0.96	-5.87	-0.38	-11.49	25
Saint-Hyacinthe	52713	0.78	-1.04	0.18	-1.06	-1.14	14
Dollard-Des Ormeaux	49940	2.04	0.00	7.13	0.78	9.95	2
Blainville	47504	3.61	0.54	7.81	-4.1	7.86	4
Châteauguay	43618	-0.45	0.82	3.04	1.88	5.29	6

Rimouski	43097	-0.92	-0.18	-2.31	3.25	-0.16	13
Saint-Eustache	42944	1.27	0.25	-1.02	-4.45	-3.95	20
Victoriaville	41316	-2.1	1.25	-1.7	0.43	-2.12	17
Rouyn-Noranda	40748	-4.21	0.68	-2.93	2	-4.46	22

Table 9 Score for Intermediate indexes with “Intra-Index” weighting and Ranking of 25 Largest Cities in Quebec Relative to Sustainable Development

Municipality	Population 2008	ED	MLP	QL	VNR	IG	Rang
Montréal	1659962	-0.18	-0.74	-0.6	0.67	-0.85	19
Quebec	502119	0.52	0.41	-0.32	0.39	1.00	8
Laval	376425	0.39	-1.02	-0.21	0	-0.84	18
Gatineau	247526	0.44	0.20	0.26	0.14	1.04	7
Longueuil	234352	-0.01	-0.52	-0.52	0.06	-0.99	22
Sherbrooke	150751	-0.11	-0.02	-0.14	0.54	0.27	11
Saguenay	146641	-0.72	0.84	-0.35	0.06	-0.17	14
Lévis	132851	1.27	0.20	0.4	0.13	2.00	2
Trois-Rivières	128941	-0.54	0.34	-0.62	-0.11	-0.93	21
Terrebonne	96795	0.86	0.56	0.17	-0.26	1.33	4
Saint-Jean-sur-Richelieu	89388	0.09	-0.45	0.84	-0.17	0.31	9
Repentigny	77744	0.78	-0.31	0.84	-0.11	1.21	6
Brossard	72707	0.43	-0.67	0.76	0.69	1.22	5
Drummondville	68841	-0.53	0.00	-0.49	-0.07	-1.09	23
Saint-Jérôme	65048	-0.61	-0.52	-0.5	-0.29	-1.92	24
Granby	60617	-0.5	0.06	0.2	-0.33	-0.58	16
Shawinigan	52865	-1.82	0.48	-0.83	-0.18	-2.35	25
Saint-Hyacinthe	52713	-0.25	-0.52	-0.13	0	-0.90	20
Dollard-Des Ormeaux	49940	0.75	0.00	0.93	0.23	1.91	3
Blainville	47504	1.28	0.27	1.1	-0.46	2.19	1
Châteauguay	43618	-0.22	0.41	0.23	-0.12	0.30	10
Rimouski	43097	-0.11	-0.09	-0.33	0.33	-0.20	15
Saint-Eustache	42944	0.4	0.13	-0.05	-0.4	0.08	12
Victoriaville	41316	-0.63	0.63	-0.11	-0.02	-0.14	13
Rouyn-Noranda	40748	-0.98	0.34	-0.55	0.49	-0.70	17

Third, we calculate the value of the global index for each city when we apply the inter-index weighting. We then compare the global index and the ranking of cities without weighting, with intra-index weighting and with inter-index weighting (see Table 10).

Table 10 Comparative Table of Global Indexes of Sustainable Development and City Rankings According to Weighting Method

Municipality	Population 2008	Global index			Ranking of cities		
		GI ₁	GI ₂	GI ₃	Rank ₁	Rank ₂	Rank ₃
Montréal	1,659,962	3.34	-0.85	2.70	9	19	3
Quebec	502,119	4.82	1.00	1.82	7	8	5
Laval	376,425	-1.87	-0.84	-0.02	15	18	14
Gatineau	247,526	5.5	1.04	1.67	5	7	6
Longueuil	234,352	-2.06	-0.99	0.02	16	22	13
Sherbrooke	150,751	1.73	0.27	1.04	11	11	9
Saguenay	146,641	-3.76	-0.17	-1.22	19	14	20
Lévis	132,851	9.4	2.00	2.29	3	2	4
Trois-Rivières	128,941	-7.02	-0.93	-1.73	23	21	22
Terrebonne	96,795	0.46	1.33	-0.70	12	4	17
Saint-Jean-sur-Richelieu	89,388	1.9	0.31	0.50	10	9	11
Repentigny	77,744	4.4	1.21	0.85	8	6	10
Brossard	72,707	11.27	1.22	3.99	1	5	1
Drummondville	68,841	-6.07	-1.09	-1.64	21	23	21
Saint-Jérôme	65,048	-10.26	-1.92	-3.01	24	24	24
Granby	60,617	-3.44	-0.58	-1.13	18	16	19
Shawinigan	52,865	-11.49	-2.35	-3.06	25	25	25
Saint-Hyacinthe	52,713	-1.14	-0.90	-0.32	14	20	15
Dollard-Des Ormeaux	49,940	9.95	1.91	2.86	2	3	2
Blainville	47,504	7.86	2.19	1.48	4	1	8
Châteauguay	43,618	5.29	0.30	1.66	6	10	7
Rimouski	43,097	-0.16	-0.20	0.41	13	15	12
Saint-Eustache	42,944	-3.95	0.08	-1.81	20	12	23
Victoriaville	41,316	-2.12	-0.14	-0.63	17	13	16
Rouyn-Noranda	40,748	-4.46	-0.70	-0.85	22	17	18

GI₁ and Rank₁ correspond to results without weighting

GI₂ and Rank₂ correspond to results with intra-index weighting

GI₃ and Rank₃ correspond to results with inter-index weighting

Table 10 shows that when we apply weighting between the intermediate indices, performances do not change markedly regardless of the evaluation method applied, with the exception of cities such as Montréal, Longueuil, Terrebonne and Blainville. Montréal rises to third place in the ranking of global scores with an inter-index weighting method, where monitoring of the viability of natural resources receives a much greater weight. Quebec moves to fifth place while the four other most popular cities improve their

performance. One of the reasons for this change is that we attributed a greater weight to the ED component for cities with a population of over 100,000 inhabitants. ED is a crucial component for cities that are pivotal to the Quebec economy. Concerning the other cities, the results of inter-index weighting tend to be similar to those without weighting.

Lastly, to consider the effect of city size in the sustainable development classification, we group cities according to population, using the population threshold recommended by Polèse & Shermur (2006). Accordingly, we differentiate cities with over 1 million inhabitants, cities with 500,000 to 1 million inhabitants, 100,000 to 500,000 inhabitants, 50,000 to 100,000 inhabitants and fewer than 50,000 inhabitants. For this ranking, Quebec is grouped with cities with 100,000 to 500,000 inhabitants even though its population is slightly larger (502 119 inhabitants). We thus eliminate the category of 500,000 to 1 million inhabitants.

This sub classification of cities allows a new comparison of urban performance in sustainable development. From the outset, Montréal is automatically excluded from the classification because it is the only city in Quebec with a population of over 1 million. The results for the 24 other cities are presented in Table 11. Not surprisingly, the cities with the best scores in the previous ranking top the list in their respective category (Lévis, Brossard, Dollard-des-Ormeaux, Blainville). This result shows that independently of their size or scope, these cities are the most sustainable. In addition, the size effect is more apparent for cities that obtained an intermediate ranking in the general classification. Thus, for cities with between 50,000 and 100,000 inhabitants, Repentigny is one of the best performers, whereas in the global classification it ranks behind at least eight cities. Among cities with fewer than 50,000 inhabitants, Rimouski is situated in the average, whereas it falls below the average in the global classification. Lastly, by comparing the three categories of cities, we note that overall, the greater the size of the population, the higher the city's ranking in terms of sustainable development performance in the categories of 50,000 to 100,000 inhabitants and that of fewer than 50,000 inhabitants. This trend is not observed for cities with 100,000 to 500,000 inhabitants.

Table 11 Comparison of Global Indexes of Sustainable Development and Rankings of Cities in the Same Category According to Weighting Method

11a Cities with 100,000 to 500,000 Inhabitants

Municipality	Population 2008	GI1	GI2	GI3	<i>Rank1</i>	<i>Rank2</i>	<i>Rank3</i>
Quebec	502119	4.82	1	1.82	3	3	2
Laval	376425	-1.87	-0.84	-0.02	5	6	6
Gatineau	247526	5.5	1.04	1.67	2	2	3
Longueuil	234352	-2.06	-0.99	0.02	6	8	5

Sherbrooke	150751	1.73	0.27	1.04	4	4	4
Saguenay	146641	-3.76	-0.17	-1.22	7	5	7
Lévis	132851	9.4	2	2.29	1	1	1
Trois-Rivières	128941	-7.02	-0.93	-1.73	8	7	8

11b Cities with 50,000 to 100,000 Inhabitants

Municipality	Population 2008	GI1	GI2	GI3	Rank1	Rank2	Rank3
Terrebonne	96795	0.46	1.33	-0.7	4	1	5
Saint-Jean-sur-Richelieu	89388	1.9	0.31	0.5	3	4	3
Repentigny	77744	4.4	1.21	0.85	2	3	2
Brossard	72707	11.27	1.22	3.99	1	2	1
Drummondville	68841	-6.07	-1.09	-1.64	7	7	7
Saint-Jérôme	65048	-10.26	-1.92	-3.01	8	8	8
Granby	60617	-3.44	-0.58	-1.13	6	5	6
Shawinigan	52865	-11.49	-2.35	-3.06	9	9	9
Saint-Hyacinthe	52713	-1.14	-0.9	-0.32	5	6	4

11c Cities with fewer than 50,000 Inhabitants

Municipality	Population 2008	GI1	GI2	GI3	Rank1	Rank2	Rank3
Dollard-Des Ormeaux	49940	9,95	1,91	2,86	1	2	1
Blainville	47504	7,86	2,19	1,48	2	1	3
Châteauguay	43618	5,29	0,3	1,66	3	3	2
Rimouski	43097	-0,16	-0,2	0,41	4	6	4
Saint-Eustache	42944	-3,95	0,08	-1,81	6	4	7
Victoriaville	41316	-2,12	-0,14	-0,63	5	5	5
Rouyn-Noranda	40748	-4,46	-0,7	-0,85	7	7	6

7. CONCLUSION AND DISCUSSION

Our contribution was to underscore the importance of developing more consensual approaches to evaluation of sustainable urban development using indicators. Researchers and practitioners should therefore make concessions to ensure that the indicators meet the needs of communication and allow evaluation and operational follow-up without compromising scientific validity. Second, by defining intermediate indices of sustainable development based on integration of traditional dimensions of sustainable development, we have created a more flexible classification of indicators by lowering the barriers between indicators of a social, environmental and economic nature. This new classification simplifies interpretation of bi- or tridimensional indicators and maximizes coverage of sustainable development dimensions while synthesizing indicators for communication and implementation purposes. Third, we examined two weighting

scenarios. Particular weights are attributed to individual indicators (intra-index weighting), and the weighting values are determined by the number of indicators that make up each index. If the number of indicators is higher, the more fractioned the shares of the weighting are, even if the proportions are preserved. In contrast, by assigning different weights to intermediate indices (inter-index weighting) we discriminately favour a particular component of sustainable development, e.g. size or other parameters that differentiates cities. We observe that certain cities where conditions are conducive to economic development play a more important role in sustainable development (Montréal, Quebec, Gatineau, etc.), whereas other cities are differentiated because they offer better conditions for household retention (Brossard, Dollard-des-Ormeaux, Repentigny, etc.). Further, monitoring of the viability of natural resources and the environment are fundamental and critical factors.

Fourth, we have proposed a classification of cities without taking into account their size and heterogeneity. We then group cities of the same size. The classification of cities provides two important insights. First, cities at the top of these general rankings are also at the top of their respective categories. Some small permutations are to be observed amongst the positioning of other cities, particularly those cities that have more than 100 000 inhabitants. Secondly, these rankings suggest that the higher ranked cities are generally larger except for cities with more than 100 000 residents. The relationship between the size of communities and their performance in terms of sustainable development figures prominently amongst cities who have fewer than 50 000 inhabitants while it has less of an influence for cities having 50 000 to 100 000 inhabitants. Finally, for such a ranking to be useful, have a persuasive effect on municipal authorities and be a tool in order to focus strategies, further research needs to be conducted in order to assess relative strengths and weaknesses of municipalities depending on their predominant functions. The main objective would be to develop a more refined typology that has the ability to suggest trends about cities of the same general characteristics or functions and furthermore to suggest more targeted strategies.

Bibliography

Abolina, K. and A. Zilans. 2002. Evaluation of urban sustainability in specific sectors in Latvia. *Environment, Development and Sustainability*, 6: 299-314.

Agence Régionale pour l'Environnement. 2001. Diagnostic, sustainable development urbain: tome 2: les indicateurs. Toulouse: Agence Régionale Pour l'Environnement.

Ambiente Italia Research Institute. 2003. European common indicators (ECI): towards a local sustainability profile. final project report. Luxembourg: Office for Official Publications of the European Communities.

Arcolatino. 2004. 21 indicateurs pour un sustainable development de l'Arc Latin. Communication présentée au module de Développement Sustainable de l'École Doctorale Biologie des Systèmes Intégrés, Agriculture, Environnement. Montpellier, France: Agropolis International Agropolis. Novembre.

Barcelo, M. 1999. Les indicateurs d'étalement urbain et de sustainable development en milieu métropolitain. Cahier 99-06. Montréal: Observatoire métropolitain de la région de Montréal.

Basiago, A.D. 1999. Economic, social and environmental sustainability in development theory and urban planning practice. *The Environmentalist*, 19: 145-161.

Bell, S. and S. Morse. 2008. Sustainability indicators: measuring the immeasurable? Second Edition. London: Earthscan.

Boston Foundation and Greater Boston's Civil Community. 2007. A Summary of the Boston indicators report: 2004-2006. Boston: The Boston Foundation.

Brazzini-Mourier, S. 2006. Indicateurs communaux intégrés. Rapport de synthèse. Onex, Genève: Ville d'Onex.

Callon M., P. Lascoumes and Barthe, Y. 2001. Agir dans un monde incertain. Essai sur la démocratie technique. Paris: Éditions Seuil.

Camagni, R. 2002. On the concept of territorial competitiveness: sound or misleading? *Urban Studies*, 39 (13): 2395-2411.

Centre Québécois du sustainable development. 2003. Tableau de bord sur l'état de la région du Saguenay-Lac-Saint-Jean. Alma, Quebec: Région laboratoire du sustainable development Saguenay-Lac-Saint-Jean.

Corporate Knights. 2007. Canada's most sustainable cities. Special report of March 6, 2007. Toronto: Corporate Knights.

Cowley, C., P. Madden, Quinn, T. and Winter, T. 2007. The sustainable cities index: ranking the largest 20 British cities. London, UK: Forum for the Future Organisation.

Dale, V.H. and S.C. Beyeler. 2001. Challenges in the development and use of ecological indicators. *Ecological Indicators*, 1: 3–10.

Federation of Canadian Municipalities. 2004. Quality of Life in Canadian Communities. Ottawa: FCM.

Fondation Rues Principales. 2008. Les centres-villes du Québec: indicateurs de performance. Montréal: Direction générale des communications, Ministère du Développement économique, de l'innovation et de l'exportation du Québec.

Fraser Basin Council. 2000. Sustainability indicators for the Fraser Basin. Fraser Basin. BC: The Fraser Basin Council.

Geniaux, G. 2006. *Indicators de sustainable development: un panorama des principales références bibliographiques, cadres conceptuels et initiatives internationales*. Marseille: Institut d'économie publique, Groupement de recherche en économie quantitative d'Aix-Marseille.

Jacksonville Community Council. 2004. Quality of life. progress report. Jacksonville, US: <http://www.jcci.org/>

Kahn, M. E. 2006. *Green Cities: Urban growth and the environment*. Brookings Institution Press, Washington D.C.

Koller, C. 2006. Le palmarès des villes romandes et le besoin de renforcer la statistique urbaine sur le plan suisse (méthodologie, sources, et résultats). *Revue économique et sociale*, 1: 101-116.

Maclaren, V.W. 1996. *Developing Indicators of Urban Sustainability: A Focus on the Canadian Experience*. Toronto: Intergovernmental Committee on Urban and Regional Research Press, January.

Martinez-Alier J., G. Munda and O'Neill, J. 1998. Weak comparability of values as a foundation for ecological economics. *Ecological Economics*, 26: 277-286.

Meier, A. and D. Wachter. 2005. Indicateurs centraux pour le sustainable development des villes et cantons. Rapport du Cercle Indicators. Berne, Switzerland: Office fédéral du développement territorial.

Ministère du sustainable development, de l'environnement et des parcs du Québec (MDDEP). 2007. *Analyse comparative de systèmes d'indicateurs de sustainable development*. Bureau de coordination du sustainable development, Québec.

Nemetz, P. (chair) 2007. SMART transportation. ranking report. Vancouver: Appleton Charitable Foundation.

Newman, P. 2006. The environmental impact of cities. *International Institute for Environment and Development*, 18(2):275-295.

Newman, P. and Kenworthy, J. 1988. The transport energy trade-off: fuel efficient traffic versus fuel efficient cities. *Transportation Research*, 22A (3): 163-174.

Niemeijer, D. and R.S. De Groot. 2008. A conceptual framework for selecting environmental indicators sets. *Ecological indicators*, 8:14-25.

Perret B. 2002. Indicateurs sociaux. Etat des lieux et perspectives. Les Papiers du CERC 2002-01, Conseil de l'emploi, des revenus et de la cohésion sociale, Paris.

Planque B. and Y. Lazzeri. 2006. Elaboration d'indicateurs pour un système de suivi-évaluation du sustainable development: tome 1: Principes et méthodologie de construction du référentiel. Programme de recherche politiques territoriales et sustainable development. Paris: Ministère de l'Équipement, des Transports, du Logement, du Tourisme et de la Mer Direction Générale de l'Urbanisme, de l'Habitat et de la Construction, Secrétariat permanent du Plan Urbanisme Construction Architecture, Réponse APR programme D2RT.

Polèse M. and R. Shearmur. 2005. *Économie urbaine et régionale*. Economica. 400p.

Sénécal, G. 2007. L'état de l'environnement urbain au Québec: un coup de sonde auprès des municipalités. Rapport présenté dans le cadre du dossier "Villes vertes" du journal *Lapresse*. INRS-Urbanisation, Culture et Société.

Shields, D.J., S.V. Šolar and Martin, W.E. 2002. The role of values and objectives in communicating indicators of sustainability. *Ecological Indicators*, 2 (2002) 149–160.

SustainLane Report. 2007. The SustainLane 2006: US city rankings. Document consulted on December 15, 2007 from: <http://www.sustainlane.com/us-city-rankings/>

Sustainable Calgary. 2004. State of our city report 2004. Calgary: City of Calgary.

Table ronde nationale sur l'environnement et l'économie. 2003. Les indicateurs d'environnement et de sustainable development pour le Canada. Ontario: Edition Renouf Lté.

Tanguay, G., J., Rajaonson, Lefebvre, J-F & Lanoie, P. 2009. Measuring the sustainability of cities: A survey-based analysis of the Use of Local Indicators. *CIRANO: Scientific series*, 2009s-02.

Thomas, J-Y. (dir) 2003. Mesurer le sustainable development en Belgique: Quel rôle pour les processus participatifs? Research paper for the Conseil fédéral du sustainable development. Belgium: Institut pour le développement Sustainable (IDD) and the Centrum voor duurzame ontwikkeling (CDO).

Tomalty, R..(dir) June 2007. The Ontario urban sustainability report, 2007. Ottawa: The Pembina Institute.

Verry, D., J-P. Nicolas. 2005. Indicators de mobilité durable: de l'état de l'art à la définition des indicators dans le projet SIMBAD. Rapport du Laboratoire d'Économie des Transports pour le compte de la DRAST (Ministère de l'Équipement) et de l'ADEME. Paris.

Ville de Montréal. 2008. Indicators de l'état de l'environnement: Bilan 2003-2006. Montréal: Conseil régional de l'environnement à Montréal. Mai.

World Commission on Environment and Development, 1987. From one earth to one world: an overview. Oxford: Oxford University Press.