DIAGNOSING TRANSPORTATION

Developing Key Performance Indicators To Assess Urban Transportation Systems

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Supervised Research Project Report

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Diagnosing Transportation:
Developing Key Performance Indicators
To Assess Urban Transportation Systems

Supervised Research Project Report
Submitted in partial fulfillment of the
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Abstract

Rapid urbanization is putting pressure on transportation agencies to respond to increasing demand for greater access to services. In response, policy makers, faced with limited budgets and time constraints, are looking for tools and processes to identify priority problems in a timely and cost effective manner. Rapid assessments can be performed using a diagnostic study that can identify cities' individual problems within the global context. Using a series of performance indicators based on a review of research and practice from around the world, this paper assesses different cities' transportation networks. The performance indicators rank cities according to an overall score as well as different categories of transportation performance. Such an approach allows planners to identify priority problems in the transportation network and design targeted solutions. The final results benchmark the performance of transportation systems according to peer cities with relatively similar sizes. Such a process assists in benchmarking performance while accounting for context, so that appropriate best practices can be shared between cities around the world.

Abrégé

L'urbanisation rapide exerce une pression sur les agences de transport afin qu'elles répondent à la demande croissante d'un plus grand accès aux services. En réponse, les décideurs, confrontés à des budgets limités et à des contraintes de temps, sont à la recherche d'outils et de processus pour identifier les priorités de manière efficace et rentable. L'évaluation rapide de ces priorités peut être effectuée à l'aide de diagnostic permettant d'identifier les problèmes spécifiques à chaque ville en les plaçant dans un contexte mondial. Référant à une série d'indicateurs de performances basée sur une revue de la littérature et des expériences internationales, cette étude se propose d'évaluer les réseaux de transport de différentes villes. Les indicateurs de performance choisis permettront de classer les villes selon leurs résultats généraux ainsi que selon leur performance dans différentes catégories spécifiques. Une telle approche sera en mesure de faciliter la tâche des planificateurs dans l'identification des priorités d'action afin d'amélioration l'accès des services de transport dans une ville. Les résultats finaux permettront également de comparer les performances des réseaux de transport entre des villes de tailles relativement similaires selon un même standard, facilitant ainsi l'analyse comparative des performances tout en tenant compte du contexte dans lequel il s'inscrit, de sorte que les meilleures pratiques puissent être partagées entre les villes des quatre coins du monde.

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Introduction

Despite pressure on governments to respond to rapidly increasing demand for greater access to services, policy makers do not always have the resources to undertake comprehensive research for informed assessments. In response, there is a growing need for tools to identify priority problems in a short time and at a low cost (Leitmann & Program, 1993). These tools can then be used to develop a broad and strategic transportation management plan. Additionally, as investment in transport infrastructure continues to be seen as a means of providing links towards competitive economic advantage (Dimitriou & Gakenheimer, 2011; Peters, Paaswell, & Berechman, 2008; Sandercock, 1998), the use of prioritization tools will also help planners identify how to best allocate infrastructure investment (Westfall & de Villa, 2001). However, before comprehensive solutions can be identified to address transportation problems, a diagnostic study needs to be performed to identify cities' individual problems within the global context.

The rationale for a diagnosis is premised upon the practice of identifying transportation problems through the use of key performance indicators (KPI). Drawing on the concept of the "wicked problems" presented by Rittel and Webber (1973), the selection of KPI and how they are measured affects the nature of the problems identified. However, transportation plans are often developed without taking into consideration such indicators. Plans may be attempting to alleviate symptoms of larger issues rather than the actual problems facing a city's transport infrastructure. This paper proposes a diagnostic tool to assist in developing an initial review of the current state of a city's transportation network. The tool utilizes a series of performance indicators, based on research and practice from around the world, to assess different cities' transportation networks. The results rank cities and allow a comparison of transportation systems between cities with similar conditions. The intent of such a comparison is to benchmark the performance of a city's transportation system according to peer cities with relatively similar networks. This approach helps designate key problems that account for context.

Comparisons between cities also help to integrate the concept of peer-learning into transportation planning. One approach is South-South cooperation, an effective tool used by the World Bank to arrive at solutions for developing countries. As defined by the World Bank Institute, South-South cooperation is "an exchange of expertise and resources between governments, organizations, and individuals in developing nations" (The World Bank Institute, 2012). A diagnostic tool that can help compare cities according to similar conditions will help in establishing exchanges that are sensitive to the local situation. For example, while London may have developed an innovative approach to public transportation, its solution may be dependent on factors that would disqualify the same solution from succeeding in Mumbai. Likewise, blanket approaches as a result of regional or nationwide censuses can be avoided for more targeted interventions.

This paper addresses three questions: what kinds of transportation performance indicators need to be measured; what kind of readily available data is appropriate for measurement; and how can results be compared to account for context?

The report is organized as follows; firstly, a review of research on transportation performance indicators is conducted to develop a guideline for the selection of transportation performance indicators. Secondly, transportation plans of a number of cities and metropolitan regions are analyzed to determine urban transportation goals and the indicators used to measure them. Thirdly, a methodology section frames how the analysis is undertaken and presented, followed by a section which identifies sources and validity of the data used for this study. Finally, a diagnosis is performed according to the composite indicators with available data. Results are presented and recommendations made for moving forward.

The final output of this project is a set of key performance indicators that measure transportation performance according to common goals and objectives of transportation agencies at different levels of governance. Aligning indicators according to a broad criterion of goals helps to harmonize performance measurement between local, national, and international agencies. The final set of core performance indicators can be used by development and planning agencies to evaluate the current state of transportation in cities.

Literature Review

Transportation planning's traditional focus on operational efficiency has been tempered by impacts on the environment, the economy, and society (Dimitriou & Gakenheimer, 2011). As a result of globalization and the role of transportation in the economy, the combination of major issues and responses around the world suggest two major themes that govern 21st century transportation planning: competitiveness and sustainable development. Cities are increasingly viewed as logistic centres in a globalized marketplace; the focus is on competition, rankings, and relative performance compared to peers rather than absolute performance (Dimitriou & Gakenheimer, 2011; Ülengin, Kabak, Önsel, Aktas, & Parker, 2011). Competitiveness is measured by a number of international agencies such as the World Bank Group (measuring Gross Domestic Product, or GDP), the United Nations (measuring the Human Development Index, or HDI), and the World Economic Forum (measuring the Global Competitiveness Index, or GCI). Measures and scores of competitiveness provide rankings which can serve as benchmarks for policy-makers and other interested parties in judging the success or relative position of their nation or city within a global context (Ülengin et al., 2011). Using a ranked score is one way to interpret the value of a city's transportation performance where benchmark data is not available. Additionally, sustainability is becoming an overarching concept behind urban transportation planning as a response to rising motorization and the ensuing public health and environmental risks (Dimitriou & Gakenheimer, 2011). The following literature review further defines sustainable development in transportation, which is the focus of this section. The theoretical basis for the use of indicators in transportation planning and policy is then explored to define a methodology for the selection of indicators for this project.

To define transportation system sustainability, two questions must be answered: what is it and how is it measured? 'Sustainability' is generally defined according to the desired results depending on the emphasis of the study or policy (Jeon & Amekudzi, 2005). The phrase "Sustainable development" has no universally agreed upon definition beyond that of the Brundtland Commission (Briassoulis, 2001), which is referenced in a number of studies on sustainable development indicators (Berke & Maria Manta, 2000; Haghshenas & Vaziri, 2012; Jeon & Amekudzi, 2005; Tanguay, Rajaonson, Lefebvre, & Lanoie, 2010). Combining the Brundtland definition of sustainable development with the practice of planning, "Planning for sustainable development" is a spatial design process for achieving and maintaining stable or increasing levels of welfare over time (Briassoulis, 2001).

In North America, and in particular in the United States, although various agencies have incorporated sustainability into their visioning and planning exercises, no comprehensive definition of urban transport sustainability is identified. However, most plans propose an "operational definition" that rests on attributes of system effectiveness, efficiency, and impacts on the economy, environment, and society (Jeon & Amekudzi, 2005). Gleason and Barnum (1982) define efficiency as "doing things right" and effectiveness as "doing the right thing." Efficiency indicators measure "the degree to which resources have been used economically" (Gleason & Barnum, 1982). Traditional efficiency indicators have a tendency to be biased towards cost savings at the expense of service increase (Gleason & Barnum, 1982; Li & Wachs, 2000). The research recommends that a single ratio is inappropriate for all situations; therefore, multiple measures are needed to identify points of convergence between cities and develop an unbiased assessment (Gleason & Barnum, 1982; Westfall & de Villa, 2001).

Efficiency measures the operational performance of the system and effectiveness measures a transportation system's progress in achieving policy goals. However, the words are often used interchangeably and their meanings confused. Because effectiveness aims to measure goal and objective achievement, potential indicators should be identified and selected after goals and objectives have been formulated (Gleason & Barnum, 1982). Binding performance indicators to policy outcomes is useful to the purpose of this project because it helps to answer the first question: what kind of indicators should be measured? By drawing upon indicators used in transport policy documents, the selected indicators will inform how urban transportation is actually measured and evaluated in different cities around the world.

Policy-related indicators are based on the social indicators movement of the 1960s and are currently in use by the World Bank and the United Nations Centre for Human Settlements (UN-Habitat). This approach stems from government or community concerns and is directed towards the formulation of public policy or strategy. Three types of indicators are encountered in the policy-related category:

1. Performance indicators: measure whether an agency or entity is meeting desirable aims
2. Issue-based indicators: draw attention to a particular issue, such as crime and safety, unemployment, sprawl, air quality, etc.
3. Needs indicators: aim to allocate resources to needy target groups.

Policy-based indicator systems tend to view a sector holistically and intend to foster dialogue between the different stakeholders in urban development (Westfall & de Villa, 2001). A holistic approach is important in dealing with externalities; since interventions will have unintended consequences it is important to try to identify all the potential effects (Gleason &

Barnum, 1982). The difficulty with using this approach rests with trying to consolidate concepts that don't have clear or easy relationships, such as "size, complexity, and level of wealth" (Westfall & de Villa, 2001). Regardless, a number of conventional indicators, such as demographics, measures of economic development, basic health, and educational achievement, are readily available and comparable (Westfall & de Villa, 2001).

On top of traditional indicators that focus mainly on demographics, mobility, costs, and benefits, new approaches to transportation indicators also measure accessibility, safety, and environmental performance (Tiwari & Jain, 2012). Accessibility is measured by a range of indicators from basic data such as average speed and travel time to spatial and utilitarian investment decisions based on individual perspectives of travel. Transportation safety levels can be adequately measured by traffic fatalities (Tiwari & Jain, 2012). Gudmundsson (2001) reviewed a number of transportation plans and policies in North America for environmental and sustainability indicators and found the literature to identify them according to two groups; quality of life and environmental and resource conservation. Examples are indicators for land use, air quality, noise, fuel use, recycling, and customer satisfaction with environmental decision making. However, while many agencies used the same few environmental measures, most of them focus on air pollution. This can either be in terms of tons of transportation emissions, or population living in areas where air quality is not up to standard based on regulations (Gudmundsson, 2001).

Having developed an understanding of the theoretical basis of developing performance measures, the following case studies describe the usage and evaluation of indicators in transportation planning. A number of studies and projects have been performed in the past that assess transportation indicators for appropriate use and implementation. At the corridor level, Tiwari and Jain (2012) illustrated that traditional indicators favour free movement of vehicles without taking into account capacities and road usage by other modes. From an infrastructure investment perspective, Li and Wachs (2000) showed that the choice of indicators can have starkly variable results. The results of the corridor level studies support the initial claim of this paper that the selection of performance measure affects the identification of key problems.

On a global level, Westfall and de Villa (2001), in cooperation with the Asian Development Bank (ADB), prepared a city performance system that measures urban development and compares results across 18 cities in Asia. The *Cities Data* Book measures city performance according to 140 indicators consolidated into a "City Development Index (CDI)," which is a mean calculation of the results of a number of sectoral indexes: infrastructure, waste, education, health, and product.

The Economist Intelligence Unit (2009), in partnership with Siemens AG, developed the Green City Index (GCI), an indicators-based evaluation project that looked at the performance of cities around the world in terms of environmental sustainability. Similar to the goals of this project, the GCI is meant for city administrators, development agencies, and NGOs who wish to report on sustainability performance. Cities are ranked and compared by continent, following the same methodology but with variations in the selected indicators and criteria for assessment. The Index is ranked according to a score based on eight categories with a total of 30 indicators, both quantitative and qualitative. Indicators for each category are weighted according to a criteria set via stakeholder consultation; each category is then weighted equally to calculate the Index. The final result is an overall ranking of scores for each city, as well as ranking by category.

Similar to the Green City Index, Siemens Canada Limited (2010) also publishes "Complete Mobility," a series of research projects that look into the transportation infrastructure of cities in Canada through a set of 15 performance indicators and compares the results according to different policy scenarios.

IBM, as part of the Smarter Planet Series, conducted a survey on traffic congestion titled "2011 Commuter Pain Survey." The survey attempted to evaluate commuter's levels of satisfaction with the levels of congestion in 20 cities around the world. The final results ranked the cities according to ease and perceptions of travel.

As the research shows, the selection of key performance indicators (KPI) and how they are measured affects the nature of problems identified. The definition of sustainability in visions and goals has an effect on the indicators and metrics chosen. Although the three dimensional framework is used universally (economy, environment, and society), each agency/study may use different indicators to measure each dimension (Jeon & Amekudzi, 2005). Regardless, the relationship between indicators and strategic plans follows a logical path: norms ("poverty is bad," "cities should be managed well," etc.) define policy objectives, which are used to identify indicators, that are then translated into action plans (Westfall & de Villa, 2001).

Research exploring the identification and formulation of indicators for transportation is abundant. However, only corridor-level studies attempt to evaluate the indicators. Most global studies reviewed generally stop at providing a list of recommended indicators for use, which are arrived at through stakeholder consultations. Those studies that evaluate the application of the indicators also largely focus on overall city performance. The *Cities Data Book* and the Green City Index evaluate a small number of urban transport performance indicators as part of a larger evaluation of urban productivity and sustainable development. To date the only projects identified in this research that utilize indicators for global urban transportation networks are the Complete Mobility series by Siemens Canada, the Commuter Pain Survey by IBM, and a similar study by Haghshenas and Vaziri (2012).

The benefits of performance measures have been debated since the 1990s. Nevertheless, their use has steadily risen over the years, especially in larger cities in North America (Folz, Abdelrazek, & Yeonsoo, 2009). Using lessons learned from transportation research on the use of performance measures, the following section frames a methodology for selecting the indicators to be used for this study.

Methodology

To select the indicators for this project, a qualitative content analysis of transportation plans and policy documents is performed to identify the most commonly used indicators around the world. However, a general criterion for selection must first be established. The Lincoln Institute of Land Policy report on Smart Growth Policies in the United States identifies three principles for the selection of indicators (Ingram, 2009):

- Validity – the indicator must have a direct linkage to a relevant policy intervention
- Availability – the indicator must be quantifiable with easily accessible data
- Reliability – the data must have been gathered by a public or governmental authority

The first step is to review the goals of the transportation plans. After goals are identified, they are placed into a set of categories to directly relate goals to indicators. Many plans do not relate goals to their relative performance measures, while others have clearly delineated performance measures for each goal. Categorizing the goals makes it easier to organize the performance indicators; thus making it easier to identify which indicator is commonly used to measure which goal or theme. Indicators are then identified in three sets of documents: transportation plans, transportation studies by international agencies, and articles from published research.

The indicators from the three sets of documents are cross-referenced against each other to develop a long list of indicators, which are then shortened to common indicators in use (used in more than one plan/study). Tying the list of common indicators to the goals/themes of the study satisfies the first criteria in the selection of indicators: validity – by establishing a direct linkage to a relevant policy intervention. Having selected the common indicators, a final list of indicators is developed based on availability of data to satisfy the second criterion of selection.

Following the selection of indicators and collection of data, the information is compared and evaluated. Previous work in this area has focused on either establishing a single measure for evaluation (Gilbert & Tanguay, 2000) or used a composite index based on weighted average scores (Westfall & de Villa, 2001). However, in order to normalize the results so that indicators and scores can be measured and compared across cities a standardization technique must be applied. Standardization can address difficulties posed by the exaggerated influence of some indicators over others (especially in comparing between, for example, percentages and real values). The most common approach to standardization in performance indicators is a Z-Score (Wong, 2006), the results of which are added using equal weights to derive a final score. This approach is the most widely utilized due to its simplicity (Hobbs & Meier, 2000). In order to establish a contextual relationship, cities are grouped according to population size: Small (under one million), Medium (one to two million), Large (two to five million), and Very Large (greater than five million). Z-Scores for each group are calculated using the average and standard deviation for the respective group. Indicators are also assessed on whether higher order numbers denote a positive or negative relationship. For example, higher travel times would denote lower access to services, so the resulting z-score is multiplied by -1 to establish a negative relationship. Likewise, higher speeds denote lower congestion and a more efficient transportation network, so a positive relationship of higher order z-scores is preserved. The result of each category is normalized to a score from 0 (lowest) to 5 (highest) so that ranking is easier to interpret. A cumulative sum of all the category scores is used as the final score of transportation performance of each city. Normalized scores allow rankings to place each city's transportation system in context with its peers around the world. This will help to answer the third question of this study: how to compare the results to better establish context.

The following section introduces the plans and studies used to derive the final list of indicators, the sources of data used to conduct performance measurement, and the final list of indicators to measure transportation performance.

Information and Data Sources

To develop a list of indicators that can provide a comprehensive assessment of transportation systems around the world, three sets of documents are reviewed. Indicators in city plans provide measures that are commonly used in transportation planning. Indicators taken from international development agencies and non-governmental organizations (NGOs) help identify measures used in global transportation policy. Finally, indicators used in academic research determine those measures that should be used for transportation system assessment.

The first review focuses on transportation plans in the US, Canada, UK, South Africa, Australia, New Zealand, and Singapore for recently published plans in English. Other English-speaking countries were considered, but policy documents were either not available or not immediately accessible. The selection of the cities was based on two criteria: first, that the city has a population in excess of 0.5 million and second that it has a plan or policy published since the year 2000 with clear transportation goals and performance indicators. The final list of transportation plans/policies consulted is provided in Table 1:

Table 1: Indicators from Transportation Policies and Plans

Country	City/Region/Authority	Policy/Plan Title	Year
Australia	Department of Planning and Infrastructure, New South Wales	Metropolitan Plan for Sydney 2036	2010
Canada	City of Calgary	Calgary Transportation Plan 2009	2009
Canada	City of Ottawa	Transportation Master Plan	2008
Canada	Metrolinx, Government of Ontario	The Big Move: Transforming Transportation in the Greater Toronto and Hamilton Area	2008
Canada	Translink, Metro Vancouver	Transport 2040: A Transportation Strategy for Metro Vancouver, Now and in the Future	2008
Canada	Ville de Quebec	Sustainable Mobility Plan: Transportation for Better Living	2011
New Zealand	Auckland Regional Transport Authority	Our World Class City: Auckland Transport Plan 2009	2009
Singapore	Land Transport Authority of Singapore	Land Transport Masterplan	2008
South Africa	City of Johannesburg	Integrated Transport Plan 2003/2008	2003
United Kingdom	Greater London Authority	Mayor’s Transport Strategy	2010
United States	Boston Region Metropolitan Planning Organization	Journey to 2030 – Amendment: Transportation Plan of the Boston Region Metropolitan Planning Organization	2009
United States	The City of New York	PlaNYC: A Greener, Greater New York	2007
United States	Houston-Galveston Region	Bridging Our Communities: The 2035 Houston-Galveston Regional Transportation Plan Update	2011
United States	Los Angeles County	2009 Long Range Transportation Plan	2009
United States	Metropolitan Transit Commission of the San Francisco Bay Area	Change in Motion: Transportation 2035	2009

To begin assessing each policy for goals and indicators, a classification system to group the information into common themes is required. While most studies that focused on sustainable transportation organized goals and indicators according to the standard three-dimensional framework (environment, economy, and society), the city transport plans and policies did not. The categories used for this report are based on the goals of the plans and a study by Cambridge Systematics (2000). Goals and objectives in most transportation plans were organized according to the categories defined in Table 2:

Table 2: Categories of Performance Indicators

Category	Description
Affordability and Accessibility	A person's ability to reach a service in reasonable time, while factoring in the density of the road network, and the financial burden of transportation on average incomes.
Mobility	The characteristics of a trip made, choice of mode, and the ease of travel
Economic Performance	Economic impacts of the transportation system, such as costs of congestion, as well as benefits, such as cost savings due to performance improvement
Quality of Life	Qualitative and difficult to measure indicators such as aesthetics, sense of community, and sense of satisfaction
Environmental and Resource Conservation	Natural resources consumed, waste emitted, or energy saved
Safety	Incidences of injuries, fatalities, or crime on transport networks
Operational Efficiency	Use of resources towards a level of output, such as costs and revenues
Infrastructure Condition and Performance	The state of the physical infrastructure of the transport network

Due to the difficulty of finding copies of transport plans in English from developing countries with clear performance indicators and data measurements listed, the plans listed are taken mostly from cities in developed countries. However, many urban transport policy papers from the developing world that were readily available on the internet were published by international agencies such as the World Bank. Therefore, indicators can be tied to developing countries by comparing city goals and indicators to those of international agencies and non-governmental organizations (NGOs) who have conducted performance evaluation of transport networks in the developing world (such as the *Cities Data Book* by the ADB or the Global Urban Observatory of UN-Habitat). To take a more global outlook, however, studies are taken from all over the world and look at both developed and developing countries. These studies used are listed in Table 3:

Table 3: Indicators from International Agencies and NGOs

Agency	Study	Year
Asian Development Bank (ADB)	*Cities Data Book: Urban Indicators For Managing Cities*	2001
Embarq: The WRI Institute for Sustainable Transport	India Transport Indicators	2007
International Association of Public Transport (UITP)	Report on Statistical Indicators of Public Transport Performance in Africa	2010
Lincoln Institute of Land Policy	Smart Growth Policies: An Evaluation Of Programs And Outcomes	2009
Partnership for Sustainable Urban Transport in Asia (PSUTA)	Sustainable Urban Transport in Asia: Making the Vision a Reality	2005
Pembina Institute	Ontario Community Sustainability Report	2007
United Nations (UN-HABITAT)	Global Urban Indicators: Selected Statistics	2009
The World Bank	Global Cities Indicators Facility	2008

The next step is to identify indicators used in transportation research. While the purpose of the plans/policies was to establish and measure system performance at the macro level, the transportation research gathered looks at both overall system-wide efficiencies as well as corridor-level measures. The studies consulted are listed in Table 4:

Table 4: Indicators taken from Academic Research

Authors	Title	Year
Aftabuzzaman et al.	Exploring the underlying dimensions of elements affecting traffic congestion relief impact of transit	2011
Badami and Haider	An analysis of public bus transit performance in Indian cities	2007
Gilbert and Tanguay	Sustainable Transportation Performance Indicators Project	2000
Haghshenas and Vaziri	Urban sustainable transportation indicators for global comparison	2012
Li and Wachs	A test of inter-modal performance measures for transit investment decisions	2000
Litman	Developing Indicators for Comprehensive and Sustainable Transport Planning	2007
Nicolas et al.	Towards sustainable mobility indicators: application to the Lyons conurbation	2003
Tanguay et al.	Measuring the sustainability of cities: An analysis of the use of local indicators	2010
Tiwari and Jain	Accessibility and safety indicators for all road users: case study Delhi BRT	2012

Having compiled three lists of indicators; one from existing transportation plans, one from international development and NGO evaluation programs, and one based on transportation research, the next step is to develop a consolidated list of indicators that satisfy all three and assess the indicators according to availability, which will answer the second question for this paper: what kind of secondary data should be used in the absence of primary data? Statistics for the three sets of indicators are gathered for a number of cities based on readily available data to ascertain what performance measures can be utilized immediately. The list of indicators for which data is available determines the final shortlist of indicators for comparison for each group.

The majority of data is collected from two sources. The *Mobility in Cities Database* of the International Association of Public Transport (UITP) supplies statistics for 52 cities, of which 45 have sufficient information for the indicators needed for this project. Data on 14 cities in Latin America is taken from a report by the "Observatorio De Movilidad Urbana Para América Latina" (Latin American Urban Mobility Observatory - translation by author) of the Corporación Andina de Fomento (Andean Development Corporation) . Of the 15 cities selected for policy review to develop the indicators, six in total collect sufficient data to be included in the study. However, two are already listed in the UITP Database (London and Singapore). The remaining four cities; Auckland, New York, Sydney, and Toronto, are assessed according to information available on the internet from public sector and research organizations. The final number of cities assessed for this project based on data availability is 63.

Figure 1: Geographic distribution of selected cities

The *Mobility in Cities* database is an update on a previous undertaking by the UITP titled "Millennium Cities Database for Sustainable Transport," conducted in 1995. *Mobility in Cities* captures statistics for 120 indicators from 53 cities, with a 90% collection rate. Published in 2005, the year of reference for the data is 2001. The "Observatorio De Movilidad Urbana Para América Latina" is a response to the lack of quantifiable data on the transportation systems in Latin America. The 2010 report used as reference in this project is the first publication of this venture, with the intention to continue to gather more data and build more robust analyses of Latin American transportation networks. Data for the remaining cities were drawn from federal, state/provincial, and municipal agencies; from sources such as censuses, policies, annual reports, and technical studies.

The major constraint to the data is the variability in time periods of collection. The UITP database is primarily referenced from 2001, data from the Andean Development Corporation was sourced between 2007 and 2009, and data on the remaining cities sourced from a number of different reports published by government agencies at various times (Auckland – 2004-2011[1]; New York – 2007-2012[2]; Sydney – 2006-2012[3]; Toronto – 2006-2012[4]). Even more current reports, however, are often extrapolations and projection from past numbers (for example, statistics on many cities in the US refer to the 2001 Census).

An additional limitation, also related to the variability of the time of reference, is in the quality of some of the data. Under Environmental and Resource Conservation, the 19 cities are all missing one indicator each, due to gaps in both the ADC and UITP data. The reliability of the

[1] Sources (Auckland): New Zealand Ministry of Transport (2009), New Zealand Ministry of Transport (2010, 2012), Auckland Regional Council (2009), Auckland Regional Council (2008), Auckland Council (2010); Auckland Regional Transport Authority (2012); Auckland Regional Transport Authority (ARTA) (2011); Jamieson (2007); Metcalfe, Fisher, Sherman, and Kuschel (2006)

[2] Sources (New York):United States Census Bureau (2011), Metro Transportation Authority (MTA) (2012a, 2012b), Schrank, Lomax, and Eisele (2011), Federal Transit Administration (2010), Bureau of Labour Statistics (2010), City of New York (2007a), New York State Department of Transportation (2009)

[3] Sources (Sydney): Bureau of Transport Statistics (2012a), Bureau of Transport Statistics (2012b), Australian Bureau of Statistics (2011b), New South Wales Government (2010a), New South Wales Government (2010c), Independent Pricing and Regulatory Tribunal New South Wales (2011), Australian Bureau of Statistics (2011a)

[4] Sources (Toronto): Statistics Canada (2006b), Statistics Canada (2006a), Toronto Transit Commission (2011), The Greater Toronto Transportation Authority (Metrolinx) (2008), ICF International (2007), Toronto Police Service (2011), The Greater Toronto Transportation Authority (Metrolinx) (2011), Statistics Canada (2009), City of Toronto (2007a, 2007b)

ERC indicators is questionable, as, while GHGs are all measured in kilograms (Kg) and energy use in mega joules (Mj), a stark variation exists between the UITP data and others. This is illustrated by the data for the GHG emissions of transport for Auckland, which, at 3,028 Kg/capita, are 32 times as high as the lowest performing city from the UITP database (Athens, with 93 kg/capita[5]). For those cities which were not supplied with emissions data in the *Mobility in Cities* dataset, the necessary statistics were drawn from a number of sources, including the International Association of Public Transport (UITP) (2009). The variability in the range of emissions from 2001 to 2009 may be a result of improved data gathering techniques pertaining to greenhouse gases over the years.

Having compiled the necessary data, the next step is to analyze the transportation plans and research to identify which indicators will be selected for the diagnosis. The final list of indicators to be used depends on the availability of data.

[5] A number of cities listed under the UITP data have higher GHG emissions. The data for these cities was retrieved from International Association of Public Transport (UITP) (2009).

Policy and Research Analysis

The initial review of the city plans is meant to identify the main issues, trends, and goals of each plan to help frame the criteria for assessment. The definition of each category according to the plans and a study by Cambridge Systematics (2000) is used to guide policy goals into a specific category. The following table shows the breakdown by category, goal, and how many cities identified with each goal:

Table 5: Goals in Urban Policy

Categories	Cities
Affordability and Accessibility	
Improve access to daily destinations by all modes	8
Provide affordable mobility	6
Coordinate transportation and land use plans	4
Mobility	
Reduce congestions, delays and travel time	10
Encourage the use of and improve transit and active transport networks	9
Provide for efficient freight travel	4
Economic Development	
Facilitate economic growth through effective management of the transport network	7
Quality of Life	
Protect and promote public health	9
Respond to public expectations	3
Address the mobility needs of the elderly, youth, and persons with special needs	8
Environmental and Resource Conservation	
Improve air quality	12
Advance environmental sustainability	7
Reduce dependence on non-renewable resources	2
Safety	
Reduce accidents	9
Ensure personal security	5

Categories	Cities
Operational Efficiency	
Provide an integrated public transport system	4
Provide transportation system that is maintained, reliable, and efficient	7
Ensure fiscal sustainability	7
Infrastructure Condition and Performance	
Maintain infrastructure in good condition	3

The most common goal across all the city plans is the improvement of air quality, followed by congestion reduction and improved mobility, and then equal references of improving active transport opportunities, promoting public health, and reducing accidents. Environmental concerns are most important to city agencies, followed by mobility, and then quality of life and safety.

However, a compilation of the indicators used to measure progress towards goals paints a different picture (for a complete list of indicators used in each set of policies or studies see Appendix I):

Table 6: Selected Indicators per Goal and Frequency of Use

Goals	Indicators	Cities	Agencies	Research	Total
Demand/Context	Total population	3	6	2	11
Affordability and Accessibility					
Improve access to daily destinations by all modes	Transit coverage by population (% of people who live within one or two km of rapid transit)	1	2		3
	Average length of commute (minutes)	5		1	6
Provide affordable mobility	Share of household income spend on transport (%)	2		3	5
Coordinate transportation and land use plans	Length of roads per 1,000 people (Km)	1	1		2
Mobility					
	Travel demand (The number of trips)	7		2	9
Reduce congestions, delays and travel time	Average speed of trip (km/hr)	4	1	2	7
Encourage the use of and improve transit and active transport networks	Transport trips by mode (% by mode)	7	6	5	18
Provide for efficient freight travel	Annual volume of container traffic (tonnes)	3			3
Economic Development					
Facilitate economic growth through effective management of the transport network	Cost of vehicle congestion (in USD)	2			2
Quality of Life					
Protect and promote public health	Number of noise/vibration exceedances per year	1		2	3
Respond to public expectations	Public transport customer satisfaction (%)	3		1	4
Address the mobility needs of the elderly, youth, and persons with special needs	Share of transport facilities with step-free access (%)	2		1	3

Goals	Indicators	Cities	Agencies	Research	Total
Environmental and Resource Conservation					
Improve air quality	Greenhouse gas emissions from passenger travel (Kg/capita)	2	3	1	6
Advance environmental sustainability	Annual energy consumption of transport (Mj)	1	4		5
Reduce dependence on non-renewable resources	Bio and fossil fuel used per VKT or per capita (L)	1		1	2
Safety					
Reduce accidents	Road fatalities	3	6	2	11
Ensure personal security	Crime rates on public transport (%)	1			1
Operational Efficiency					
Provide an integrated public transport system					
Provide a transportation system that is maintained, reliable, and efficient	Public transport capacity (Passenger-km)	2		2	4
Ensure fiscal sustainability	Cost recovery from fares (Fare-box Recovery Ratio - %)	1	2	1	4
Infrastructure Condition and Performance					
Maintain infrastructure in good condition	Percent of roads meeting a state of good repair (%)	2			2

Mobility indicators are the most cited, followed by safety indicators. Air quality and environmental indicators are only used in seven documents, while quality of life is measured in four. The low number of indicators for quality of life goals might speak to the difficulty of quantitative assessment of quality of life measures, but the same cannot be said of air quality indicators. Additionally, measurements of active transportation are generally cited under mobility improvements rather than air quality or quality of life measures. While air quality concerns top the list of goals in urban transportation plans, a relatively lesser emphasis is placed in research and policies reviewed to take measurements towards improvement.

The selection of headline indicators for use is based on two criteria: first, they have a high frequency of usage and second, they are used in both transportation plans and research. Some of the indicators are only available in one set of documents and are selected because no alternative is available.

The first set of indicators listed under "Demand/Context" help to determine the contextual basis for comparison, as indicated earlier in the discussion of South-South cooperation. The Green City Index developed by the Economist Intelligence Unit (2009) takes a similar approach, establishing socio-economic clusters within which candidate cities are grouped and compared.

In measuring accessibility, the most commonly cited indicator is public transport coverage by population, which only measures access to destinations via public transportation. Affordability is measured by percentage of income spent on transportation per household. Coordination between transportation and land use planning is a more difficult goal to measure, as most of the indicators cited (such as physical growth rate) do not directly relate between transport and land-use. Instead, Tomalty et al. (2007) suggest measuring the length of roads per 1000 people as a measure of density and sprawl, which takes into account both land development and transportation infrastructure.

While travel demand is the most cited indicator for measures of congestion, the indicator used in both policy and research is average speed of travel. There are some variations in how the indicator is used, however. Policy documents generally refer to average speed of personal motor vehicle travel, while in the research network speeds (average speeds by mode) are highlighted. Average speed of travel is a suitable measure because it also takes into account travel time and distance, both cited in six documents each.

Measures of the use of active transportation and transit networks are represented by the modal share of transport use, which is the most cited indicator in the study. Finally, although the international policy and transportation research reviewed in this study did not mention freight traffic, it is cited in three urban and regional transportation plans. Since freight traffic still contributes to overall transport volume, an indicator to measure the tonnage of cargo is preserved.

Direct economic development indicators are more difficult to measure, since most readily available data does not provide information on the economic benefits of transportation for specific cities. Gasoline prices are used as an indicator by San Francisco's MTC and Vancouver's Translink because the cost and consumption of fuel has a direct effect on transportation revenues (San Francisco and Vancouver collect gas taxes). New York City and Sydney measure the costs of congestion, which provides a baseline for the economic impacts of congestion. Benefits of transportation network improvements are mentioned in the Auckland

and Houston transportation plans, but no data or actual metric is provided. As such, the headline indicator for economic development depends on the data available.

Quality of Life indicators, which are generally more qualitative and difficult to measure to begin with, provide no directly quantifiable headline indicators. Additionally, since public health issues are related to active transportation and air quality measures, indicators of public health rest in other categories. The simplest approach is to measure comfort levels with noise benchmarks. Public satisfaction with the transportation system conducted through surveys is one way that Johannesburg, London, and Ottawa measure public expectations. For physical accessibility, Litman (2007) and the City of Ottawa propose step-free access and number of specialized transit users. The London Mayor's Transport Strategy also proposes the use of step-free access, but provides no means of measurement.

Air quality measurements are straightforward and general greenhouse gas emissions data is readily available. While the most cited indicator is general GHG emissions in tonnes, ideally transport-specific emissions should be used. This is reflected by the fact that transport emissions are cited in both policy and research. Transportation energy use and use of renewable fuels have only one indicator each; annual energy consumption of transport (in Gigajoules) and bio and fossil fuel used per vehicle-kilometers traveled (VKT) or per capita, respectively.

Transportation system safety measures are cited largely as two indicators; total casualties and total fatalities. Some studies listed highlight specific modal casualties, which is an approach preferred by Tiwari and Jain (2012) to assess risks imposed by different types of road users. However, the majority of studies and plans offer road fatalities as a suitable indicator to measure transportation safety. While security issues are mentioned throughout the literature, only one plan (London) measures safety and security on the transit network. In the study by Tomalty et al. (2007), "crime codes per 100,000 people" is listed as an indicator of security.

For operational efficiency, no indicators can be identified for measuring progress towards an integrated transport network. For transportation system reliability, only indicators on public transit are available, where most plans and studies focus on system capacity utilization through passenger-kilometers traveled. Fiscal sustainability is measured either in terms of capital and operating investment or through fare-box recovery ratio. Because fare-box recovery is a measure of operating return on investment, it makes sense to utilize it as the headline indicator for fiscal sustainability. Fare-box recovery rates are collected commonly around the world, so data is easily accessible. The infrastructure condition and performance category lists three indicators for infrastructure maintenance that are all cited in city plans only. A headline indicator cannot be selected due to lack of data.

The final list of indicators drawn from research was compared to those in the UITP database and matching indicators were used for analysis. However, it should be noted that not all the cities are assessed according to 100% data. Only 13 of the 63 cities were provided with 100% data for all indicators, 35 with 94% data, and 15 with 88% data. Data availability also limited the final list of indicators to be used for assessment. Out of the final 20 indicators shortlisted for assessment, data was only available for 14. These 14 indicators are the shortlist of the final set of indicators to be used in this study, and are presented in Table 7:

Table 7: Final set of indicators to be used

Category	Indicator	Unit	Data Availability
Demand/Context	Population	Number	100%
Affordability and Accessibility	Average duration of trip	Minutes	100%
	Percent of monthly income spent on transport	Percent	78%
	Length of road per thousand inhabitants	Kilometers	97%
Mobility	Average speed of Trip	Kilometers/Hour	86%
	Percentage of daily trips on foot and by bicycle	Percent	100%
	Percentage of daily trips by private motorised modes	Percent	100%
	Percentage of daily trips by public transport	Percent	100%
Operational Efficiency	Annual public transport passenger-Km per inhabitant	Kilometers	95%
	Recovery rate of public transport operating expenditure by farebox revenue	Percent	95%
Environmental and Resource Conservation	Annual polluting emissions due to passenger transport per inhabitant	Kilograms/capita	71%
	Annual energy consumption for passenger transport per inhabitant	Megajoules	78%
Safety	Passenger transport fatalities per million inhabitants	Number	97%

Sufficient data for Economic Development, Quality of Life, and System Condition and Performance indicators is not available. Under affordability and accessibility measures, very few cities publish data on population with access to different modes of transport. Cambridge Systematics (2000) provides a list of indicators which includes trip travel time. Due to the unavailability of data on access to services or the transportation network, trip travel time is used as a measure of convenience using the transportation network.

Data transportation affordability is limited to the average cost of trip or average fare of a public transport service. In order to calculate the percentage of monthly income spent on transportation, average monthly income is derived from Wellershoff, Hoefert, Hofer, and

Fröhlich (2006). Share of income spent on transport is then calculated using the "transportation affordability index" provided in Carruthers, Dick, and Saurkar (2005).

Having shortlisted the final indicators for assessment from the long list in various transportation documents, the following section discusses the analysis and results of the benchmarking exercise.

Analysis and Assessment

With headline indicators selected and the necessary data gathered, a z-score analysis is conducted and initial results normalized according to each category: affordability and accessibility, mobility, operational efficiency, environmental and resource conservation, and safety. In order to establish a contextual relationship, the cities are grouped according to population. The following table lists the four population groups that the cities are compared within:

Table 8: Population Groups

Small (under 1 Million)	Medium (1-2 Million)	Large (2-5 Million)	Very Large (5 Million Plus)
Ghent, Belgium	Newcastle, UK	Glasgow, UK	Madrid, Spain
Graz, Austria	Lille, France	Hamburg, Germany	Toronto, Canada
Clermont-Ferrand, France	Bilbao, Spain	Stuttgart, Germany	Santiago, Chile
Bern, Switzerland	Seville, Spain	Manchester, UK	Hong Kong, China
Geneva, Switzerland	Prague, Czech Republic	Lisbon, Portugal	London, UK
Bologna, Italy	Lyon, France	Rome, Italy	Bogotá, Columbia
Nantes, France	Rotterdam, Netherlands	Curitiba, Brazil	Chicago, USA
Marseilles, France	Munich, Germany	Caracas, Venezuela	Lima, Peru
Zurich, Switzerland	San José, Costa Rica	Singapore, Singapore	Río de Janeiro, Brazil
Amsterdam, Netherlands	Montevideo, Uruguay	Berlin, Germany	Paris, France
Dubai, UAE	León, Mexico	Porto Alegre, Brazil	Moscow, Russia
Brussels, Belgium	Turin, Italy	Athens, Greece	Buenos Aires, Argentina
Helsinki, Finland	Auckland, New Zealand	Guadalajara, Mexico	Sao Paulo, Brazil
Oslo, Norway	Vienna, Austria	Barcelona, Spain	New York, USA
	Warsaw, Poland	Sydney, Australia	México City, Mexico
	Budapest, Hungary	Belo Horizonte, Brazil	
	Copenhagen, Denmark		
	Stockholm, Sweden		

Having been grouped into population groups, cumulative scores for each category of indicators is calculated using the sum of all the z-scores in that category. Final results are normalized to a score between 0 (lowest) and 5 (highest) for all cities, so that the results are easier to rank and interpret. The final scores are provided in Figures 2 to 5:

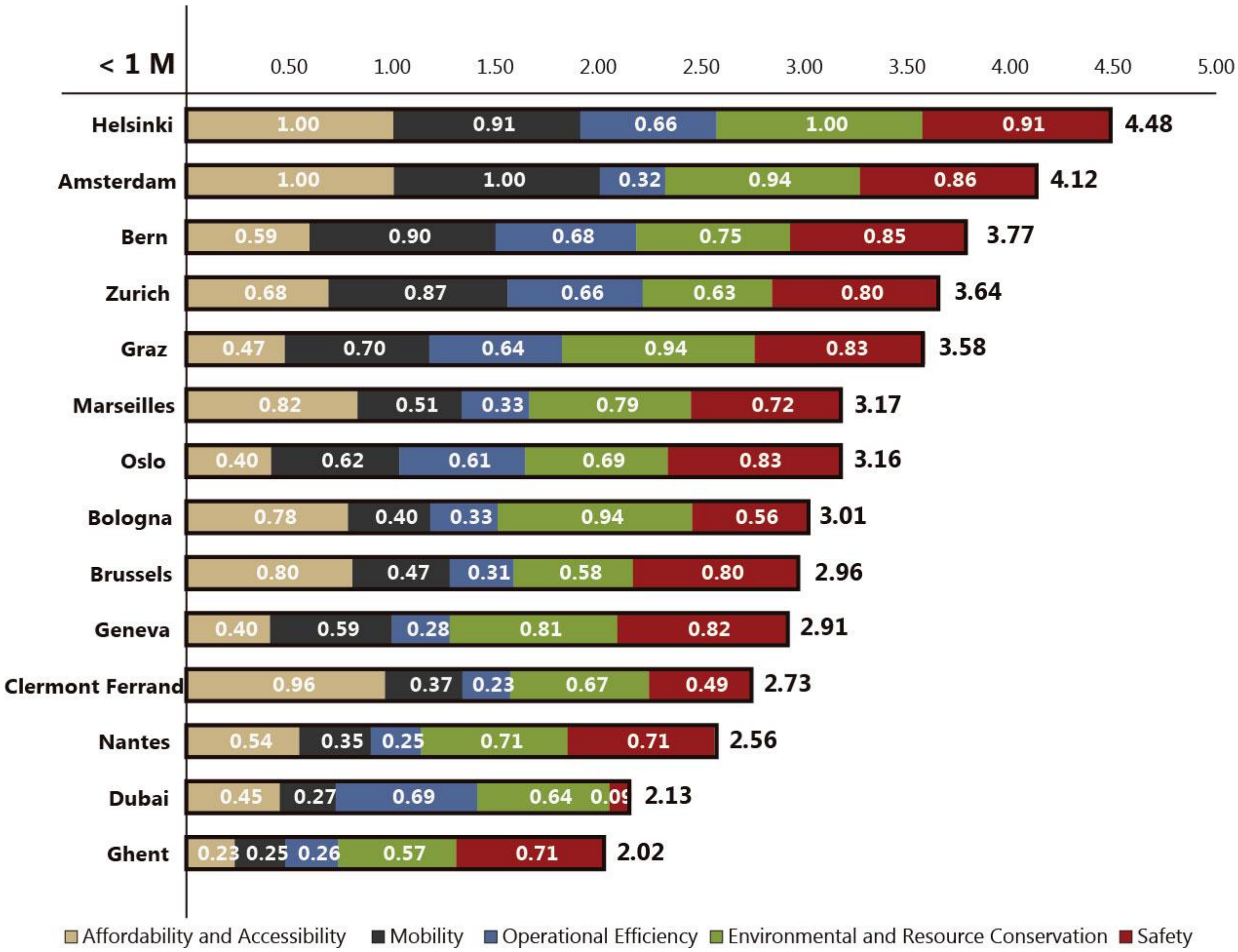

Figure 2: Rankings for Cities with fewer than 1 million people

Under the small cities group, Helsinki scores the highest, scoring above average in every category. Amsterdam follows second, with the strongest affordability and accessibility (AA) and mobility performance. The highest score for operational efficiency (OE) is not reserved for the highest ranking cities. Rather, Dubai scores very well in OE due to a very high fare-box recovery ratio, denoting the city's public transport services operate at a profit. The city of Ghent lags behind in total due to lower than average scores across the board. However, data on share of income spent on transportation and number of fatalities on the transportation network are missing. The city's standing may change with further information.

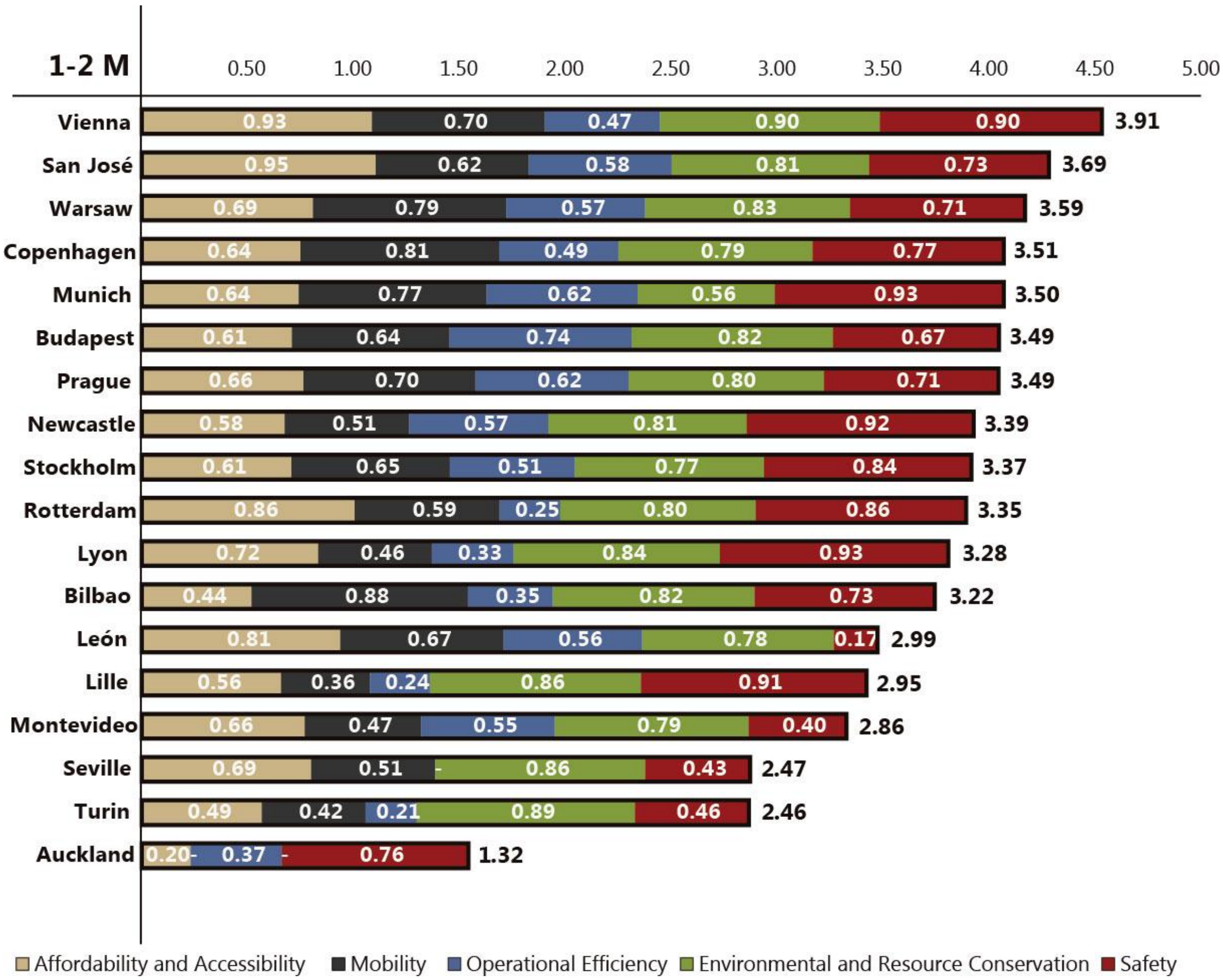

Figure 3: Rankings for Cities with 1 to 2 million people

Vienna scores the highest overall. However, in the individual categories, Vienna only ranks at the top in environmental and resource conservation (ERC), due to very low transport GHG emissions. The city of San Jose (Costa Rica) takes the top score for AA for very low transportation costs per capita. The city of Bilbao ranks highest in the mobility category for a very high mode share for walking and cycling (49%). Budapest excels in OE due to a combination of high public transport capacity utilization and fare recovery (although the cities of San Jose and Montevideo both boast 100% fare recovery). Lyon and Munich tie for lowest fatality rates on the transportation network, thereby scoring the best for the safety category.

Auckland scores the lowest overall, with very low scores in AA as well as extremely low scores for mobility and ERC. Auckland's AA data indicates high travel times to reach services, higher than average cost of travel, and a very low road network density. Additionally, it also has the highest private vehicle mode share of this population group (80%). Furthermore, Auckland also has some of the highest emissions and energy use for transport in the entire sample of 63 cities.

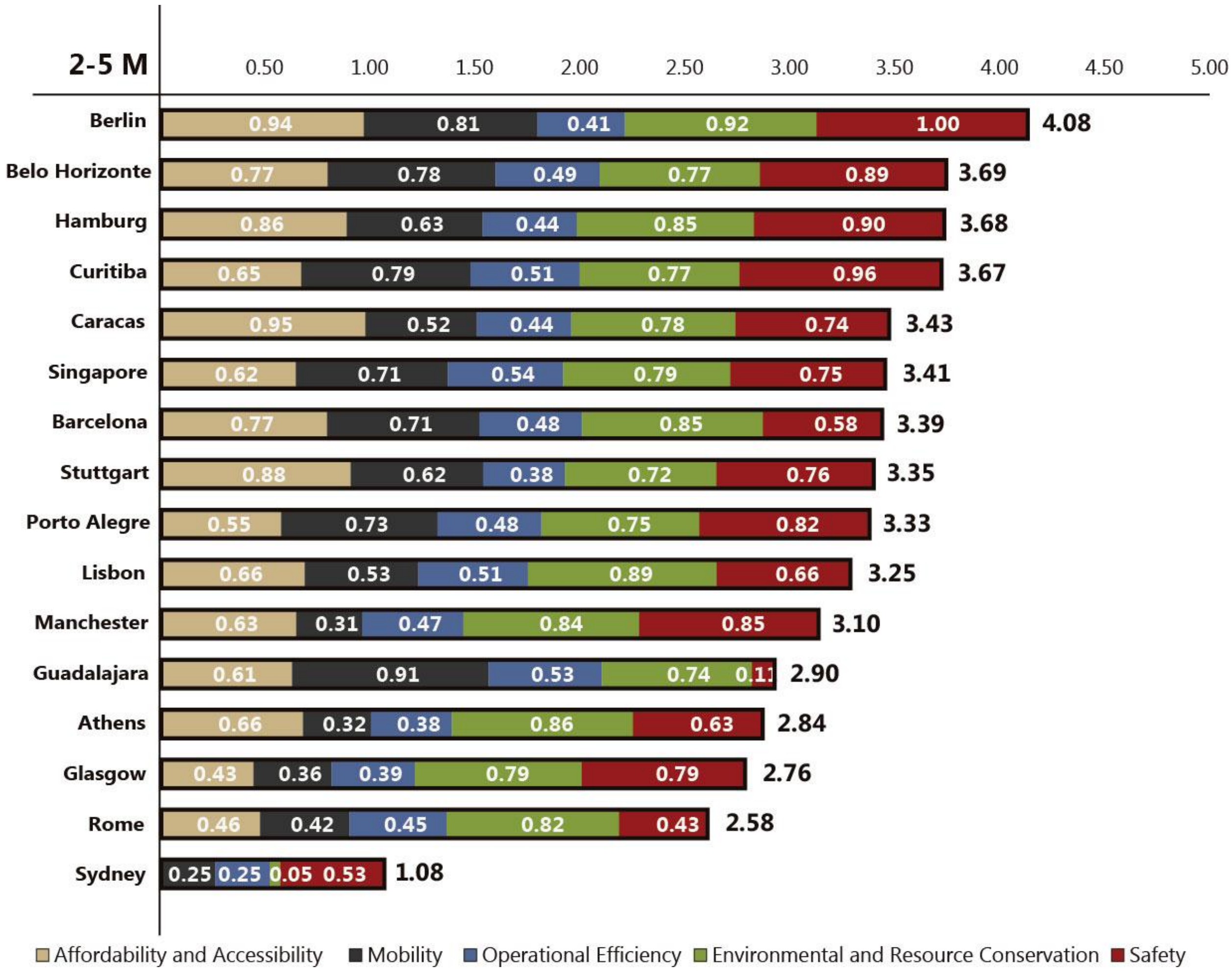

Figure 4: Rankings for cities with 2 to 5 million people

In the large cities category, Berlin scores highest overall as well as in the ERC and safety categories. Caracas has the best AA ranking, due to very low costs of transportation in the city and a low road network density. In mobility, Guadalajara scores the highest due to an even distribution of modal share. Singapore scores highest for OE even though the city has the lowest fare-box recovery ratio. However, Singapore also has the greatest public transport capacity utilization of this population group. Sydney scores the lowest in this population group due to very low road network density, which ties into travel times that are roughly twice the average for the group. This is not necessarily be due to congestion, as, even with a very high private vehicle mode share (68%), average travel speeds are not far below average.

Figure 5 displays the final population group, very large cities with more than 5 million people:

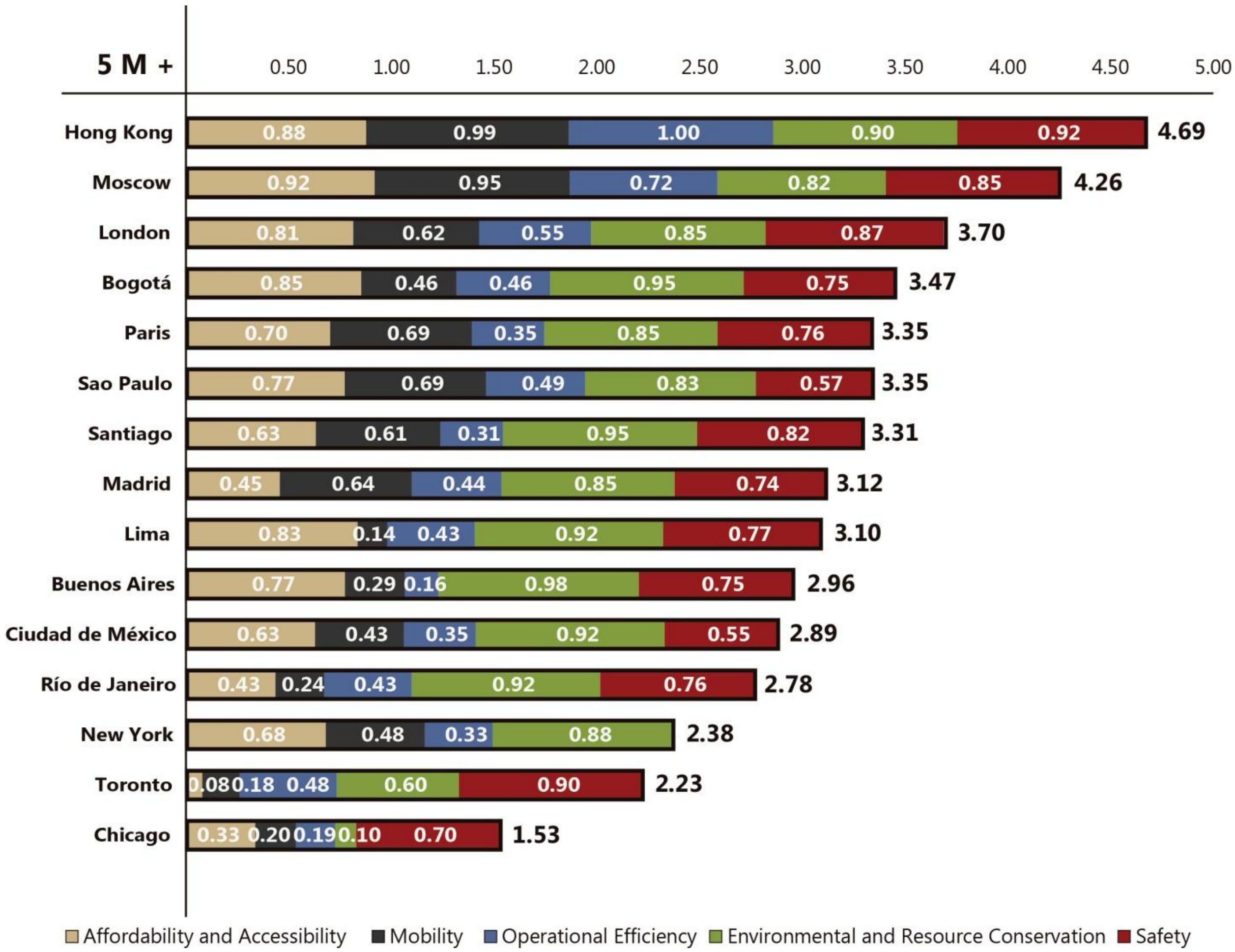

Figure 5: Rankings for cities with more than 5 million people

Hong Kong scores highest in this group due to very strong performance in mobility, OE and safety, followed by ERC and AA. AA scores are not as high because the cost of travel in the city is only slightly below average. Overall highest score for AA is awarded to Moscow which, due to a very low road network density, allows residents to reach services much faster. The highest performance in ERC is that of Buenos Aires. However, the city is missing data on the energy usage of transport, so there is a possibility of the city's performance in this category changing should the data become available. Chicago scores the lowest overall. The city suffers from a low road network density and high cost of travel per capita. However, average travel speeds are higher than the mean for the group, and the private vehicle mode share is also very high, meaning congestion may not be the primary factor in the low AA score. Chicago has the highest private vehicle mode share (88%) as well as the highest emissions and transportation energy use for this population group.

Figure 6 illustrates all the population groups graphically to represent the distribution of cities between demographics and transportation performance within each population group:

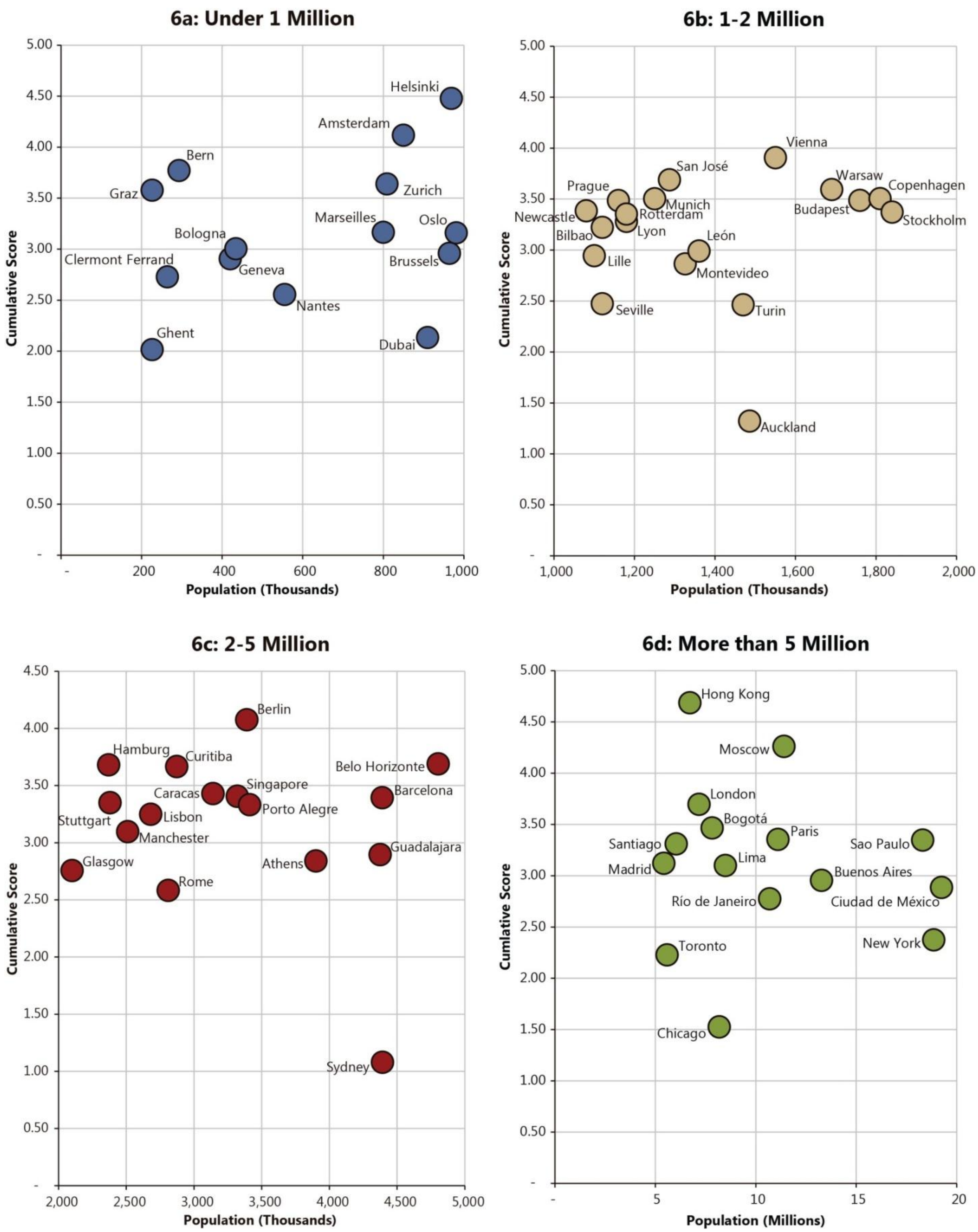

Figure 6: Cities ranked by Population and Cumulative Scores

Although the scores establish a ranking, they are not meant to be interpreted as a final judgement of each city's transportation infrastructure. As an example, while Hong Kong has the highest mobility, OE, safety, and cumulative scores for its group, it does not rank amongst the highest in AA and ERC. In such a situation, clustering according to socio-economic characteristics of the cities is useful, so that Hong Kong may look to a city with a similar profile for inspiration on how best to tackle its problems in AA and ERC.

While population groups provide one way to cluster the results according to context, another means of organizing the results is by GDP per capita[6] (Siemens Canada Limited, 2010). The following table ranks scores by per capita GDP, and accounts for the population group (as indicated by the size of each circle):

[6] Source: Data provided by Vivier and Pourbaix (2006) and Hawksworth, Hoehn, and Tiwari (2009)

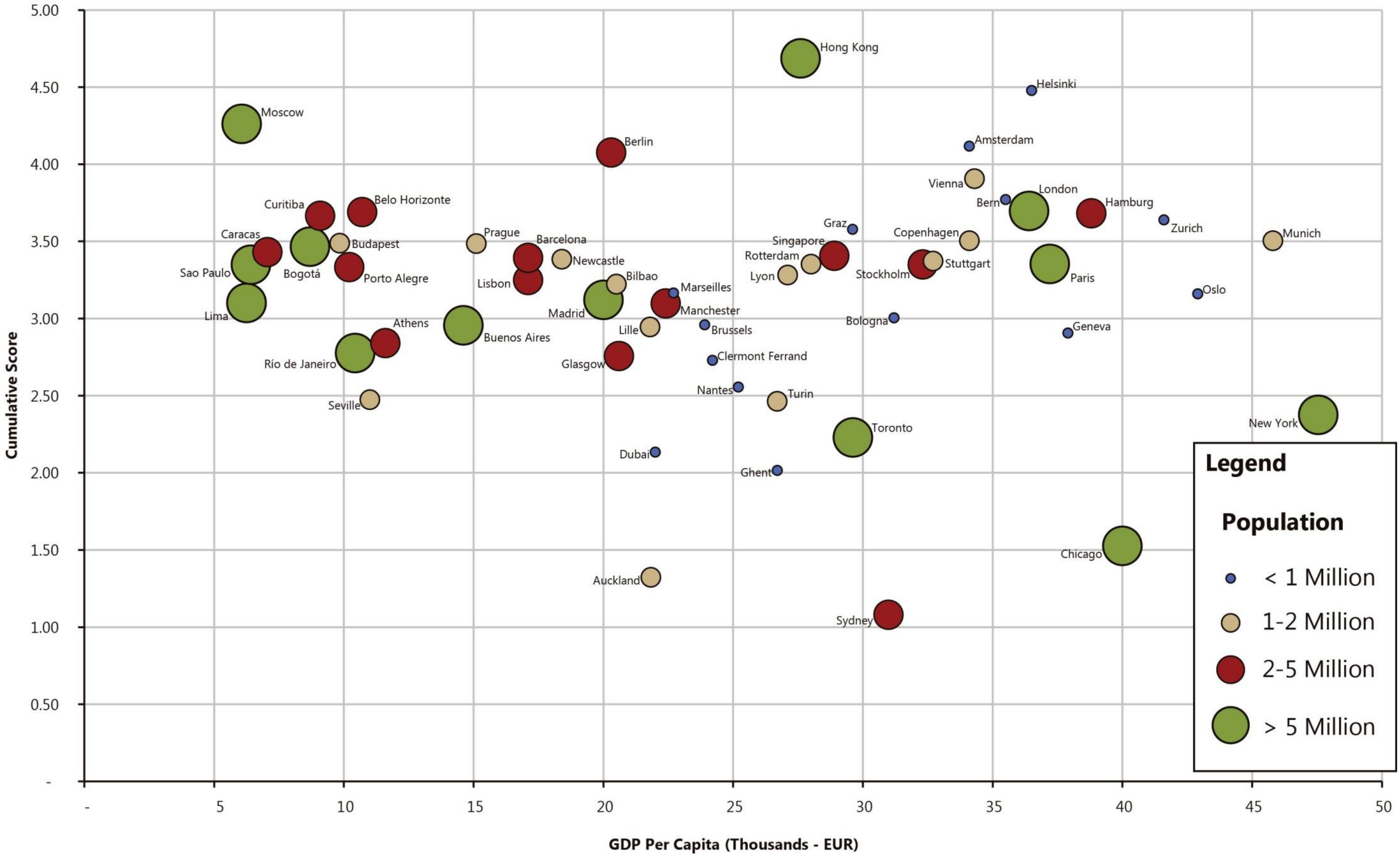

Figure 7: Cities ranked by GDP per Capita and Cumulative Scores

The result of the graph shows that high earning cities do not necessarily function better, as a wide variety of incomes are distributed across the spectrum. In the very large cities population group, Hong Kong, standing at a little above average GDP per capita for the sample (at 27,600, for an average of 22,803), ranks the highest, followed by Moscow, which holds one of the lowest per capita GDP rates. Likewise, Curitiba ranks higher than Singapore, even though the GDP per capita in Curitiba is less than half that of Singapore. The lack of a strong relationship between high earnings and high cumulative scores may indicate that a city does not need to maintain high GDP rates in order to maintain an efficient and functional transportation network. However, further study is required to establish an exact relationship.

Figure 8 shows the distribution of city rankings geographically, with colors representing the range of scores and size of circles representing the population group. Scores are distributed using the equal interval attribute in ArcGIS. As illustrated, most of the cities are distributed in the 2.52 – 3.97 range of scores, with a few clear outliers (Hong Kong, Moscow, etc.). While cities in Europe take up the majority of the sample size, none of them rank within the lowest category. The addition of cities in Asia, Australasia, and North America may help balance the overall sample and provide a greater variation in scores.

City administrators and policy makers who wish to use this dataset to benchmark their transportation networks can do so using the averages and standard deviations for each population group in this study. It should be noted that the averages provided are the mean of means, since many of the original numbers are already averaged. Likewise, the standard deviation numbers provided are the standard deviation from the mean of means. Table 9 provides the data.

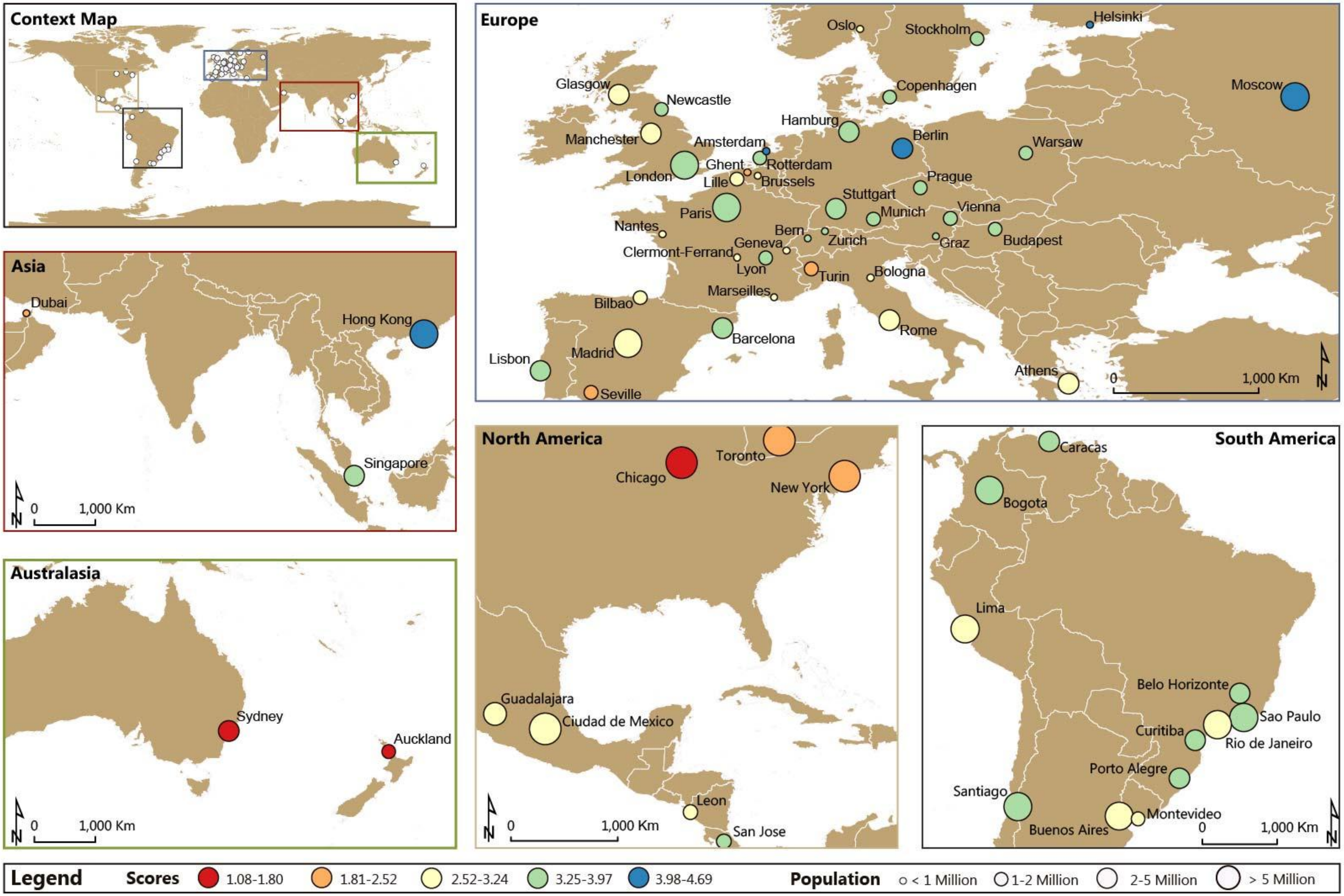

Figure 8: City rankings by geographic distribution

Table 9: Data for calculating Z-Scores and Normalized Scores

Indicator(s)	Unit(s)	Under 1 Million		1-2 Million		2-5 Million		5 Million and more		Normalization	
		Mean	St.Dev.	Mean	St.Dev.	Mean	St. Dev.	Mean	St. Dev.	Min	Max
Affordability and Accessibility										-4.66	2.49
Average duration of trip	min	25	3	25	6	28	12	36	13		
% of monthly income spent on transportation	%	9%	2%	11%	5%	15%	8%	12%	5%		
Length of road per thousand inhabitants	m	3,828	1,351	2,961	1,028	2,376	1,621	2,205	1,392		
Mobility										-6.45	4.55
Average speed of Trip	Km/h	31	8	29	7	30	6	27	6		
Daily trips on foot and by bicycle	%	31%	8%	31%	9%	27%	10%	24%	12%		
Daily trips by private motorised modes	%	54%	11%	47%	13%	50%	13%	48%	17%		
Daily trips by public transport	%	15%	6%	23%	14%	22%	9%	27%	13%		
Operational Efficiency										-3.13	3.89
Annual public transport passenger-Km per inhabitant	Km	1,272	762	1,730	1,219	1,337	992	1,768	1,418		
Recovery rate of public transport operating expenditure by farebox revenue	%	52%	23%	58%	28%	67%	31%	75%	32%		
Environmental and Resource Conservation										-6.19	1.93
Annual polluting emissions due to passenger transport per inhabitant	Kg	63	21	459	894	333	604	627	786		
Annual energy consumption for passenger transport per inhabitant	Mj	15,321	2,844	14,255	8,883	15,613	6,123	14,443	11,897		
Safety										-3.19	1.29
Passenger transport fatalities per million inhabitants		65	49	57	36	64	35	77	50		

By using the mean and standard deviation for each population group provided in the table, transportation planners in any city around the world can participate in this exercise. The min and max normalization scores provided for each category will allow any city to be ranked within the results tables, so that planners can best identify where weaknesses in their local transportation networks exist and what cities they may look into for best practices.

The comparison of the results of key indicators helps to establish a level of context amongst the transportation networks in cities around the world. Analyzing the variables that lead to high scores opens up the discussion on what constitutes the characteristics of an efficient and effective transportation network. The study intends to provide a framework for discussions that can lead to more targeted and resourceful approaches to identifying problems and devising solutions. By comparing the results of the rankings to contextual indicators such as demographic data (population, density, GDP, etc.), policy makers can better decide how to interpret the results and where to draw inspiration for solutions.

Conclusion and Recommendations for Further Study

This paper begins by posing three questions for the development of a transportation network diagnosis: what needs to be measured, what kind of data should be used, and how should the results be compared to establish context? The answers are found through a thorough analysis of policy and research to identify the most appropriate key performance indicators to assess urban transportation at the global level. These indicators compose a diagnostic tool based on the framework of rapid assessment processes, providing policy makers and planners with a way to quickly identify weaknesses in transportation networks and develop targeted solutions. The diagnostic tool measures transportation performance according to a number of categories, identified through an analysis of urban transportation goals around the world; affordability and accessibility, mobility, operational efficiency, environmental and resource conservation, and safety. The plan/policy analysis also identifies the following additional categories; accessibility, economic development, quality of life, and infrastructure condition and performance. However, indicators measuring these categories are not selected due to lack of data. The final result is a set of 14 indicators measuring the performance of 63 cities.

Using a methodology derived from transportation research, the 63 cities are grouped according to population size. Each city is then scored based on cumulative results according to the five categories, with 0 set as the lowest score and 5 as the highest. Amongst cities with less than 1 million people, Helsinki scores the highest (4.48) and Ghent the lowest (2.02). In the population group of one to two million, Vienna has the best performing transportation network (3.91) and Auckland the lowest (1.32). In cities with two to five million, Berlin scores the highest

(4.08) and Sydney the lowest (1.08). Finally, amongst cities with more than five million people, Hong Kong maintains the strongest performing network (4.69) while Chicago the weakest (1.93). Using the data provided for each of the population groups in this database, any city around the world can benchmark its transportation performance and compare to other cities of similar size.

The study has revealed that transportation policy and research have sufficient information needed for an agency to develop a benchmarking process. However, the weakness lies in the availability of secondary data that can be used to develop a comprehensive database. With available and reliable data, a number of analytical tools are available, the simplest of which was demonstrated for this project (The CDI of the Asian Development Bank uses indexes based on weighted scoring, for example). Armed with such tools, transportation planners around the world can conduct very rapid assessments of transportation systems to identify where major weaknesses lie and where to look for inspiration. By centralizing the information and making it publicly available, policy makers, community organizers, as well as interested citizens can participate in the exercise and provide input into the process. Such initiatives are already under way, with national level data provided by the World Bank and the United Nations (amongst others), and cities around the world launching open data platforms. Improved access to more reliable data will expand this tool and make it an effective means of continuous improvement for urban transportation networks around the world.

In order to further enhance the dataset and provide a better distribution of results, the following are recommended:

1. Data: The current number of indicators helps provide a sufficient performance benchmark based on currently available data. However, as illustrated by the initial policy

analysis, additional data is needed to create a holistic picture of a transportation network. Statistics are needed for the remaining indicators to enhance the dataset:

a. Accessibility – access to jobs and services is becoming a key driver in improving the interplay between transportation networks and land development. Progress in the accessibility category can be a good indicator of the integration of transportation and land use.
b. Economic development – provides a means to better frame the costs of congestion (in many cases, the costs of business as usual) as well as potential benefits from system improvements.
c. Quality of life – will help to integrate universal design principles into the transportation network.
d. Infrastructure condition and performance – tied to operational efficiency, accounts for the state of the physical assets and will help ensure that system infrastructure is maintained.

2. Sample Size: A geographically wider sample of cities will balance the indicators, which are currently more in line with statistics for European cities. As cities around the world improve data gathering techniques and expand their databases, perhaps a greater number of cities will be available for assessment.

The process developed in this project is able to stand on its own and be utilized immediately. Transportation planners can use this tool to identify priority problems and to place the performance of their transportation network in the right context. Increased use of tools and processes such as the one presented in this paper can help harmonize available data around the world, thereby allowing anyone with access to the internet to partake in this exercise and help expand the dataset.

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Appendix I: Complete list of Indicators in policy and research documents.

Categories	Cities	Agencies	Research	Total
Demand/Context				
Total population	3	6	2	11
Motor Vehicle Population	2	6		8
Population Density	2		4	6
City GDP	1	4		5
Average household income	1	2	2	5
Car ownership (cars per household)			3	3
Population by Sector	2			2
Population growth rate (%)		2		2
Percentage of population aged 65 or over	2			2
Annual sale of motor vehicles (all types)		2		2
City per capita income		2		2
Population/Jobs Balance (Jobs/1000 People)	1		1	2
Employment by sector	2			2
Employment Density	2			2
Labour Force	2			2
Affordability and Accessibility				
Access to daily destinations is improved by all modes				
Average length of trip (minutes)	5		1	6
Transit coverage by population	1	2		3
Per cent of population/jobs within 400m of Primary Transit Network	2			2
Job Accessibility (% of work trips within 60 minutes by transit)	2			2
The average number of jobs within a 40-min transit trip and a 20-min auto trip	2			2
Access to services (Local area score of average journey time by mode)	2			2
Provide affordable mobility				
Percentage of household income spend on transport	2		3	5
Transportation costs per household	2			2
Total per capita transport expenditures			2	2
Coordinate transportation and land use plans				
Land development (acres)	2			2
Length of roads per 1,000 people (Km)	1		1	2
Mobility				
Congestions, delays and travel time are reduced				
Travel demand (The number of trips)	7		2	9
Average speed of trip	4	1	2	7
Average Trip distance	4	2		6
Total Motor VKT/VMT	5			5
Total Lane Miles or Km	4		1	5
Total length of transit service	3	2		5
Average distance traveled per capita			3	3

Categories	Cities	Agencies	Research	Total
Congestion Time (Hours)	2			2
Reduction in VMT and VHT in town centers	2			2
Car use (annual passenger car km per capita)			2	2
Auto occupancy rate (persons per vehicle)	2			2
Number of single occupancy vehicle trips in the region	2			2
Total length of surface rail		2		2
Total length of underground metro		2		2
Encourage the use of and Improve the Transit and Active Transport networks				
Transport trips by mode	7	6	5	18
Transit Ridership	5	3	3	11
Cycling/walking modal share (%)	6	2	1	9
Transit mode split (%)	6			6
Average Daily VKT on Transit	2	1		3
Private Vehicles mode split (%)		2	1	3
Completion of Urban Cycling Network (%)	3			3
Change in transit volume minus change in auto traffic volume	2			2
Passenger-km			2	2
Transit use (annual transit passenger-km per capita)			2	2
Efficient Freight Travel				
Annual volume of container traffic (tonnes)	3			3
Economic Development				
Facilitate economic growth through effective management of the transport network				
Fuel prices at the pump	2			2
Cost of vehicle congestion	2			2
Annual Cost Savings from Improvements	2			2
Quality of Life				
Protecting And Promoting Public Health				
Number of noise/vibration exceedances per annum	1		2	3
Number of one hour NO2 exceedances (> 200 μm/m3) per annum	1		1	2
Sidewalk Coverage	2			2
Respond to public expectations				
Public transport customer satisfaction	3		1	4
The mobility needs of the elderly, youth, and persons with special needs are addressed				
Physical accessibility to the transport system (Step free access)	2		1	3
Specialized transit usage (specialized transit riders per capita)	1		1	2
Environmental and Resource Conservation				
Improve air quality				
GHG emissions (tonnes)	3		4	7
Greenhouse gas emissions from passenger travel (kg per capita or tonnes)	2	3	1	6
CO2 Emissions	4		1	5
NOx emissions	3		1	4

Categories	Cities	Agencies	Research	Total
PM10 emissions	3		1	4
PM 2.5 Emissions	3			3
VOC Emissions	2		1	3
CO Emissions	2		1	3
NOx emissions by mode	2			2
Advance environmental sustainability				
Annual energy consumption of transport (Gj)		1	4	5
Land consumption for transportation infrastructure per capita (M)			4	4
Energy use per capita (Gj)	2	1		3
Greenhouse gas emissions per unit of electrical power	1		1	2
Reduce dependence on non-renewable resources				
Bio and fossil fuel used per VKT and per capita	1		1	2
Safety				
Reduce Accidents				
Road fatalities (number)	3	6	2	11
Total casualties (fatal, serious and minor)	5	2	3	10
Reported pedestrian collisions (number)	3			3
Reported cyclist collisions (number)	3			3
Security				
Crime rates on public transport (Crimes per million passenger journeys)	1			1
Operational Efficiency				
An integrated public transport system				
The transportation system is maintained, reliable, and efficient				
Public transport capacity (Passenger-km)	2		2	4
Fiscal Sustainability				
Cost recovery from Fares (Farebox Recovery Ratio)	1	2	1	4
Operating investment (dollars per capita)	1		3	4
Transport revenue and subsidies ($)	4			4
Gross operating cost per passenger	3			3
The ratio of transit maintenance and capital expenditures per capita to road infrastructure maintenance and capital costs per capita.			3	3
Capital investment (dollars per capita)	1	1		2
Funding allocated versus funding spent	2			2
Real fares levels	2			2
Revenue vehicle miles			2	2
Local taxes (total, per resident and per employee)			2	2
Infrastructure Condition and Performance				
Maintain infrastructure in good condition				
% of roads meeting a state of good repair	2			2
Lane Miles Resurfaced Per Year	2			2
Walking and cycling infrastructure condition	2			2

Appendix II: Cities assessed according to the source of data used

	UITP		ADC	Various Sources
Amsterdam	Glasgow	Newcastle	Belo Horizonte	Auckland
Athens	Graz	Oslo	Bogotá	New York
Barcelona	Hamburg	Paris	Buenos Aires	Sydney
Berlin	Helsinki	Prague	Caracas	Toronto
Bern	Hong Kong	Rome	Ciudad de México	
Bilbao	Lille	Rotterdam	Curitiba	
Bologna	Lisbon	Sao Paulo	Guadalajara	
Brussels	London	Seville	León	
Budapest	Lyons	Singapore	Lima	
Chicago	Madrid	Stockholm	Montevideo	
Clermont Ferrand	Manchester	Stuttgart	Porto Alegre	
Copenhagen	Marseilles	Turin	Río de Janeiro	
Dubai	Moscow	Vienna	San José	
Geneva	Munich	Warsaw	Santiago	
Ghent	Nantes	Zurich		

Appendix III: Normalized Results

Cities	Affordability and Accessibility	Mobility	Operational Efficiency	Environmental and Resource Conservation	Safety	Cumulative
Ghent	0.23	0.25	0.26	0.57	0.71	2.02
Graz	0.47	0.70	0.64	0.94	0.83	3.58
Clermont Ferrand	0.96	0.37	0.23	0.67	0.49	2.73
Bern	0.59	0.90	0.68	0.75	0.85	3.77
Geneva	0.40	0.59	0.28	0.81	0.82	2.91
Bologna	0.78	0.40	0.33	0.94	0.56	3.01
Nantes	0.54	0.35	0.25	0.71	0.71	2.56
Marseilles	0.82	0.51	0.33	0.79	0.72	3.17
Zurich	0.68	0.87	0.66	0.63	0.80	3.64
Amsterdam	1.00	1.00	0.32	0.94	0.86	4.12
Dubai	0.45	0.27	0.69	0.64	0.09	2.13
Brussels	0.80	0.47	0.31	0.58	0.80	2.96
Helsinki	1.00	0.91	0.66	1.00	0.91	4.48
Oslo	0.40	0.62	0.61	0.69	0.83	3.16
Newcastle	0.58	0.51	0.57	0.81	0.92	3.39
Lille	0.56	0.36	0.24	0.86	0.91	2.95
Bilbao	0.44	0.88	0.35	0.82	0.73	3.22
Seville	0.69	0.51	-	0.86	0.43	2.47
Prague	0.66	0.70	0.62	0.80	0.71	3.49
Lyon	0.72	0.46	0.33	0.84	0.93	3.28
Rotterdam	0.86	0.59	0.25	0.80	0.86	3.35
Munich	0.64	0.77	0.62	0.56	0.93	3.50
San José	0.95	0.62	0.58	0.81	0.73	3.69
Montevideo	0.66	0.47	0.55	0.79	0.40	2.86
León	0.81	0.67	0.56	0.78	0.17	2.99
Turin	0.49	0.42	0.21	0.89	0.46	2.46
Auckland	0.20	-	0.37	-	0.76	1.32
Vienna	0.93	0.70	0.47	0.90	0.90	3.91
Warsaw	0.69	0.79	0.57	0.83	0.71	3.59
Budapest	0.61	0.64	0.74	0.82	0.67	3.49
Copenhagen	0.64	0.81	0.49	0.79	0.77	3.51
Stockholm	0.61	0.65	0.51	0.77	0.84	3.37
Glasgow	0.43	0.36	0.39	0.79	0.79	2.76
Hamburg	0.86	0.63	0.44	0.85	0.90	3.68
Stuttgart	0.88	0.62	0.38	0.72	0.76	3.35
Manchester	0.63	0.31	0.47	0.84	0.85	3.10
Lisbon	0.66	0.53	0.51	0.89	0.66	3.25
Rome	0.46	0.42	0.45	0.82	0.43	2.58
Curitiba	0.65	0.79	0.51	0.77	0.96	3.67
Caracas	0.95	0.52	0.44	0.78	0.74	3.43
Singapore	0.62	0.71	0.54	0.79	0.75	3.41

Cities	Affordability and Accessibility	Mobility	Operational Efficiency	Environmental and Resource Conservation	Safety	Cumulative
Berlin	0.94	0.81	0.41	0.92	1.00	4.08
Porto Alegre	0.55	0.73	0.48	0.75	0.82	3.33
Athens	0.66	0.32	0.38	0.86	0.63	2.84
Guadalajara	0.61	0.91	0.53	0.74	0.11	2.90
Barcelona	0.77	0.71	0.48	0.85	0.58	3.39
Sydney	-	0.25	0.25	0.05	0.53	1.08
Belo Horizonte	0.77	0.78	0.49	0.77	0.89	3.69
Madrid	0.45	0.64	0.44	0.85	0.74	3.12
Toronto	0.08	0.18	0.48	0.60	0.90	2.23
Santiago	0.63	0.61	0.31	0.95	0.82	3.31
Hong Kong	0.88	0.99	1.00	0.90	0.92	4.69
London	0.81	0.62	0.55	0.85	0.87	3.70
Bogotá	0.85	0.46	0.46	0.95	0.75	3.47
Chicago	0.33	0.20	0.19	0.10	0.70	1.53
Lima	0.83	0.14	0.43	0.92	0.77	3.10
Río de Janeiro	0.43	0.24	0.43	0.92	0.76	2.78
Paris	0.70	0.69	0.35	0.85	0.76	3.35
Moscow	0.92	0.95	0.72	0.82	0.85	4.26
Buenos Aires	0.77	0.29	0.16	0.98	0.75	2.96
Sao Paulo	0.77	0.69	0.49	0.83	0.57	3.35
New York	0.68	0.48	0.33	0.88	-	2.38
Ciudad de México	0.63	0.43	0.35	0.92	0.55	2.89

Appendix IV: Raw Data

	Demand/ Context	Affordability and Accessibility			Mobility				Operational Efficiency		Environmental and Resource Conservation		Safety
Indicator(s)	Population	Average duration of trip	% of monthly income spent on transport	Length of road per 1000 inhabitants	Average speed of Trip	% of daily trips on foot and by bicycle	% of daily trips by private motorised modes	% of daily trips by public transport	Annual public transport passenger-Km per inhabitant	Farebox recovery ratio	Annual polluting emissions due to passenger transport per inhabitant	Annual energy consumption for passenger transport per inhabitant	Passenger transport fatalities per million inhabitants
Unit(s)		min	%	m	Km/h	%	%	%	Km	%	Kg	Mj	
Ghent	226,000	31.00		5,480	22	30%	65%	5%	959	31%	86	16,700	
Graz	226,000	28.00		4,400	27	35%	46%	18%	1,580	75%	36	14,900	40
Clermont Ferrand	264,000	19.25		3,400	25	33%	61%	6%	423	43%	83	14,700	114
Bern	293,000	27.00	9%	3,920	34	39%	40%	21%	2,670	48%		15,700	35
Geneva	420,000	27.50	10%	4,900	26	34%	51%	15%	724	42%	25	19,200	41
Bologna	434,000	25.50		2,490	18	29%	57%	14%	642		71	10,100	99
Nantes	555,000	24.00		5,410	26	23%	64%	13%	642	39%	80	14,200	65
Marseilles	800,000	26.50		1,630	24	35%	54%	11%	581	54%	74	13,300	63
Zurich	809,000	22.00	10%	4,700	41	31%	46%	23%	2,460	50%		18,400	45
Amsterdam	850,000	23.00	8%	2,750	33	51%	34%	15%	1,220	33%		11,100	33
Dubai	910,000	25.00	13%	3,100	45	16%	77%	7%	527	113%		18,100	203
Brussels	964,000	28.50	8%	1,940	29	28%	59%	14%	1,400	27%	69	18,800	46
Helsinki	969,000	21.00	8%	3,610	39	29%	44%	27%	2,200	59%	41	12,800	21
Oslo	981,000	25.00	10%	5,860	43	26%	59%	15%	1,780	63%	66	16,500	39
Mean	621,500	25	9%	3,828	31	31%	54%	15%	1,272	52%	63	15,321	65
Standard Dev	303,633	3	2%	1,351	8	8%	11%	6%	762	23%	21	2,844	49
Newcastle	1,080,000	22.00		4,120	35	27%	57%	16%	976	99%	35	15,100	23
Lille	1,100,000	26.00		3,480	30	31%	63%	6%	472	47%	62	11,100	25
Bilbao	1,120,000	30.60	7%	4,360	35	49%	35%	16%	1,150	52%		9,910	54
Seville	1,120,000	29.00		2,020	22	42%	48%	10%	422	1%		7,450	103
Prague	1,160,000	22.50	14%	2,910	29	21%	36%	43%	4,460	31%		11,800	58
Lyon	1,180,000	26.50	10%	2,470	27	33%	54%	13%	776		67	12,500	22
Rotterdam	1,180,000	11.00		4,070	28	42%	48%	10%	836	39%		11,800	34
Munich	1,250,000	32.50	11%	1,830	35	38%	41%	22%	2,910	64%	1,390	19,700	22
San José	1,286,877	20.74	3%	3,448		24%	42%	34%	1,059	100%	141		54
Montevideo	1,325,968	16.98	21%	2,271		27%	54%	19%	1,168	90%	263		108
León	1,360,310	24.95	11%	1,946	18	39%	32%	29%	913	100%	326		143
Turin	1,470,000	33.25		2,710	26	25%	54%	21%	930	30%	56	9,000	98
Auckland	1,486,000	28.04	15%	4,927	24	16%	80%	4%		44%	3,028	43,742	50
Vienna	1,550,000	24.00	8%	1,810	28	30%	36%	34%	2,350	49%	11	9,040	26
Warsaw	1,690,000	24.00	17%	1,680	29	20%	29%	52%	3,270	46%		9,090	
Budapest	1,760,000	29.50	12%	2,430	22	23%	33%	44%	3,640	72%		10,000	63
Copenhagen	1,810,000	25.00	8%	3,850	46	39%	49%	12%	1,630	68%	86	15,800	47
Stockholm	1,840,000	29.50	9%		34	31%	47%	22%	2,450	54%	42	17,800	36
Mean	1,376,064	25	11%	2,961	29	31%	47%	23%	1,730	58%	459	14,255	57
Standard Dev	259,619	6	5%	1,028	7	9%	13%	14%	1,219	28%	894	8,883	36

	Demand/ Context	Affordability and Accessibility			Mobility				Operational Efficiency		Environmental and Resource Conservation		Safety
Indicator(s)	Population	Average duration of trip	% of monthly income spent on transport	Length of road per 1000 inhabitants	Average speed of Trip	% of daily trips on foot and by bicycle	% of daily trips by private motorised modes	% of daily trips by public transport	Annual public transport passenger-Km per inhabitant	Farebox recovery ratio	Annual polluting emissions due to passenger transport per inhabitant	Annual energy consumption for passenger transport per inhabitant	Passenger transport fatalities per million inhabitants
Unit(s)		min	%	m	Km/h	%	%	%	Km	%	Kg	Mj	
Glasgow	2,100,000	22.50		5,800	33	24%	66%	11%	978	65%	40	17,000	53
Hamburg	2,370,000	26.00	5%		31	37%	47%	16%	1,570	58%	27	14,400	35
Stuttgart	2,380,000	18.00		1,190	42	30%	59%	11%	1,070	61%	53	20,700	57
Manchester	2,510,000	21.00		3,700	32	23%	68%	9%	561	96%	39	14,600	42
Lisbon	2,680,000	40.00	14%	889	24	25%	48%	28%	2,030	59%		9,220	73
Rome	2,810,000	40.00	16%	2,800	26	24%	56%	20%	2,610	29%	48	15,400	108
Curitiba	2,872,486	14.37	25%	2,324	19	42%	28%	30%	694	100%	303		26
Caracas	3,140,076	28.91	6%	878		18%	54%	27%	219	100%	231		60
Singapore	3,320,000	33.00	21%	940	32	14%	45%	41%	4,070	1%		14,200	58
Berlin	3,390,000	23.50	7%	1,570	33	36%	39%	25%	1,840	43%	37	10,700	19
Porto Alegre	3,410,676	16.06	26%	2,904		32%	42%	27%	657	96%	406		47
Athens	3,900,000	37.00	10%	2,310	27	8%	64%	28%	890	66%	96	13,100	77
Guadalajara	4,374,721	26.66	18%	2,525		39%	30%	30%	840	100%	458		158
Barcelona	4,390,000	29.85	9%	2,100	35	34%	47%	19%	1,400	71%		11,000	84
Sydney	4,391,674	59.25	16%	5,475	28	19%	68%	12%		25%	2,277	31,423	93
Belo Horizonte	4,803,198	17.20	26%	237		36%	38%	26%	621	98%	315		37
Mean	3,302,677	28	15%	2,376	30	27%	50%	22%	1,337	67%	333	15,613	64
Standard Dev	847,874	12	8%	1,621	6	10%	13%	9%	992	31%	604	6,123	35
Madrid	5,420,000	29.50	12%	4,870	34	26%	51%	22%	2,330	61%	53	15,100	71
Toronto	5,583,064	82.00	13%	2,866	19	6%	71%	23%		82%	1,533	16,713	35
Santiago	6,038,971	37.15	13%	1,887	18	37%	36%	27%	949	63%	384		53
Hong Kong	6,720,000	33.50	11%	284	27	38%	16%	46%	3,700	157%	378	4,850	30
London	7,170,000	29.00	9%	2,030	30	31%	50%	19%	2,520	81%	29	14,700	42
Bogotá	7,823,957	30.66	11%	990	26	18%	57%	25%	803	100%	405		69
Chicago	8,180,000	35.55	14%	4,770	34	6%	88%	6%	700	42%	2,910	43,600	80
Lima	8,482,619	34.79	8%	1,457		26%	53%	21%	511	100%	569		63
Río de Janeiro	10,689,406	23.68	28%	1,438		37%	45%	18%	511	100%	561		67
Paris	11,100,000	33.50	12%	1,980	32	36%	46%	18%	2,170	46%	77	14,600	66
Moscow	11,400,000	29.00	11%	406	33	24%	26%	49%	5,340	57%		8,530	47
Buenos Aires	13,267,181	31.05	5%	3,391		9%	40%	51%	694	36%	186		69
Sao Paulo	18,300,000	40.00	7%	1,960	21	37%	34%	29%	2,170			7,560	109
New York	18,852,000	34.60	14%	1,433	31	7%	61%	32%	1,770	49%	530	4,335	236
Ciudad de México	19,239,910	38.93	7%	3,312	19	25%	51%	23%	584	81%	543		113
Mean	10,551,141	36	12%	2,205	27	24%	48%	27%	1,768	75%	627	14,443	77
Standard Dev	4,837,946	13	5%	1,392	6	12%	17%	13%	1,418	32%	786	11,897	50
No. of Indicators	63	63	49	61	54	63	63	63	60	60	48	49	61
Data Availability	100%	100%	78%	97%	86%	100%	100%	100%	95%	95%	76%	78%	97%