Sustainable Indicators for Cities: A Framework from Social Indicators

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Abstract

This thesis proposes a tiered sustainability indicator system for cities to evaluate and share their progress. To achieve global sustainability, cities must measure their progress as well as begin to share knowledge with other cities. However, many existing sustainability indicators are not relevant to the different audiences that use these indicator systems. Further, there are many existing indicator sets for studying social, economic, and environmental factors separately. In particular, the social indicators have encouraged the use of Tiers to help with policy relevance and public acceptance of indicators. Using knowledge from these tiered social indicators, a tiered sustainability indicator system could overcome their current relevancy problems. Thus, this proposal focuses each Tier towards a different audience and purpose. The different Tiers, when sequenced together, can provide cities with a means of evaluating their city sustainability, but also a means to compare their progress with other cities, and potentially share knowledge from successful policies, strategies, and programs.
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Abbreviations

BLS Bureau of Labor Statistics

CEQ US Council on Environmental Quality

GDP Gross Domestic Product

GFN Global Footprint Network

GPI Genuine Progress Indicator

GHG Greenhouse Gas

ICLEI International Council for Local Environmental Initiatives

IPCC Intergovernmental Panel on Climate Change

LGO Local Government Operations Protocol

MSY Maximum Sustainable Yield

NEPA National Environmental Policy Act

OECD Organization for Economic Co-operation and Development

UN United Nations

WRI World Resources Institute

WWF World Wildlife Fund
Introduction

"Humanity stands at a defining moment in history. We are confronted with a perpetuation of disparities between and within nations, a worsening of poverty, hunger, ill health and illiteracy, and the continuing deterioration of the ecosystems on which we depend for our well-being. However, integration of environment and development concerns and greater attention to them will lead to the fulfillment of basic needs, improved living standards for all, better protected and managed ecosystems and a safer, more prosperous future. No nation can achieve this on its own; but together we can - in a global partnership for sustainable development."¹

As stated by the United Nations (UN), there is a wide range of problems in the modern day to address. Social equity and justice, as well as economic welfare have been part of the global discussion for development for a long time. However, more recently, environmental concerns are also becoming a higher priority at international, national, and local scales. This relationship between social, economic, and environmental welfare was identified as a key issue for sustainable development by the UN in 1992 at the Rio De Janiero conference. At the conference, sustainable development was defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."² While this definition of sustainability is widely accepted, there is a lot of variation in the meaning of sustainability, depending on the context and application. Further, as the term gains popularity, the frequency of applications increases, but the definition becomes more unclear.

Cities are an important part of global sustainability and sustainable development. According to the UN, in 2008, half of the world's population lived in urban areas.³ Further, the impact of the high concentration of population in cities is often associated with increases of emissions and environmental impacts. Cities often have much higher per capita impacts than rural areas. On the other hand, some research indicates that it is not population growth alone, but economic growth in urban areas that contributes more significantly to greenhouse gas emissions.⁴ In either scenario, cities encompass large quantities of consumption, economic activity, and large demands on the environment. Thus, targeting cities with sustainability movements and programs can be a quick and effective way rather than focusing on sustainability on the individual level, where only a few people make better choices. If cities were to adopt more holistic, sustainable approaches

¹ (United Nations n.d.)
² (United Nations 1992)
³ (United Nations Population Fund 2007)
⁴ (United Nations Population Fund 2009)
to development, the potential for achieving a more socially, economically, and environmentally responsible future seems more within reach.

Despite the importance of cities, many argue that the idea of a sustainable city is an unachievable utopian vision when you take into account the intensity of population and infrastructure. Not only are there many elements to deal with, both natural and man-made, but the relationship between elements is often complex and ambiguous. Even further, the concept of sustainability is also as unclear or vaguely defined. Thus, when discussing the important issue of sustainability in cities, there needs to be a tool that helps to evaluate and drive progress.

The complexity of measuring city sustainability can be simplified with the use of indicators. Indicators are tools that can help describe the state of a phenomena or environment. Indicators for economic performance, such as the GDP, are used daily to interpret the current performance of a country and their respective policies. These indicators, while particularly useful to policy-makers, are also very clear and understandable to everyone. Thus, indicators like GDP also become tools that the general public can identify and use to make informed decisions. For sustainability, there are many indicator systems as well.

On the individual level, there are ecological footprints that allow people to gauge their relative consumption activities in light of a representative amount of land, such as the systems developed by the Center for Sustainable Economy, World Wildlife Fund, Conservation International, and the Global Footprint Network. Ecological footprints can also be used for corporations and organizations. The Global Footprint Network has created tools for businesses to account for their environmental impact.

Further, greenhouse gas emissions accounting, like ecological footprinting is popular at different scales. The World Resources Institute (WRI) has developed the Greenhouse Gas (GHG) Protocols for corporations, or governments to measure their environmental impact. Nationally, ecological footprints, greenhouse gas accounting, and various checklists by the United Nations, OECD, and various other agencies are also available. Appendix A compares various sustainability indicator systems.

Indicators are not just popular, but they offer many benefits for cities. For policy makers, they provide valuable feedback in decision making. Understanding progress using a few select measures makes it useful

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5 (Blassingame 1998)
6 (OECD 1998)
7 http://www.myfootprint.org/
8 http://footprint.wwf.org.uk/
in decision making, but also, the indicators can be used as measures in planning as well, giving quantification for potential future programs or policy. If communicated effectively, indicators can also be used to help guide the general public towards a common goal.

Using indicators to quantify difficult or complex problems is not uncommon to other disciplines outside of sustainability. Social, environmental, and economic indicators have been popular fields since the 1930s and 1940s. Most sustainable indicators contain indicators from each of the three fields, making the indicator sets more comprehensive as a whole; however, there is typically no provision for the complex interactions between the indicators or between the fields. It is clear that these interactions are key, as even the preamble to UN's Agenda 21 indicates, "the integration of environment and development concerns" are the key to an improved future.11 Thus, despite the potential usefulness of sustainable indicators, there are still many things to improve upon in order to make them truly useful to sustainable development. Some of the main problems stem from the inconsistency of the definition of 'sustainability.' The general definition given at by the Brundtland Commission is often criticized as being vague. The vagueness of the definition makes it "difficult or impossible to operationalize and implement."12 So while it is clear sustainability requires us to meet our basic needs without compromising the future, it is unclear what a city must do to achieve this goal. Thus, many believe the definition requires an impossible forecast of both the future needs and future technologies. Marshall refers to the confusion of the definition of sustainability as "definitional chaos."13

Further, an important issue in global sustainability is the ability for cities to learn from each other. A key problem in comparing city sustainability, however, is the lack of clarity in evaluating successful strategies. There is currently no consistent set of indicators to provide a basis for comparison. In addition, the goals and the context in which the goal was made, must also be captured in order for knowledge to be transferred or shared.

With the challenges of evaluating sustainability and transferring the knowledge, it is difficult for cities to approach sustainability and contribute meaningfully to global sustainability. As a way to address these challenges, this thesis proposes a different system for sustainable indicators for cities. Utilizing a "tiered" system of indicators, which takes lessons from social indicator research, the proposal offers a consistent set of indicators that considers relationship to policy, contextual issues, and interactions between indicators.

11 (United Nations n.d.)
12 (Marshall and Toffel 2005)
13 (Marshall and Toffel 2005)
Key Terms

This thesis defines a few key terms in order to maintain clarity and ensure consistency when discussing the methodology of sustainability indicator sets.

'Framework' will describe the model, or an underlying structure for indicator sets. The framework not only describes the organizing structure, but can also indicate other underlying philosophies or concepts in the indicator set. One popular framework in national sustainability indicators is called the 'pressure-state-response framework.' Some action or event, pressure, asserts itself on a situation, described as state, and the response is the result of the interaction. The pressure-state-response is only one framework, there are many other categories and organizational variations across different indicator systems.

'Indicators' are the measures that describe a changing phenomenon to account for that change. In the case of this paper, indicators are the measures that describe sustainability. These measures may be quantitative or qualitative. In the case of qualitative measures, however, there are usually scales applied to describe the measure. For example, if there is a measure of quality of life, it may still be on a scale of 1-5, with each number representing a different subjective level of quality. Indicators are also often described as accounting tools that help the decision-making process.

Further, some scales used to measure indicators utilize 'reference data.' These reference values may be targets or goals for the future, benchmarks from past performance, or thresholds. This reference data is important to bring any results from indicators into an understandable scale. For example, a carbon quantity in tons may not be very meaningful to most people, but put in terms of a reference point like the benchmark of carbon emissions from the 1950s, then it becomes clear that carbon and greenhouse gases have increased significantly by 25% since the 1950s. 14

An 'indicator set' or 'indicator system' is a collection of indicators that are selected to represent the entire scope of what is being measured. One key aspect of indicator sets is that they do not include every possible measure, but a few representative measures that best describe the phenomena being studied.

There are many different types of sets or systems, organized by different frameworks. One type of indicator set is a 'checklist,' which uses a series of indicators and produces a full list of the results at the end.

14 (Energy Information Administration 2004)
(Figure 1). While often long and tedious, these lists allow transparency in the study, and offer more detailed information for anyone using the results.

An 'index' is another type of indicator set that aggregates the indicator values into a single value. Some indicator sets must manipulate each indicator result to achieve a common unit. Other sets cater the indicators to have matching units. For example, an ecological footprint must convert all the collected data into a quantity of land. But, in the Genuine Progress Indicator (GPI), all the indicators measure dollar values, so they are easily added together to get a final monetary number. In examining sustainability, these are popular because of the simplicity of the result and the ease of sharing the information. They are also often used in comparison tables to rank performance or to compare to a reference value.

Sustainable indicator systems, regardless of the framework or type, are used to measure progress towards sustainability. There are many systems available to measure national, corporate, and individual sustainability, however city sustainability measures are relatively new. Many of the systems for city sustainability are adapted from the existing national, corporate, and individual indicator sets. For example, ICLEI's Local Government Operations Protocol for Greenhouse Gas Inventories is adapted from the Greenhouse Gas Protocol's corporate accounting tool, developed by the World Resources Institute.15 On the other hand, ecological footprints for cities are adapted from original accounting methods for national footprints. Further, lists or tables of these indicators are often used as a means to compare progress across nations. The Living Planet Report, produced by the World Wildlife Fund, organizes the ecological footprints of various nations, showing not only how each country compares to each other, but also how they measure up to a benchmark of the available natural resources, called biodiversity (Figure 2).16 In general, however, there is no consistency across these different sustainability indicator sets, and in particular, cities have more of a challenge to not only establish their own indicators, but to ensure comparability with other city studies. Thus, when cities decide to measure progress towards sustainability, there are often many choices and no clear path as to how to account for sustainability.

15 (ICLEI 2010)
16 (World Wildlife Fund 2008)
### Inset 4  Structure of OECD Indicators Core Set by Environmental Issue

<table>
<thead>
<tr>
<th>Major Issues</th>
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<th>STATE</th>
<th>RESPONSE</th>
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<td>Indicators of environmental pressures</td>
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<td>13. Soil degradation (desertification, erosion)</td>
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<td>14. Socio-economic, sectoral and background indicators</td>
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**Figure 1** OECD checklist of environmental indicators. (OECD 1998)

**Figure 2** Ecological footprint of various nations, excerpt from Living Planet Report. (World Wildlife Fund 2008)
History of Indicators

While the history of sustainable indicators, and sustainable indicators for cities, is relatively short, the use of quantification tools to simplify complex issues has a long history. Even as early as the 1930s, groups of social scientists began studying how to use knowledge from their field to improve society. The publication of ‘Knowledge for What?’ by R.S. Lynd is one of the earlier examples of social indicators. Economic indicators were developed around the same time in the 1940s. Even the concept of environmental indicators was utilized as early as the 1930s and 1940s, when animal population changes were studied with a logistics curve by Gause in 1934. The concept of studying these animal populations became more popular in the 1970s, and became the indicator of environmental health known as "maximum sustainable yield."

In light of the long history of using indicators to measure complex social, environmental, and economic issues, these three philosophies were brought together by the Rio Earth Summit in 1992, in a plan of action document called Agenda 21. Indicators for sustainable development, which encompass social, environmental, and economic considerations, were introduced as a global priority. Nonetheless, even with the international emphasis, standards and protocols for sustainable indicator systems often vary drastically from one project to another. Further, there are many similarities between the current goals and challenges of sustainable indicators and the past history of social, economic, and environmental indicators. Thus, it is useful to understand the history of various other indicators for social, economic, and environmental study, to arrive at a better understanding of the difficulties faced in creating sustainable indicators.

Social Indicators

Different social scientists claim different beginnings for social indicators. Judith Innes, a professor for city planning and researcher of social indicators and public policy, claims that an elite group of social scientists have been interested in social indicators since the publication of Knowledge for What? in 1939. The book brought to light the need to transform social knowledge into something useful that could improve society. On the other hand, Cecilia Wong, a social indicator researcher out of the UK, notes that Raymond Bauer set the stage for social indicators as a field in 1966, when he was commissioned to study the impact of the

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17 (Innes, Knowledge and Public Policy: The Search for Meaningful Indicators 1990)
18 (Wong 2003)
19 (Bell and Morse 2008)
20 (Bell and Morse 2008)
21 (Innes, Knowledge and Public Policy: The Search for Meaningful Indicators 1990)
NASA program on American society. While these are two very different starting points, most social scientists agree that the 1960s was a period of growth for social indicators. Not only was society interested in social projects to improve conditions for everyone, but the movement was popular in various countries outside the US, including the UK. Presently, the UK is one of the leading nations utilizing sustainability indicators for cities, regions, and the nation.

However, despite the excitement for social indicators in the 1960s, they fell out of favor in the 1970s. Some blame the indicator systems themselves. Methodological problems in the social indicators led to unsubstantiated cause and effect relationships, and many questioned the social engineering that was being proposed as a result of studying these indicators. On the other hand, many social scientists blamed the policy makers for failing to utilize the indicators correctly, or interpreting them inappropriately. At the same time, there was a general movement that argued social programs were ineffective. As the pendulum for social welfare programs swung towards blaming the poor for any problems they had, social indicators also fell out of favor. If society believed that there was nothing governments and policy makers could do to improve social conditions, these indicators did not provide any meaningful information to the general public or to politicians.

The 1970s was an important time for social indicators for many other reasons. While they fell out of public favor, there was also a lot of work done in the 1970s that paradoxically proved the need for social indicators. Innes notes that in 1971, Alice Rivlin of the White House Budget Office concluded that cost-benefit analysis while useful, were not enough to draw any clear conclusions on which policies the US should adopt. On the other hand, social indicator researchers like Caplan, a policy expert out of London, were developing tools inform policy-makers. The conclusion of Caplan's studies showed that many policy makers favored having more knowledge and information, such as the kind the social indicators provided; but ironically a majority of them did not use this knowledge. Caplan explained this contradiction in a different report in 1977, claiming that policy makers and social scientists were from two entirely different communities and cultures, creating a rift between the data that the social scientists collected to the actual use of the information by the policy-makers. Despite the conclusions of why the gap between the indicators and the actual policy-making occurred, there was a clear need for indicators, yet in the 1970s and 1980s, no one could figure out how to bridge that gap and make social indicators useful for policy.

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22 (Wong 2003)  
23 (Wong 2003)  
24 (Innes, Knowledge and Public Policy: The Search for Meaningful Indicators 1990)  
25 (Innes, Knowledge and Public Policy: The Search for Meaningful Indicators 1990)
Nevertheless, the study of social indicators prevailed in the 1990s. Even though there were many critiques of social indicators in the 1970s, social scientists still continued to improve the methods and created more sophisticated means for measuring social phenomena. In 1979, Weiss created a system to categorize different methods of measuring social indicators. There were six general categories covering traditional uses of knowledge such as linear progressions through research to implementation of policy, to more contemporary and dynamic models. The contemporary models, called "interactive" models of knowledge, bring together researchers as well as policy makers in a non-linear process of discussion and exploration. This interactive model reflects many of the principles of interdisciplinary work that is popular in sustainable design practices. Both processes include representatives from many disciplines and various stakeholders to work together throughout the project. Social indicator work in the 1990s began moving towards contemporary models for indicators that went beyond what other indicators, such as economic or environmental, were doing. These indicators from other fields were still rooted in the more traditional models of knowledge, working linearly with researchers and scientists generating information for indicators, and handing it to policy makers to implement. In many ways, social indicators already dealt with the same issues that sustainable indicators are struggling with today. Thus, social indicators can offer many lessons from its history to sustainable indicators.

Economic Indicators

Economic indicators began in the 1940s, and are often cited as the origin of the interest in quantification indicators. Unlike social indicators, economic indicators were accepted upon introduction, and have been widely used since. The most popular economic indicator is the GDP measurement, which is used not only to indicate economic health, but also used to infer a number of quality-of-life issues. Originally conceived as a means to measure wartime production capacity during WWII, the system was then adapted to be the overall economic health indicator on an international scale. The method is derived from the Kuznets curve, which posited the theory that income inequality had a curved relationship to national income. Simon Kuznet, a Nobel Prize economist, came up with the theory that as national economy grew, the level of income inequality would also grow to a point, but at another point during the national economy growth, income inequality would then lessen, creating an upside down U shape. His theory, published before the 1940s, was not intended for use as a global economic indicator. Kuznets, while winning a Nobel prize for his work, specifically states that the method does not distinguish between socially productive spending,

26 (Innes, Knowledge and Public Policy: The Search for Meaningful Indicators 1990)
27 (Innes, Knowledge and Public Policy: The Search for Meaningful Indicators 1990)
28 (Wong 2003)
such as the cost for creating affordable housing, or socially negative spending, such as costs incurred from crime, pollution, or natural disasters. Thus, there is no indication of quality, but only quantity in the GDP measurement. The wide usage of the GDP measure to approximate economic welfare can be misleading in terms of quality of life factors.

There are many critics of the widespread use of economic indicators in determining the overall success of nations. Redefining Process, a private research center that specializes in quantifying city and national sustainability, claims the system is too narrowly focused. They claim that in the 1990s was a time when the US GDP was up very high. However, many studies indicated that many Americans did not get a sense of this economic health, and often felt left behind in the economic growth. The GDP indicator did not cover an issue of great concern to many Americans. Further, there is no account of other social breakdowns, and quality of life or environmental sustainability issues. Redefining Progress thus generated a new proposal for an economic indicator, called the Genuine Progress Indicator (GPI). This indicator system still accounts for welfare in economic terms, however, it incorporates costs of environmental degradation, social breakdowns, and other insecurities that a nation experiences. Talberth, Cobb, and Slattery, the authors of the GPI method, concluded that after using their GPI method on data from 2006 that the US was not experiencing a period of great success and sharp economic growth, but rather on a slow decline of overall process in terms of economic, environmental, and social aspects since the 1980s. While this is a less optimistic viewpoint of the U.S., this indicator could potentially be more holistic and more reflective of the actual experience of Americans. However, despite the existence of new forms of economic indicators, GDP is still the most widely used and accepted measure. Even further, is it clear that economic measures do not capture key social and environmental issues that are also equally important in measuring performance.

29 (Talberth, Cobb and Slattery 2007)
30 (Talberth, Cobb and Slattery 2007)
31 (Talberth, Cobb and Slattery 2007)
Environmental Indicators

Environmental indicators, which are often confused with sustainable indicators, are generally scientific measures and do not include the more intangible qualities that are often measured in social and sustainable indicators. As early as the 1930s, environmental concerns over animal populations were studied.32 While they may not have been called environmental indicators, these studies had similar goals in that they attempted to verify the state of the natural resources. Further, these indicator systems were often based on mathematical theories from even earlier decades. For example, the Maximum Sustainable Yield (MSY) indicator has been used since the 1970s to determine if fish harvesting is depleting certain species.33

Early environmental indicators, and even indicators from today, have very narrow views of environmental sustainability. In Peru, anchovy harvests were monitored by the MSY indicator in the 1960s-1970s. At the time, Peru had the world's largest fishery, partly due to the specific conditions from the deep water, and climate conditions bringing nutrients to the surface, which provided phytoplankton for the rich ecosystem. However, the system collapsed in 1971, resulting in a drastically declining population of anchovies. Throughout the 1960s however, anchovy fishing was monitored by MSY, and the harvests were within the guidelines given, despite the fact that it was heavy exploitation of the ecosystem. After the collapse, Peru realized a number of factors were not accounted for in the MSY indicator. At the time of the collapse, a number of other ecosystem and climate changes were occurring. The MSY calculation failed to take into account other species that preyed on the anchovy, including various seabird populations. Further, the fishing intensity was not incorporated. Heavy fishing of reproductive-age anchovies could wipe out the population without harvesting beyond the MSY limit. Finally, at the time, climate changes from the El Nino event in 1972 began bringing warmer water to the fishing grounds, which became a better system for the horse mackerel, a major predator of the anchovy. Because these factors were not accounted for in the MSY indicator, there was a false sense of security in the Peruvian fishing industry. Most years' harvests were even under the MSY limit, but the reliance on the MSY alone proved to be misleading.34

The MSY, as well as many other environmental indicators are actually based on the Kuznets curve. In the 1990s, scientists began applying the same Kuznets curve, which is the basis of the GDP calculation to environmental issues. Similar to its application to economic issues, the Kuznets curve offers a narrow view of the problem. Each element is only studied in isolation, forgoing many other social and ecosystem

32 (Bell and Morse 2008)
33 (Bell and Morse 2008)
34 (Bell and Morse 2008)
complexities. Further, the scientific nature of the calculations, whether GDP or MSY leads to a false sense of accuracy. Peru's fisheries dogmatically followed the MSY, but that indicator ignores other symptoms such as the increase in seabird or horse mackerel populations, or the change in climate. These same narrowly-focused environmental indicators are the basis of many sustainable indicator systems. Values related to forestry, fishing industries, and agricultural yields are often used as part of the discussion of sustainable nations, cities, or communities. While these systems often measure many aspects of a city, and often use social and economic indicators, each indicator is still isolated from other factors, resulting in a collection of narrowly-focused indicators. A system that incorporates the interactions between various parts of the ecosystem, economic factors, and social impacts would be the ideal to discuss the complex issue of environmental sustainability.

![Figure 4 Concept of the Maximum Sustainable Yield indicator. (Bell & Morse 2008)](image)

*Sustainable Indicators*

The history of sustainable indicators may be traced as far back as the 1970s as well, even though it was not officially called sustainable indicators. The US Council on Environmental Quality (CEQ) was created in 1969 as part of the National Environmental Policy Act (NEPA). In the 1970s, the Environmental Quality Improvement Act gave NEPA more power to oversee the environmental performance of other agencies. The 1970s was also when the CEQ began using sustainable indicators to inform the American people about the quality of the environment, including the air and water. This policy occurred at a time when river fires and polluted ground water threatened significant environmental degradation. Thus, it was clear to the general public that the environment should be a major point of focus for the federal government. The CEQ would serve as an independent agency and assess the federal government's policy and its environmental impact. During the period from the 1970s to the 1990s, CEQ would create an annual report, which began
the first form of environmental and sustainable indicators. One of the main goals of the group was to "achieve a balance between population and resource use that would permit a high standard of living." Thus, even though environmental protection was the primary goal, there was still consideration for social and economic implications.

The CEQ is still part of NEPA, but in recent years, the group has been downgraded as funding was decreased. The annual reports are no longer done by the independent agency, but rather by each of the affected agencies. This makes the annual reports since the 1990s biased and often not particularly critical of any of the federal policies. Further, despite the earlier success of the annual reports, in the 1980s, the indicators for environmental quality were questioned in terms of comprehensiveness. For example, water quality is a complex phenomena involving the monitoring of many chemicals and compounds. Despite the capability of monitoring larger numbers of chemicals, because they are considered individually, there is no way to capture the chemical reactions between them. What is needed is a way to integrate the measures.

Other sustainable indicators are also flawed in their ability to capture the complexity of sustainability. For example, one of the early and leading sets of sustainable indicators for cities was the Norwich 21. The set was custom created by the city to monitor their environmental health and get involvement from the general public. Of the 20+ indicators from the Norwich 21, there is a strong focus on publically accepted environmental, economic, and social issues. For example, the swan population was monitored because of the popularity of the species, while, many other species were ignored. The indicator set had to balance public interests with actual performance of the environment. Despite strong efforts for a participatory process, the Norwich 21 set was replaced with a top-down implemented set from the UK national government.

Another indicator set called AMOEBA was developed in the Netherlands. Unlike the Norwich 21, the AMOEBA indicator set was done by ecologists for policy makers, without much participation from the general public. Nevertheless, the set was created with non-specialists in mind. A small, representative set of environmental indicators are compared to reference values in most cases this is a target value. Thus, the measured value for each indicator is scaled to the target value, very quickly and easily depicting the

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35 (Rogers, Jalal and Boyd 2008, 142)  
36 (Rogers, Jalal and Boyd 2008)  
37 (Bell and Morse 2008)
progress required to achieve their definition of sustainability. These indicators and their references values are depicted in a graphic that allows quick reading and comparing (Figure 5).

The Norwich 21 and AMOEBA, as well as other sustainable indicator sets, have many challenges. They are subject to many different agendas or biases, depending on the set. Looking at the Norwich 21, there was clearly a bias from the general public. On the other hand, the AMOEBA set would be biased towards the scientists that authored the set and the policy makers that commissioned it. Further, the relationship to policy is also often critiqued. While the AMOEBA set may have been written with policy-makers, the set is still only a guideline for what the current state of the environment is. These measures and targets do not indicate to the policy makers what policies or programs to implement, and thus, compromises the ability to transition from the knowledge given by the indicator to the implementation of effective policy.

Figure 5 Example of an AMOEBA indicator set. (Simon & Morse 2008)

38 (Bell and Morse 2008)
There are also many other sustainability indicator systems. For sustainable development, a Cost of Remediation (COR) indicator is often used. These COR indicators present the state of the environment as a total invoice, if the environmental degradation were to be repaired.\(^39\) For example, any air pollution is reflected by a cost to reduce air pollutants and emissions to a particular target. This index type of indicator is very easy to understand, and can also be put in terms of a country's GDP. Figure 6 shows an example of the COR indicator, which is often used by the Asian Development Bank (ADB) countries. Development and Environmental Diamonds are used by the World Bank.\(^40\) These only utilize four indicators that are independent of each other. Arranged on two axes, the indicators are presented in a graphic form and scaled to the target value, so the results are always a percentage of the goal (Figure 7). There is also a 'Snowflake Variation' to the Diamonds (Figure 8), where more than four indicators are arranged in a radial graphic.\(^41\) These Diamond and Snowflake indicator systems are very similar to the AMOEBA system, and can provide a concise and clear picture of a few key measures. On the other hand, there are also more comprehensive sustainability indicators. Greenhouse gas (GHG) emissions accounting has become popular with many nations, cities, and corporations. These indicator systems sum all the emissions associated with the measured scope. The Intergovernmental Panel on Climate Change has created several guidelines for GHG accounting. And, other organizations, such as the World Resources Institute have adapted these guidelines for specific sectors. While the GHG indicator systems account for many sources of emissions, and also other environmental impacts by using emissions equivalents, they are often much more intensive to generate than indicator systems that only use a few measures.

\(^{39}\) (Rogers, Jalal and Boyd 2008)
\(^{40}\) (Rogers, Jalal and Boyd 2008)
\(^{41}\) (Rogers, Jalal and Boyd 2008)
Despite the known flaws of sustainable indicators, there is still much promise in utilizing these tools to help monitor the state of sustainability, as well as to aid in decision making towards a sustainable city. Bell and Morse consider indicator sets to be "the bad application of good science." And while there are still many resolutions required to overcome the challenges associated with the current indicators, there is still much indicators can offer for city sustainability.
Hypothesis

To achieve global sustainability, cities play an important role and must have a consistent method to evaluate and share their sustainable development strategies and programs. However, the available sustainability indicator systems fail to provide a consistent and easily applicable means of measuring sustainability in cities. The history of social, economic, and environmental indicators have shown that the main needs of city sustainability indicators include the following:

- Accounting for interactions across indicators;
- Policy relevance;
- Consistency and comparability across cities.

Thus, this thesis proposes to use a 'tiered' system of indicators, taking lessons from social, economic, and environmental indicators, to improve upon the sustainable indicator systems for cities. The tiered system includes four Tiers that each target a different audience and purpose. In this way, each Tier can focus on their particular goals, whether it is to capture complex technical issues, or to be policy relevant, or to guide cultural shifts towards thinking sustainably. Further, there are more opportunities to use interdisciplinary working methods, given the more clear goals for each Tier.
The tiered Sustainable Indicator Framework

"...environmental issues have to operate at different levels simultaneously... Empirical understanding of the different scales and their interconnections requires different levels of theoretical abstraction and generalization." (Anderson 2006)

One of the many problems of sustainable indicators is the relevance to policy-makers and other key audiences. Policy-makers find that they cannot directly translate indicators into policy. Scientists and technicians find indicators too vague to make any conclusions, but ironically, these same indicators are often found to be too technical by the general public. More importantly, the general public does not always believe that the particular sustainable indicators are issues that are important to them. Still others see indicators as too simplistic, and unable to capture the true complexities of natural systems. Thus, using and comparing indicators across cities does not seem to be able to satisfy any audience's needs.

In social science, tiered approaches to indicators have been proposed to help address the relevancy of indicators. These tiered indicator systems are a means of structuring indicators so that specific needs of different audiences and stakeholders are met by different Tiers. For example, Wong proposes a two-Tier system, separating conceptual from technical indicators.\(^{42}\) The conceptual indicators are directed at everyone from the general public to the scientists, while the technical indicators are the working indicators for the policy makers and scientists to take action towards the conceptual indicator goals. Innes and Booher, also part of the social indicator movement of the 1990s, propose three Tiers, including conceptual, technical, and feedback indicators.\(^{43}\) Like Wong, Inness and Booher have broad, conceptual indicators for all audiences, technical indicators for scientists and policy makers, and feedback indicators to help communicate results back to the general public. In particular, both authors propose that upper Tier, or conceptual indicators must be developed with the general public, or as many stakeholders as possible. They believe that without participation, the general public will not accept that these indicators are a reflection of issues that are significant to them.

The phenomenon of acceptance is an important aspect in these new social indicator systems. In 1996, Macnaghten began a study to gauge Lancashire residents' acceptance of a recently released set of sustainability indicators. However, during the study, it was found that the definitions of sustainability and

\(^{42}\) (Wong 2003)
\(^{43}\) (Innes and Booher, Indicators for Sustainable Communities: A Strategy Building on Complexity Theory and Distributed Intelligence 2000)
trust in the local government were even more important than the specific measures. In his study, most residents of Lancashire did not agree with the specific indicators, and did not believe they reflected their sustainability concerns as citizens. But, the origin of the disagreement stemmed back to the definition of sustainability and a mistrust of the government that is making decisions for them. It was an even larger systemic problem than the study anticipated. Part of the disagreement about the definitions and indicators of sustainability was due to a general distrust of the government and their knowledge of what is right for the general public. With this revelation, it is clear that there was no set of sustainability definitions or indicators that would meet the public’s approval.

In light of the issues depicted in the Macnagten study, participatory processes must be used in order to get public acceptance. A participatory process would involve as many stakeholders from the community as possible. Further, the involvement must be deep in nature, giving participants responsibility for these indicators. The effectiveness of this participation stems from what Douglas and Wildavsky study in their work on risk perception of environmental dangers. Douglas and Wildavsky discusses the importance of social understanding to overcoming perceived risks. It is clear that people have varying levels of concern and perceived risk from the sustainability and environmental issues of today, much like in Lancashire. But, when people work as a group, many of these risks become less threatening. This means, that as a group, people are more willing to accept things that they may not be familiar with, or they may at least be more likely to give consent. Any disagreements while working in a group setting can often be mitigated by simply allowing people to be heard. Thus, a working process that includes the general public in a meaningful way can go a long way to having successful indicators that are not only utilized by government officials, but also by the general public.

Further, one of the key issues of sustainability is the relationship between social, economic, and environmental issues. By dedicating another Tier to technical indicators, it allows these issues to be explored without the pressure of making them understandable by all audiences. This also allows scientists and technicians to begin working in an interdisciplinary manner to develop indicators that don't just simply measure one dimension. Thus, a higher level of complexity would be introduced into sustainability indicators.

44 (Macnaghten, et al. 1996)
45 (Douglas and Wildavsky 1982)
For policy-makers, there can also be a Tier to establish that link between information and policy. The knowledge gathered from the other Tiers can then be worked into indicators that directly translate into policy, or even measure the effectiveness of implemented policies.

Finally, using multiple Tiers also allows certain Tiers to focus on comparability. Certain Tiers can be dedicated to producing a simple, communicable indicator that can be share progress with other cities. Thus, using Tiers allows sustainability indicator sets to cater each Tier for different audiences and purposes.

**Tier 1: Conceptual goals**

For many social indicators, the first Tier of indicators includes only a few broad measures that reflect the overall goals of the city. In city sustainability indicators, these goals must be defined in such a way to reflect the city's definition of sustainability. If a city's main goals are to ensure cleaner air and water, then the first Tier of indicators would be the health of the air and water. Another city may view human health as more important, which would then lead their first Tier indicators to be measures of human hazards, or obesity and other health concerns. Thus, Tier 1 has a wide audience, ranging from the general public to policy makers, scientists and researchers, and business owners.

One of the other important aspects of this set of Tier 1 indicators is the process by which they are developed. As mentioned earlier, a participatory process that involves all the stakeholders from the government side to the citizens and businesses in a city would help the acceptance of any indicator sets. The participatory process, where many people work together to develop the indicators reduces the sense of fear and risk of these indicators, resulting in a more widely accepted or consented set of indicators. Tier 1 indicators are the overarching goals and main ideas behind the city's drive towards sustainability, thus, these indicators must be developed in a participatory process. Further, because Tier 1 represents the overall goals and must be limited to few indicators, it is relatively easier for a group to develop and propagate.

The target performance of these goals must also be set as a large group of stakeholders in this participatory process. While the indicator itself reflects the issues that are widely accepted in a particular city, there also needs to be a definition of what it means to be successful. References must be set, such as benchmarks of

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46 (Douglas and Wildavsky 1982)
past performance, or targets for future levels. Without these reference values, there is no scale to measure these indicators by.

Another aspect of the Tier 1 indicators is the time frame by which these indicators are written. Overarching goals for sustainability often have very long-time frames. Achieving clean air quality and maintaining it involves a long scope of time, as opposed to something as specific as implementing a recycling program. Thus, Tier 1 indicators are often long-term thinking in their scope, and while they are more general, they reflect the specific needs and concerns of the city for their future. Time can also be used to set more achievable, intermittent steps towards ultimate goals. For example, cities might use CO2 operational emissions as their main Tier 1 indicator, and want to ultimately become carbon neutral by 2050. But, in the meantime, they may want to see a 20% reduction every 15 years until their ultimate goal is achieved.

An example of Tier 1 indicators can be seen in the city of Vaxjo, Sweden. The city viewed fossil fuel dependency as the main issue of sustainability. From electricity usage for homes to gasoline usage in cars, they targeted the reduction of fossil fuel usage. This goal also aligned with their concept of security, as fossil fuel supplies are often dependent on other nations with larger resources of coal or oil. With this goal in mind, all residents and officials in Vaxjo work to reduce fossil fuel usage through conservation of energy, replacement of these fuels with renewable energy sources, planning strategies that reduce travel distances, or design strategies that reduce heating. With this indicator and these strategies in mind, Vaxjo was also able to set up targets for reduction for various stages in the future, and measure their progress using a single, widely understood and accepted measure.47

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47 (City of Vaxjo n.d.)
Seattle's sustainability indicators, while covering 40 measures, also embody the participatory nature of Tier 1 indicators. The Sustainable Seattle project brought together the city and residents to create a set of indicators reflecting environment, population and resources, economy, education, and health and community. The process, which occurred in the 1990s, produced one of the most well-known city-level sustainability indicator sets. Originating from a citizen-led process, these indicators are used by the general public to hold the policy makers accountable for sustainability, and to ensure they are communicating the sustainability goals of the community. While this does not involve policy makers, the participatory process and the dialogue about the future of Seattle reflects the proposals of Doulgas and Wildavsky.

Finally, it is important that these cities create clear, and specific Tier 1 indicators, as these can also be compared to other cities. In Vaxjo's case, their fossil fuel reduction goal can be used as a comparison to other cities. If St. Paul wished to do the same fossil fuel reductions, then they may look to Vaxjo' strategies, knowing their overarching goals are the same. But, they may also realize when comparing Tier 1 goals, that another city with water quality as a Tier 1 goal, may be less useful as a case study.

**Tier 2: Technical measures**

Tier 2 is narrower in scope and only involves specialists, researchers, and scientists from various agencies and centers in a city. These indicators are technically focused. For example, if a city proposes that water quality is a key goal for sustainability in their Tier 1 indicators, then their Tier 2 set of indicators includes any specific measures specialists must monitor in order to conclude that the water quality is improving or reaching a certain target.

Because of the narrow scope of these measures, a participatory process is not necessary. It would be infeasible to have everyone agree on indicators that the general public may not understand or care about. But, these measures do require technical expertise. Cities must allow their technical experts to determine the necessary indicators for achieving their Tier 1 goals. For example, water quality may involve the expertise of the Department of Natural Resources, along with local ecologists and researchers, working together to determine if the water quality goals have been achieved. In order to determine what the Tier 2 indicators should be, the technical entities from various agencies and research groups must come together and determine the specific measures they wish to monitor and agree to the other factors that may impact the issue. Rather than allowing these indicators to sit within the respective agencies in isolation, Tier 2 indicators must be worked on by task forces or committees, consisting of the correct range of experts to not only address the specific measures, but the other influences and impacts that may be important to the larger picture of Tier 1.
One example of a technical indicator for Tier 2 could be an air quality index. The concept of air quality includes specific particulates and gases in the air. Figure 10 shows an example air quality index, which is part of another index that also includes water and land quality factors. Experts developing Tier 2 indicators may decide to go for this type of indexing of specific measures. It is not always necessary to develop a single index value. Tier 2 indicators can also use checklists and incorporate more subjective and qualitative issues if the committee determines the need.

![Air Quality Index](image)

**Air Quality Index**

\[ I_{\text{AIR}} = \sqrt{0.1 I_{\text{SO}_2} + 0.1 I_{\text{PM}} + 0.1 I_{\text{COH}} + 0.2 I_{\text{CO}} + 0.2 I_{\text{Ox}} + 0.2 I_{\text{NO}_x}} \]

*where*

- \( I_{\text{SO}_2} \) = Index for sulphur dioxide
- \( I_{\text{PM}} \) = Index for suspended particulate matter
- \( I_{\text{COH}} \) = Index for coefficient of haze
- \( I_{\text{CO}} \) = Index for carbon monoxide
- \( I_{\text{Ox}} \) = Index for total oxidants
- \( I_{\text{NO}_x} \) = Index for oxides of nitrogen

**Comprehensive Environmental Quality Index**

\[ I_{\text{AIR}} = \sqrt{0.3 I_{\text{AIR}} + 0.3 I_{\text{WATER}} + 0.3 I_{\text{LAND}} + 0.1 I_{\text{MISCELLANEOUS}}} \]

Air Indices are based on ratio of average annual concentrations in the atmosphere to the prescribed atmospheric standard.

Figure 10 Air quality index calculation and variables, and its role in the environmental quality index. (Rogers et al 2006)

In many cities, these technical-type indicators are often left to specific agencies, which leads to the type of isolation that causes oversights like in the fishing industry in Peru. But, integrating these multi-disciplinary factors into the study of the sustainability is achievable. In the US, in the 1970s, NEPA created the Council on Environmental Quality (CEQ) to advise the President on environmental issues. The CEQ served as an interagency group, or as a centralized group, to aggregate data from various agencies and summarize the state of the environment to the President of the United States. By centralizing this responsibility with a third group, the reports on the environment were not only less biased, but also captured interactions between systems that specific agencies do not normally look at. The success of these reports by the CEQ was also revealed over time as funding was cut to the agency and reports became the responsibility of the separate agencies. All of a sudden, reports were authored by each agency, and did not result from the interaction of these agencies responsibilities within the context of the city. Only after the centralized
reports disappeared, was it clear that the interaction between the groups was highly important. It is also clear that complex sustainability issues can most effectively be captured by some centralized group that represents all the interests and agencies.

Targets and time frames must also be set for this Tier of indicators. However, because these indicators are specific to the task forces or inter-agency committees that create them, they must also be determined by the same group. They should be more specific in terms of the target values; rather than ranges, they should target key values and the time frames should be shorter, so that a quicker feedback loop can occur.

It is also worth noting that these Tier 2 indicators may vary drastically from one city to another. As many cities have different contextual issues, it is up to Tier 2 indicators to capture them. For example, the different political structures, ecological systems, and even climate differences of a city must be considered in these indicators. These are often not transferable to other cities, since they are specifically catered to the city authoring them.

**Tier 3: Policy Driven Indicators**

Taking knowledge and acting upon it or operationalizing it into something that policy makers can use is particularly challenging. Often, the general goals of Tier 1 indicator sets are too vague. For example, there is no clear path of policies that should be enacted that will get a city towards cleaner water, or healthy citizens. Conversely, Tier 2 indicators are too technical. A complex air quality index calculation also cannot provide clear direction for policy-makers. Thus, a specific Tier of policy-relevant indicators must be developed. The knowledge from the other Tiers of indicators can feed into these indicators to propose specific policies that fit the needs of a particular city.

Like Tier 2, Tier 3 indicators are specifically designed around the needs of the city utilizing them. They are difficult to compare to other cities, as they represent contextual issues that are specific to that city, such as climate, political structures, and social implications. When thinking about policy, the key difference between policy relevant indicators and non-relevant indicators is the understanding of the political system. Thus, each city is likely to have different needs for policy relevance, depending on the process by which policy and programs are made. The specific processes of analysis of local policy must be considered in Tier 3.  

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48 (Innes, Knowledge and Public Policy: The Search for Meaningful Indicators 1990)
These Tier 3 indicators are unique in that they are written by the technical experts for policy makers. In particular, given the success of the integrated manner of working, it would be ideal to have a separate committee or task force combining some of the experts that work on Tier 2 indicators with professionals that are well immersed in the political system of the city. But, it is also important that current policy-makers must not serve on this committee or task force; otherwise, their interests in certain policies may cause them to generate biased indicators. It is ideal for the group creating Tier 3 indicators to be representative of a range of political interests. While these indicators should be policy relevant, they should not be too easily biased.

The targets and time frame for these indicators would follow the needs of the structure of the local political system as well. Innes discusses the critical need for indicators that can evolve as contexts and politics change within a city. Otherwise, they become irrelevant to policy makers and the general public. A rotating set people may be involved in the committees for Tier 3 indicators depending on the issue or context as well. However, it is important to still maintain consistency despite utilizing different people for different indicators. Innes emphasizes the need to use standardized methods within a city in order to remain true to the concepts in Tier 1.49

There are not many good examples of indicator systems that are well designed for policy-making; however, the Bureau of Labor Statistics (BLS) is one example of the type of independent group that should work on Tier 3 indicators. The group is removed enough from politics that the statistics they produce are not biased to current political leanings, allowing them to be critical. They target both general public and politicians with their indicators and statistics. For example, the employment statistics collected by the BLS, which includes the Employment Cost Index, and the Employer Cost for Employee Compensation indicators are used in both public and private sectors. Public policy uses these indicators to formulate monetary policy and understand the state of the American public's finances. In conjunction with the Consumer Expenditure Survey, also done by the BLS, policy makers can determine if minimum wage needs to be raised, or if savings programs should be encouraged, or if interest rates should be adjusted. The CEQ is also an example of centralized means of getting independent feedback on environmental performance. Unlike the BLS, the CEQ was more active in evaluating the environmental performance of each federal agency. Once the reporting responsibility fell back to the separate agencies, their reports lost credibility in that they were now being produced by the groups that were being evaluated.50

49 (Innes, Knowledge and Public Policy: The Search for Meaningful Indicators 1990)
50 (Rogers, Jalal and Boyd 2008)
A combination of the environmental measures of the CEQ, and the policy-relevance of the BLS measures and indicators would be ideal for Tier 3. These indicators could bridge between technical issues, and propose policies that could bring results that are directly targeted to the needs of Tier 1 and 2. Further, many city policies only address environmental issues as problems arise. After a lake is polluted, or the ground is contaminated, policies are developed to avoid future harm. However, using knowledge from Tier 2, Tier 3 can propose policies that could potentially prevent damage. These policies could also be more progressive in their proposals, thinking beyond the existing policies. Even further, cities could use Tier 3 as an opportunity to evaluate new policies, and help refine and evolve them over time.

**Tier 4: Feedback indicator**

Finally, Tier 4 indicators feedbacks performance in terms of Tier 1 goals. Tier 4 indicators are not technical, but communicative. They must be easily understood by everyone. The main goal of Tier 4 is to provide some feedback to individuals and businesses in the city so that they can make daily decisions around this information. Tier 4 aligns with the Tier 1 goals, but adds a layer of communication principles.

Tier 4 indicators should be designed so that people can react to the information; thus, it must not be too vague or too technical. In many ways, Tier 4 is rooted in marketing and communication tactics. Thus, following marketing principles, sustainability information for the general public cannot be pure fact, but must also involve a story that people can identify with. One of the most successful advertising campaigns drew on concepts from Joseph Campbell's *The Hero with a Thousand Faces*, where the common archetypes that are shared across nations and cultures were used to engage people in the messages. Utilizing this concept, the apple computer campaign in the 1984 Super Bowl transformed the image of the computers and created a specific personality around the computer. Even today, the slogan "I'm a mac" is internationally known and engaging through other versions of the apple computer advertisement.51

The particular strategies for the advertisements also go beyond utilizing personality archetypes and stories to incorporate four key marketing tactics - segmentation, targeting, positioning, and differentiation are all utilized in the successful campaigns.52 Further, Diffusion Theory describes the acceptance of innovations and ideas into the public realm. The rate of adoption by the public changes over time. Early only a small group adopt, encompassing about 2.5% of the population; these people are called the "innovators," who may very quickly adopt new ideas or products at high risk to themselves. After innovators, "early

51 (Sachs and Finkelpearl 2010)
52 (Yudelson, Marketing Green Building Services: Strategies for Success 2008)
adopter," who are slightly more risk-sensitive, make up 13.5% market share. At a certain point, the theory also describes a "critical mass," where adoption of the innovation has hit a turning point and the rest of the market adoption becomes self-sustaining. Reaching the critical mass is the difficult part, since innovations that do not cross past this stage often are forgotten and never reach full adoption. In order to work within this diffusion principle, the 4 key strategies of segmentation, targeting, positioning, and differentiation are used by most marketing firms. Segmentation is the process of truly understanding the market and breaking it up by demographics, geography, or other groups. Targeting then allows marketing campaigns to select one of the segmented groups to focus on. Finally, positioning and differentiation begin to create a unique role for the innovation, which can then be leveraged to acquire more segments of the market or to gain a larger portion of the targeted segment. Looking back to the apple computer ads, they utilize these tactics by targeting ads toward a particular demographic, and by differentiating their product and creating an iconic role for themselves in the computer industry.

In many ways, at the scale of the city, the scope of the proposed sustainable indicators already has defined a segment of the market to target. However, these marketing and advertising strategies further engage people to see themselves using a product or innovation. For sustainable cities, the strategies must be used to encourage people to change their behavior and make different decisions on a daily basis. Communicating Tier 4 indicators may require the use of different tactics, aimed at different demographics. Like the diffusion theory states, innovations typically only have a small group that make up the innovators and early adopters. But, gaining acceptance is not enough, as is typical with sustainability movements. Once early adopters accept an idea or innovation, critical mass must still be reached in order for the majority groups that comprise 74% of the population to also adopt. The Diffusion Theory also indicates several strategies to get to critical mass. Utilizing change agents or highly respected groups in a society can help convince others to adopt. For example, strongly accepted political leaders or popular celebrity figures can strongly influence public opinion. Other tactics include implying that adoption of the innovation is inevitable, or targeting introduction of the innovation to the most innovative groups rather than the general public. Finally, a popular tactic is incentives. Many innovations offer free services or special deals for early adopters. Thus, going by the Diffusion Theory, blindly attempting to advocate sustainability to all groups in the general public could result in no acceptance. The Tier 4 indicators should strategically target people or groups from the general public that are more likely to adopt and utilize the indicators first. Then, after an initial group has accepted these indicators, should these indicators begin to target other groups.

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53 (E. M. Rogers 2003)  
54 (E. M. Rogers 2003)
Many sustainable movements and campaigns have found the internet to be another means to engage people worldwide. Further, the new popularity of social networking, which not only provides one-way information, but encourages discussions and commenting, has been another outlet to encourage sustainable decision-making on the individual level. An example of this engagement is the campaign 350.org and the website co2now.org. 350.org is a blog that encourages decisions towards reducing CO2 in the atmosphere. The website also includes a CO2 indicator measure, which comes from the co2now.org website. It is a straightforward measure shared on the web. The website also has a target value for the indicator. Annual CO2 levels are from the co2now.org website, but the 350.org campaign has further outlined a target of 350 ppm of CO2 in the atmosphere.

The 4th Tier must be a sensitive indicator, that can show change on, at least, a monthly basis for each city, unlike the other Tiers which may be updated anywhere from 1-5 years. One of the downfalls of the 350.org and co2now.org websites are that the CO2 measures are an average annual value. The lack of change of this value does not incentivize changes in daily decisions. The indicator using an annual, global CO2 level, while important for climate change issues, seems very distant to the individual and thereby not quite scaled to the daily individual actions the indicator is trying to target. Part of the issue is that 350.org and similar websites are international campaigns. Tier 4 in this city indicator system has a much smaller scale audience. The indicator measurement should only capture city-scale phenomena, and must be updated monthly in order to be relevant to the daily decisions of residents in the city.

Further, vagueness must be balanced with technical information for these types of Tier 4 indicators. One popular indicator system that has been scrutinized is the U.S. Homeland Security Agency’s color code system to convey national security threats. The scale is not only too simplistic, but the indicator system

55 (Sachs and Finkelpearl 2010)
56 (350.org n.d.)
became a joke in both political and general public forums, associating the colors with childish naiveté.\textsuperscript{57} Many conjectured that the system even had the opposite effect, where people ignore and turn away from alertness because of the vagueness.\textsuperscript{58} The Congressional Research Service eventually outlined ways to improve the system in a public policy report. One of the major changes proposed was specificity and targeting these specific messages to cities and regions. Thus, scaling indicators to cities are an important means of reaching and engaging individuals. Further, specificity and credible information are also important, as no one will change behavior from an indicator system that insults the general public’s intelligence.

Thus, Tier 4 indicators should apply communications theories to make them useful for the general public. These indicators would depict the status of Tier 1 goals, but also present the information in a way that is useful to people on a daily basis. The design of this Tier of indicators is highly complex when compared to Tier 1-3. There needs to be an understanding of the market segments in a city, catering the marketing strategy to the specific group. Further, the indicator cannot just be simply released to the public, but must be advertised strategically. Balancing simplicity with information and catering it to different groups will be a difficult task for cities. Thus, the Tier 4 indicators should be created and marketed with communication and marketing specialists.

\textit{Comparing Cities}

These Tier 4 indicators should also be consistent from one city to another so that performance can be compared. Thus, when comparing the sustainability of cities, Tier 1 would show relationship of goals, and Tier 4 would show the relative performance. Thus, if a city such as Malmo, Sweden were to compare itself to Vaxjo, Sweden, they would first notice that their Tier 1 indicators are very similar. Malmo, a city that has often been praised for their planning and energy management towards sustainability, would most likely adopt Tier 1 indicators relating to their goals of achieving 100\% renewable energy using their new developments to provide value to the existing town. On the other hand Vaxjo also clearly states their goals for a fossil fuel free city. Both cities have very similar goals, although their specific contexts and sustainable strategies may differ. As such, Tier 4 strategies for both cities would also be similar as a result of their Tier 1 goals. However, it is important to note that there are slight differences in the goals as well. Fossil fuel reductions in Vaxjo also rely on transportation planning and policy focuses that Malmo does not

\textsuperscript{57} (Brigham 2005)  
\textsuperscript{58} (Lee 2003)
focus on in their renewable energy discussions. Thus, Malmo may compare Tier 1 and 4 indicators to Vaxjo’s, but it is likely their detailed Tier 2 and 3 indicators will be slightly different.

The tiered indicator system may also be used to establish that two cities have very different goals and cannot use each other as case studies. This incongruity can be seen when comparing Minneapolis, Minnesota and Vaxjo, Sweden. Minneapolis created a set of 26 sustainability indicators, but there is no sense of an overarching goal is. The 26 indicators range from health issues, such as teen pregnancy and infant mortality, to air quality, tree canopies, and social issues like unemployment and homelessness. These 26 may be better as Tier 2 or 3 indicators, given their detail. However, without a Tier 1, or some concept or overarching goal, it is difficult to compare Vaxjo and Minneapolis. Given the 26 goals, and the common theme of increasing general wellbeing while minimizing its impact on the environment, the actions and strategies Minneapolis takes will likely be very different. This is very clearly depicted when comparing Minneapolis' renewable energy and climate change goals of reducing CO2 by 17% in 2020, and adding 1 Mw renewable energy to the city energy mix.\footnote{(City of Minneapolis n.d.)} Compared to Vaxjo and Malmo's goals of complete transition to renewable energy or removable of fossil fuels, there is a very different set of priorities between the Minneapolis and Vaxjo or Malmo.

**Structuring the Tiers**

The term tiered indicators implies a hierarchy of indicators, however, the structure of the Tiers actually describes the sequence of implementation. Cities may determine the sequencing and structuring of the Tiers. Some cities may have different needs or constraints that require one structure over another. There are two basic forms of structures for the Tiers that cities may use or adapt. One structure is a vertical organization. In the vertical order, indicators trickle down the Tiers, and finally, receive information back from Tier 4. This indicates that a city will work in a linear fashion, moving from Tier 1 to Tier 4 sequentially (Figure 12). This structure allows cities to focus their resources on each Tier, but takes more time. In particular, this works well for cities with fewer resources and more time available. However, because of the linear sequencing, the indicators or information collected for the indicators may become outdated by the time Tier 4 is reached. Thus, with this structure, fewer resources are required, but the timing will be very important to maintain momentum and maintain the indicator system.
Structuring the four Tiers in a vertical order implies a different relationship between the four than the second basic type, called the horizontal order (Figure 13). In the horizontal order, Tiers 2, 3 and 4 may work in conjunction with each other. In this case, Tier 1 must still be established first so that the main goals are in place before working on technical, policy-oriented, or feedback indicators. The horizontal structure requires more resources to maintain, however, the timing can be much shorter than with the vertical structure since Tiers 2-4 are established at the same time.
These different organizations imply a different working relationship. The vertical is more simple, and most likely easier to implement for most city municipal structures, but the horizontal could potentially provide an even more integrated system of indicators. There is opportunity for Tiers 2-4 to collaborate and develop more meaningful indicators. Tier 2 and 3, the technical and policy-oriented indicators can collaborate and provide share their indicator needs. For example, if a clean air policy is being discussed, Tier 3 and Tier 2 can both work that issue into their indicators, without having to wait for each other. Further, Tier 4 can be implemented earlier and pick up some of the excitement after the development of Tier 1. It also gives Tier 4 more time to be adopted by the general public.

**Limitations**

Many criticize sustainable indicators for attempting to simplify a complex issue, which may result in some aspects being lost or misrepresented. Critiques of misrepresentation originate from the ability to skew or bias statistics and data. Tier 2 and 3 are clearly susceptible to this kind of manipulation since cities are left to customize the indicators to their needs. Oftentimes, authors of indicators and the researchers who generate the statistics bring their own personal experience and considerations in. Further, sustainability
calls for an entirely different way of approaching problems which may not be in the mindset of the people writing these indicators. Anderson, Amodeo, and Hartzfeld, discuss cultural shifts in corporate moves towards sustainability. In particular, they note that it is not for a lack of technical information, but an inability to change outdated perspectives that holds our society back from sustainability. Thus, there are many potential lost opportunities when authors fail to shift out of their paradigms of thinking.

More practically, creating and using indicators is also very time and resource intensive. Systems that are created quickly tend to be less effective, and fall into the same weaknesses discussed earlier in the paper. Thus, cities must find ways of funding the participatory process with the general public to create Tier 1 indicators, and support the various task forces made up of researchers, scientists, policy makers, and professional experts creating Tier 2 and 3 indicators. Further Tier 4 involves sophisticated understanding of marketing and communication, which results in the need to bring in experts from those disciplines as well. It is also time consuming to generate these indicators for the first time, and allow for time in use to evolve and tweak the indicators. Many of these lessons come from extended periods of monitoring and additional assessment. Thus, local authorities would need to find the funding to support all these activities for an extended period of time. Or, alternatively, federal programs could be established to support local indicator creation and use, taking the pressure off of creating a national system for measuring sustainability.

But, one of the advantages of using the Tiers to compare cities and find cities with similar goals and situations is that funding and financing knowledge can also be transferred. If cities like St. Paul or Minneapolis decide to use Vaxjo, Sweden as a model, they can also learn from their funding mechanisms, as well as their sustainability policies and programs.

Finally, it can be seen that poorly constructed indicators are not only ineffective, but take up resources that could have gone toward other local projects. The Macnaghten study reveals that the time and resources spent in Lancashire to produce sustainable indicators was essentially wasted when people responded negatively not only to the specific indicators but to the definition of sustainability and the intentions of the local government. In this instance, the indicators also had an alienating effect, as people felt the government was imposing upon them actions that did not align with their ideas of sustainability. Thus, it is important to take on sustainable indicators with a full understanding of the resources needed and the importance of public acceptance, otherwise, the effort will be wasted.

60 (Anderson, Amodeo and Hartzfeld 2010)
61 (Innes, Knowledge and Public Policy: The Search for Meaningful Indicators 1990)
While indicators are difficult and complicated, and pose a risk of loss to cities if they are not useful, there are many advantages to using a multi-tier evaluation system. With multiple Tiers, there is a possibility that some Tiers may be effective, while others may not. Thus, the entire effort is not wasted. Further, allowing for evolution and change over time of indicators opens the possibility of indicators towards a paradigm shift discussed by Anderson, et al.\textsuperscript{62} In the end, there is a lot that can learned even in the process of creating indicators, which makes the process and the systems valuable for cities, even if the final result is not a perfect set of measurements.

**Conclusions**

In conclusion, the use of a tiered, or multi-level, indicator set for cities may resolve many of the failings of traditional sustainable indicators. The proposed Tiers attempt to create processes that allow for publicly accepted overarching goals to working groups that can discuss the complex interactions of various aspects of the environment, society, and economics. Finally, addressing policy relevance puts emphasis on the need to carry the knowledge from indicators forward into actions, policies, and programs.

Not only is the tiered sustainable indicator a useful tool for cities to come together and address their sustainability goals, it is also a means for researchers and cities to compare indicators across cities and nations. One of the main goals of the project was to find a way to compare case studies of exemplary sustainability strategies in cities, and transfer the knowledge to cities that are only beginning the sustainability discourses. In the tiered indicators, there is less pressure to create a fully consistent indicator set for every city, and attempt to meet the needs and contextual issues of each. At the same time, there are Tiers that can be consistent, so that key goals and progress can still be compared. The UN Commission on Sustainable Development’s Sustainable Indicator set runs into this problem. Out of the 50 core indicators, there are many that deal with social justice and equality issues in developing nations. It is even noted in the UN handbook that countries need to adjust the indicators that work for them. Thus, there is already a need for different indicators for developing versus developed nations. At the same time, there are many more differences that need to be captured moving from one city to the next. The role of Tiers, with different audiences and purposes for the Tiers can achieve this balance of comparability and customization.

Further, the lessons of the Tiers comes from social sciences, which has been struggling to define ways to quantify difficult, intangible issues, so that relationships can be understood, and action towards improvement taken. In many ways, the fuzzy nature of social sciences relates to the difficulty of the

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\textsuperscript{62} (Anderson, Amodeo and Hartzfeld 2010)
sustainability problem. Sustainability goes beyond the scope of environment and ecological welfare, to human quality of life, social justice, and economic stability. And while there are a number of quantitative measures, the qualitative measures tend to be forgotten. Thus, the use of social science and lessons from tiered social indicators can help bring the discussion back into a more holistic view of sustainability that considers the whole city as a system, rather than individual parts.

Implications

This project arose out of an initial research proposal that studied various sustainable city projects. In attempting multiple case studies of these projects, it became more difficult to come to any conclusions about the projects. It was unclear whether one city was more successful than another, and if the strategies could be applied to other cities and have the same success. As more information was gathered about each case study city, it became clear that I needed a different approach to study and compare these sustainable cities, which led me to sustainable indicators.

At that point, I planned to use an indicator system to evaluate each of my case studies. But, the research on indicators expanded and grew into its own project. Surprisingly, sustainable indicators were as ambiguous and wide ranging a topic as sustainable cities. The key emerging theme out of my first research proposal was that there was no good way to consistently study city sustainability, compare the cities, and apply their strategies successfully to other cities. Aside from the interest in evaluating sustainability programs and policies in successful cities, there is a great need to discuss how to take those lessons and apply them appropriately to other cities that have very different contexts. In order to address global sustainability, it seemed that my project would have to first address a more rigorous means to study sustainability before even evaluating city progress to date.

Thus, what began as tangential research for another project, has since taken on a life of its own. In the end, the study of sustainable indicators turned out to be far more interesting. There are further studies that can grow out of this project. Applying the framework to measuring several cities would provide great insight as to the operational challenges that might arise. Much like Macnaghten's study of Lancashire, applying the framework, and interviewing various stakeholders could help refine the framework into a tool.
350.org.


City of Minneapolis.

City of Vaxjo. "Climate Strategy of Vaxjo."


### Appendix A: Comparison of Existing Sustainability Indicator Systems

<table>
<thead>
<tr>
<th>Framework</th>
<th>LEED-ND</th>
<th>Hart</th>
<th>ICLEI LGO</th>
<th>AMOeba</th>
<th>Seattle</th>
<th>Minneapolis</th>
<th>Norwich 21</th>
<th>Genuine Progress Indicator</th>
<th>UN CSD v3</th>
<th>OECD</th>
<th>GHG Accounting</th>
<th>Eco-Footprint</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Intended scale</strong></td>
<td>Community</td>
<td>Community</td>
<td>City</td>
<td>City</td>
<td>City</td>
<td>City</td>
<td>Nation</td>
<td>Nation</td>
<td>Nation</td>
<td>Nation</td>
<td>Nation</td>
<td>City, Corporation, Individual</td>
</tr>
<tr>
<td><strong>Calculation Foundation</strong></td>
<td>None</td>
<td>None</td>
<td>IPCC / EPA / GHG Protocol</td>
<td>MSY / Kuznets</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>Monetary</td>
<td>UN</td>
<td>UN</td>
<td>IPCC / EPA</td>
<td>GFN</td>
</tr>
<tr>
<td><strong>Number of Indicators</strong></td>
<td>10-40</td>
<td>100+</td>
<td>1-10</td>
<td>1-10</td>
<td>10-40</td>
<td>10-40</td>
<td>10-40</td>
<td>10-40</td>
<td>40-100</td>
<td>40-100</td>
<td>1-10</td>
<td>1-10</td>
</tr>
<tr>
<td><strong>Precision</strong></td>
<td>Whole number points</td>
<td>Undefined</td>
<td>Thousandths (given by the equivalence factors)</td>
<td>Whole number percentage</td>
<td>Undefined</td>
<td>Undefined</td>
<td>Undefined</td>
<td>Whole dollar</td>
<td>Undefined</td>
<td>Undefined</td>
<td>Thousandths (given by the equivalence factors)</td>
<td>Thousandths (given by the equivalence factors)</td>
</tr>
<tr>
<td><strong>Transparency</strong></td>
<td>Semi Open requires purchase of reference book</td>
<td>Open - Available in reference book and online for free</td>
<td>Open - System follows publically available GHG Protocols for Corporations; also published on ICLEI website</td>
<td>Semi Open - Published literature available, but not easy to replicate calculations</td>
<td>Open - Reports available online</td>
<td>Open - Report formerly available online, now system is no longer used</td>
<td>Open - Report available online</td>
<td>Open - Specific calculations not easy to replicate</td>
<td>Semi Open - Report available online</td>
<td>Open - Report available online</td>
<td>Open - Tools and reports available online</td>
<td>Closed - Reports available online, but specifics of calculation not published</td>
</tr>
<tr>
<td><strong>Communicability to Public</strong></td>
<td>Clear - Results categorized into platinum, gold, silver, and certified</td>
<td>Not clear - Too many factors, no clear results</td>
<td>Clear - Results are in CO2, NOx, SOx emissions</td>
<td>Clear - Graphic and scale are simple to understand</td>
<td>Fairly Clear - Concise set of factors, but no clear results</td>
<td>Fairly Clear - Concise set of factors, but no clear results</td>
<td>Fairly Clear - Concise set of factors, but no clear results</td>
<td>Clear - Results given in dollars</td>
<td>Not clear - Too many factors, no clear results</td>
<td>Not clear - Too many factors, no clear results</td>
<td>Clear - Results in CO2, NOx, SOx emissions</td>
<td>Clear - Results are in global hectares of land, or number of earths</td>
</tr>
<tr>
<td><strong>Linked to Policy</strong></td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes - Grassroots factors can be translated into local policy</td>
<td>Yes - Developed by local policymakers</td>
<td>Yes - Developed with policy in mind</td>
<td>No</td>
<td>Yes - Developed as international sustainable development guidelines</td>
<td>Yes - Developed as international sustainable development guidelines</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>LEED-ND</td>
<td>Hart</td>
<td>ICLEI-LGO</td>
<td>AMOeba</td>
<td>Seattle</td>
<td>Minneapolis</td>
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<td></td>
</tr>
<tr>
<td>Extent of context included</td>
<td>Captures existing site and buildings</td>
<td>Captures many social factors</td>
<td>No contextual factors included</td>
<td>Captures only factors of concern to the authors</td>
<td>Captures only factors of concern to the authors</td>
<td>Captures only factors of concern to the authors</td>
<td>No contextual factors included</td>
<td>Not region specific enough to capture contextual issues</td>
<td>Not region specific enough to capture contextual issues</td>
<td>No contextual factors included</td>
<td>No contextual factors included</td>
<td></td>
</tr>
<tr>
<td>Intended audience</td>
<td>Developers, city planners</td>
<td>City government</td>
<td>City government</td>
<td>Technical Experts</td>
<td>City government</td>
<td>City government</td>
<td>City government</td>
<td>National government</td>
<td>National government</td>
<td>National government</td>
<td>City government, corporations, individuals</td>
<td>National and city government, corporations, individuals</td>
</tr>
<tr>
<td>Type</td>
<td>Checklist</td>
<td>Checklist</td>
<td>Index</td>
<td>Graphic Index</td>
<td>Checklist</td>
<td>Checklist</td>
<td>Checklist</td>
<td>Index</td>
<td>Checklist</td>
<td>Checklist</td>
<td>Index</td>
<td></td>
</tr>
<tr>
<td>Strengths</td>
<td>Considers design from site to buildings.</td>
<td>Captures many social, economic, and environmental factors.</td>
<td>Considers city government operations.</td>
<td>Easy to communicate.</td>
<td>Meets the perceived needs of Seattle.</td>
<td>Meets the perceived needs of Minneapolis.</td>
<td>Meets the perceived needs of Norwich.</td>
<td>Captures many more factors than the traditional GDP indicator.</td>
<td>Captures global sustainability concerns.</td>
<td>Captures global sustainability concerns.</td>
<td>Considers from a number of industries.</td>
<td>Considers consumption.</td>
</tr>
<tr>
<td>Weaknesses</td>
<td>Not large enough scope.</td>
<td>Too many indicators make it difficult for cities to use, and for people to understand.</td>
<td>Does not capture consumption of city residents.</td>
<td>Does not capture anything beyond species population.</td>
<td>Not easily comparable with other cities or usable to other cities.</td>
<td>Not easily comparable with other cities or usable to other cities.</td>
<td>Not easily comparable with other cities or usable to other cities.</td>
<td>Not easily used by cities.</td>
<td>Not specific to developed cities.</td>
<td>Complex and extensive undertaking for a city.</td>
<td>Complex and extensive undertaking for a city.</td>
<td></td>
</tr>
</tbody>
</table>