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Analyzing the sustainability performance of public transit

Patrick Miller *, Alexandre G. de Barros, Lina Kattan, S.C. Wirasinghe

University of Calgary, 2500 University Dr NW, Calgary, AB T2N 1N4, Canada

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ABSTRACT

In recent years there have been many advances in understanding how transportation can promote or detract from sustainability. The role of public transit has been established as a critical element in promoting sustainable and vibrant cities. While decision making tools, such as composite indices, have been developed to understand overall urban and transportation sustainability, few tools exist to directly analyze public transit systems based on sustainability criteria.

This paper introduces the Public Transit Sustainable Mobility Analysis Tool (PTSMAT) framework, which uses composite sustainability index techniques along with research into transport sustainability to propose a new transit analysis tool that can be used in both planning/decision making and research contexts. First, this paper reviews definitions of sustainability and sustainable transport, and sustainability analysis tools and relates them back to a legible analytic framework for public transit systems. Next, the PTMSAT framework is introduced along with a description of its data collection, data analysis, and index calculation processes. The application of PTSMAT to decision making and research scenarios is also outlined. A summary of relevant indicators for public transits sustainability and integrates them into the PTSMAT framework using a quadruple bottom line approach. Next, a case study of the framework's application is provided for the UBC Corridor study in Vancouver, Canada. This case study demonstrates how the tool may be used to inform decision making and planning efforts.

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Introduction

Background and research questions

Public transit is often cited in research and policy as a key tool to achieving sustainable urbanization. However, developing or expanding transit systems is an expensive process with a variety of urban and regional impacts. While studies such as Kennedy (2002) agree transit has a positive role in reaching sustainability goals and there are many indicator frameworks for understanding how transportation on a whole can be assessed with respect to sustainability, there are limited tools to clearly qualify and quantify the extent to which a particular transit system or transit project alternative will contribute to sustainability goals. Many studies have focussed on comparing individual transit modes (e.g. BRT compared to rail in Rahman (2009)), or looked at understanding the environmental impacts of a specific system/geography, such as Kane (2010), but do not fully address the planning, development, and operations of a general transit system in a holistic sense. Cost benefit

* Corresponding author.
E-mail addresses: patrick.bv.miller@gmail.com (P. Miller), debarros@ucalgary.ca (A.G. de Barros), lkattan@ucalgary.ca (L. Kattan), wirasing@ucalgary.ca (S.C. Wirasinghe).

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analysis, a common approach to assessment, may not be able to capture system impacts that are not readily monetized, or may undervalue certain impacts.

Composite sustainability indices (CSI) are a relatively new technique used to understand the wide ranging sustainability impacts and benefits of policies and projects. A CSI framework rely on the use of weighting and normalization techniques. Normalization is a process that ensures that different variables become comparable so they can be summed up (Nardo et al., 2005). In addition, allocating different weights for each criteria relative to one another is an important step in a CSI framework to reflect the decision making policy and priorities (Sinha and Labi, 2007). Recently CSIs have found use in other transportation studies to determine the overall sustainability of transport systems based on historic or foretasted data. These studies have shown how CSIs can provide insight into managing and developing transport systems. Studies have explored different growth plans and their impacts on urban sustainability (Jeon and Amekudzi, 2005), or on how numerous urban factors at a city scale can also enable sustainability (Haghshenas and Vaziri, 2012). However, the use of the CSI approach for transit system sustainability evaluation, to aid in the understanding of transit performance or the potential success of a future transit project have not been explored.

This research addresses three critical questions in the field of public transit and the application of sustainability assessment through the application of CSIs to public transit. These questions are:

- What is a legible CSI framework that can assess the contributions of public transit to sustainable mobility?
- How can CSI techniques be used in modal comparison to understand how different transit modes and systems compare in the delivery of sustainable mobility?
- How do different weighting and normalization techniques impact CSI development for public transit analysis?

To answer these questions, this paper outlines the development and application of the Public Transport Sustainable Mobility Analysis Project (PTSMAT) framework PTSMAT – an analytic framework developed for analyzing the extent to which a public transit system or planned transit improvement contributes to sustainable mobility. Within this framework, different weighting and normalization techniques can be applied and are tested in this paper to clarify their impact on public transit analysis. Additionally, this framework sets out how to use CSI tools to aid in decision making and research settings through theoretical developments and a case study.

The development of the PTSMAT framework is demonstrated through a three steps process:

(1) A thorough critical literature review to identify sustainability analysis and CSI tools, indicators, and techniques that may be applicable to public transit.
(2) Appropriate indicators and techniques are selected to create a new framework (PTSMAT) capable of assessing a public transit system's sustainability performance.
(3) The PTSMAT framework is applied to planning data from Vancouver, BC, Canada in order to demonstrate the tool's use based on three different normalization techniques and two weighting techniques.

The contributions of this research are thus two fold. First is develops a PTSMAT framework – which provides a legible tool based on summing different sustainability factors into a CSI that reflects the sustainability performance of the transit system being analyzed. Second, it demonstrates the application of three different normalization techniques to public transit analysis and also outlines how to resolve weighting issues through a stochastic Monte Carlo based technique.

The rest of the article is organized as follows. First, the PTSMAT framework is described in a three part methodology. As part of this outline, the article details the specific indicators that have been selected for studying transit systems based on current practice and understanding of sustainable transportation from a comprehensive literature review. Next, the article shares how the methodology is utilized across three alternative techniques for developing composite indices – the z score approach, the reference value approach, and the rescaling approach. The article then compares these three approaches for calculating composite sustainability indices (CSI), and contrasts this methodology to other sustainability analysis methodologies from the literature. Finally, the paper concludes with key findings from applying this methodology and how it could be expanded or improved in future studies to provide a more comprehensive understanding of the sustainability of public transportation.

Sustainability literature review

Sustainability is commonly explored in terms of the theories of sustainable development. A commonly used definition of sustainability comes from the Brundtland Commission's report, Our Common Future, "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987). While this definition was not the first appearance of the general idea of sustainable development, it is seen as the first widely utilized definition and the report is commonly referred to as the first credible study on this subject (Theis, 2012).

One way in which sustainability can readily be applied to research and decision making is through the triple-bottom line framework, which breaks sustainability into environmental, economic, and social categories (Theis, 2012; Black, 2010; Jeon,

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