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Time-based life-cycle assessment for environmental policymaking: Greenhouse gas reduction goals and public transit

Mikhail V. Chester *, Alex Cano [1]

Civil, Environmental, and Sustainable Engineering, Arizona State University, 660 S College Avenue, Tempe, AZ 85287-3005, USA

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ABSTRACT

As decision-makers increasingly embrace life-cycle assessment (LCA) and target transportation services for regional environmental goals, it becomes imperative that outcomes from changes to transportation infrastructure systems are accurately estimated. Greenhouse gas (GHG) reduction policies have created interest in better understanding how public transit systems reduce emissions. Yet the use of average emission factors (e.g., grams CO_2e per distance traveled) persists as the state-of-the-art masking the variations in emissions across time, and confounding the ability to accurately estimate the environmental effects from changes to transit infrastructure and travel behavior. An LCA is developed of the Expo light rail line and a competing car trip (in Los Angeles, California) that includes vehicle, infrastructure, and energy production processes, in addition to propulsion. When results are normalized per passenger kilometer traveled (PKT), life-cycle processes increase energy use and GHG emissions up to 83%, and up to 690% for smog and respiratory impact potentials. However, the use of a time-independent PKT normalization obfuscates a decision-maker's ability to understand whether the deployment of a transit system reduces emissions below a future year policy target (e.g., 80% of 1990 emissions by 2050). The year-by-year marginal effects of the decision to deploy the Expo line are developed including reductions in automobile travel. The time-based marginal results provide clearer explanations for how environmental effects in a region change and the critical life-cycle processes that should be targeted to achieve policy targets. It shows when environmental impacts payback and how much reduction is achieved by a policy-specified future year.

Introduction

Environmental life-cycle assessment (LCA) is becoming more frequently utilized to understand the direct, indirect, and supply chain impacts of transportation systems. Cities are increasingly developing sustainability plans that call for coupled air quality improvement and greenhouse gas (GHG) emissions reductions, and strategies often target passenger transportation systems, given their large share of emissions across urban activities. These strategies often include vehicle fuel economy improvements, fuel switching, improved emission control devices, and mode shifting from personal automobile travel to

* Corresponding author. Tel.: +1 480 965 9779.
E-mail addresses: mchester@asu.edu (M.V. Chester), acano3@asu.edu (A. Cano).
[1] Tel.: +1 559 892 9913.

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public transit, biking, and walking. LCA practitioners have begun developing methods for comprehensively assessing the impacts of passenger transportation systems to aid in assessing these strategies. At an urban or regional scale, LCA frameworks have been developed for city-wide assessments of personal vehicle use (Fraser and Chester, 2016; Kimball, 2014), the efficiency of transit configurations (Griswold et al., 2013), comparative assessment of personal vehicle and public transit use (Chester and Horvath, 2009; Chester et al., 2013), and the potential benefits of fuels and public transit vehicle technologies (Cooney et al., 2013). Transportation LCAs have provided great value in identifying (i) how transportation vehicles cannot operate in isolation but require extensive infrastructure, operations, and supply chains to support them and (ii) that the impacts of urban sustainability mobility decisions can have consequences (both positive and negative) far beyond the geopolitical boundary where policies are instituted. There remains, however, a gap in our understanding of how life-cycle effects accrue over time and how time-based life-cycle results (such as the changes in GHG emissions that result from the decision to deploy transit) can be positioned to aid policymakers when establishing future year targets (such as reducing GHG emissions to 20% of 1990 levels by 2050).

A time-based LCA framework is needed for sustainable mobility policymaking and we develop such a framework using Los Angeles Metro's new Exposition light rail line as a case study. The Expo line is being positioned to help Los Angeles meet Assembly Bill 32's (AB32) GHG goals. AB32 directs California to meet 1990 GHG emissions by 2020 and 20% of 1990 GHG emissions by 2050 (CARB, 2006). The companion Senate Bill 375 (SB375) calls for metropolitan planning organizations to develop strategies that consider the integration of transportation and land use planning to reduce GHG emissions. The deployment of new public transit options (as well as biking and walking) is at the center of many city plans to meet AB32 goals yet little information exists that characterizes the life-cycle costs and benefits over time of the decision to deploy new transit options and whether these life-cycle effects accrue to produce enough emissions reductions by 2020 and 2050 (in this case) to meet policy targets. More generally, however, improved thinking is needed for characterizing how the impacts from the deployment of a new transit system (e.g., the construction of tracks and stations, and the manufacturing of trains) results in significant upfront emissions that enable lower impact travel. Fundamentally, the time-based assessment of life-cycle effects moves policymakers towards considering the marginal impacts of decisions and away from the attributional (or average) thinking which seeks to allocate impacts in the life-cycle without consideration for when they occur (Eisenstein et al., 2013; Plevin et al., 2014).

Using the Los Angeles Metro's Expo line, a time-based LCA framework is developed that includes vehicle (manufacturing and maintenance), infrastructure (construction, operation, and maintenance) and energy production life-cycle processes and their supply chains, in addition to vehicle propulsion. Energy use and air emissions (greenhouse gases and conventional air pollutants) are assessed. The framework advances the existing state-of-the-art approach in passenger transportation LCA by analyzing life-cycle processes at the time they occur, thereby creating an opportunity to assess how policies and decisions that implement transit to reduce emissions (a) produce emissions during construction (i.e., capital investment), (b) produce emissions from the operation of the transit system, but then (c) potentially avoid emissions by shifting passengers out of cars (and other modes). Ultimately, at some future time, the shifting of passengers from cars to transit can produce benefits that overcome construction and new transit vehicle operation, resulting in a breakeven point. During this time, technologies are changing (e.g., auto fuel economy is improving and the electricity mix is becoming greener). This breakeven point and the subsequent benefits that accrue later on are critical for air quality and GHG policies when specific future year targets exist. We contrast life-cycle results from the current state-of-the-art time-independent approach with the policy-focused time-based approach to highlight the benefits to decision makers of temporally assessing outcomes.

Methodology

An environmental LCA is developed for the Exposition LRT line and a competing automobile trip in Los Angeles (LA). The LCA is structured with time-based information of when impacts in the life-cycle occur, thereby producing a richer understanding of how the decision to implement transit to meet air quality and environmental goals produces the desired benefits (e.g., reductions in GHG emissions) and when those benefits occur. The LCA includes vehicle (e.g., manufacturing and maintenance), infrastructure (e.g., construction and operation), and energy production components, in addition to vehicle propulsion effects (Chester and Horvath, 2009). To inform a broad array of transportation policy and decision makers, two different LCA framings are utilized: attributional and consequential. The attributional framing evaluates the long term average footprint of each system allocating impacts to a passenger-kilometer-traveled (PKT). It includes, for example, the construction impacts of the existing road system for an automobile trip. However, given the importance of understanding how public transit investments contribute to urban sustainability goals, a consequential analysis of the decision to build the Expo LRT system is also produced, culminating in a cumulative impact savings at some future time. The analysis answers how and when the Expo line may contribute to LA meeting its GHG and air quality goals as a result of the region's decision to deploy a new transit line. The results from the attributional and consequential approaches should be considered independently.

The methods that are utilized follow those reported in existing research by the authors (Chester and Horvath, 2009; Chester et al., 2013), however, significant efforts were made to obtain system-specific data from LA Metro and model life-cycle impacts with regionalized energy mixes and processes. The following discussion focuses on the data collection and methods used to assess the life-cycle processes that results are most sensitive to. We start by showing how for the