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Greenhouse gas and air quality effects of auto first-last mile use with transit

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A R T I C L E I N F O

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A B S T R A C T

With potential for automobiles to cause increased greenhouse gas emissions and air pollution relative to other modes, there is concern that using automobiles to access or egress public transportation may significantly increase the environmental impacts from door-to-door transit trips. Yet little rigorous work has been developed that quantitatively assesses the effects of transit access or egress by automobiles. This research evaluates the life-cycle impacts of first-and-last mile trips on multimodal transit. An environmental life-cycle assessment of transit and automobile travel in the greater Los Angeles region is developed to evaluate the impacts of multimodal transit trips by utilizing existing transportation life-cycle assessment methods. First-last mile automobile trips with transit may increase multimodal trip emissions significantly, mitigating potential impact reductions from transit usage. In some cases, multimodal transit trips with first-last mile automobile use may have higher emissions than competing automobile trips. In the near-term, first-last mile automobile trips in some Los Angeles transit services may account for up to 66% of multimodal greenhouse gas emissions, and as much as 75% of multimodal air quality impacts. Fossil fuel energy generation and combustion, low vehicle occupancies, and longer trip distances contribute most to increased multimodal impacts. Supply chain analysis indicates that life-cycle air quality impacts may occur largely locally (in Los Angeles) or largely remotely depending on the propulsion method and location of upstream life-cycle processes. Reducing 10% of transit system greenhouse emissions requires a shift of 23–50% of automobile first-last mile trips to a neutral emissions mode.

1. Introduction

With heightened awareness of the impacts of greenhouse gas (GHG) emissions and criteria air pollutants (CAP), focus on understanding and mitigating human and environmental impacts from transportation has become a major priority for many planning and government agencies. In 2014, the transportation sector accounted for over a quarter of all GHG emissions in the United States (EPA, 2016). In the last two decades, extensive research and literature has evaluated the human and environmental impacts of various transportation modes. This has led to increased regulations for air quality (CARB, 2000), improvements to automobile fuel economies (Jaffe et al., 2005), and frequent use of life-cycle assessment (LCA) to evaluate the direct and indirect effects of transportation systems (McKenzie and Durango-Cohen, 2012; Nordelöf et al., 2014). Public transit has been shown to reduce human and environmental impacts and is increasingly utilized to meet policy goals of

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reduced GHG and CAP emissions (Matute and Chester, 2015). Public transportation can reduce GHG and CAP emissions per passenger mile in comparison to private automobile travel (Chester and Horvath, 2009), especially when considering the low occupancy of auto travel (Santos et al., 2011) and the use of alternative fuels transit vehicles (Neff and Dickens, 2016). Most studies, however, focus on comparative assessments of modes, not accounting for access and egress in door-to-door travel. In Los Angeles (LA), approximately 25% of rail trips begin with an automobile trip (LA Metro, 2016a). There remain significant gaps in our understanding of how first-last mile transit access and egress contribute to human and environmental impacts. With high potential for automobiles to contribute to multimodal transit trip emissions, this research aims to evaluate the life-cycle impacts of first-last mile trips in multimodal transit using LA as a case study.

Environmental LCA has become a powerful tool to aid in the understanding of direct, indirect, and supply chain impacts in many systems including electric supply technologies (Turconi et al., 2013; Weisser, 2007), agriculture processes (Meisterling et al., 2009), and transportation systems (Chester and Horvath, 2009; Facanha and Horvath, 2007). LCA has also been used to aid in transportation policy and decision making (Chester and Cano, 2016; Eisenstein et al., 2013; Plevin et al., 2014). With the National Ambient Air Quality Standards, agencies such as the California Air Resource Board (CARB) regulating air quality, and metropolitan planning organizations developing policies to reduce GHG emissions through transportation planning, there continues to be great value in using LCA to evaluate transportation related life-cycle impacts.

Some literature has investigated multimodal environmental impacts in transit systems, however, there is a lack of analyses that comprehensively assess first-last mile automobile travel in transit systems with both regional travel characteristics and life-cycle modeling. Chester and Cano (2016) utilize environmental LCA to evaluate time-based impacts of the LA Expo light rail transit (LRT) line with comparison to a LA automobile. In this study, first-last mile auto use with the Expo LRT line was found to have similar or more GHG and CAP emissions per trip compared to a typical auto trip. However, there remains room for improvement because competing and first-last mile auto trips were assumed to occur with average LA travel characteristics. Additionally, the study focuses on only one transit line, so it is unclear if this travel profile is representative. In another study, Mathez et al. (2013) evaluates GHG emissions in Montreal, Canada across multiple modes of transportation by conducting and analyzing a comprehensive regional travel survey. However, this analysis omits LCA and instead utilizes average GHG emission factors for auto and transit modes, with GHG emission factors for regional transit modes provided by the regional transit authorities. These emissions factors only account for the operation phase, therefore LCA would provide a more comprehensive evaluation of impacts. For example, the Montreal Metro is assumed to emit no GHG emissions per passenger mile citing that the system is fully powered by hydro-electric power. Although hydro-electric power has very low GHG emissions, they are non-zero (Varun et al., 2009). Despite limitations, both studies similarly conclude that auto first-last mile trips with transit can produce comparable emissions to a competing auto trip.

Due to a lack of comprehensive studies on first-last mile human and environmental impacts in multimodal transit, it is unclear if targeting these trips could promote emission reductions and continue to aid in policy decision making. A case study of transit and automobile travel in the LA metropolitan region is used to evaluate the impacts of multimodal transit trips to address this question. Through urban planning and sustainable transportation development, public and urban transportation may be positioned to reduce human and environmental impacts. This requires comprehensive LCA with inclusion of first-last mile travel in transportation systems to establish the underlying characteristics that govern human and environmental impacts in multimodal transit.

2. Methodology

An environmental LCA framework is developed by expanding on previously related work to evaluate the impacts of multimodal transit trips. LCA is applied to ten transit services in the LA metropolitan region consisting of four light rail lines, one heavy rail line, three bus services, one bus rapid transit service, and one commuter rail service. In addition, regional automobile impacts are developed to evaluate the characteristics of competing automobile trips and automobile trips accessing or egressing transit. The LCA is designed to account for near-term and long-term life-cycle impacts to provide estimates of how technological improvements, ridership changes, and changes in energy mixes will affect environmental performance in the coming years as well as several decades out. The LCA includes vehicle manufacturing, vehicle maintenance, vehicle operations (e.g., fuel combustion or propulsion effects), infrastructure (construction, maintenance, and operation), and energy production following the methodology developed by Chester and Horvath (2009). Trip characteristics in the LA region are compiled using travel survey data from the California Household Travel Survey (CHTS) and combined with environmental impacts characterized through LCA to estimate multimodal trip impacts.

2.1. Energy and environmental indicators and stressors

The LCA focuses on attributional impacts allocated to each transit service by evaluating near-term and long-term footprints per passenger-mile traveled (PMT). The life-cycle inventory includes end use energy and emissions of GHGs, carbon monoxide (CO), nitric oxide and nitrogen dioxide (NO_X), fine and coarse particulate matter ($PM_{2.5}$ and PM_{10}), sulfur dioxide (SO_2), and volatile organic compounds (VOC). GHG emissions are reported as carbon dioxide equivalence (CO_2e) using radiative forcing multipliers of 25 for CH_4 and 298 for N_2O over a 100 year horizon. CO, NO_X, PM, and SO_2 are evaluated because they are regulated through National Ambient Air Quality Standards and NO_X and VOC are ozone precursors (EPA, 2006). To