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# INDUSTRIAL ECOLOGY: THE ROLE OF ENVIRONMENTAL LIFE-CYCLE ANALYSIS IN TRANSPORTATION SYSTEMS

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## Abstract

The environmental consequences of transportation are significant; and, vehicular sources account for one-quarter to more than one-half of all nationwide emissions of pollutants including carbon monoxide, nitrogen oxides, and organic substances and carcinogens such as benzene, 1,3-butadiene, formaldehyde, toluene, xylene, and others. However, it is spurious to conclude that vehicular (primarily tailpipe) emissions are the only, or only significant, environmental consequence of transportation. And, to identify and assess these other consequences, the use of life-cycle analysis (LCA) methods is recommended. For example, when transportation is examined on this basis, significant environmental consequences are identified in other life-cycle stages including vehicle production and the extraction, production, and distribution of fuel. And, because of these life-cycle consequences, it is clear that "simple" solutions such as cleaner fuels and electric vehicles are inadequate to mitigate the environmental impacts of vehicular travel.

There has been only limited research to-date that has modeled and optimized the operation of a transportation network or system where environmental impacts were considered among the optimization objectives. And, previous research has been limited primarily to consideration of criteria pollutants (tailpipe emissions) and/or to optimization of a single variable. More importantly, from the perspectives of decision theory and environmental sustainability, it is not the *impacts* (e.g., pollutant emissions) that should be optimized; but, rather, it is the *consequences* of the impacts (e.g., human health and ecological damage) that are important and should serve as the basis for optimization. And, available life-cycle impact assessment (LCIA) methodologies provide a means for identifying and assessing such consequences.

This paper will develop and demonstrate a methodology for optimizing the operation (vehicle assignment, routing, and scheduling) of a public transit (demand-responsive, paratransit) system based on the joint optimization of cost, service, and environmental (consequence) objectives. In order to do this, a life-cycle inventory (LCI) model of the transit operation will be developed, wherein environmental (and cost and service) impacts are specified as functions of vehicle routing and scheduling parameters.