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Network design for personal rapid transit under transit-oriented development

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ABSTRACT

This study addresses guideway network design for personal rapid transit (PRT) favoring transit-oriented development. The guideway network design problem seeks to minimize both the guideway construction cost and users' travel time. In particular, a set of optional points, known as Steiner points, are introduced in the graph to reduce the guideway length. The model is formulated as a combined Steiner and assignment problem, and a Lagrangian relaxation based solution algorithm is developed to solve the optimal solution. Numerical studies are carried on a real-sized network, and illustrate that the proposed model and solution algorithm can solve the PRT guideway network design problem effectively.

1. Introduction

Personal rapid transit (PRT) is an automated transit system in which vehicles are used to transport a batch of passengers on its own right-of-way on demand to their destinations without stops and transfers (Anderson, 1998). A PRT system provides a service similar to taxi because passengers are served on demand and there are no pre-determined schedules for PRT. At the PRT station, a group of passengers first select the intended destination station. A PRT vehicle is then dispatched to the station to carry the passengers to the desired destination. Stations are offline such that vehicles can accelerate/decelerate on auxiliary lanes without interfering with the vehicles passing by the main through-lanes. Hence, a PRT vehicle can operate in a non-stop manner by bypassing all intermediate stations. Currently, PRT vehicles supported by modern technologies are usually designed to run on electricity, and are operated by computer control requiring no driver. In general, the size of a PRT vehicle can accommodate three to six passengers.

PRT vehicles run exclusively on tracks called guideways. The guideways are designed as facilities to eliminate at-grade crossings or interference with other transportation modes. In the U.S., PRT has been implemented as a mode of automated people movers at airports and institutions such as schools (for example, the PRT system in West Virginia University campus in Morgantown, WV (Sproule and Neumann, 1991)). Worldwide, PRT systems have been considered in several real-world applications recently, including in Korea (Suh, 2001), Sweden (Tegner et al., 2007) and United Arab Emirates (Mueller and Sgouridis, 2011).

In recent planning practice for urban development in the future, there has been an increasing emphasis in the global community on sustainable transportation systems. The excessive use of personal cars has been identified with issues related

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to congestion, energy consumption, air pollution, noise, safety and excessive land use. Transit-oriented development (TOD) has emerged as a promising alternative for sustainable communities to overcome the aforementioned issues by creating compact environments using convenient and efficient public transportation systems. TOD is deployed to reduce people's dependence on personal cars for mobility and to help make livable and vibrant communities. The most vital element in a TOD design is the planning and design of the public transportation network which serves as the backbone of urban infrastructure systems (Lin and Shin, 2008; Li et al., 2010). A recent trend in TOD deployment is to introduce efficient transit systems such as bus rapid transit (BRT), light rail transit (LRT) and personal rapid transit (PRT) (Parent, 2006). Among these modes, PRT has received significant attention as it connects personal, private, and public transportation, and because of its flexible operational characteristics and competitive financial aspects (Muir et al., 2009). For instance, Tegner and Andreasson (2005) estimated that the construction cost of a PRT system is about a third that of light rail, as PRT entails much lighter vehicle size and lower design standards for guideways compared to LRT.

Mass transportation systems such as trains, metros and rapid buses constitute the major modes of TOD development (see Fig. 1). These modes are efficient for transporting passengers, measured in terms of per unit of space or energy, provided that the demand is adequate. However, if the demand decreases, the ridership drops while the operational cost remains the same, degrading the system efficiency. This is the key reason why most mass transit systems reduce frequencies during off-peak hours (Clerget et al., 2001). Therefore, each mass transit system has a certain operating range in terms of passengers per hour to maintain an efficient operation of the system. To facilitate TOD development, an alternative to the personal car needs to provide a public transit mode which offers the same door-to-door flexibility at an acceptable cost. This could be achieved through a mixed design combining high passenger-flows mass transit and flexible public transportation carrying low passenger-flows for those times or places. PRT is one such flexible system serving as a supplementary mode for TOD development, where a PRT system functions as a local area network, connecting the traditional transit systems and other transit modes within its network.

PRT could be a sustainable solution to urban problems as well. Congestion in major cities results in not only severe travel time delay, but also excess energy use and emissions. PRT is a potential solution to reduce congestion on urban highways. Further, because a PRT system is electrically powered, there are no emissions, and thus overall energy and emissions could be significantly reduced. Compared with automobiles, the energy savings for a PRT vehicle could be about 75%, and CO_2 emissions reduction could be more than 60% (Lowson, 2003a). Land use area is also reduced because of the small footprint of the system compared to the traditional road infrastructure.

While PRT has been recognized as an important component of alternate solutions to passenger cars in sustainable transportation systems in the future, it has not yet achieved widespread commercial deployment in the U.S. Two major factors that restrict the PRT deployment in practice are cost and line capacity. Studies show that the construction cost of guideways is estimated between \$5 and \$15 million per lane per mile; of the stations about \$0.5–\$3 million per station, and of the

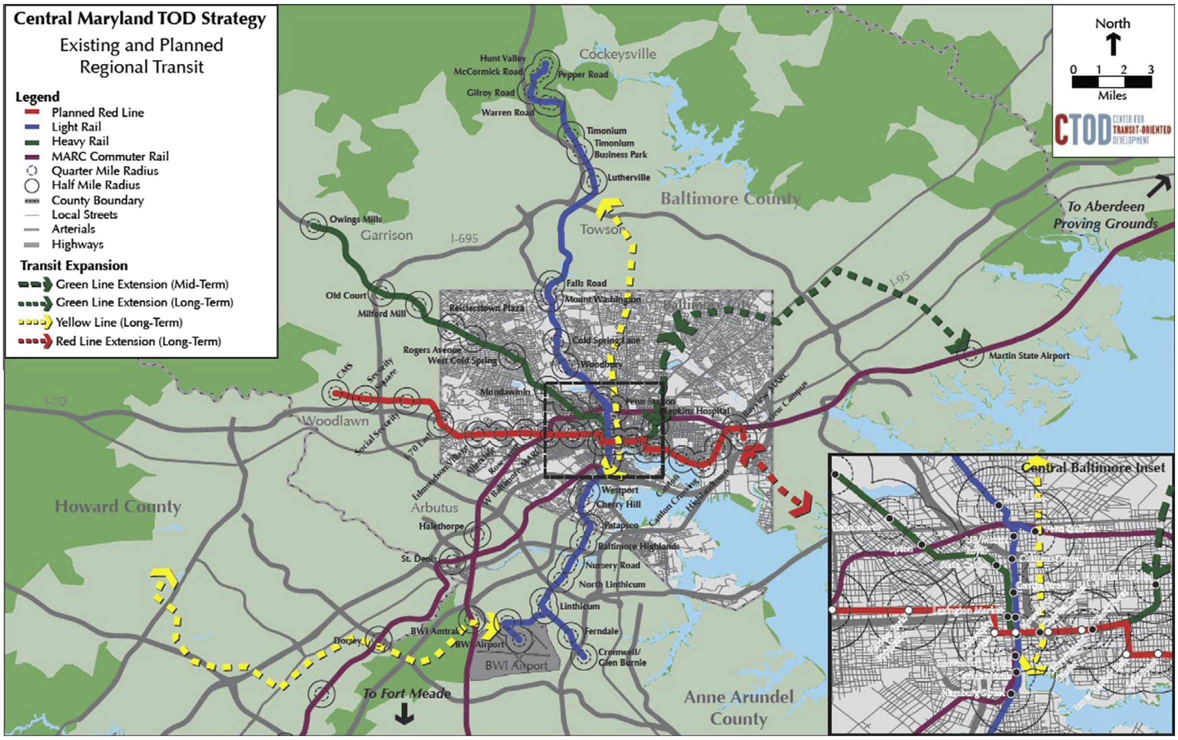

Fig. 1. An example of TOD development in Maryland. (*Source:* Central Maryland Transportation Alliance, 2009.)