

# Alternative methods for estimating full marginal costs of highway transportation

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## Abstract

This paper presents various methods of estimating the full marginal cost (FMC) of highway passenger transportation. First, the computation of FMC is performed using the marginal cost functions, most of which were developed by Ozbay et al. [Ozbay, K., Bartin, B., Berechman, J., 2001. Estimation and evaluation of full marginal costs of highway transportation in New Jersey. *Journal of Transportation and Statistics* 4 (1)]. FMC is defined and calculated as “total cost per trip” as explained in this paper. However, in multiple origin-destination and multiple route highway networks, the practical application of the network-wide FMC concept is complicated. These issues are addressed in detail in this paper. Therefore, in the second method, a multiple route based FMC approach is proposed for a given origin-destination pair in the network. It is observed that the marginal values of different paths vary as much as 28%. Third, a comparison of FMC estimation results of two distinct measurement tools is presented. The FMC estimation is performed between a selected OD pair using the static transportation planning software output (TransCAD). The same analysis is repeated using the stochastic traffic simulation software output (PARAMICS). The differences in FMC values estimated by static transportation planning software and microscopic traffic simulation software are discussed.

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## 1. Background and objectives

At the heart of many congestion mitigation options lies the accurate estimation of full marginal highway travel costs accrued to the State. This information is essential for allocating resources efficiently, for ensuring equity among users of different transportation modes, and for developing an effective pricing mechanism. Full Marginal Cost (FMC) means the overall costs accrued to society from servicing an additional unit of traffic. FMC includes vehicle operating costs, infrastructure costs, accident costs, congestion costs and environmental costs.

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The full costs of highway transportation are usually categorized as *direct* and *indirect* costs. *Direct costs* (sometimes also called private or internal costs) include the costs that auto users directly consider in making a trip, such as vehicle operating cost, car depreciation, time lost in the traffic, tolls and other parking fees, etc. *Indirect costs* (also called social or external costs), on the other hand, refer to the costs that auto users are not held accountable for. These include the congestion costs that every user imposes on the rest of the traffic, costs of accidents, and costs of air pollution and noise.

The main objective behind the accurate estimation of FMC is to ensure that prices paid by highway users correctly reflect the true costs of providing the services. Optimal user charges should be set equal to the value of the resources consumed through the use of the transportation facilities.

The idea of road pricing is certainly not new; dating back to the seminal paper by Vickrey (1968). More recently it has been gaining support both by transportation planners and policy makers. However, most studies in this area focus on the estimation of average cost of highway transportation (Churchill, 1972; Cipriani et al., 1998; Peat Marwick Stevenson & Kellogg Technical Report, 1993). Very few studies deal with the estimation of marginal costs, which are essential for congestion pricing (Levinson et al., 1996; Levinson and Gillen, 1998; Mayeres et al., 1996; Ozbay et al., 2000). Ozbay et al. (2000), deal with both marginal and full costs of supplying transportation services. Mayeres et al. (1996), deal with the estimation of marginal external costs only. The “British Columbia Lower Mainland” study (PMSK, 1993) uses societal costs such as cost of roadway land value, cost of air and water pollution, cost accidents, and cost of loss of open space and user costs. Ozbay et al. (2000) estimate FMC based on one additional trip, presenting variations in FMC with respect to trip distance, facility type, urbanization degree and the time of the day. Link (2006) deals with estimating the marginal infrastructure costs in Germany, using 20 years of roadway maintenance data to model a relationship between maintenance costs and roadway volume.

This paper aims to estimate the FMC of highway passenger transportation. The novelty of this paper lies in three areas.

- First, the computation of FMC is performed using the marginal cost functions, most of which were developed by Ozbay et al. (2001). FMC is defined and calculated as “total cost per trip” as explained in detail in the next section.
- In multiple origin–destination (OD) and multiple route highway networks, the practical application of the network-wide FMC concept is complicated to apply. These issues are addressed in detail in this paper. A multiple route based FMC approach is proposed for a given OD pair in the network.
- A comparison of FMC estimation results of two distinct measurement tools is presented. First, the FMC estimation is performed between a selected OD pair using the static transportation planning software output (TransCAD). Second, the stochastic traffic simulation software output (PARAMICS) is applied.

The design of this paper is as follows. Section 2 describes the FMC. Section 3 explains the marginal cost functions developed by Ozbay et al. (2001) for each cost category. Section 4 discusses two methodologies for the FMC estimation in a highway network. Section 5 presents the FMC estimation process on a hypothetical urban highway network developed in PARAMICS microscopic simulation software. Section 6 presents the key findings of the analyses and some suggestions for a future study.

## 2. Proposed marginal cost estimation methodology

The cost of a trip between an OD pair in a network is defined as a function of several variables denoted by  $V_j$ . The average cost  $C_{rs}$ , of “one trip” performed between a specific OD pair  $(r, s)$

$$C_{rs} = F(V_j; q) \quad (1)$$

where  $q$  denotes the demand between the OD pair and  $F(V, q)$  is the cost function. It is assumed that there are  $q$  number of homogeneous users making the same trip at a given time period. The Full Total Cost (FTC) of providing a transportation service between any OD pair for  $q$  trips is

$$\text{FTC}_{rs} = q \cdot (C_{rs}) = q \cdot F(V_j; q) \quad (2)$$

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