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Analyzing the structure of informal transit: The evening commute problem

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ABSTRACT

Through the use of a profit-maximizing continuum approximation model, this paper systematically analyzes the development and structure of informal transit systems as a function of the network, user, and modal characteristics. This study examines the evening commute problem along a linear corridor where passengers originate uniformly from a central business district and have destinations uniformly distributed along the corridor. Informal transit drivers who are profit-maximizing will be compared against the traditional case of coordinated, government service that aims to maximize the total welfare. Policies, such as fare regulation and vehicle licensing schemes, will be presented to help rationalize informal transit service using a government-operated service as the baseline.

1. Introduction

In many parts of the world, particularly in developing countries, informal privately-operated transportation plays an integral role in people's mobility. Informal transport is private mass transport that operates without regulation and official endorsement. These systems may be the primary mode of transport (e.g. the matatus in Nairobi), provide feeder services (e.g. Hong Kong light buses), or serve niche markets (e.g. Little Cuba cabs of Miami). Most informal transport modes are not subject to a fixed route. The amount of flexibility varies; while some vehicles have fixed routes along popular corridors, others generally smaller vehicles, have variable, demand responsive routes. In addition to the routes, the size of the vehicle varies, with vehicles ranging from motorcycles to minibuses. This paper will focus on larger, fixed route systems serviced with minibuses.

1.1. Motivation

The prevalence of informal transit can impose significant costs to passengers, as a lack of oversight can lead to erratic scheduling and service, and poor safety records. Due to cutthroat competition, aggressive driving and cream skimming (only operating at busy hours or locations, or waiting for full vehicles before operating) are also prevalent. The lack of accountability and captivity to these systems makes it difficult for passengers to express complaint. Often drivers work long hours at low wages. This stiff competition for passengers is called 'la Guerra del Centavo' or 'the war for the cent' in Latin America.

Despite all these disadvantages, informal transit has many benefits. Informal transportation provides service coverage when government agencies lack the capital and/or organization. In addition, informal transit can fill important gaps, such as feeder services, in the market. Private operators are more responsive to changes in the market and, by organizing into cooperatives and route associations, can provide service with relatively low costs per-seat. In addition, smaller vehicle sizes allow for reduced headways and therefore, reduced overall travel times (Cervero & Golub, 2007).

2. Literature review

2.1. Practice-based

Reviews of the various types of informal transport systems across the world are provided in Bly and Oldfield (1986), Iles (2005), and Cervero and Golub (2007). There are many interest holders with regards to informal transit such as vehicle owners/operators, drivers/conductors, government officials, and association officials, each of which are trying to capture a share of the profits. These systems flourish when there is an abundance of cheap labor. Vehicle owners/operators typically charge drivers a fee for the use their vehicles. This causes still competition amongst drivers who must meet this daily quota.

Due to this stiff competition such systems are typically regulated. Regulation can appear in many forms but generally fall into three main categories: quality (ex. insurance, vehicle inspections,

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and crew licensing), quantity (ex. route licensing and frequency of service), and fare (Iles, 2005). This paper will address quantity and fare regulations.

2.2. Model-based

Extensive literature in both engineering and economics exists regarding the optimal operating structure of bus systems — both public and private. The literature can be divided into two broad categories: (1) studies which determine the system optimal design for a given mode; and (2) studies which model competition amongst and within modes.

2.2.1. System optimal design for a given mode

Much of the existing research jointly models the generalized operator and user costs (both monetary and time) of fixed-route public transport using continuum-approximations. Continuum-approximation models, which model discrete variables such as the number of buses or passengers as continuous variables, can be beneficial because their reduced complexity allows for more general insights. Assuming exogenous demand, Holroyd (1967), Mohring (1972), and Jansson (1980) determined the optimal frequency of fixed-route transit systems by minimizing the total generalized system cost (or conversely, maximizing the total welfare). Mohring (1972) analyzed a single corridor and found the optimal frequency to be proportional to the square root of demand. Jansson (1980) studied the optimal fleet size and concluded that observed conventional bus frequencies are generally too low and bus sizes too large. By looking at the welfare-maximizing subsidy level for urban transport, Mohring (1972) and Jansson (1980) determined that due to the economies of scale of public transport, subsidies are necessary to produce socially optimal frequencies. All of the above studies, were for a single mode − transit.

2.2.2. Competition amongst and within modes

Viton (1982) presented an equilibrium model for a duopoly of two transit operators, one private and the other public, competing on a simplified corridor. Later, Harker (1988) expanded this model and looked at a network of competing modes. Each mode served a separate, non-overlapping corridor without transfers between modes. Fernandez and Marcotte (1992) presented a fully deregulated network model that accounted for competition within and between modes (car and transit) where transit operators allocated their vehicles to lines in order to maximize profit given user equilibrium. Subsequently, Zubieta (1998) relaxed the perfect competition assumption of the previous study to examine the case where few companies control the transit market. By relaxing the exogenous fare assumption and allowing for elastic demand, Zhou, Lam, and Heydecker (2005) extended the Zubieta (1998) model. Zhou et al. (2005) assumed operators were allowed to vary only their fare structure as opposed to frequency as seen in earlier works. Along similar lines, Yang Kong, and Meng (2001) modeled the effect of value-of-time on the price and frequency of competing bus modes (minibus vs. conventional bus) along a corridor where buses also compete with private vehicles. In a similar analysis, Gronau (2000), from the perspective of a central transport authority, studied the optimal mix of conventional buses and minibuses when the value-of-time varied across passengers.

To the author's knowledge, no such study exists that jointly models the decision processes of both the users and operators and compares the results to a welfare-maximizing model with endogenous demand. The goal of this study is to simultaneously represent the decision processes of both the users and operators of the system in a competitive environment, recognizing that operators can change both the fares and frequencies. In our study, the users have the option of walking, taking transit, or not to travel (elastic demand), and the operators of the bus system take into account the user's mode choice options when establishing the headway and fare. Continuum approximations are used as a modeling tool.

3. Methodology

Private operators aim to maximize their profits and public operators (governments) aim to maximize welfare while users choose the mode that minimizes their total individual generalized cost ($). A simplified analysis is performed for a linear corridor of length (L). It is assumed that all trips originate from a terminal in the central business district (CBD) to which users arrive at a uniform rate and that the desired destinations are distributed uniformly along the corridor. There are a sufficient number of buses on the system so that the queue of passengers clears with each dispatch. Moreover, passengers and buses are served in the order they arrive.

Section 3.1 analyzes user costs and Section 3.2 operator costs. Three idealized operator regimes will be analyzed: (a) government, (b) collusion, and (c) full competition.

3.1. User sub-model

It is assumed that potential users do not have access to private automobile and therefore have three possible options: walk to the destination (w), take transit to the destination (t), or forego the trip due to prohibitively high costs (ϕ). Potential users originate at the CBD at rate λL (pax/hr), where λ (pax/hr km) is the number of users wishing to travel to a unit distance of corridor per unit time. These users are assumed to have perfect information and choose the option that minimizes their total generalized cost ($). The generalized cost takes into account all out-of-pocket costs, as well as the times associated with walking, riding, and waiting. These times are converted into monetary costs by multiplying them by appropriate values of time, which have dimensions of (money/time).

The generalized cost of a user whose destination is a distance l (km) away from the CBD is denoted by the lower envelope of the three curves in Fig. 1, where $ø denotes the maximum generalized cost a person is willing to pay to make the trip, and $w and $t is the cost by walking and transit, respectively. Each user is assumed to derive the same benefit ($o) for making the trip regardless of destination. Thus, the net utility from making the trip is the difference between $o and the minimum generalized cost as shown in Fig. 1. Note that the generalized cost of not traveling is $ø=$o, i.e. the net utility is zero since the benefit of making the trip is not realized if one does not travel.

The generalized costs of walking, $\$_{\mathrm{w}}$, and transit, $\$_{\mathrm{t}}$, depends on the location, l, of the destination, as shown in Fig. 1. Walkers only incur a travel time cost whereas transit passengers incur a fixed fare (F), delay costs at the CBD due to waiting for the bus arrival and passenger boarding, and travel time costs which include the 'line-haul' travel time plus an additional lost time due to passenger alighting. Equation (1) below gives the generalized cost for each mode:

$$\$_{\mathrm{w}} = \beta \mathrm{o} l \nu \mathrm{w} \tag{1a}$$

$$\$_{\mathrm{t}} = F + \beta \mathrm{o} H2 + \beta \mathrm{i} l \nu t + \beta \mathrm{i} \tau \lambda \mathrm{H}12Lt - L\mathrm{w} + l - Lw \quad \text{for } L_{\mathrm{w}} \le l \le L\mathrm{t} \tag{1b}$$

$$\$_{ø} = \$\mathrm{o} \tag{1c}$$

where β_{i} = the value of time in vehicle, β_{o} = the value of time out of vehicle, τ = lost time per pax boarding or alighting, l = distance from CBD of destination, L_{w} = the distance at which walking has the same cost as transit, $L_{\varnothing}$ = distance where transit cost equals $\$_{\phi}$, L = length