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The implications of travel profiles for transportation investment: The Bronx Center Project

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Abstract. Investment in transportation infrastructure is generally regarded as an effective means for inducing economic growth and employment in a region. However, the ability of such investments to achieve these objectives, to a large extent, depends on the degree to which travel results from these investments support or conflict with present travel patterns and needs in this region. Using this view as a basis, this paper analyzes travel conditions and choices in the Bronx New York, where large scale transportation and other development projects (commonly called the Bronx Center Project) are presently taking place. Using a large data base, composed of census tract information on socio-economic and travel behavior, the paper first examines the travel profile of the Bronx population, by estimating travel choice elasticities. On the basis of these elasticities it then assesses the impact of the Bronx Center Project on travel patterns and trends.

1. Introduction

This paper is part of a series of papers addressing the Bronx Center (the Center), a community development project in the Bronx, NY. A large scale urban investment project, the Bronx Center is designed to achieve economic and social improvements by means of transportation changes, development and redevelopment activities and innovative social service delivery programs. A major policy issue rising from the Center's objectives is to understand and assess the economic implications of the transportation investments in terms of increased employment, location of new firms and their volume of business, and other activities with significant economic impact. Another policy issue is to establish the level and kinds of transportation investments necessary to reinforce the overall project development and social service activities.

To begin the assessment it is necessary to review current conditions of the Bronx's transportation system, identify major attributes of those components and explore principal characteristics of travel of the Bronx's residents. In this paper we will examine a transportation profile of the Bronx relative to key variables which affect the transportation behavior of the Bronx trip-makers. The focus of this paper is to derive travel choice elasticities and provide explanation of travel behavior shown by residents of the Bronx. Our emphasis is on data analysis and interpretation describing current behavior. The primary source of our data is the Census of 1990, the most current applicable data for the region. Since the prime objective of the Bronx Center Project is to increase employment and economic activity in the Bronx, in this study we examine work trips only with respect to three main variables: mode use, time of day of departure and trip length. These variables, particularly, the first two, seem to have the greatest impact on travel conditions and needs in this region. By deriving the elasticities of these travel decisions variables with respect to key explanatory variables we, subsequently, will be able to assess the impact of increased employment from the Bronx Center Project on travel behavior and choices.

This study is an exploratory analysis looking at the links between readily available measures of travel and influencing factors. The authors are quite familiar with the decades of literature describing trip generation and mode choice. Our intent is not to replace or change the existing approaches to demand analysis. Rather, we will look at behavioral factors that can lead to models underlying modern investment decisions. Eventually, these decisions will have to make some intuitive sense to policy makers and investors. We assume the housing and work choices have been made. With lower than City wide median house hold income, Bronx residents have fewer affordable housing choices, and fewer job choices than their more affluent peers. Of the 1.2 million persons living in the Bronx (1990 census), 471,000 are employed. This is actually higher than the City wide average, 48% for the Bronx and 46% for the City. However, the jobs, within the five boroughs are distributed quite differently. Of the more than 3.5 million jobs in the five boroughs, 215,000, or 6% are in the Bronx, while 65% are in the neighboring borough, Manhattan. The distribution of jobs by category also differs by borough. While each maintain similar levels of manufacturing jobs at 8%, the Bronx has 5% of its jobs classified as FIRE (Finance, Insurance, Real Estate), while 20% of the jobs in Manhattan are FIRE. It is clear that with a strong pull of jobs outside the Bronx (i.e. more workers than jobs in the Bronx) and with many transportation choices available to the workers, including the Nation’s largest transit system, a complex set of variables will be needed to explain observed travel.

Housing choice, or residential choice models, and job choice models would clearly help explain, in more detail, the behavior we are to examine. However, the purpose of this paper is to structure more simple transportation models first, letting the current distribution of jobs and housing act as constraints. We are not building a Land Use Transportation Model, but, rather are taking the first step in examining the types of variables that will help decision makers develop investment policies. These policies include increases in transit operating costs to improve reliability and safety, decrease headways, and improve on time performance. Capital investments might include such as vehicle procurement, added highway capacity, station improvements, and improved communications systems. Our analysis won't justify any of these single investments, but will show the travel determinants impacting mode choice based upon the nature of the trip and the characteristics of the trip maker. Such determinants help define the markets that justify or deny subsequent investments.

The design of this paper is as follows. Section 2 describes the analytical approach pursued in this paper. Section 3 gives the structure of the data base. Sections 4 and 5, discuss model specification and tests and the main results. Interpretation of these results is given in Section 6. On the basis of the estimated equations, Section 7 discusses prediction of travel behavior from changes in the exogenous variables. Principal conclusions are in Section 8. Basic statistics about the Bronx can be found in Appendix A.

2. Analytical approach

Following the conventional approach in transportation analysis, we regard travel decisions to be a consequence of a complex process which can be attributed to four key categories: socio-economic attributes, spatial structure, transportation supply conditions and public policies. These relationships are depicted in Fig. 1.

Given these components, the literature contains several alternative approaches to the analytical modeling and empirical estimation of the relationships depicted in the Fig. 1 (see Berechman 1993, Chapter 2, for a review). One approach is to regard all locational factors as given and estimate travel demand as a function of socio-economic (e.g. income) and travel cost variables (Douglas 1984). A second approach (e.g. Lerman 1976, Ben-Akiva & Atherton 1975), is to assume a comprehensive hierarchial travel decision-making process in which long-range location decisions (e.g. of home and job) lead to medium-term decisions (e.g. car ownership) which, in turn, constrain short-term travel decisions (e.g. time of departure). In such a process decisions made at one level determine the set of choices for the next lower level (e.g. Lerman & Ben-Akiva 1975). A third alternative (e.g. Anas 1982), is to cast the problem within an equilibrium model framework in which demand for locations and for travel are equilibrated with supply of land and transportation infrastructure to generate a general equilibrium solution.[1]

Since the overall goal of the Bronx Center study is to assess the economic

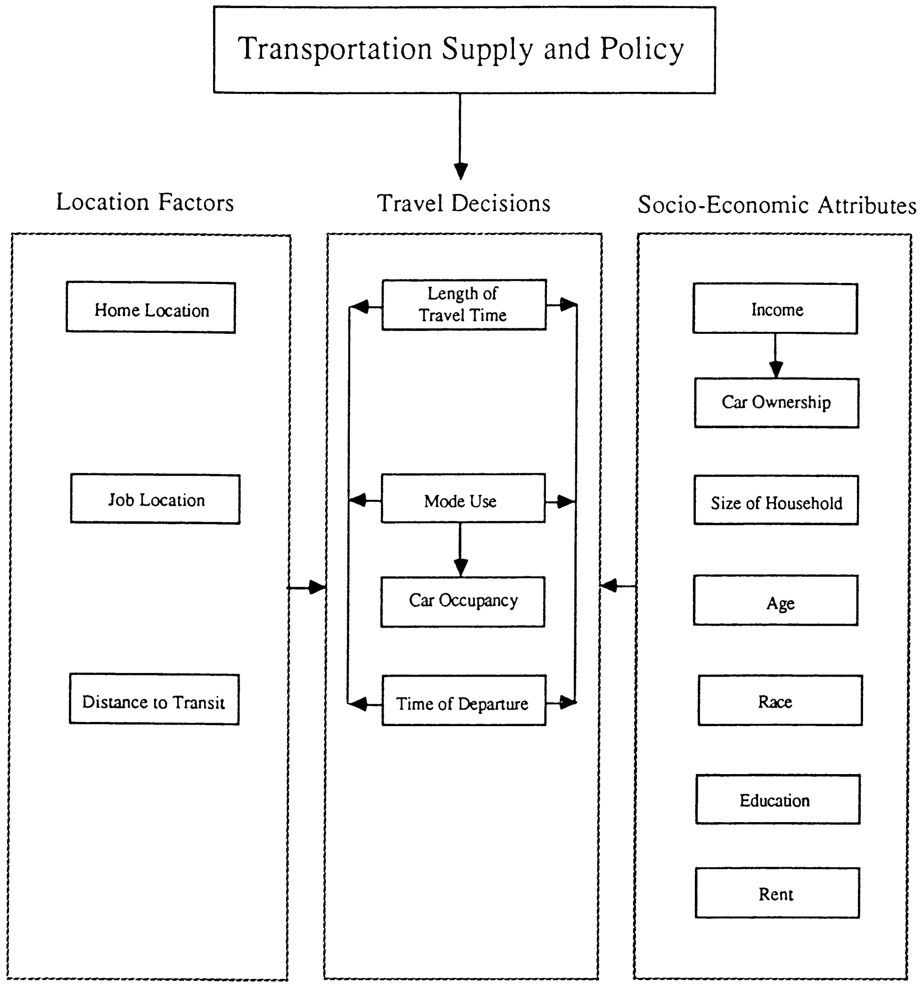

Fig. 1. Structure of model approach framework.

and travel implications of transportation and non-transportation investments, we consider the effect of the socio-economic and locational groups of factors on travel behavior of the Bronx's population. Thus, the modeling approach to be pursued here explicitly assumes travel decisions to result from the socio-economic and locational factors, taking supply and policy factors as given. Following this approach we distinguish between exogenous and endogenous variables where the latter refer to factors which directly reflect daily travel choices and attributes, and the former are variables that define the boundaries (or explain, in a functional sense) these choices. Thus, locational factors like home and job locations are regarded as exogenous to daily travel choices. Similarly, income, size of an household and car ownership are also treated as exogenous.

It is important to observe that this analysis does not assume a sequential daily travel decision process in which mode use, say, precedes time of departure which, in turn, determines travel time length. As we view these elements of daily travel choices as inseparable, they are regarded as being carried out simultaneously. Since we wish to derive travel choice elasticities, we use the exogenous variables as explanatory variables. That is, the socio-economic factors and the locational factors (or their proxies) are used as independent variables to explain travel decisions. Moreover, to derive appropriate elasticities, it is necessary to estimate all three major travel decisions simultaneously to show their interdependency in the travel decision process as explained above. The three equations used for the analysis, mode use, time of departure and length of trip are treated as a system of equations to be estimated accordingly. In the data base available to this study we do not have observations on individual households travel behavior. Thus, we cannot use discrete choice techniques to estimate choice elasticities. We use regression analysis for the evaluation of the models.

The first two equations, mode use and departure time, clearly reflect user choices and can be specified as demand functions with the added locational variables. Thus, the number of work trips using a mode is a function of travel costs (approximated in this study by total travel time), of socio-economic variables, mainly income and household location and of type and location of employment. Time of departure is also specified as a function of total travel time which is assumed to vary between different time periods, reflecting varying travel conditions at these time-periods. It is also a function of income, locational and other socio-economic variables. The third equation, length of travel time, is not readily amenable to a demand function interpretation. Under normal circumstances supply conditions (e.g. in-vehicle time, headway or location of stops), would be of critical importance. Nonetheless, the choice of a mode and time of departure by a user can affect his total travel time (given socio-economic and employment constraints). Given also that this variable enters, as an explanatory variable, into the other two choice equations we have specified a separate choice equation for it as well, where the other two choices (mode and departure time) along with socio-economic variables serve as the explanatory variables. These three equations are estimated first separately and then within the framework of a system of equations. In section 4, we further discuss the empirical analysis carried out in this study.

3. Source and structure of the data base

The major sources of data for this study are two US Census data files: the Summary Tape File (STF1a) and Summary Tape File 3 (STF3a) (US DOC 1990). The prime source of data used for the analysis in this paper comes from STF3a which contains data at the census tract level. There are 355 census tracts in the Bronx. All census tracts with 0 or an insignificant number of responses to this sample survey, were not used in the analysis.[2] Table 1 describes the basic structure of the data base.

Table 1. Structure of data base.

	WP-Work Place [4]	PH Pers/ H.H. [7]*	I-H.H. Income by range [5]	M-Mode Use# [4]	C-H.H. Car Ownership [3]	PC-Persons per Car (work trips)# [4]	TD-Time of Departure (Work Trips)# [9]	T-Job# Type	LT-Length of Travel Time [7]
Tract 1									
Tract 2									
.Tract n									
.									
.									
Tract 353									

* Figure in parenthesis is number of variables in each category in each census tract.
\# Individuals, not households.

Since the size of the population in the individual census tracts which make up the data base is uneven (some tracts are larger than others), it was necessary first to weight the raw data according to the relative population size of each census tract. Each of the observation of a given variable of a given census tract was weighted by a factor corresponding to the percentage of this tract's population in the total population of the Bronx.

The principal variables used in the analysis and their ranges are:

I. *PH – Number of households with x number of people where*: (1) x = 1; (2) x = 2; (3) x = 3; (4) x = 4; (5) x = 5; (6) x = 6; (7) x = 7+ [total of 7 variables].

II. *I – Households Range of Income*: (Number of households within an income range): (1) $0–9,999; (2) $10,000–19,999; (3) $20,000–29,999; (4) $30,000–39,999; (5) $40,000–49,999; (6) $50,000–59,999; (7) $60,000+ [total 7 variables].

III. *M – Mode Use*: (Number of employed people, 16 years of age or older, that use a mode to travel to work): (1) Car; (2) Transit (bus, street car, trolley, subway, rail, taxi-cab, ferry), (3) Other (bike, motorbike); (4) Walk [total of 4 variables].

IV. *C – Car Ownership*: (Number of households that own x cars): (1) 0 cars; (2) one car; (3) two or more cars [total of 3 variables].

V. *PC – Persons per Car*: (Number of people employed 16 years of age or older, during one week prior to the census that): (1) drive alone; (2) two to three persons per car; (3) four or more persons per car [total of 3 variables].

VI. *TD – Time of Departure*: (Number of employed people, 16 years of age or older, during one week prior to the census, that leave to work at): (1) 12 AM–5.59 AM; (2) 6:00 AM–6:29 AM; (3) 6:30 AM–6:59 AM; (4) 7 AM–7:29 AM; (5) 7:30 AM–7:59 AM; (6) 8 AM–8:29 AM; (7) 8:30 AM–8:59 AM; (8) 9 AM–9:59 AM; (9) 10 AM–11:59 AM [total of 9 variables].

VII. *TJ – Type of Job*: (Number of people, 16 years of age or older, during one week prior to the census, that work at): (1) home; (2) agriculture and fishery; (3) manufacturing; (4) transport, communication, utilities; (5) wholesale trade; (6) retail trade; (7) finance, insurance, real-estate; (8) business and repair, personal, entertainment; (9) public administration [total 9 variables].

VIII. *LT – Length of Travel Time Home to Work* (*in minutes*): The following travel time categories were selected on the basis of their percent distribution in the Bronx: (1) 0–14; (2) 15–29; (3) 30–34; (4) 35–45; (5) 45–59; (6) 60–90; (7) 90+ [total of 7 variables].

IX. *PW – Place of Work*:[3] Living in MSA/PMSA working in MSA/PMSA[4] of residence: (1) central city; (2) Remainder of this MSA/PMSA; Working outside MSA/PMSA of residence (3) central city; (4) remainder of different MSA/PMSA [total of 4 variables].

Altogether, there are 53 variables in 9 major categories.

Basic statistics concerning these variables, their percent distribution by category, means and standard deviation are given in Appendix A. In general, this statistics shows that the Bronx's population is composed of low income households (about 60% below $30,000 annual income), with low rate of car ownership (about 60% without a car); small size households (about 55% of the populating in households of 2 persons or less), using transit as the predominant mode of travel to work (close to 60%), and a large number of employees in public administration type jobs (over 36%). In other NY boroughs, income and rate of car ownerships distributions are much less skewed, though other variables, like household size, exhibit similar distribution patterns. In the analysis that follows, these characteristics of the Bronx's population are found to strongly affect transportation behavior.

4. Model specification

To drive elasticities we have used two types of regression analysis. First, the following three regression models were estimated independently using Ordinary Least Squares (OLS). All dependent variables in these models reflect home to work trips. Each of these models was assumed to have exponential type structure. Thus, for estimation purposes, all variables were transformed into a log form so that each of the estimated parameters is actually the elasticity of its respective dependent variable.

(1) *Model use*

$$\ln(M) = a_M + \beta_{LT}\ln(LT) + \beta_I\ln(I) + \beta_{TD}\ln(TD) + \beta_{TJ}\ln(TJ) + \beta_C\ln(C) \quad (1)$$

Underlying this model specification is the hypothesis that the use of a mode (M) for work trips, is a function of travel time (cost), (LT), of income (I), time of departure (TD), type of job (TJ). Travel time, more than any other variable will affect mode choice, when given income, trip type and home and job locations. Since data on the latter variables are not available at the census tract level, the variables: time of departure, type of job and length of travel time serve as reasonable proxies.

(2) *Time of departure*

$$\ln(TD) = a_{TJ} + \beta_{LT}\ln(LT) + \beta_I\ln(I) + \beta_M\ln(M) + \beta_{TJ}\ln(TJ) + \beta_C\ln(C) \quad (2)$$

It is assumed the primary factors affecting the choice workers make regarding the time-period they depart to work are travel time (costs), income, mode use, type of job. Car availability is also included to reflect other non-measured socio-economic effects. The left-hand-side of (2) is the number of people that depart to work at a given time period.

(3) *Length of travel time (in minutes)*

$$\ln(LT) = a_{LT} + \beta_M\ln(M) + \beta_I\ln(I) + \beta_{TD}\ln(TD) + \beta_C\ln(C) \quad (3)$$

In general car ownership, car availability and car use affect access and egress times as well as waiting and in-vehicle times. Under normal circumstances, car travel is much faster compared to public transit. In the Bronx, very short transit headways, and extensive service area coverage, make transit an extremely competitive mode, especially to the Manhattan CBD core. The car may not be the fastest mode when traveling long distances. We hypothesize that car is mostly used for relatively short travel time trips (up to 30 minutes), and for the very long ones (over 90 minutes). These short trips would serve intra borough travel, where transit loses its advantages, because most trips on transit must then be made by bus. Transit, on the other hand is mostly used for medium and long travel time trips.

To account for the possibility that the three travel choices: mode, time of departure and trip length, are not independent but are carried out simultaneously, we have next estimated the three equations within a system of simultaneous equations using a Three Stage Least Squares (3SLS) estimation procedure. In particular we used the SURE (seemingly unrelated regression equations) procedure with instrumental variables (see Ghosh 1991, Chapter 11; and Gujarati 1988, Chapter 19, for details). As instrumental variables we have selected to include: place of employment and size of household. The results of the empirical estimation (OLS and 3 SLS) are presented in Section 5.

5. Results

5.1. *OLS Estimates for each choice model*

Estimates for the three type regression models are presented in Tables 2 through 5. For brevity, the reported estimated parameters are only for those whose level of significance is 5% or less.

(a) *Mode use for work trips*
The following two tables (2a and 2b) describe elasticity estimates for mode use. Since car ownership and income are highly correlated, we first show estimates without car ownership (Table 2a) and than for all variables (Table 2b).

(b) *Time of day departure (work trips)*
Table 3 below shows of “time of day departure” choice elasticities with respect to income category, mode choice, type of job, car ownership and length of travel time.

(c) *Length of travel time homo to work (in minutes)*
Table 4 below presents the elasticities of “length of travel time” choice with respect to income, mode, type of job and time of departure.

Table 2a. Mode use elasticities (without car ownership.)[a]

Variable\Mode	Car	Transit	Walk
Income Range:			
\$0–9,000	–0.060[d]	0.067	
\$10,000–20,000	–0.120		
\$20,000–30,000			0.375[d]
\$30,000–40,000			
\$40,000–50,000			
\$50,000–60,000			0.250
\$60,000+	0.198	–0.078	
Time of Departure (AM):			
12:00–6:00		0.038[d]	
6:00–6:30	0.094		
6:30–7:00			
7:00–7:30		0.106	
7:30–8:00		0.053	
8:00–8:30			0.527
8:30–9:00	–0.079	–0.044	
9:00–10:00	–0.072	–0.074	
10:00–12:00			0.214
Type of Job:			
Transport & Communication			
Retail	0.103[d]	0.064[d]	
Public Administration			
Business Services	0.308	0.539	
FIRE[b]			
Manufacturing			
Agg. & Fish[c]			
Travel Time (Min.):			
0–15		–0.097	
15–30	0.459		
30–35		0.096	
35–45			
45–60		0.223	
60–90		0.165	
90+			
Constant:	0.198	0.397	–0.859[d]
R^2 adjusted:	0.96	0.98	0.27

[a] Unless so indicated, parameter values shown are only for level of significance of 5% or better; [b] FIRE = Finance, Insurance, Real Estate; [c] Agg. & Fish = Agriculture and Fisheries; [d] Significance at less than 10% level.

Table 2b. Mode use elasticities (all variables.)[a]

Variable\Mode	Car	Transit	Walk
Income Range:			
$0–10,000			
$10,000–20,000	–0.174		
$20,000–30,000	–0.097	0.080	0.430[d]
$30,000–40,000	–0.088		
$40,000–50,000			
$50,000–60,000			0.262
$60,000+	0.068	–0.046	
Time of Departure (AM):			
12:00–6:00		0.047	
6:00–6:30	0.079		
6:30–7:00			
7:00–7:30		0.102	
7:30–8:00		0.062	
8:00–8:30	0.079[d]		0.501
8:30–9:00			
9:00–10:00	–0.046	–0.072	
10:00–12:00	–0.046		0.207
Type of Job:			
Transport & Communication			
Whole Sale	0.038[d]		
Retail	0.162		
Public Administration		0.540	
Business Services	0.226		
FIRE[b]			
Manufacturing			
Travel Time (Min.)			
0–15		–0.073	
15–30	0.241		
30–35		0.078[d]	
35–45		0.040	
45–60		0.205	
60–90		0.182	
90+			
Car Ownership			
no car	–0.096[c]		
1 car	0.481	–0.108	
2+	0.089		
Constant	0.255	0.352	
R^2 adjusted	0.97	0.98	0.28

[a] Unless so indicated, parameter values shown are only for level of significance of 5% or better; [b] FIRE = Finance, Insurance, Real Estate; [c] Agg. & Fish = Agriculture and Fisheries; [d] Significance at less than 10% level.

Table 3. Time-of-day-departure elasticities.[a]

Variable\Time of Departure	12–6	6–6:30	6:30–7	7–7:30
Income Range:				
$0–9,000				
$10,000–20,000	0.211			
$30,000–40,000	0.153[d]			
$40,000–50,000				
$50,000–60,000			0.096	
$60,000+				
Mode Use:				
Car		0.169[d]		
Transit	0.326			0.260
Walk				
Type of Job:				
Transport & Communication			0.127[d]	
Retail				
Public Administration				
Business Services				
FIRE[b]				
Manufacturing		0.299	0.269	0.087[d]
Agg. & Fish[c]	0.107	0.090	0.082[d]	0.059
Car Ownership:				
No car	–0.283			
One car				0.215
Two or more			0.097	–0.087
Travel Time (Min.):				
0–15			0.101[d]	
15–30		–0.185		
30–35				
35–45		0.082[d]	0.094	
45–60				
60–90				0.110[d]
90+	0.072[d]	0.110	0.072	
Constant	–0.328[d]		–0.295[d]	–0.255
R^2 adjusted	0.89	0.92	0.92	0.96

[a] Unless so indicated, parameter values shown are only for level of significance of 5% or better; [b] FIRE = Finance, Insurance, Real Estate; [c] Agg. & Fish = Agriculture and Fisheries; [d] Significance at less than 10% level.

Table 3. Continued.

Variable\Time of Departure	7:30–8	8–8:30	8:30–9	9–10	10–12
Income Range:					
$0–9,000		–0.128			
$10,000–20,000				0.210[d]	
$20,000–30,000					–0.312
$30,000–40,000	0.237	0.164			
$40,000–50,000					0.340
$50,000–60,000					
$60,000+		0.151			
Mode Use:					
Car		0.141		–0.230[d]	–0.533
Transit	0.257		–0.255[d]	–0.773	
Walk					
Type of Job:					
Transport & Communication					
Whole Sale				0.096[d]	0.169
Retail	–0.167				
Public Adm.		0.068[d]			
Bus. Services	0.246			0.750	
FIRE[b]	0.255				
Manufacturing					
Agg. & Fish[c]				0.152	
Car Ownership:					
No car		0.155			
One car		0.316			
Two or more			0.182		
Travel Time:					
0–15		0.074[d]	0.150		
15–30		0.305			
30–35	0.150[d]	0.121[d]	0.286		
35–45		0.118	0.141	0.140	
45–60		0.232		0.373	
60–90	0.267				
90+					
Constant:			–0.301[d]		
R^2 adjusted	0.95	0.96	0.89	0.86	0.72

[a] Unless so indicated, parameter values shown are only for level of significance of 5% or better; [b] FIRE = Finance, Insurance, Real Estate; [c] Agg. & Fish = Agriculture and Fisheries; [d] Significant at 10% or less.

Table 4. Length of travel time elasticities.[a]

Variable\Length of Travel Time	0–15	15–30	30–35	35–45
Income Range:				
$0–9,000				
$10,000–20,000				
$20,000–30,000			–0.073[d]	
$30,000–40,000		–0.085		
$40,000–50,000			0.066[d]	
$50,000–60,000		–0.064		
$60,000+			–0.065	
Mode Use:				
Car		0.267	0.102[d]	
Transit	–0.502	0.173		0.328
Walk				
Other				
Type of Job:				
Transport & Communication			0.158	
Whole Sale	0.079		0.046	0.156
Retail	0.189		0.257	
Public Adm.	0.100	0.047[d]	0.070	
Bus. Services	0.572	0.192	0.283	
FIRE[b]	0.122[d]			
Manufacturing		0.150	0.092	
Agg. & Fish[c]				
Car Ownership:				
No Car				–0.293
One car		0.131		0.273
Two or more			–0.080	
Time of Departure (AM):				
12:00–6:00		–0.057[d]		
6:00–6:30		–0.108		
6:30–7:00			0.128[d]	
7:00–7:30		0.168		
7:30–8:00				
8:00–8:30	0.137[d]	0.160		0.264
8:30–9:00	0.100			0.113
9:00–10:00				0.128
10:00–12:00		0.045		
Constant:	0.273[d]			–0.428
R^2 adjusted:	0.92	0.97	0.96	0.90

[a] Unless so indicated, parameter values shown are only for level of significance of 5% or better; [b] FIRE = Finance, Insurance, Real Estate; [c] Agg. & Fish = Agriculture and Fisheries; [d] Significant at 10% or less.

Table 4. Continued.

Variable\Length of Travel Time	45–60	60–90	90+
Income Range:			
$0–9,000			0.254
$10,000–20,000			
$20,000–30,000		0.187	
$30,000–40,000			
$40,000–50,000			
$50,000–60,000			
$60,000+		0.066	
Mode Use:			
Car		0.199	
Transit	0.475	0.375	
Walk			
Type of Job:			
Transport & Communication	0.253		0.342
Whole Sale			
Retail			
Public Adm.		0.117	
Bus. Services	–0.212		
FIRE[b]	0.118	0.080[d]	
Manufacturing		0.164	
Agg. & Fish[c]			
Car Ownership:			
No car			–0.366
One car		0.229	
Two or more			
Time of Departure (AM):			
12:00–6:00			0.158[d]
6:00–6:30			0.341
6:30–7:00		0.062[d]	
7:00–7:30			
7:30–8:00		0.135	
8:00–8:30	0.198		
8:30–9:00			
9:00–10:00	0.111		
10:00–12:00			
Constant:	–0.277	0.176[d]	–0.534
R^2 adjusted:	0.96	0.96	0.80

[a] Unless so indicated, parameter values shown are only for level of significance of 5% or better; [b] FIRE = Finance, Insurance, Real Estate; [c] Agg. & Fish = Agriculture and Fisheries; [d] Significance at less than 10% level.

5.2. *Three stage least square (3SLS) results*

Given the many variables in each of the above three choice equations and the need to estimate these equations simultaneously using instrumental variables, we have estimated the following model using a 3SLS (using SURE procedure). These are: mode use (eq. 4), time of departure (eq. 5) and length of travel time (eq. 6):

$$\ln(M) + a_M + \beta_{LT}\ln(LT) + \beta_I\ln(I) + \beta_{TD}\ln(TD) \quad (4)$$

$$\ln(TD) = a_{TJ} + \beta_{LT}\ln(LT) + \beta_I\ln(I) + \beta_M\ln(M) \quad (5)$$

$$\ln(LT) = a_{LT} + \beta_M\ln(M) + \beta_I\ln(I) + \beta_{TD}\ln(TD) \quad (6)$$

In estimating these equations we have considered 2 modes (car, transit); 3 income levels ($0–30,000; $30,000–50,000; $50,000+); 3 periods of time of day departure (12 AM–7 AM; 7 AM–9:00 AM; 9:00 AM–12 AM); 3 categories of length of travel time (0–30 minutes; 30–45 minutes; 45–90 minutes). As instrumental variables we have used: place of employment (all categories), income (3 categories), type of job (all types), and car availability (all categories).[5] The results of the analysis are presented in Tables 5–7 below.

6. Discussion of results

As evident from the data in Appendix A, Bronx demographics are skewed towards low income, low auto ownership and use and high transit use. The estimation results presented above, to a large extent, are manifestations of these realities. The results discussed in this section are from both the OLS and 3SLS analyses. Given the large number of estimates (presented in Table 2a–7) we will focus mainly on key results.

We start the analysis with mode use (see Tables 2a and 2b). In the Bronx sixty percent of all households have income under $30,000. Car use is negatively affected by income in the low-level categories and positively affected at the high income range ($60,000+). The opposite is true for transit. Thus, holding as constant all other variables, the income elasticity of car use is negative for low and medium income categories ($0–20,000, $30,000–$40,000), indicating a potential low level of accessibility of these income groups. Middle level income groups, are transit oriented with income elasticity of about 0.06–0.09. For the highest income group ($60,000+) income elasticity of car use is about 0.198 without car ownership (as an explanatory variable),

Table 5. 3SLS estimation of mode use elasticities.[a]

Variable\Mode	Car	Transit
Income Range:		
$0–30,000	–0.141	0.090
$30,000–50,000	–0.076[d]	
$50,000+	0.291	–0.078
Time of Departure (AM):		
12:00–7:00	0.170	0.155
7:00–9:00	0.174	0.218
9:00–12:00 (noon)	–0.303	–0.177
Travel Time (Min.)		
0–30	0.698	–0.242
30–45		0.415
45–90	0.191	0.670
Constant:	–0.144	
R^2 adjusted	0.96	0.98

[a] Unless so indicated, parameter values shown are only for level of significance of 5% or better; [b] Significance at less than 10%.

Table 6. 3SLS estimation of time-of-day departure elasticities.[a]

Variable\Time of Departure	12–7:00 AM	7–9:00	9–12:00 (noon)
Income Range:			
$0–30,000	–0.040[d]		–0.062[d]
$30,000–50,000	0.168		
$50,000+		0.099	0.268
Mode Use:			
Car	0.170	0.149	–0.889
Transit	0.256	0.300	–1.193
Travel Time (Min.):			
0–30	0.090[d]	0.351	0.704
30–45	0.399		0.872
45–90		0.090[d]	1.201
Constant:		0.185	–0.230
R^2 adjusted	0.96	0.97	0.89

[a] Unless so indicated, parameter values only for level of significance of 5% or better; [b] Significance at less than 10%.

Table 7. Length of travel time elasticities.[a]

Variable\Length of Travel Time (min.)	0–30	30–45	45–90
Income Range:			
$0–30,000	0.102		–0.053
$30,000–50,000			
$50,000+	–0.211		
Mode Use:			
Car	0.533	–0.093	0.206
Transit	–0.448	0.437	0.712
Time of Departure (AM):			
12:00–7:00	0.222	0.390	–0.112
7:00–9:00	0.600	0.148	
9:00–12:00	0.239	0.173	0.211
Constant		–0.257	0.179
R^2 adjusted	0.96	0.96	0.97

[a] Unless so indicated, parameter values only for level of significance of 5% or better; [b] Significance at less than 10%.

and is 0.067 when this variable is included. Similar result regarding the effect of income on mode use are obtained from the 3SLS analysis.

Walk is, in general, not very sensitive to income, though the estimated elasticities indicate that people within the income levels of $20,000–$30,000 and $50,000–$60,000, walk. Walking is probably more sensitive to additional factors.

The use of car and transit is further affected by car ownership which is related to income, given locational factors (as depicted in Fig. 1). Not owning a car implies (negative) car use elasticity of –0.096 (see Table 2b). Car ownership, on the other hand, has a very strong effect on car use (elasticity of 0.481, Table 2b) and a marked negative effect on transit use (elasticity of –0.108). It can be concluded from the income and car ownership results that, when assuming the present locations (places of home and employment), as well as type of job, the simultaneous effect of increase in the number of households at the medium income level and a reduction in the number of households at the lower income levels will stimulate transit use for work trips. On the other hand, increase in the number of people at the high income level and/or increase in car ownership rates, will tend to encourage more car use. While these results characterize mode use in general, they have a unique implications for the Bronx. Given the very large proportion of low income households in this borough (see Appendix A) transportation and non-transportation public projects which will increase income will also stimulate transit use. The degree to which this income effect will indeed occur and estimation of the resultant added transit ridership are subjects for further analysis to be addressed by the Bronx Center Study.

Mode use is also affected by locational factors, mainly the proximity of residential to job locations (measured by the length of travel time variable) and by type of job. The OLS and 3SLS results indicate that, *ceteris paribus*, short distance trips (0–30 minutes) have a positive effect on car use (travel time elasticity of car use about 0.459, Table 2a, and 0.698, Table 5) and negative effect on transit use (–0.097, Table 2a and –0.242, Table 5). Transit use, on the other hand, is positively affected by medium to long travel times (30–90 minutes), elasticity of 0.096 to 0.165 (Table 2a), and 0.415 to 0.670 (Table 5). Intra borough trips are being made, in increasing numbers, by private for hire vehicles (not always legal), New York's most rapid growing transit mode.

These results can be explained as follows. In New York metropolitan area the use of a car for long distance travel is quite costly due to expensive tolls, very high levels of traffic congestion and acute shortage of parking space in central areas. Given the income effect on mode use (see above), in the Bronx car is therefore not used in conjunction with lengthy travel times. It is mainly used for short trips when access (to transit) and wait time constitute a significance proportion of total travel time. The cost of transit use, on the other hand, is invariant to travel times and, in many cases, transit has better accessibility to centers of economic activity than cars have. Hence, transit is the preferred mode for medium to long travel times. Thus, on the basis of location effect alone (proximity of home to work locations), increasing the economic activity in the Bronx through investments which will encourage more employment within the Bronx, and therefore short to medium travel times, is likely to increase the rate of auto use at the expense of transit use, by the local population.

Examining the effect of job category on mode use, it is seen that transit is not affected by FIRE (Finance Insurance and Real Estate) employment (insignificant elasticity estimate) but is positively affected by Retail (elasticity of 0.064), and more pronouncedly by Business Services and by Public Administration (elasticities of 0.539 and 0.540, Tables 2a and 2b, respectively). The elasticity of car use with respect to wholesale, Retail and to Business Services is positive (see Tables 2a and 2b). These particular job types may be effected by location. That is, many workers in these categories must serve a number of locations during a given day, rather than be fixed at one employment site. In addition, employment located close to residential locations (e.g. retail and some Business Service jobs) positively affect car use since, noting that the elasticity of car use relative to short travel times is positive. Public Administration (i.e. city jobs), which is the predominant job type and which is scattered all over the Bronx, stimulates transit use via the travel time effect. In the case of city jobs, they are site dependent, as opposed to service jobs that make the worker travel to many locations throughout the day. Based on these results it can be concluded that if the Bronx Center project concentrates growth in Retail or Business Services type jobs, located within or near the Bronx Center area, increased car use can be expected.

The results pertaining to the time of day departure (Table 3) suggest that the use of a car in the Bronx mainly encourages late rush-hour (8–8:30 AM) departures (elasticities of 0.141). It adversely affect late departures (after 9:00 AM) as is evident from the estimated elasticities (–0.230 for 9–10:00 AM and –0.054 for the 10–12:00AM period). These results are in accord with the above finding that car is used in the Bronx primarily for short trips (0–30 minutes travel time). Transit use, on the other hand, mostly affect very early departures (until 6:30 AM) and departures at the early rush-hour time period (7–8:00 AM, elasticity of about 0.260). Like with car, the use of transit adversely affect late departures. The results from the 3SLS analysis (Table 6) suggest that, in general, in the Bronx the use of both modes favor early and rush-hour departures and dampen late (after 9:00 AM) departures. A high proportion of Bronx workers are salaried and must follow a fixed daily clock.

The results in Table 3 also indicate that, in general, a lengthy travel time coincides with early departure. This is rather an expected finding that reinforces why specific job types like Business Services, that are close to residential areas, have a positive effect on rush-hour and late period departure times. Manufacturing jobs, on the other hand, which in the Bronx are located much further away (including in other boroughs) motivate early departures. Hence, if the jobs created by the Bronx Center Project will mainly be located within the Bronx with shorter travel times for Bronx residents, the distribution of time of day departure can be expected to concentrate more in the later periods (8–9 AM and after) than is today. One positive aspect of such job shifts and travel times shifts would be to distribute travel demand, and corresponding supply needed, more evenly during peak periods.

The length of travel time is mainly a function of the proximity of place of employment to place of residence. In a general equilibrium model framework (e.g. Anas 1982) it was shown that the location of places of employment relative to places of residence, the level of income and mode use are all interrelated and thus affect each other. Since the present analysis does not assume such relationships, the statistical association between these variables (presented in Table 4) cannot be explained on such a theoretical basis.

Nevertheless, the results shown in Table 4 and in Table 7 indicate that income, especially in the higher classes ($50,000–60,000 and 60,000+), is negatively associated with mid-range travel times (15–35 minutes), probably due to the higher propensity to use a car by the higher income trip makers. Low and mid-income groups are more prone to undertake trips length of 30–60 minutes.

Mode use affects travel times via ease of access, wait time, in-vehicle time, egress time, and parking time. In this regard the automobile, in general, provides the best opportunity for minimizing work travel times, given home and work locations. In New York, however, transit has travel time advantages, particularly in medium to long distance travel, due to severe conditions of highway congestion in the region. The majority of trips from the Bronx are to Manhattan, the most congested corridor. A subway trip to Manhattan may take less time than a bus trip cross Bronx, indicating car might be preferable to transit for intra borough travel. For trips from the Bronx to suburban work locations, transit becomes more difficult to use, stimulating auto travel. This may explain the results which indicate elasticity of 0.475 and 0.375 for trip length of 45–60, 60–90 minutes, respectively, with regard to transit use (in Table 4) and 0.712 (in Table 7). It also explains the positive elasticity with respect to car use for short to medium trip length (15–30, 30–35 minutes). Hence, if the Bronx Center Project will encourage auto trips, short trip lengths can be expected.

7. Prediction

What impacts do changes in exogenous variables have on mode use and departure time? To answer this question we consider simultaneously the effect of all exogenous variables (which do not always have a similar effect); and we also need to estimate the degree of change in these exogenous variables. As explained above, the third choice variable, length of travel time, to a large extent, is determined by location factors as well as by mode use; we do not estimate the effect of likely changes in this variable.[6]

For prediction purposes, for each category of the explanatory variables we choose that variable with both the highest frequency of occurrence and a statistically significant estimate as shown in Appendix A and in the relevant table of estimates. Thus, from Tables 2a and 2b, a typical example of the estimated equation for mode use for low income ($20,000 < I < $30,000), for 8–8:00 AM departure time and for Business Service type job is:[7]

$$\ln(CAR) = 0.255 - 0.097\ \ln(I) + 0.079\ \ln(TD) + 0.226n(TJ) \qquad (7)$$

For a higher income range (I = $60,000+), with one car the mode use equation is:

$$\ln(CAR) = 0.255 + 0.068 \ln(I) + 0.079 \ln(TD) + 0.226 \ln(TJ) + 0.241 \ln(LT) + 0.481 \ln(C) \quad (8)$$

For public transit use, with income level of ($20,000 < I < $30,000), departure time at 7:30 AM, Public Administration and trip length of 60–90 minutes, we get:

$$\ln(TRANS) = 0.352 + 0.080 \ln(I) + 0.102 \ln(TD) + 0.540 \ln(TJ) + 0.182(LT) \quad (9)$$

The same equation with higher income (I = $60,000+) and one car would be:

$$\ln(TRANS) = 0.352 - 0.046 \ln(I) + 0.102 \ln(TD) + 0.540 \ln(TJ) + 0.182 \ln(LT) - 0.108 \ln(C) \quad (10)$$

Turning now to Time of Day Departure (the primary category being 7:30–8:00 AM), the following equation is used for prediction, assuming income range of 30,000 < I < $40,000; transit use; business service; and 60–90 minutes travel time length:

$$\ln(TD) = 0.237 \ln(I) + 0.257 \ln(TRANSIT) + 0.246 \ln(TJ) + 0.267 \ln(TL) \quad (11)$$

Cautious should be exercised when trying to derive general policy inferences from these equations. Thus, for example, from equation (7), a 10% increase in the number of employees in the category "Business Services"[8] is predicted to increase the number of car trips (for work purpose) by 2.26%, given all other factors. But, if these additional employees will earn the low income level that this equation is based upon (between $20,000 and $30,000), the number of work trips by car will decline by 0.97%. This qualification notwithstanding, from these illustrative equations it is possible to predict the effect of changes in the exogenous variables on the home-to-work travel behavior of the Bronx's population. Thus, from equation (7), a 10 percent increase in the number of trips departing at 7:30–8:00 AM (TD), will increase car use only very slightly (by 0.79%) since, as we saw above, car use tends to concentrate at other times of departure. Equation (11) indicates that increase in number of employees in Business Services will increase total number of trips at this peak time period (7:30–8:00 AM) by 2.46%. From equation (10) it will also encourage transit use by about 1.0 percent.

8. Conclusions

The principal objective of the Bronx Center Project is to generate employment and economic growth in this borough by means of large scale investments in transportation facilities and other land use projects. If these planned investments will indeed generate the desired economic effects, e.g. more employment (an issue examined in Berechman & Paaswell 1994) they will significantly affect work-trip patterns of the Bronx's population relative to present day conditions. The main objective of this paper is to determine the current transportation characteristics and behavior of the Bronx's population relative to three major categories of work travel determinants: mode use, time-of-day departure and trip length. To that end, we estimate the travel demand elasticities of these variables and, based on these, predict how changes in exogenous variables like income or additional employment of specific types will affect these travel characteristics.

Given the underlying objectives of the Bronx Center project, the results from the analysis of this paper suggest a paradoxical employment-transportation situation. That is, if the additional employment (thus income) from the targeted investments will be located outside the Bronx, more long distance, rush-hour, transit trips can be expected. On the other hand, if employment will concentrate mostly within the Bronx (as is Project's overall objective) then the propensity of trip makers will be towards short-distance, auto type trips. However, car ownership in the Bronx is very low so that this potential new demand may not be satisfied as no personal, low cost, auto type mode, presently exists in the Bronx.[9] The present transit system, which favors medium and long distance rush-hour travel, is inadequate to meet this demand.

If the desire economic effects occur, the new employment may find it infeasible to commute to their places of work inexpensively and conveniently. This likely predicament calls for an innovative approach to fulfill the needs of local employment stemming from Bronx Center Project. A contemplated project, providing a para transit – like circulator is a positive step. Such a circulator, identified as needed by community groups, would add new short range transit to the predominately Manhattan oriented system.

Another conclusion from the above analysis is that the new employment should concentrate mainly in Business Services, Retail and Public Administration type jobs if transit travel, rather than car travel, is to be encouraged. The question of whether these types of jobs will, in fact, be generated by the proposed investments needs, therefore, to properly be explored.

Lastly, in New York the economic well-being of one borough strongly affects the economic state of the other boroughs. Hence, if new jobs will indeed occur in the Bronx, commuting from other boroughs is liable to increase. It is, therefore, important to analyze this possibility since it may impose additional distress on the presently crowded subway and bus transit systems. We note that the kind of analysis carried out in this study is now being performed for the other four boroughs of New York.

Notes

1. For a comprehensive review of transportation choices and their relationships with locational factors see Berechman and Small (1988).
2. Within the Bronx, there were 21 such tracts, although some of them do have a significant number of populations. A comparison of STF1a with STF3a was used to locate these census tracts.
3. For definitions see census of Population and Housing, 1990, Summary Tape File 3 (1992).
4. MSA = Metropolitan Statistical Area; PMSA = Primary Metropolitan Statistical Area.
5. The aggregation was done on the basis of the distribution of the entire set of variables in the input database.
6. Within the framework of assessing the overall consequences from investment in transportation and economic projects in the Bronx, travel times choices will be examined relative to firms' relocation emanating from these investments (see Berechman & Paaswell 1994).
7. The constant term in equation (7) is e^x where x is the constant parameter in the estimated function.
8. The unit of analysis is "work trips", so that a 10% increase in a variable actually refers to the number of work trips of this type.
9. The purpose of the "circulator" is to complement existing fixed route service.

Appendix A: Basic statistics for the Bronx

In 1990, the total land area of the Bronx county was 41.5 square-miles. The number of households was 440,995, total population 1,203,800 people. Below, the main socio-economic and travel characteristics of the borough, in terms of the seven key variables, are presented.

I. *Number of households with x number of people*

In the Bronx, the distribution of the population by household size category is as below:

Category	x = 1	x = 2	x = 3	x = 4	x = 5	x = 6	x = 7+
Percent	29.45	26.20	17.66	13.33	7.2	3.35	2.73
Mean (%)	26.3	24.3	18.4	15.0	8.5	3.0	3.4
Std. Dev (%)	10.6	6.7	5.4	5.8	4.3	3.0	2.9

The mean of the distribution for the 334 census tracts is 2.77 with standard deviation of 0.46.

II. *Households' range of income (I)*

Range ($1,000)	0–10	10–20	20–30	30–40	40–50	50–60	60+
Percent	26.57	17.37	16.09	12.70	9.22	6.07	11.94
Mean (%)	28.7	17.39	15.55	11.06	8.55	6.29	12.46
Std. Dev (%)	16.6	6.95	5.75	4.97	4.60	4.75	11.07

The mean of the distribution for the 334 census tracts is $29,030 with standard deviation of $22,020.

III. *Mode use (M)*

Mode	Car	Transit	Other	Walk
Percent	36.29	56.34	0.66	6.69
Mean (%)	34.21	56.34	0.75	7.43
Std. Dev (%)	14.93	14.41	1.22	5.75

IV. *Car ownership (C)*

Category	No Cars	One Car	Two or More
Percent	60.29	30.49	9.20
Mean (%)	59.27	28.79	11.95
Std. Dev (%)	22.98	13.54	12.03

The mean of the distribution for the 334 census tracts is 0.52 cars per household with standard deviation of 0.386.

V. *Persons per car (PC)*

Category	Drive Alone	2–3 per Car	4 + per Car
Percent	73.36	23.33	3.29
Mean (%)	24.4	8.1	1.4
Std. Dev (%)	12.2	4.9	1.8

The mean of the distribution for the 334 census tracts is 1.46 per car with standard deviation of 0.617.

VI. *Time of departure (TD)*

Category	12–5:59	6–6:29	6:30–6:59	7–7:29	7:30–7:59	8–8:29	8:30–8:59	9–9:59	10–12
Percent	17.36	9.07	10.43	20.75	17.92	18.73	6.47	5.78	3.44
Mean[a] (%)	8.19	9.94	10.03	20.52	16.17	18.40	6.76	6.46	3.52
Std. Dev (%)	4.47	5.16	4.83	6.76	6.40	7.06	3.80	5.27	3.39

[a] Mean number of people per census tract that leave the house for work at each time period.

VII. *Type of job (TJ)*[a]

Type	Agr & Fis	Manuf	Trn & Co	Wholes	Retail	FIRE	BusSer	PubAd
Percent	4.74	10.16	10.51	3.61	12.48	10.02	10.53	36.72
Mean (%)[b]	5.3	11.43	9.5	3.8	13.2	9.4	11.2	35.8
Std. Dev (%)	3.7	5.5	4.1	2.6	5.1	3.9	4.4	9.7

[a] The category: “Work at Home” is not included in this table since these data come from a different source of data. In any case, we not use this category in the regression analysis; [b] Form the sample of 334 tracts.

VIII. *Length of travel time (in minutes) home to work (LT)*

Range (minutes)	0–15	15–30	30–35	35–45	45–60	60–90	90+
Percent	12.08	20.41	15.06	7.22	17.56	22.80	4.87
Mean (%)*	153.3	259.1	191.2	91.6	222.8	289.5	61.8
Std. Dev (%)	136.0	220.3	149.0	87.1	192.3	265.2	81.3

* Mean number of people per tract, that report travel time at a given category.

IX. *Work place (WP)*

Place of Work	Live in NYC work center city NYC[a]	Live in NYC Work outside center city NYC	Live in NYC Work in center city other than NYC	Live in NYC Work outside center city Other than NYC
Percent	90.18	5.58	0.78	3.45
Mean (%)	90.05	5.58	0.78	3.45
Std. Dev (%)	6.27	4.91	1.87	3.14

[a] In the case of NYC the central city is considered to be the five boroughs and White Plains (definition from Bureau of the Census).

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