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## PROCEEDINGS —

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Theme:

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TRANSPORTATION RESEARCH FORUM

ON FEBRUARY 17th, 1972 the Metropolitan Atlanta Rapid Transit Authority (MARTA), a public agency created in 1965, purchased the privatelyowned Atlanta Transit System, Inc. MARTA immediately took over operation of the company's bus lines, and commenced the implementation of a "short-range transit improvement program" assisted by a \$33 million capital grant from the Urban Mass Transportation Administration. Details of this program have been described by Kiepper et al. (1973).

MARTA's policy for the operation of both the bus lines and the new fixed rail rapid transit system currently under design in the city is to maintain "low fares"—that is to say, fares well below both the market level and the level necessary to recover operating costs fully. Deficits on operating account (as well as the city's contribution to the construction costs of the new system) are to be recouped from the revenues of a special one percent sales and use tax imposed over the participating local jurisdictions.

Consequently, on March 1st, 1972 the basic bus fare was reduced from  $40\phi$ to  $15\phi$  per ride. In addition, during the first year of the transit system's operation under public ownership various other aspects of the short-range transit improvement program were implemented. Of these the most significant are several increases in service provision, equivalent in total (by February 1973) to an increase of roughly 30 percent in the annual vehicle miles operated.

This paper documents a very simple empirical exercise in which MARTA's monthly operating statistics for the period from January 1970 through February 1973 were examined to investigate what might be deduced about the demand response to the fare and service changes. Despite the fact that the time span considered is a short one and that the limited data available are of a very aggregate nature, it has proved possible to account successfully for the month-to-month ridership variations on the system, and hence to identify the effects of MARTA's innovations.

### Atlanta's transit system, 1970 to 1973

In calendar year 1970 Atlanta Transit System, Inc. operated a total of 19.43 million vehicle miles over roughly 80 bus routes. Approximately 48.1 million passengers paid a base fare of  $35\epsilon$ , and of these about 12.6 million paid an extra  $5\epsilon$  in order to transfer between lines. The population of the area served by the system was approximately 780,000.

The base fare was increased on March 5th, 1971 to 40¢, still retaining the 5¢ transfer charge. On March 1st, 1972, after MARTA had assumed operation of the system, the fare was reduced to a flat 15¢, all zonal surcharges were abolished, and so was the transfer charge. This reduction, however, did not apply throughout the entire system. Clayton County had not approved the one percent sales tax levy, and fares for services within that county remained at the previous level. Fares for special services (the Stadium Shuttle, the Falcon Flyer, Six Flags services, for example) were not reduced, nor was the 10¢ school fare. Overall, MARTA estimates that at the time of the fare cut roughly 83 percent of the revenue passenger trips were affected by the reduction.

In addition, over the first year of public operation of the system (March 1972 through February 1973) a total of 5.80 million annual vehicle miles were added, an increase of roughly 30 percent.

### THE ADOPTED MODEL OF TRANSIT RIDERSHIP

The analysis described here is posited on the hypothesis that longitudinal variations in aggregate transit ridership in a metropolitan area can be accounted for adequately by a relatively small number of explanatory variables. Previous work by the statistical laboratory of the Massachusetts Institute of Technology (Rainville, 1948) and by Carstens & Csanyi (1968), both using annual rather than monthly operating statistics, support this hypothesis.

The model further assumes that the observed time series of rider volumes can be decomposed into three component series which are additive:

 $y_t = d_t + s_t + \epsilon_t$  (t=1....N)

where y<sub>t</sub> is the t<sup>th</sup> observation of the time series,

d<sub>t</sub> is a non-seasonal deterministic component

s<sub>t</sub> is a seasonal component

and  $\epsilon_t$  is a random error component. If  $d_t$  and  $s_t$  are themselves linear functions of other parameters, then a model of this nature satisfies the hypothesis of the general linear statistical model and may be estimated by standard methods of linear regression.

From the longitudinal data available, it was decided to select the revenue passenger volumes for use as the principal endogenous variable in this analysis. The revenue passenger volumes for

## The Effects of Atlanta's Short-Range Transit Improvement Program on System Ridership

each month from March 1970 through February 1973 are graphed in Figure 1.

### PATRONAGE OF ATLANTA'S TRANSIT SYSTEM: ACTUAL PASSENGER VOLUMES



### **FIGURE 1**

Examining first the period prior to March 1972, the graph exhibits some fairly strong seasonal variations with, as one might expect a priori, a periodicity of one year. Ridership is lowest in the summer months of June, July, and August (probably due in some measure to school vacations in these months), and peaks in March and October. Underlying the monthly variations there appears to be, as with the majority of U.S. transit systems, a downward trend.

Ridership rose sharply in March 1972 following the MARTA fare cut, but the seasonal variation during the subsequent year broadly followed the pattern of the preceding years with a summer trough and an October peak.

### The variables used in the analysis

The model adopted here hypothesizes that the month-to-month variations ob-

### by Michael A. Kemp\*

served in revenue passenger volumes are, in part, determined by:

• the money price (to the passenger) of the service. A priori we would expect that the higher the transit fare, the lower will be the ridership—since as the price rises, consumers at the margin will divert to other modes or cease to travel.

• the level of service provided by the system. The available empirical evidence (a review of which appears in Kemp, 1973) strongly suggests that transit ridership is relatively more sensitive to changes in the level of service supplied—in particular, to door-todoor journey times—than it is to changes in money price.

• the number of days in the month. Part of the monthly variation in ridership may be expected to reflect differences in the lengths of months, and in particular, variations in the number of working days in the month. MARTA estimates that Saturday and Sunday ridership averages roughly 43 percent and 15 percent respectively of a weekday's ridership.

In addition to these three deterministic variables, the model quantitatively incorporates two other components:

• a secular trend variable, representing the effects of those non-seasonal influencing factors not considered explicitly

• a pattern of seasonal variations, with annual periodicity, representing the effects of those seasonal influencing factors not explicitly considered.

Table 1 defines the set of basic variables entering into the analysis. The only available measure of the level of service provided by the system was the total vehicle miles operated during the month (TVM). Since the transit passenger or potential passenger predominantly evaluates service in terms of such factors as door-to-door journey times, access (walking and waiting) times, number of transfers, and reliability, TVM must be regarded as a very inadequate measure for this purpose.

The money price variable, FARE, is the basic bus fare for the system, which is not the same as the average fare paid per revenue passenger. An average fare value would be a more appro-

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t This paper is a condensation of an Urban Institute Paper by the same author (Kemp, 1974a). The work reported here was performed under funding from the Research Applied to National Needs (RANN) Program of the National Science Foundation. Opinions expressed are those of the author, and do not necessarily represent the views of The Urban Institute or the study sponsor.

### BASIC VARIABLES USED IN THE ANALYSIS

Description

Т	time variable
NWD	Months are numbered con- secutively, commencing with January 1970 as unity. number of non-working days
WD	Total number of Saturdays, Sundays, and public holi- d a y s occurring in the month. number of working days This is the difference be
	tween the total number of days in the month and the n u m b er of non-working days in the month
FARE	system basic bus fare The basic fare (in cents) in operation during the month, using a weighted mean for
RP	those months in which fare charges occurred. revenue passengers Total number of revenue
T)/M	passengers (that is, count- ing transferring passengers once only) carried during the month, in thousands.
	Total bus miles operated over the whole system dur- ing the month, in thou- sands.
$D_i$ (i = 1,212)	dummy variable for each month $D_i=1$ for the ith month of
	$D_i = 0$ for all other months in the year
	TABLE 1
priate measur sons it is diff estimate of th Seasonal eff the model by dummy varia month of the technique of time series a Since twelve the revenue p ed slightly (h closely with	re, but for technical rea- ficult to form an accurate is from the available data. fects are accounted for in introducing a set of twelve bles $(D_i)$ , one for each year—this is one standard seasonal adjustment in nalysis (Jorgenson, 1964). month moving averages of assenger volumes correlat- out not significantly) more the logarithmic transform

of the trend variable T, log<sub>e</sub>T was employed in preference to T throughout

Other variables, formed from the bas-

ic set, were used in some model estima-

tions. Revenue passengers per working day (RP/WD) was computed by dividmonth (RP) by the total number of working days in the month (WD); total vehicle miles per working day (TVM/ WD) was calculated similarly. On the hypothesis that the demand reaction to service improvements may be a slow one because of imperfections in information dissemination, a lagged value of the service supply variable was also tested; this variable represents the total vehicle miles operated during the preceding month.

ing the total revenue passengers in each

### Estimation of the model

Using ordinary least squares estimation, a number of models were calibrated<sup>1</sup> in which ridership (either RP or RP/WD) was expressed as a linear function of various sets of the explanatory variables. Fourteen of these models are summarized in Tables 2, 3, and 4. They are categorized into four different groups:

• Group A models use RP as the endogenous variable, and are based on the data for March 1970 through February 1972, just prior to the MARTA fare decrease; • Group B models use RP/WD as

• Group B models use RP/WD as the dependent variable, based on the March 1970 to February 1972 data; • Group C models use RP as the de-

• Group C models use RP as the dependent variable, and are based on data for March 1970 through February 1973, thus implicitly incorporating the effects of MARTA's short-range improvement program;

• Group D models use RP/WD as dependent variable, based on the March 1970 to February 1973 data.

Tables 2, 3 and 4 present the estimated coefficients for the variables in each of the models, together with the values of Student's t statistic associated with each coefficient. Summary statistics for the goodness-of-fit for the model as a whole are also presented.

It is readily apparent from inspection of these tables that all fourteen of the model formulations summarized there give a good explanation of the monthto-month variations in revenue passenger volumes over the time period on which they are based. All but one of the formulations calibrated on pre-March 1972 data (groups A and B) account for over 90 percent of the total longitudinal variance in ridership; all of the models based on 1970 through 1973 data (groups C and D) explain at least 86 percent of the variance. The coefficient of multiple determination and the variance ratio for every one of the fourteen are highly significant at the 0.1 percent level.

Moreover, the signs and magnitudes of the estimated coefficients are predom-

Variable

name

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all model estimations.

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Period: March 1970 through February

1972

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	3	8		1.36		1.17		2.44		2./0	
	•			20.06		19.51		17.52		66.54	
	51 <sup>0</sup>	6750	32.634	5747	1.35	1418	0.93	5887	9.33*	1903	2.28*
	114	(11)	33.16*	5799	1.40	1484	1.00	5696	9.25*	2007	2.44+
	01 <sup>0</sup>	2064	36.02*	6332	1.47	181	0.99	6231	9.65*	2048	2.34*
	<b>6</b>	489.2	35.51*	5889	1.43	1562	1.03	6076	9.29#	2105	2.51*
	<b>8</b>	4323	32.07#	1162	1.26	1106	0.76	5524	8.33*	1709	2.10
	۲đ	4298	32.69*	5290	1.24	1079	0.74	8188	8.20*	1704	2.09
	9 <b>e</b>	4380	34.27*	5372	1.30	1911	0.79	3624	8.22*	1814	2.23*
	۶ <sup>۵</sup>	4769	38.56*	5974	1.39	1335	0.85	6038	8.65#	1959	2.26*
ficients	4	4846	40.78+	5833	1.41	1444	0.93	6146	8.61*	2116	2.464
Coef	e <sup>a</sup>	4762	42.12*	1695	1.34	1329	0.85	6085	8,39*	2022	2.33*
	D2	4602	30.69*	5658	1.44	1413	0.97	5713	9.24*	1906	2.38*
	۱a	4639	31.52*	5929	1.38	1369	16.0	5782	9.26*	1850	2.244
	logf	-332.0	-7.59*	-347.6	-9,48*	-288.8	-6.80	-115.0	-0.925		
	Q714			-108.0	112.0-						
	9			0.827	0.006						
	1415							-46.71	- 1.8	-60.04	-13,30*
	INI					2.005	2.20			2.598	5.484
		4		7		4		4		8	

NOTES:

The number appearing beneath each coefficient represents the value of Student's t statistic for that coefficient. An asterisk identifies those values which are significant at the 5% significance level.
F is the variance ratio for the model as a whole. All of the values cited are highly significant at the 0.1% level.
DW is the value of the Durbin-Watson Statistic.
R<sup>2</sup> is the coefficient of determination for the model as a whole, corrected for the number of degrees of freedom. It represents the proportion of the total variance in the dependent variable which is explained by the model. All of the values cited are highly significant at the 0.1% level.

2 TABLE

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			AR	REGRES	SION	MO	DELS	ΟF	RIDI	RSH	≥ ≥	DLUN	ES	GROU	8 6			
Dependent	Variable:	RP/WD								:			Period :	March	1970 thre	ugh F	sbruary	1972
Lauat foa						Coef	ic fent a											~
•	TVH	FARE	logT	<sup>D</sup> 1	D2	°.	D4	°5	9 <sup>0</sup>	۲ <u>م</u>	D8	6 <mark>0</mark>	D10	<sup>0</sup> 11	<sup>D</sup> 12	•	8	<b>e</b>
16		1	-17.25	239.9	246.9	216.6	233.8	6.962	212.0	200.5	205.9	236.8	260.2	234.7	222.0	29.94	1.07	938
		L	-9.13*	37.57*	38.13*	44.36*	45.54*	4.924	38.40*	35.30*	35.37*	39.79#	42.85*	37.96*	35.31*			
		I																
<b>1</b> 12	-0.060		-18.54	9.766	342.0	318.9	335.2	342.2	308.0	296.4	301.8	336.1	364.3	332.0	321.3	29.90	1.43	0.942
	-1 36		+60.6-	4.66*	4.87#	4.22*	4.48+	4.53*	4.35*	4.18*	4.26*	4.58*	4.74*	4.62*	4.38*			
5	1	-2.926	-3.656	310.3	316.6	299.5	315.2	4.610	289.9	277.0	281.1	310.9	333.2	306.8	293.2	54.74	1.93	0.968
		-3.38*	-0.862	14.56*	15.00#	12.09#	12.94*	*14.61	12.40*	12.05#	12.42*	13.93*	15.12*	14.09*	13.61*			
	,																	
4	-0.031	-2.695	-5.408	356.3-	361.1	346:8	362.2	367.0	334.2	321.4	325.6	357.3	382.2	352.3	9.915	50.07	2.01	0.968
	-0.916	-2.97#	-1.15	6.52*	6.81*	6.05*	6.37*	6.41*	6.21*	5.98*	6.07#	6.45*	6.60*	6.49*	6.14*			

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NOTES:

The number appearing beneath each coefficient represents the value of Student's t statistic for that coefficient. An asterisk identifies those values which are significant at the 5% significance level.
F is the variance ratio for the model as a whole. All of the values cited are highly significant at the 0.1% level.
DW is the value of the Durbin-Watson Statistic.
R<sup>2</sup> is the coefficient of determination for the model as a whole, so whole, corrected for the number of degrees of freedom. It represents the proportion of the total variance in the dependent variable which is explained by the model. All of the values cited are highly significant at the 0.1% level.

http://www.hathitrust.org/access use#cc-by-nc-nd-4. / https://hdl.handle.net/2027/mdp.39015023117792 Generated at University of Minnesota on 2021-10-07 16:17 GMT Creative Commons Attribution-NonCommercial-NoDerivatives LINEAR REGRESSION MODELS OF RIDERSHIP VOLUMES-GROUPS C AND D

Dependent Variable: RP (Group C); RP/WD (Group D)

Period: March 1970 through February 1973

a: [e							3	efficien	5							ļ	•	Z	~#	
	¥.		TALE	logT	L L	a".	<b>~</b>	4	sa Sa	9 <b>0</b>	r.	<b>•</b>	<b>.</b>	°1 •	<sup>111</sup>	<sup>0</sup> 12				1
_			-27.46	4.915-	5357	5347	5967	3500	3399	2113	5037	<b>1173</b>	5614	1185	3316	2400	18.26	2.61	0.845	
			-11.04*	-5.05*	26.22*	23.94	31.76*	30.48*	30.37*	27.23*	26.41*	26.740	28.65*	29.32*	27.52*	26.684				
~	457.0		-21.87	-206.3	7986	3094	4110	109	101	7216	3655	3762	4167	4282	1011	7944	22.86	2.25	0.247	
	2.82+		-7.440	-5.474	6.92*	7.13	7.62*	7.78*	7.57+	7.18*	7.05*	7.120	7.70*	7.52*	7.480	7.22*				
			-1.377	-11.71	7.672	283.5	255.4	274.0	275.1	246.2	C.CAS	1.04	276.6	296.3	211.6	260.9	35.12	2.06	2: 6.9	
			-13.19	-6.38	31.72*	32.57*	34.51*	35.96*	35.24	31.05*	30.21*	29.64*	33.42*	35.39*	32.10*	30.51*				
-	0.602		-1.361	-11.68	269.4	279.3	231.2	269.9	270.9	242.2	4.602	8.905	1.112	292.0	267.5	256.7	11.16	2.09	0.923	
	0.162		-9.34+	-6.194	• 7/*	10.32*	<b>9.40</b>	10.37*	10.02*	9.42+	•.13+	9.164	10.16*	10.34*	9.93*	9.494				
		0.759	-1.106	-11.12	197.9	204.1	189.9	204.1	203.5	180.4	177.6	178.6	206.0	218.6	201.0	191.5	4.22	1.67	0.945	
		3.53%	-8.81+	-6.85*	8.46*	8.67	9.39*	9.52*	9.26*	8.824	8.66*	8.76*	9.41*	.17	9.15*	8.85±				
	-																			

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NOTES: • The number appearing beneath each coefficient represents the value of Student's t statistic for that coefficient. An

therisk identifies those values which are significant at the 5% significance level. L.F is the variance ratio for the model as a whole. All of the values cited are highly significant at the 0.1% level. DW is the value of the Durbin-Watson Statistic. The coefficient of determination for the model as a whole, corrected for the number of degrees of freedom. The proportion of the total variance in the dependent variable which is explained by the model. All of the cited are highly significant at the 0.1% level.

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inantly in line with a priori expectations, with a very small number of exceptions. For example, all coefficients of the variable FARE are negative, as are all of the coefficients of the trend variable  $\log_e T$ ; the coefficients of the supply variables TVM and TVM/WD are predominantly positive. The t statistic values show that many of the coefficients are significantly different from zero (at the 5 percent level), and in no case does a significant coefficient possess an anomalous sign.

### RIDERSHIP AND THE FARE LEVEL

It is possible to use the estimated models of system ridership to isolate out the effects of fare changes alone on the volumes of revenue passengers. We shall discuss first the derivation of a fare elasticity of demand for the major price reduction of March 1, 1972.

Each of the fourteen equations summarized in Tables 2 through 4 may be used to predict the volumes of traffic which could have been expected during each month from March 1972 through February 1973, had the base fare remained at 40¢. This is done by extrapolating the models using the actual values for all exogenous variables except FARE (which is set equal to 40) when it appears explicitly in the equation. The predicted monthly revenue passenger volumes are then summed to provide total ridership estimates (at the 40¢ base fare) for three months, six months, and twelve months following the fare change. These totals can be compared with the actual traffic volumes observed over the same time periods, and the implied fare elasticities (designated  $\eta_3$ ,  $\eta_6$ , and  $\eta_{12}$  respectively may be computed.

ly) may be computed. The results of this procedure are summarized in Table 5. The elasticity estimates quoted there are arc-type values, computed from the formula

### ∆ log q

## $\eta = \frac{1}{\Delta \log p}$

where q is the total revenue passenger volume over the time period

and p is the value of FARE.

There are several features of interest in Table 5. First, with the exception of three of the model formulations (A3, A5, and B2), the traffic volumes predicted at a 40¢ fare by the remainder of the equations are highly clustered, all estimates lying within six percent of the mean. The implied fare elasticities are consequently also very uniform. Secondly. the majority of the models show a numerically larger fare elasticity

### FARE ELASTICITIES FOR THE MARCH 1972 FARE REDUCTION

	Revenue	bereafter .	re Lunet	Implied	fare els	actic Ley
	3 months, Mar '72 to May '72	6 months, Mar '72 to Aug '72	12 mmoths, Haz '72 to Fab '73	۳,	۲	٦.
	threeads	chrosenis.	thousends			
Actual riders at 13¢ fare	13,083	34,996	50,948			
Prodicted tide at 40c fare, i undel:	irs Iran					
A1	33.098	20,640	42,246	-0.17	-6.20	-0.19
42	11.053	20.643	42,068	-0.17	-0.30	-6.29
~	11.172	21,474	46,544	-0.16	-0.15	-0.09
<u> </u>	11,515	21,393	43,309	-0.13	-0.16	-0.17
25	11,782	22,640	49,147	-0.10	-0.10	-0.04
31	11,021	20,579	41,990	-0.17	-0.29	-0.20
32	10,929	20,011	39,364	-0.18	-0.23	-8.36
33	11,694	21,592	43,39F	-0.12	-0.15	-0.10
34	11,952	21,797	42,856	-0.12	-0.14	-8.18
C1	21,178	20,946	42,703	-0.16	-0.18	-0.18
C2	31,362	21,449	44,412	-0.14	-0.16	-6.14
34	11,110	30,605	42,423	-0.16	-0.19	-0.19
34	11,122	30,839	42,523	-0.16	-0.19	-0.18
25	11,279	21,902	44,000 '	-4.15	-8.16	-0.15
Modion value from the pode	de 11,175	91,134	42,780	-0.16	-8.17	-9.19
MARK estimat	aa 11,235	30,411	41,392	-0.15	-0.19	-0.21

### TABLE 5

over six months than over three—but the twelve month elasticity values are typically very close to the six month values.

The  $5\phi$  fare increase of March 1971 may be examined in a similar way, although in this case not all of the fourteen models can be used to derive elasticity estimates—the Group A and B equations which do not explicitly incorporate the FARE variable are not appropriate for the purpose. The results are summarized in Table 6.

The models calibrated on the data through February 1972 (Groups A and B) imply elasticity values of the order of -0.4 to -0.7 for the March 1971 fare increase—a somewhat higher elasticitv<sup>2</sup> than those estimated for the March 1972 fare cut. However, the models calibrated on the data through February 1973 (Groups C and D, shown below the broken line in Table 6) imply markedly lower fare elasticities for the March 1971 increase, of the order of -0.15 to -0.3. The reason for this is not difficult to determine. The estimation of the Group C and D equations is heavily influenced by the effects of the large MARTA fare reduction, which dominates the much smaller 1971 increase. These equations provide a good fit to the post-March 1972 data at the expense of being a poorer fit (than the Group A and B calibrations) to the pre-MARTA experience. One therefore coa-

### FARE ELASTICITIES FOR THE MARCH 1971 FARE INCREASE

		orunes	Implied	i fare e	lasticity
3 months, Mar '71 to May '71	6 months, Mar '71 to Aug '71	12 months, Mar '71 to Feb '72	η3	η <sub>6</sub>	7 <sub>12</sub>
thousands	thousands	thousands			
1,734	21,715	44,000			
12,439	23,187	46,790	-0.44	-0.49	-0.46
12,631	23,519	47,599	-0.55	-0.60	-0.59
12,737	23,582	47,670	-0.61	-0.62	-0.60
12,818	23,741	47,949	-0.66	-0.67	-0.64
11,976	22,479	45,605	-0.15	-0.26	-0.27
12,028	22,508	45,408	-0.19	-0.27	-0.24
11,991	22,343	45,707	-0.16	-0.21	-0.29
11,994	22,345	45,696	-0.16	-0.21	-0.28
12,025	22,390	45,521	-0.18	-0.23	-0.25
	months, iar '71 to iay '71 thousands 11,734 12,439 12,631 12,737 12,818 11,976 12,028 11,991 11,994 12,025	B months, iar '71 to kay '71         6 months, Mar '71 to Aug '71           thousands         thousands           thousands         thousands           t1,734         21,715           12,439         23,187           12,631         23,519           12,737         23,582           12,818         23,741           11,976         22,479           12,028         22,508           11,994         22,345           12,025         22,390	B months, iar '71 to kay '71         6 months, Aug '71         12 months, Mar '71 to Feb '72           thousands         thousands         thousands           thousands         thousands         thousands           11,734         21,715         44,000           12,631         23,187         46,790           12,631         23,519         47,599           12,737         23,582         47,670           12,818         23,741         47,949           11,976         22,479         45,605           12,028         22,308         45,707           11,991         22,343         45,707           11,994         22,390         45,521	B months, iar '71 to kay '71         6 months, Mar '71 to Aug '71         12 months, Mar '71 to Feb '72         73           thousands         thousands         thousands         thousands         mar '71 to Feb '72         73           thousands         thousands         thousands         thousands         mar '71         73           thousands         thousands         thousands         thousands         mar '71         73           thousands         thousands         thousands         thousands         thousands           11,734         21,715         44,000         -0.44           12,631         23,519         47,599         -0.55           12,737         23,582         47,670         -0.61           12,818         23,741         47,949         -0.66           11,976         22,479         45,605         -0.15           12,028         22,508         45,408         -0.19           11,991         22,343         45,707         -0.16           11,994         22,345         45,696         -0.16           12,025         22,390         45,521         -0.18	B months, 6 months, 12 months, far '71 to Aug '71 to Feb '72 $\eta_3$ $\eta_6$ thousands thousands thousands 11,734 21,715 44,000 12,631 23,519 47,599 -0.55 -0.60 12,737 23,582 47,670 -0.61 -0.62 12,818 23,741 47,949 -0.66 -0.67 11,976 22,479 45,605 -0.15 -0.26 12,028 22,508 45,408 -0.19 -0.27 11,991 22,343 45,707 -0.16 -0.21 11,994 22,345 45,696 -0.16 -0.21 12,025 22,390 45,521 -0.18 -0.23

TABLE 6

cludes that, for the 1971 fare change, the higher elasticities implied by the Group A and B models are to be preferred to the lower values implied by the Group C and D equations.

### RIDERSHIP AND THE LEVEL OF SERVICE

This analysis proved less successful in identifying the effects of service changes on ridership than it did in identifying fare change effects. There are two principal reasons for this. First, the variable TVM is an inadequate measure of the level of service as it is perceived by the individual passenger. Partly as a consequence of this, the coefficient of TVM does not play a significant role in most of the model formulations in which the variable was entered. In only three of the equations summarized in Tables 2, 3, and 4 is the coefficient of TVM significantly different from zero at the five percent level.

Secondly, although after MARTA assumed control of the system an extra 30 percent of vehicle miles (on an annual basis) had been added by February 1973, the additions were made on a gradual basis over the year. This means that there are hardly any individual

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changes of sufficient magnitude to allow a meaningful examination of the effects of that specific service improvement (in a manner akin to the one used to estimate the demand elasticities relating to specific fare changes). The one exception to this occurred too late in the data period to be assessed in this way.

Point elasticities of ridership with respect to vehicle miles operated were computed from equations A5, C2, and D3, the only ones with significant coefficients for the TVM variable. Using the values of the exogenous variables as they were for February 1972, the month of MARTA's takeover, equation A5 yields an elasticity value of +1.13, equation C2 gives a value of +0.33, and equation D3 implies an elasticity of  $+0.31^3$ . However, since model A5 is estimated from a data base which does not include any of the post-March 1972 experience (which is when the major service improvements were made), it appears reasonable to accept a supply elasticity of roughly +0.3 as implied by models C2 and D3.

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than lion more revenue passengers would have otherwise been the case, given the MARTA fare reduction. On this basis, a full year's operation at the February 1973 supply level could be expected to generate some 3.0 to 4.5 million more revenue passengers than at the February 1972 level.

### SUMMARY AND CONCLUSIONS

This analysis has confirmed that it is possible to model successfully the longitudinal variations in transit patronage in Atlanta (on a month-by-month basis) using a small number of explanatory variables. The fourteen linear model formulations estimated here provide a very good fit indeed to the Transit Authority's operating data over a three year time period which incorporate a fare change of a relatively large magnitude and significant improvements in service levels.4

For an increase in base fare from  $35\phi$  to  $40\phi$  in 1971, the fare elasticity appears to have been of the order of -0.45 to -0.7, and probably was close to -0.6. However, when the fare was reduced to  $15 \notin$  in 1972, the elasticity was roughly -0.15 to -0.2. In both cases, the demand was still changing in response to the fare change after three months, but appeared to have stabilized after six months.

Over the first twelve months of operation at low fare, the fare reduction appears to have added roughly 8.2 mil-lion revenue passengers to the 42.8 million revenue journeys which would otherwise have been made at the 40¢ base fare level, given the MARTA service improvements. This is an increase of just over 19 percent.

The cost to MARTA of these fare cuts, measured solely in terms of foregone revenue, is consequently a net of roughly \$10 million per year, or some-where between \$1.00 and \$1.25 per revenue passenger gained. This is, of course, not the total cost of the ridership growth because to the lost revenue needs to be added the incremental transit operating costs of carrying these additional passengers.

Over the first year of MARTA's operation of the system, a total of almost 2 million more vehicle miles were op-erated than in the preceding twelve month period. It is estimated that this supply increase added roughly 1.5 to 1.6 million more revenue passengers than would have otherwise been the case, given the MARTA fare reduction. This is equivalent to a demand elasti-

city with respect to vehicle miles of roughly +0.3. On this basis, a full year's operation at the February 1973 supply level could be expected to generate some 3.0 to 4.5 million more revenue passengers than at the February 1972 level.

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### FOOTNOTES

FOOTNOTES 1 All data manipulation and model estima-tion was carried out using PLANETS, a com-puter program developed by the Brookings In-stitution Social Science Computation Center for the analysis of economic time series data. 2 Here and throughout this paper, a "high" elasticity refers to one with a relatively large numerical value, disregarding the negative sign. 3 The magnitude of the variation in these es-timates illustrates the inadequacy of TVM as an index of service provision. 4 Similar linear time series models have more recently been estimated for major fare and service changes in San Diego and Cincinnati (Kemp, 1074b), giving comparable levels of ex-planation of month-to-month variations in ag-gregate ridership. gregate ridership.

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