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ANALYZING THE EFFECT OF PASSENGER-REQUESTED UNSCHEDULED STOPS ON DEMAND

ABSTRACT

This paper discusses the effect of unscheduled stops requested by passengers on bus transit demand and presents the results of its study. In the research a set of regression models that estimate the route-level demand were developed using data collected with Automatic Passenger Counters and Automatic Vehicle Location systems installed on buses, and demographic, socio-economic and land use information from other sources. The results obtained indicate that the number of rider-requested unscheduled stops have no significant effect on demand, suggesting that the company policy which tolerates unscheduled stops is inadequate for attracting new riders.

KEY WORDS

public transit, reliability measures, statistical models, unscheduled stops

1. INTRODUCTION

During the testing period of new Automatic Vehicle Location (AVL) and Automatic Passenger Counter (APC) system on the bus system in the city of Koper, it was found out that about 8% of all bus stops were unscheduled. Due to a relatively high number of these, a detailed investigation on the causes of the stops was performed. The investigation shows that during the observation period there were no unscheduled maintenance stops or unscheduled emergency stops. Thus, all unscheduled stops (with doors opened) were attributed to passenger activity, either boarding or alighting. It is obvious that when passengers made requests for unscheduled activities during trips, the bus driver usually agreed to them, knowing that by doing so he is violating the law, that many times this can be unsafe for the passengers and that it will infringe upon the dwell time and may cause bus delay at the next bus stop. This practice is widely supported by service providers operating on these routes, with a conviction of offering a more user-friendly service and this way attracting more riders; however, thus they ignore the fact that unscheduled stops are a violation of the law.

1.1 Motivation and Background

In the bus service based on the schedule, the rider-requested unscheduled stops are forbidden by the law. The primary reason is the safety of passengers boarding and alighting, the second similarly important reason is the unfair competition among service providers. The objective of this study was to explain the effect of rider-requested unscheduled stops on transit demand, so the service providers may understand the true "benefits" of violating the law.

A number of econometric models have been developed analyzing the determinants of bus transit demand. The models differ according to method used, variable selection and level of aggregating data. Most previous studies seeking to explain the determinants of transit demand have been conducted at either route level [1], [2], [3], [4] or route-segment level [5], [6]. Stop-level transit demand has been discussed in the literature as being the most appropriate level of analysis, but there are very few actually applied models at that level [6], [7]. Historically, regression models have been popular because they are relatively easy to use, well established, comparable with other available procedures, and well suited for parameter estimation problems. Nonetheless, regression is not the only possible estimation approach, and other methods such as time series analysis have been explored [8].

Previous research used the number of unscheduled stops primarily as a measure of service reliability. Kimpel used variability in the number of unscheduled stops as a control for operator experience and behaviour in his reliability models [6]. He found unscheduled stops variation to be significant and positive at radial routes in the morning and mid-day time periods. An increase in the number of unscheduled stops is an indicator of service reliability problems [6]. Besides transit service reliability, the number of unscheduled stops could also influence driver off duty and rest time [9].

Although the effects of unscheduled stops on the reliability are fairly well understood, there is no known literature regarding the explicit effect of rider-requested unscheduled stops on demand. Kimpel in his work argues that an increasing number of unscheduled stops has little bearing on the demand, but there is no empirical model to confirm it [6].

It is reasonable to expect a positive relation to the transit demand, but the effect could be partially neutralized by the negative influence of a decreasing level of transit reliability. Although the rider-requested unscheduled stops, demand, and service reliability are inherently linked, the influence of unscheduled stops on service reliability was not addressed in this study. The motivation to develop a model was mainly to provide information available to transit operators about the effect of rider-requested unscheduled stops on demand.

2. STUDY AREA AND DATA COLLECTION

The study area was part of the bus transit system in the city of Koper. The city is situated in the southwestern part of Slovenia, at the northern edge of the Adriatic Sea. With 25,000 inhabitants, the city of Koper is a regional centre of the Slovenian coastal area. The settlement pattern is distinctively longitudinal, stretching along the coast. This makes it difficult to set up an effective transit service. In addition, rapidly increasing car ownership in the last 10 years has had negative impact on transit use. In the past, there have been different attempts to revitalize the transit public system; one of the latest was the introduction of a small bus transit system. The system runs on fixed routes with a fixed schedule, connecting the old city core with newer, high density suburban areas. The aim of the new system was to offer the commuters a more attractive transit service. The response of the passengers and the level of use did not meet the operator's expectations, and to motivate the passengers to use those new routes, the community of Koper began subsidizing this service.

The data used in this study were collected within four bus routes. The route lengths are between 6.4 and 7.8 km, with 9 to 12 bus stops in each direction. There are two common bus stops with higher passenger demand, and routes cross 4 to 5 signalized intersections. All the routes start near the old city core, passing near the port, shopping malls, downtown, and enter a high density suburban area. The scheduled headway differs during the day with a minimum value of 7 minutes during morning and evening peak periods, and increasing to 30 during off-peak. The evening headway varies from 30 minutes up to 130 minutes during late evening.

The sample was collected between January 1 and February 15 of 2005. GPS-based bus positioning system was used coupled with Automatic Passenger Counter to record the data at the bus stop level. The GPS receiver recorded the location each time the bus stopped and opened the doors. When the door opened, the APC unit started to count passengers boarding and alighting; when the doors closed the data were recorded. During the observation period, the sample of a total of 2,996 stops was recorded.

In the study the "rider-requested unscheduled stop" was defined as any unscheduled stop connected with passengers' activity. Unscheduled stops were recorded when the bus stopped to serve passengers outside the 70m buffer of each bus stop. The unscheduled stops without passenger activity (doors remain closed) were not recorded.

The data show that the rider-requested unscheduled stops represent nearly eight percent (n= 267) of total stops (n=2,996). On the average, there were 0.44 unscheduled stops per bus trip, with a minimum of zero, maximum of six and standard deviation of 0.8.

Figure 1 presents the number of passengers served and the number of unscheduled stops according to the hour of the day. It is evident that the number of unscheduled stops varies according to time. To identify the relationship between scheduled/unscheduled stops and time period, the statistical Chi-square test was used. The conducted test was significant, and suggested that there is a relationship between observed variables, number of unscheduled stops, scheduled stops and time (Chi-Sq = 57.558, DF = 3, P-Value = 0.000).

Table 1 presents the descriptive statistics for the number of stops and the number of passengers boarded per hour of the day. The mean number of unscheduled stops is 11.9, with a standard deviation of 7.48 unscheduled stops. On the average, there were 260 boardings per hour, with a maximum of 705 passengers boarded and a minimum of only 9 boarded passengers.

In addition, a regression model was run to examine the relationship between the number of passengers served and the number of unscheduled stops. The model produced small R-square values (R-square = 0.14), with a positive coefficient, but the parameters were not significant at a 95% confidence level (F = 2.98, P-value = 0.101). The results suggested that, regardless of the number of passengers on the bus, the bus drivers were willing to meet the passengers' re-

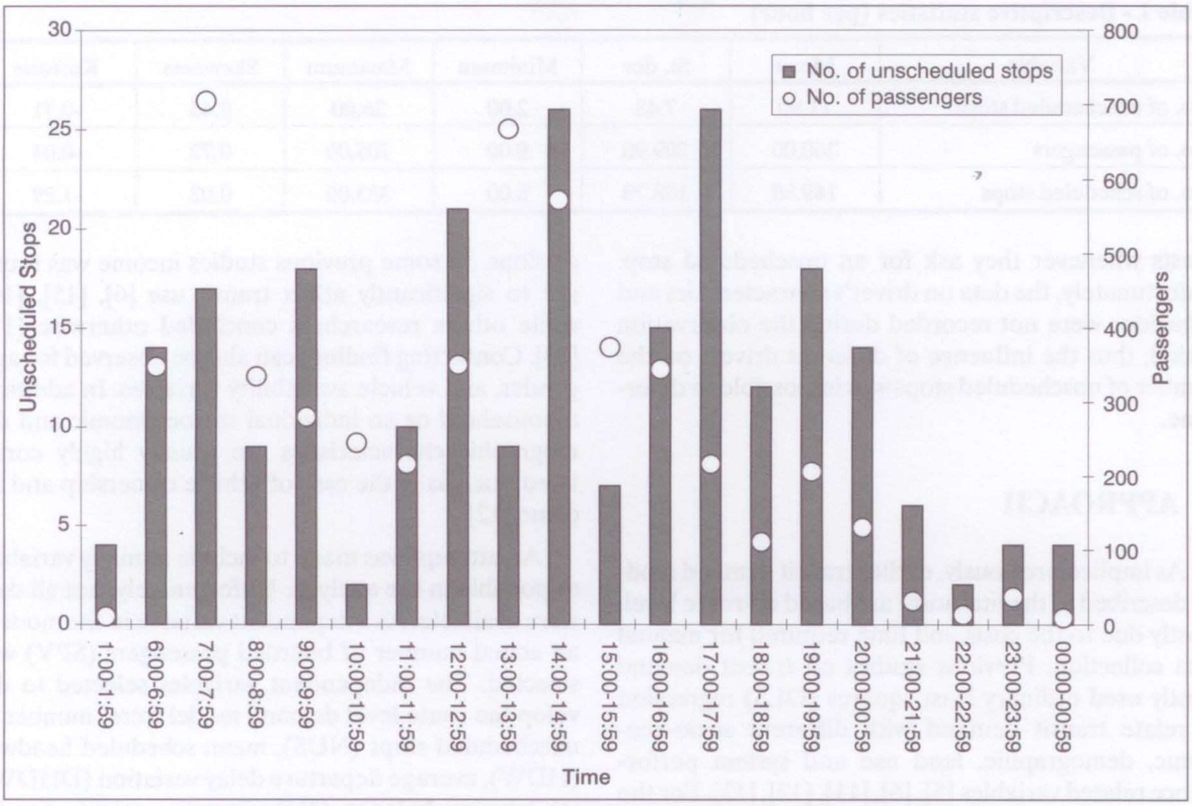

Figure 1 - Passenger and unscheduled stops summed by the hour

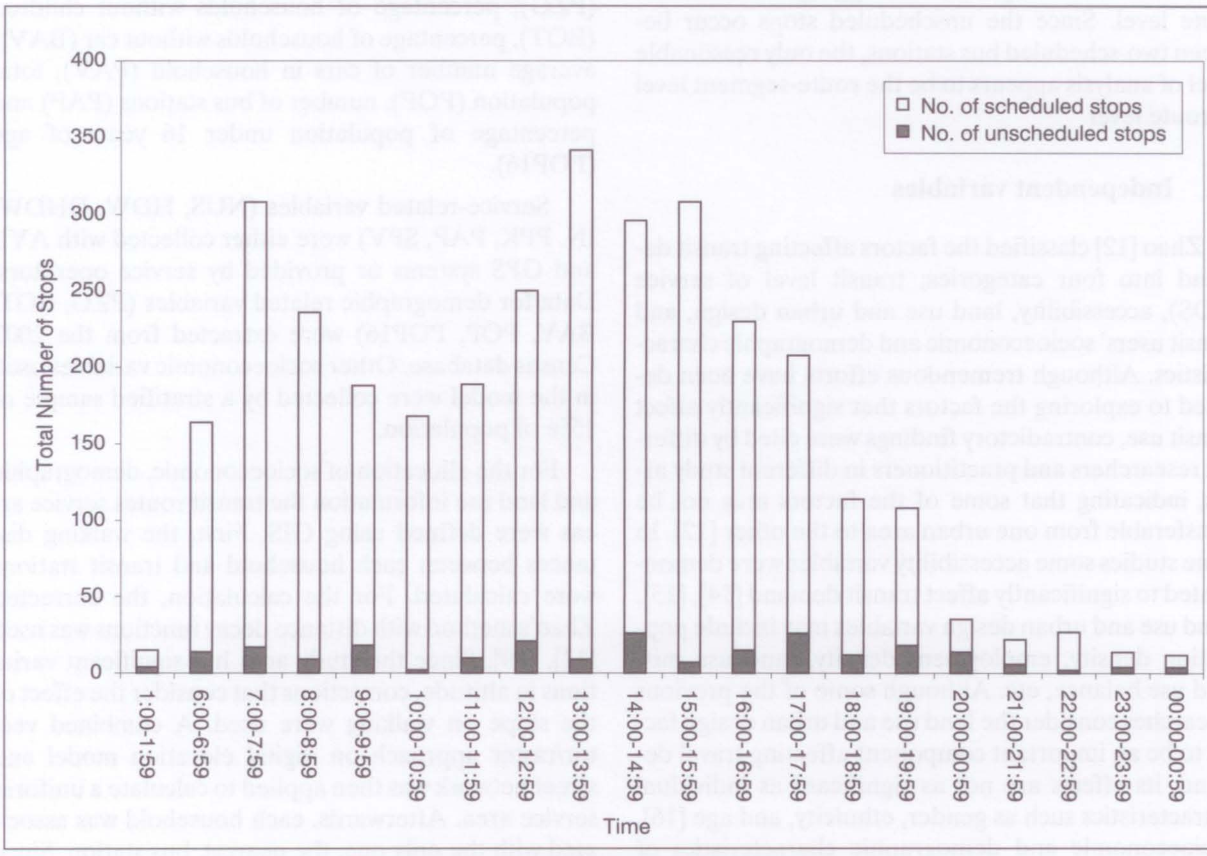

Figure 2 - Total number of stops by the hour

Table 1 - Descriptive statistics (per hour)

Variable	Mean	St. dev	Minimum	Maximum	Skewness	Kurtosis
No. of unscheduled stops	11.90	7.48	2.00	26.00	0.45	-0.71
No. of passengers	260.00	209.90	9.00	705.00	0.72	-0.04
No. of scheduled stops	149.80	108.70	8.00	333.00	0.02	-1.29

quests whenever they ask for an unscheduled stop. Unfortunately, the data on driver's characteristics and behaviour were not recorded during the observation period, thus the influence of different drivers on the number of unscheduled stops was impossible to determine.

3. APPROACH

As implied previously, earlier transit demand models described in the literature are based on route level, mostly due to the costs and time required for manual data collection. Previous studies on transit demand mostly used ordinary least squares (OLS) regression to relate transit demand with different socio-economic, demographic, land use and system performance related variables [5], [6], [11], [12], [13]. For the study of the relationship between riders-requested unscheduled stops and transit demand, the data collected on the bus stop level were aggregated at the bus route level. Since the unscheduled stops occur between two-scheduled bus stations, the only reasonable level of analysis appears to be the route-segment level or route level.

3.1 Independent variables

Zhao [12] classified the factors affecting transit demand into four categories; transit level of service (LOS), accessibility, land use and urban design, and transit users' socioeconomic and demographic characteristics. Although tremendous efforts have been devoted to exploring the factors that significantly affect transit use, contradictory findings were cited by different researchers and practitioners in different study areas, indicating that some of the factors may not be transferable from one urban area to the other [12]. In some studies some accessibility variables were demonstrated to significantly affect transit demand [14], [15]. Land use and urban design variables may include population density, employment density, land use mix, land use balance, etc. Although some of the previous researches consider the land use and urban design factor to be an important component affecting travel demand, its effects are not as significant as individual characteristics such as gender, ethnicity, and age [16]. Socioeconomic and demographic characteristics of transit users result in significantly contradictory conclusions. In some previous studies income was found not to significantly affect transit use [6], [15], [16], while others researchers concluded otherwise [17], [18]. Conflicting findings can also be observed for age, gender, and vehicle availability variables. In addition, a household or an individual socioeconomic and demographic characteristics are usually highly correlated, such as in the case of vehicle ownership and income [12].

An attempt was made to include as many variables as possible in the analysis. Unfortunately, not all data were available. As a dependent variable in the models, an actual number of boarded passengers (SPV) was selected. The independent variables selected to develop the route level demand model were: number of unscheduled stops (NUS), mean scheduled headway (HDW), average departure delay variation (DHDW), job-housing balance (JH), dummy variable for inbound (IN), number of other buses in all transit centres (PPK), average number of workers in a household (PZG), percentage of households without children (BOT), percentage of households without car (BAV), average number of cars in household (PAV), total population (POP), number of bus stations (PAP) and percentage of population under 16 years of age (POP16).

Service-related variables (NUS, HDW, DHDW, IN, PPK, PAP, SPV) were either collected with AVL and GPS systems or provided by service operators. Data for demographic related variables (PZG, BOT, BAV, POP, POP16) were extracted from the 2002 Census database. Other socioeconomic variables used in the model were collected by a stratified sample of 15% of population.

For the allocation of socioeconomic, demographic and land use information the transit routes service areas were defined using GIS. First, the walking distances between each household and transit stations were calculated. For the calculation, the corrected Zhao's method with distance decay functions was used [12], [19]. Since the study area has significant variations in altitude, corrections that consider the effect of the slope on walking were used. A combined vector/raster approach on digital elevation model and street network was then applied to calculate a uniform service area. Afterwards, each household was associated with the only one, the nearest, bus station. Since all four routes have the same starting point, ending

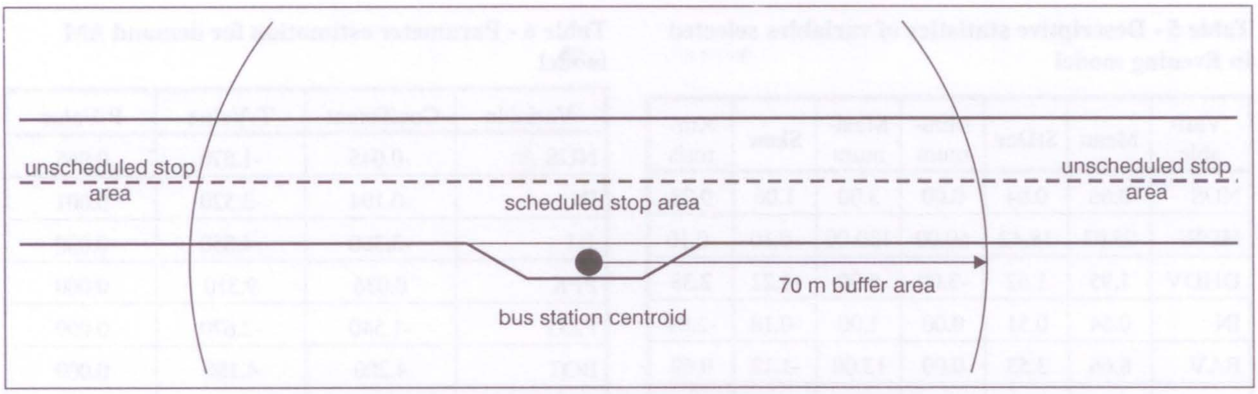

Figure 3 - Definition of unscheduled bus stop area

points, and there are no significant differences in service frequency, the assumption was that the riders would most likely walk to the nearest station. In this way the problem of service areas overlapping was avoided. At the end, the variables allocated according to bus station service areas were either summed or averaged in routes service areas.

3.2 Model estimation

Multiple regression analysis was performed to determine the most significant factors that effect transit demand. In MINITAB 14 the best subset and the stepwise (backward and forward) procedure was employed to select independent variables. The variables having significance level values higher than 0.1 were considered to be insignificant and were not included in the models. The decision whether a model was reasonable, was based on the signs (+, -) of the coefficients, R-square value, and analysis of the residuals. The presence of autocorrelation was controlled with Durbin-Watson statistics and multicolinearity was detected by examining the variance inflation (VIF) score. If the VIF factor exceeded the value of 10, the correlation factors between independent variables were examined, and the model was corrected either by eliminating or by joining the variables.

The analysis of numerous regression model results indicated that it was best to develop a separate model for each time period as follows: AM (6:00-9:59); Mid-day (10:00-14:59); PM (15:00-18:59); and Evening (19:00-00:00).

The statistical correlation matrix between different independent variables indicated strong multicolinearity between certain demographic variables. Thus, the independent variables that caused most multicolinearity problems, the percentage of the population under 16 years of age (POP16) and the entire population (POP) were removed from further analysis.

The summary statistics for selected independent variables in each model are presented in Tables 2, 3, 4 and 5.

Table 2 - Descriptive statistics of variables selected in AM model

Variable	Mean	StDev	Minimum	Maximum	Skew	Kurtosis
NUS	0.36	0.71	0.00	4.00	2.52	8.04
IN	0.11	0.31	0.00	1.00	2.50	4.36
JH	0.54	0.05	0.37	0.70	-0.09	0.86
PPK	15.89	7.19	0.00	40.00	0.60	1.17
PZG	1.70	0.03	1.62	1.78	0.05	-0.11
BOT	0.14	0.02	0.07	0.23	0.74	0.69
BAV	7.69	2.32	2.00	12.33	-0.15	-0.79
PAV	1.58	0.06	1.25	1.70	-1.42	5.46

Table 3 - Descriptive statistics of variables selected in Mid-day model

Variable	Mean	StDev	Minimum	Maximum	Skew	Kurtosis
IN	0.23	0.42	0.00	1.00	1.32	-0.27
JH	0.53	0.05	0.43	0.68	0.67	1.52
PPK	16.84	5.80	6.33	33.00	0.69	0.57
PZG	1.71	0.05	1.45	1.77	-3.02	16.45
BOT	0.14	0.02	0.06	0.21	0.47	3.14
BAV	8.42	2.32	0.00	15.00	-0.70	2.91

Table 4 - Descriptive statistics of variables selected in PM model

Variable	Mean	StDev	Minimum	Maximum	Skew	Kurtosis
HDV	60.09	5.50	30.00	100.00	4.19	30.23
JH	0.52	0.07	0.37	0.76	0.09	1.04
PPK	16.02	7.27	0.00	32.00	0.31	0.14
BOV	0.13	0.02	0.07	0.25	1.32	5.63
BAV	9.27	2.88	0.00	15.00	-0.39	1.00
PAV	1.52	0.11	1.25	1.78	-0.93	0.81

Table 5 - Descriptive statistics of variables selected in Evening model

Vari-able	Mean	StDev	Mini-mum	Maxi-mum	Skew	Kur-tosis
NUS	0.66	0.84	0.00	3.00	1.06	0.28
HDW	95.03	18.42	60.00	130.00	-0.10	-0.10
DHDV	1.95	1.62	-3.00	5.00	-1.21	2.38
IN	0.54	0.51	0.00	1.00	-0.18	-2.09
BAV	8.66	3.53	0.00	13.00	-1.12	0.69
PAV	1.53	0.16	1.25	1.83	-0.26	-0.40

Four models with intercept were developed using the acquired data, with the R-square values obtained ranging from 0.59 up to 0.86. As shown in Tables 6 to 9, the highest value of R-square was obtained in the PM model and the smallest in the AM peak model. Only one demographic-related variable is shown to have a significant impact on the dependent variables in three models. All the coefficients are positive, suggesting that the percentage of households without children (BOT), mostly pensioners or young families contribute significantly to transit demand. All models have a statistical significance and positive coefficients for variables, percentage of households without car (BAV). This makes sense, because the study area with high variation in altitude and street slope that reach up to 30 degrees is less appropriate for non-motorized trips i. e. walking or cycling - and an increasing number of households without cars impose additional demand for transit service.

As expected, the variable number of other buses in all transit centres has significant positive coefficients. The coefficients are statistically significant in three models. Since there is no other, directly competing bus route, it was expected that a higher value of this variable would be associated with greater level of passenger demand during all periods.

Another interesting observation that can be made from the results is that the average number of cars per household (PAV) have either a small contribution or no contribution in demand during the Evening and Mid-day time period. The coefficients for the other two models were negative.

The significance of bus performance variables is different between models. The mean scheduled headway was found to be significant in PM and Evening models. Both coefficients were positive. These results may be due to the fact that buses in the AM period and in the Mid-day period operate at almost equal headways, resulting in small variability in variables. As shown in Table 9, the average departure delay variation (DHDW) was significant only in the Evening model, with a negative coefficient".

Table 6 - Parameter estimation for demand AM model

Variable	Coefficient	T-Value	P-Value
NUS	-0.045	-1.870	0.065
IN	-0.194	-3.520	0.001
JH	-3.360	-4.850	0.000
PPK	0.036	9.310	0.000
PZG	-1.540	-2.670	0.009
BOT	4.200	4.180	0.000
BAV	0.063	5.430	0.000
PAV	-2.040	-4.790	0.000
Constant	1.852		
S	0.145		
oR-Sq	59.210		
R-Sq(adj)	54.610		
F statistic	12.880		0.000

Table 7 - Parameter estimation for demand Mid-day model

Variable	Coefficient	T-Value	P-Value
JH	-0.930	-3.910	0.000
PPK	0.012	8.310	0.000
PZG	-0.580	-3.010	0.004
BOT	1.120	2.130	0.037
BAV	0.052	11.880	0.000
Constant	1.852		
S	0.049		
R-Sq	83.010		
R-Sq(adj)	81.470		
F statistic	53.750		0.000

The variable number of unscheduled stops (NUS) was found significant only in the Evening model. The coefficient for NUS is 0.037, indicating that a change of 1 rider-requested unscheduled stop is associated with a change of 0.037 in passengers demand on the observed routes, other factors being held constant.

Due to the small value of the coefficient we can conclude that the variable is significant but with marginal effect on demand. The fact that in other models the variable was not statistically significant suggests that the riders-requested unscheduled stops attract passengers only during the late evening period (due to safety, bad street lights, etc).

However, the results are interesting; the variable in the AM time period just missed the cut-off point at the 0.05 P-value. The negative value of coefficient in the

Table 8 - Parameter estimation for demand PM model

Variable	Coefficient	T-Value	P-Value
HDW	0.003	3.140	0.000
JH	-2.740	-5.800	0.000
PPK	0.016	5.230	0.000
PAV	-2.600	-10.870	0.000
BOT	3.780	5.080	0.000
BAV	0.118	14.800	0.000
Constant	-3.111		
S	0.103		
R-Sq	86.830		
R-Sq(adj)	86.090		
F statistic	117.360		0.000

Table 9 - Parameter estimation for demand Evening model

Variable	Coefficient	T-Value	P-Value
NUS	0.037	2.110	0.042
HDW	0.004	3.680	0.001
DHDW	-0.024	-2.000	0.056
IN	-0.078	-2.260	0.032
PAV	0.300	2.040	0.050
BAV	0.031	4.430	0.000
Constant	-3.111		
S	0.093		
R-Sq	67.500		
R-Sq(adj)	60.530		
F statistic	9.690		0.000

AM time period may be associated with the increasing unreliability of service during the peak morning period. According to a previous study unscheduled stops affect the service reliability [6], and hence have a negative effect on demand.

4. CONCLUSION

This article has sought to investigate the relationship between rider-requested unscheduled stops and transit demand from the perspective of the transit service operator. The analysis develops a statistical model for estimating the effect of rider-requested unscheduled stops on transit demand at the route level. Different socio-economic, demographic, land use and bus performance variables together with a variable that describes rider-requested unscheduled stops were included in the models. The models explain up to 86% of the variability in the number of passengers.

The consistency of the results and the models would certainly improve if more data were available. There were no data available on bus drivers; hence no information on driver behaviour was included in the models. Although the available data were not complete and up to date, and some interpolation had to be made, the results presented here appear to be reasonable.

Empirical evidence has shown that the coefficient of variable associated with rider-requested unscheduled stops was statistically significant only in the evening model. The coefficient sign was positive. The analysis has suggested that the effect of rider-requested unscheduled stops on transit demand is rather limited to one time period or null. Since the value of the coefficient is very small, we could conclude that rider-requested unscheduled stops in practice have no effect on demand. We can conclude that riders-requested unscheduled stops have only negative effect, since the service providers are risking to pay the fine for violating the law.

A high level of unscheduled stops may be an indicator that the number of transit stops and their location in space are not optimal. Since the locations and spacing of bus stops is one of the most important elements of transit service planning, the transportation planners should address their research to examine the route redefinition and adequateness of bus stop locations first. The transportation planners should investigate other methods and different policies to increase the use of public transit in the city of Koper. In the long term, the actual policies will have negative rather than positive effect on demand.

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POVZETEK

VPLIV NEPREDVIDENIH POSTANKOV IZVEN OZNAČENIH AVTOBUSNIH POSTAJALIŠČ NA POVPRAŠEVAJE PO STORITVI

Prispevek obravnava vpliv nepredvidenih postankov avtobusov izven označenih avtobusnih postajališč na povpraševanje. Predstavljen je zasnovan sistem za zajemanje podatkov, ki temelji na avtomatskem števcu potnikov (APC) in GPS sprejemniku. Statistični model je zasnovan na nivoju avtobusnih prog in razlaga vpliv različnih operativnih, demografskih, socialnih, ekonomskih in drugih spremenljivk na povpraševanje po storitvi. Rezultati pokažejo, da postanki izven postajališč, ki jih zahtevajo potniki, nimajo signifikantnega vpliva na povpra-

ševanje po storitvi, ampak negativno vplivajo na točnost in zanesljivost nudene storitve.

KLJUČNE BESEDE

javni potniški avtobusni promet, kazalci zanesljivosti storitve, statistični model, nepredvideni postanki po voznem redu

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