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How do adverse weather conditions affect demands on urban transport systems?

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Abstract:

Mode choice research in urban transportation constitutes a very important part of transportation planning in terms of studies such as decision-making on public transportation policies, mode-shifting and traffic calming practices, etc. Mode choice researches, which are usually made for an ordinary day within the scope of transportation masterplan studies, are also carried out for some special cases such as public holidays, adverse weather conditions, and the day of sports competitions, in order to shed light on the decisions that policy-makers and local governments will take in different scenarios. In this study, the changes in the daily user counters of the public transportation systems in Izmir, Turkey, according to the weather conditions were examined. The mode shifts and changes in demands were evaluated according to the adverse weather conditions, and the measures to be taken are discussed.

Key words: Adverse weather, mode choice, mode shift, public transportation, urban transport demand.

1. Introduction

In urban transportation planning, mode choice research is very important in terms of studies such as investment planning, operation and management of public transportation systems, and traffic calming and intelligent transportation system applications. Mode choice research as a part of a transportation master plan study is usually conducted for an ordinary day. Therewithal, mode choice and mode shift studies are also carried out for some different cases such as public holidays, adverse weather conditions and sports competition days, etc. Thus, the factors causing the mode choice and shift, and demand for modes of transportation can be investigated [1-3].

When the literature is examined, there are some studies on the change in mode choice and demands of transportation systems due to adverse weather conditions. In a behavioral study conducted according to a survey conducted in Brussels in 1994, individuals' route choice decisions and departure time, and factors such as travel conditions, and personal and household characteristics were examined with ordered probit model. For more than a quarter of those who changed their travel patterns due to adverse weather conditions, adverse weather was found to be important in changing their mode. While 60% of the individuals changed their departure time due to adverse weather conditions, it was observed that 35% of them diverted to alternative routes [4]. A 2005 study in the Irish city included several performance measures such as number of passengers, frequency, headway, regularity of travel, and travel time analyzed both in the presence and absence of adverse weather conditions. Adverse weather conditions have been observed to have a significant negative impact on the service level of a system and increase personal vehicle usage

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[5]. In another research; a stochastic network model is proposed for a multimodal transportation network that takes into consideration private car, bus, underground and walking modes, in which supply uncertainty due to random capacity reduction and adverse weather conditions and demand variables are the factors [6]. In a study conducted for the Metropolitan City of Busan, the effects of factors such as rain, fog and snow among the weather conditions affecting the public transportation demand were investigated. Accordingly, it has been observed that adverse weather conditions have a significant effect on the mode choice and cause a decrease in bus demand. As a result of the research, the reasons for modal shift were analyzed and the policy implications for the desired public transportation systems were discussed [7].

In this study, the changes in the demands of the urban public transportation systems according to the daily total precipitation amount and wind speed variables were examined and the mode shifts were investigated in different adverse weather conditions. For this purpose, open source weather data and daily public transportation systems boarding quantities from the open data portal of Izmir Metropolitan Municipality were used [8].

2. Materials and Method

Linear regression analysis was used to investigate the effects of adverse weather conditions, which are the subject of the study, on public transportation systems. For this purpose, daily passenger boarding numbers in İzmir city center between January 2018 and December 2021 were used as dependent variables, and daily total precipitation (TP, mm) and wind speed (WS, kph) variables were used as independent variables (Table 1).

Table 1. Variable Descriptions of Data Set

Variables	Abbreviation	Unit/Format	Type
Date	Date	date	Date
Total precipitation amount	TP	mm per hour	Numeric (continues)
Wind speed	WS	km per hour	Numeric (continues)
Daily boarding numbers for metro lines	ML	passengers	Numeric (integer)
Daily boarding numbers for tramway lines	TL	passengers	Numeric (integer)
Daily boarding numbers for suburban lines	SL	passengers	Numeric (integer)
Daily boarding numbers for bus lines	BL	passengers	Numeric (integer)
Daily boarding numbers for ferry lines	FL	passengers	Numeric (integer)

According to the data of the Turkish State Meteorological Service, since the "heavy rain" starts from 21 mm and the "high wind" starts from 39 kph, the TP values in the data set are proportioned to 21, and the WS values to 39, so that it can be understood clearly in the graphics and analyses [9, 10]. Since the change in demand between public transportation modes will be examined within the scope of the study, the daily boarding numbers daily for each mode have been converted into shares with a total of 100. Linear regression model parameters have been estimated based on these transformed data. The graphs of the change in the total precipitation rate (*21 mm) and the share of trips made by each public transport mode (%), and the graphs of the change in the wind speed rate (*39 kph) and the share of each public transport mode trips (%) are shown in Figure 1 and Figure 2, respectively. As can be seen from the graphs, most trips in the public transportation system on an ordinary day are made by buses. It is observed that the highest total precipitation rate recorded is 2.03 (42.63 mm), and the strongest wind rate is 1.01 (39.39 kph).

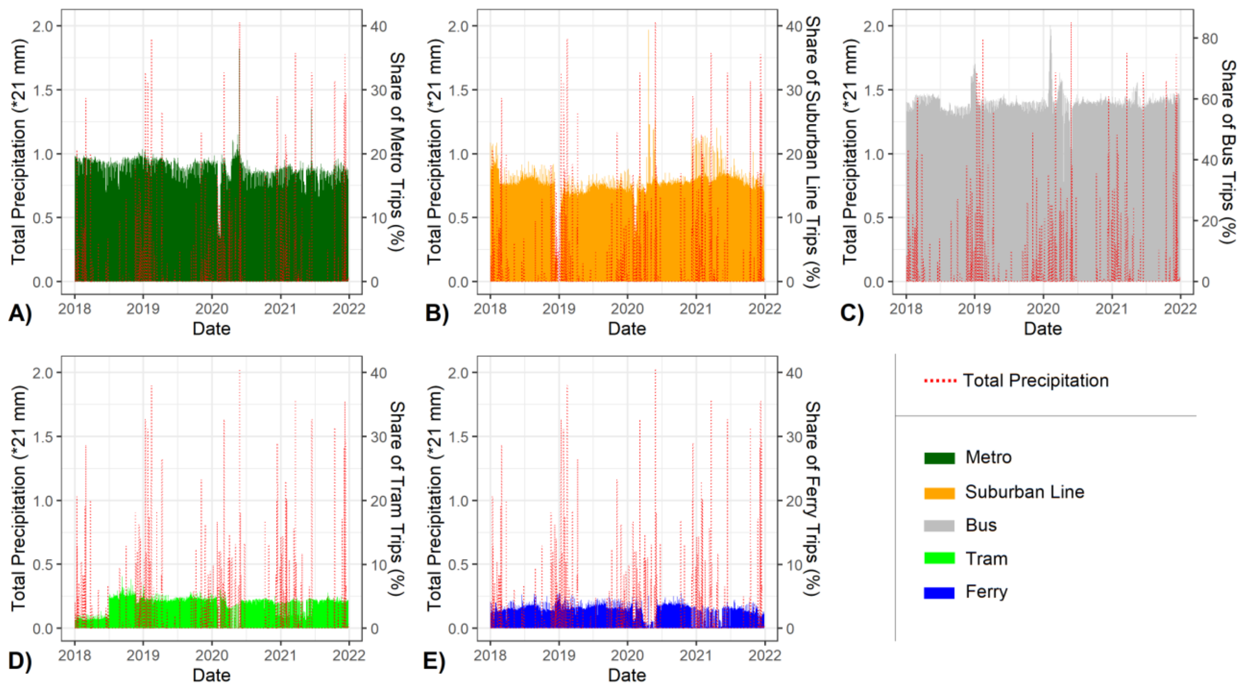

Figure 1. The graphs of the change in the total precipitation and the share of each public transport mode trip: A) Metro, B) Suburban Line, C) Bus, D) Tram, E) Ferry

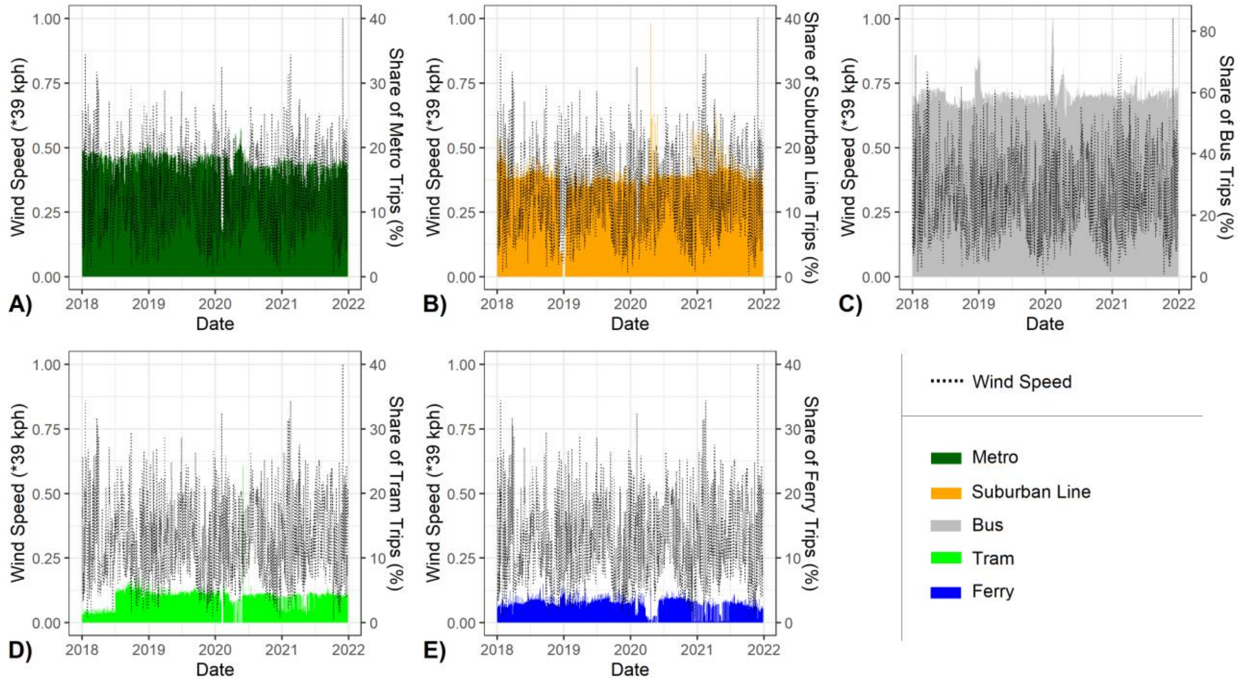

Figure 2. The graphs of the change in the wind speed and the share of each public transport mode trip: A) Metro, B) Suburban Line, C) Bus, D) Tram, E) Ferry

3. Results

The results of the linear regression analysis, in which the shares of each public transportation mode trips are estimated, are given in Table 2. In order to predict different weather condition scenarios, analyzes were carried out without standardizing the data.

Table 2. The Results of the Linear Regression Analysis

Public transport mode	Coefficient	Estimation	t-value
Metro (ML)	$Constant_{ML}$	17.889	168.28 [a]
	TP_{ML}	0.587	2.89 [a]
	WS_{ML}	-0.485	-1.63 [c]
Tram (TL)	$Constant_{TL}$	4.0976	46.11 [a]
	TP_{TL}	-0.315	-1.86 [b]
	WS_{TL}	-0.069	-1.28 [c]
Suburban (SL)	$Constant_{SL}$	15.626	90.71 [a]
	TP_{SL}	-0.655	-1.99 [a]
	WS_{SL}	0.668	1.38 [c]
Bus (BL)	$Constant_{BL}$	59.048	314.86 [a]
	TP_{BL}	1.050	2.93 [a]
	WS_{BL}	0.364	1.69 [b]
Ferry (FL)	$Constant_{FR}$	3.339	51.38 [a]
	TP_{FL}	-0.666	-5.37 [a]
	WS_{FL}	-0.479	-2.63 [a]

Level of significance; [a] 95% confidence interval, [b] 90% confidence interval, [c] 80% confidence interval

According to the observed data, the average share of each public transport mode trips, the average TP and WS rates, and the model estimations of the shares of each public transport mode trips according to different adverse weather condition scenarios are given in Table 3.

Table 3. Observed Averages and Model Results of Different Adverse Weather Condition Scenarios

	weather condition		*share of each public transport modes*				
	TP *(*21 mm)*	**WS** *(*39 kph)*	**Metro** *(ML)*	**Tram** *(TL)*	**Suburban** *(SL)*	**Bus** *(BL)*	**Ferry** *(FR)*
Observation							
Average	0.07	0.32	17.8%	4.1%	15.8%	59.2%	3.1%
Model							
Scenario 1	0	0	17.9%	4.1%	15.6%	59.0%	3.3%
Scenario 2	0	1	17.4%	4.0%	16.3%	59.4%	2.9%
Scenario 3	1	0	18.5%	3.8%	15.0%	60.1%	2.7%
Scenario 4	1	1	18.0%	3.7%	15.6%	60.5%	2.2%
Scenario 5	0	2	16.9%	4.0%	17.0%	59.8%	2.4%
Scenario 6	2	0	19.1%	3.5%	14.3%	61.1%	2.0%
Scenario 7	2	2	18.1%	3.3%	15.7%	61.9%	1.0%

Considering the coefficient estimates, all estimated parameters were found to be significant at a minimal 80% confidence interval. It can be comprehended that the negative effects between the shares of ferry and suburban line trips and the total precipitation rates are more than the other public transport modes (TP_{FL}=-0.666 and TP_{SL}=-0.655). Similarly, it can be observed that the negative effects between the shares of metro and ferry trips and the wind speed rates are more than others (WS_{ML}=-0.485 and WS_{FL}=-0.479). It can also be seen from the model results, respectively, the share of bus trips with an increase in the total precipitation rate and the share of suburban line trips with an increase in wind speed will increase more than other modes (TP_{BL}=+1.050 and WS_{SL}=+0.668) (see also Table 2).

When the scenario results are examined, it is seen that the system that increases its share the most in cases of heavy rain only as an adverse weather condition is metro trips, and the system that increases its share the most in cases of strong wind only is suburban line trips, the system that increases its share the most in cases where both strong wind and heavy rain is bus trips (see also Table 3).

Conclusions

Within the scope of this study, the shares of each public transportation mode trip were calculated with linear regression analysis using the independent variables of total precipitation rate and wind speed rate. In this study, only the demands between the modes of the public transport system were examined and the demands of those using the transport system were evaluated despite the adverse conditions, even if the total demand for travel decreased in adverse weather conditions. The increase in the shares here is not the increase in the total demands, but the change in the shifts between the public transport systems, even though the total trips are decreasing.

According to the results, in case of heavy rain and/or strong wind, ferry trips will shift to other modes, on the other hand, the share of bus trips increases when both adverse weather conditions are experienced separately or together. In only strong windy weather, while the share of suburban line trips increases the most, it is estimated that metro and tram trips shift to other modes. It is also estimated that while the shares of metro and bus trips increase in only heavy rainy weather, suburban, tram and ferry trips shift to other modes. And it is predicted that the shares of bus trips will increase the most in both heavy rainy and strong windy weather and most ferry trips will shift to other lines.

The decrease in ferry journeys in adverse weather conditions is significant due to the suspension of ferry services. Due to the relatively less sheltered stops on the tram and suburban lines, it can be said that in adverse weather conditions, individuals prefer the metro with full sheltered (most of which are underground) or the bus system which is closer to the trip origin of travelers.

Road traffic generally increases due to adverse weather conditions. Depending on the increase in traffic, decrease in visibility and slippery road surface, average travel times and accident risk increase while reliability and level of service decrease. Considering these, more accessible and more sheltered stops can be provided to shift bus trips to tram and suburban lines.

Trips that start with a private car or bus that can be easily accessed can be transferred to the rail systems by establishing transferring hubs to reduce traffic congestion and accident risks in the center.

For further studies, since the current data set is time series ARIMAX/ARMAX model, or robust regression techniques that overcome some traditional limitations (e.g. outliers can be masked) would be performed. In addition, with the disaggregated data set, more powerful mode shift and mode choice causality studies can be conducted using more independent variables according to the trip preferences and socio-economic characteristics of the individuals.

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