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Travel Behaviour Analysis and Exploration of Mode Choice Variability of Short-Distance Travellers

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Abstract: Commuters tend to shift from public to private transport modes due to various reasons. This results in an increased traffic volume in the urban road network. The ultimate consequence is traffic congestion which creates massive economic losses and adverse environmental pollution. To provide a feasible solution for the above problems, this study is set to examine the factors affecting transport mode choice. Factor analysis was used to identify the factors influencing the mode choice variability of the commuters. Parameter estimation is done using the Multinomial Logit (MNL) model based on the utility maximization theory. The adjusted likelihood ratio index is used to show the model fits. Also, t-statistics and the respective sign of parameters are used to show the validity of estimated parameters. The outcome of the factor analysis shows that age and occupation significantly affect the public transport mode choice under personal characteristics. For private mode choice, the contributing factors are gender, age, occupation and monthly income. Trip distance, in-vehicle travel time, and travel cost are significantly influencing both public and private transport mode choices. Results of the estimated parameters and elasticity analysis suggest that more commuters can be attracted to public transport by reducing the total travel time of buses.

Keywords: Travel Behaviour, Mode Choice, Factor Analysis, Utility Maximization, MNL Modelling

1. Introduction

Having an effective and efficient transportation system is one of the decisive factors that has a major impact on the development of a country [1]. Public transportation plays a major role to fulfil the travel requirements of the commuters in a country. Nevertheless, most of the commuters are converting their mode of transport to private modes for various reasons. According to the central bank report of Sri Lanka in 2019, 99% of total registered vehicles in Sri Lanka are private vehicles [2]. Therefore, many private vehicles are accumulated to the road network day by day, creating adverse effects on society. Among them, traffic congestion is one of the main problems that make people suffer a lot.

In Sri Lanka, there has been great concern about traffic congestion and the government seeks possible remedies to control this problem. Traffic congestion tends to grow as many private vehicles are added to roads every day. Other modes of transport services such as taxi and three-wheeler services by the private sector are also expanding rapidly, encouraging passengers to leave the public transport modes. This has been well revealed by the Kandy traffic study which was carried out in 2016 by the University of Moratuwa and the University of Peradeniya [3]. The study revealed that public transport usage has decreased from 78.3% in 1999 to 62.4% in 2016.All categories of private vehicles carry 19% of the passenger percentage that contributes to 65% of the traffic flow entering

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the Kandy city. Route buses contribute 8.5% to the total traffic flow, but they carry 63.4% of passenger movement [3].

In Kandy, Sri Lanka, the main mode of public transportation is the bus. There are 500 - 600 buses operating under Sri Lanka Transport Board (SLTB) and around 1900 buses are operating under private operators. Nearly 300,300 passengers are using the public bus transport service in Kandy city. Passenger queues can often be seen in Kandy city due to the lack of adequate space, which creates significant safety risks for pedestrians [4].

Limited road infrastructure, conflicting land use, poor orientation of bus routing, terminal and stops, inadequate by-pass roads for Kandy Municipal Area and Central Business District, inappropriate traffic circulation and parking demand management measures, underutilisation of the railway network, and lack of management of para-transit modes such as school vans and three wheelers are identified as the the major transport related issues in Kandy [5]. Therefore, to minimize these problems, improving the public transport system in Kandy becomes more and more important.

To attract more commuters toward the public transport system, it is very important to identify the factors affecting the mode choice behaviour of the commuters. These factors can be categorized into three main categories as socio-economic characteristics, transport system variables and attitudinal variables[6]. Among the three categories, socio-economic characteristics and transportation system variables have a significant effect on the mode choice behaviour of commuters.

Therefore, this research is focused on the effect of socio-economic characteristics and transportation system variables on the mode choice behaviour of the commuters in Kandy, Sri Lanka, by using factor analysis and creating a discrete choice model based on a well establish utility function.

2. Literature Review

Traffic congestion is a timely recognized issue by researchers due to its impact on economic growth and the quality of human life. Even though researchers have come up with different solutions over the years, traffic congestion continues to grow. One such solution is to improve the public transport system so that commuters will shift from private transport modes to public transport modes. This solution seemed to be more practical and efficient since a high-quality public transport system is capable of retaining existing customers as well as attracting private vehicle users.

Improving the public transportation system is an innovative approach to meet the challenges due to rapid growth in demand for private transport modes. Therefore, it is very important to identify the factors which are affecting the mode choice behaviour of the commuters.

Talagala and Kalukottege, (2014) studied the factors affecting public transport ridership [7]. Even though the study was limited to the capital Colombo, it revealed important factors that affect passengers' perception of the bus-transport service. It has been identified that over 90% of the road space is used by private and hired vehicles which served only 35% of total travel demand. Therefore, it is clear that attracting commuters to the public transport system is crucial in reducing traffic congestion. Further, it is reported that the existing bus transport system is not satisfactory for both existing commuters and private vehicle users. In addition, the major discouraging reasons to use public transport areinconvenience, lack of seating facility, delay and lack of an alternative.

Ashalatha et al. (2013) studied the mode choice behaviour of commuters in Thiruvananthapuram city by using the multinomial logistic regression [6]. The study was restricted only for the work trips in the city. Three categories of variables were considered for the study, socio-economic variables, transport system variables and attitudinal variables. The choice behaviour of modes, car, two-wheeler and bus, was evaluated and compared with each other. The findings revealed that, when age increases, the preference for car increases and preference for two-wheeler decrease compared to public transport. An increase in time per distance and increase in cost per distance cause the commuters to shift from public transport to private modes. A similar kind of study was done by Maduwanthi et al. (2015) to identify the factors affecting the selection of the transport mode for the regular activities of commuters in the aspects of personal characteristics and travel based characteristics [8]. From factor analysis using SPSS software, four main substantial factors which are influenced to choose the travel mode were identified as income, vehicle ownership, safety and comfort.

Ten significant factors which affect the mode choice behaviour of the commuters were identified by Maduwanthi et al. (2016) considering the Colombo metropolitan area [9]. The factors are the number of earning members in the family, vehicle ownership, education, age, gender, occupation, trip distance, trip time, total cost and safety of the mode. The analysis was done by using the binary logistic method and SPSS software was used to estimate the model through the maximum likelihood function.

Ding and Zhang (2016) studied the travel behaviour of individual travellers based on their personal characteristics in the central business district (CBD) in Nanjing City of China [10]. Two-mode choices were investigated as public transport and car. The personal information of the travellers was collected through a revealed preference survey and a stated preference survey. Gender, occupation, income and car ownership were considered as the personal information while mode choice, waiting time, walking time, in-vehicle travel time, fare and comfort were considered as travel information. The travel mode choices were estimated using a discrete choice model and compared with the mode choices in the revealed preference survey and a stated preference survey. The study revealed that the mode choice estimation using individual grouping was remarkably higher than without grouping.

Chiu Chuen et al. (2014) studied the possible mode shift of travellers in the Klang Valley towards public transport based on the utility function of available transport modes through a review preference survey [11]. The results of the study revealed that travellers' likelihood of choosing the car mode depends on the parking cost, car prices and fuel prices. The factors affecting the public mode choice is identified as, transport network, accessibility distance, transit time and in-vehicle travel time.

Jian and Shoujie (2017) have developed an improved discrete choice model that better explains the travel behaviour of the decision-makers when choosing public transport [12]. Five latent variable sets were used to model the public transport mode choice behaviour. The five variables were convenience, personal safety, modal comfort, service environment and waiting feelings. The model formation was done in two stages as (1) the latent variable structural equation model and the latent variable measurement equation model and (2) the mode choice model.

As a first step to identify the factors affecting the mode choice behaviour of the commuters in Kandy, Sri Lanka, this study focuses on the personal characteristics and travel-based characteristics which are affecting the mode choice behaviour of the commuters

3. Methodology

3.1 Study Area

Kandy district contains 20 Divisional Secretariat Divisions (DSDs). Figure 1 graphically illustrates the administrative boundaries of the Kandy district with DSDs. Five class-A roads are connected with Kandy district, Kandy – Colombo (A001) in the south-west direction, Peradeniya - Badulla – Chenkaladi (A005) in the south direction, Kandy – Jaffna (A009) in the north direction, Katugastota - Kurunegala – Puttalam (A010) from the north-west direction and Kandy - Mahiyangana – Padiyatalawa (A026) from the south-east direction. 24 Class-B roads are connecting to the Kandy district covering a total length of 274.12 km. The population in the Kandy district is 1.38 million and the population density is 715 per sq. km.

Figure 1 – Administrative boundaries of the Kandy district

3.2 Sample Size

The sample size for the study was selected based on the population in the district according to Solvin's formula as shown in Eq.(1)

$$n = \frac{N}{1+NE^2} \quad \ldots(1)$$

where,

n = Sample size
N = Population size
E = Error tolerance

The confidence interval was selected as 95% which implies that the margin of error is 5%. The population of the Kandy district is 1,375,382.

$$n = \frac{1,375,382}{1+1,375,382\times(0.05)^2}$$
$$= 399.88$$
$$\approx 400$$

Hence, the minimum sample size should be 400 respondents. However, the sample size of the study was taken as 513 respondents who are more than 16 years old.

3.3 Data Collection

Data collection was done in two categories as primary data and secondary data. Individual mode choice of the commuters who live in Kandy district was collected through a questionnaire. Participants were randomly selected and all of them are more than or equal to 16 years old.

The questionnaire included three main sections. The first section was about the social demographic characteristics of the commuters to gain a general view of the personal profile. It included gender, age, educational background, occupation, monthly income, number of family members, number of earning members in the family, vehicle ownership and driving licence ownership.

The second section of the questionnaire considered the travel behaviour of the commuters which included travel mode, starting time of the trip, origin, destination, trip distance, in-vehicle travel time, and total travel cost, commonly for both private and public transport users. Additionally, for the commuters, who are using public transport modes, access time, mode of access, egress time, and mode of egress were collected. Moreover, from private transport users, parking mode, parking cost and the reasons to choose private transport instead of a public mode were obtained. 12 vehicle categories were used when obtaining the travel behaviour of the commuters as bus, train, bicycle, motorbike, three-wheeler, car, van, jeep, lorry, taxi (three-wheeler), taxi (car) and other modes.

The third part of the questionnaire considered the public opinion about the bus-based public transportation system in Kandy district, Sri Lanka. It consisted of 12 questions with a five point Likert scale to rate the answer between never and always. The 12 questions were identified using a pilot survey to describe three main latent variables, operator behaviour, comfort level and service quality. The comments from the respondents about the bus-based public transportation system were obtained in this section. The respondents for the third section were selected from the commuters who are using the bus-based public transport system daily, several times a week or several times a month. Responses from the commuters who use the public buses rarely and very rarely are omitted in the third section of the questionnaire.

The secondary data for the study was collected through published data. Train schedules, train fares, bus fares, fuel consumption for different vehicle categories, fuel prices, and fare rates of taxi (three-wheelers) and taxi (cars) were obtained from published literature and authority websites as secondary data.

3.4 Factor Analysis

Before the statistical analysis using the SPSS software, collected responses were screened to ensure the reliability and completeness of the data. Responses of the trips within the Kandy district were selected for the analysis and the others were removed. After screening, the responses were coded into SPSS. Factor analysis was used as the data analysis method.

Factor analysis is a collection of a procedure for analysing the relations among a set of measured or observed variables for each individual of a group. Factor analysis examines the interrelationships among a large number of variables, then attempts to explain them in terms of their common underlying dimensions.

There are a few assumptions that should be completed before starting the factor analysis. The main three assumptions are, (1) Correlation among the variables should be strong. (2) Variables should be spread normally. (3) Comparison index between the correlation coefficient and partial correlation coefficient should be small.

3.5 Parameter Estimation

Multinomial Logit (MNL) Model is one of the widely used methods to analyse mode choice assessments. The mathematical form of a discrete choice model is determined by the assumptions made regarding the error components of the utility function. Three assumptions lead to the MNL model as, (1) the error components are extreme-value (or Gumbel) distributed, (2) the error components are identically and independently distributed (IID) across alternatives and (3) the error components are IID across observations/individuals. The most common assumption for error distributions is the normal distribution. However, in the case of choice models, it creates numerical problems. Hence, the Gumbel distribution is selected due to computational advantages and it approximates the normal distribution.

Discrete choice models have usually been derived under an assumption of utility-maximizing behaviour by the decision-maker. The decision-maker would obtain a certain level of utility (or profit) from each alternative. This utility is known to the decision-maker but not to the researcher. The decision-maker chooses the alternative that provides the greatest utility. The researcher does not observe the utility of the decision-maker, but instead observes some attributes of the alternatives such as travel time, access time, waiting time, egress time, travel cost etc. Some of the socio-economic characteristics of the decision-maker such as, gender, age, monthly income, education level, etc. are also observed by the researcher. Since there are aspects of utility that the researcher does not or cannot observe, the utility is decomposed by including a random error term.

Including all these factors, the utility function can be expressed as in Eq.(2).

$$U = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + \varepsilon \quad (2)$$

where U is the utility, $X_1, X_2, X_3, \ldots$ are attributes and $\beta_0, \beta_1, \beta_2, \ldots$ are parameters, and ε represents the random error term.

The logit model is used to calculate the proportion of trips that will select a specific travel mode. The probability of the decision-maker choosing an alternative can be calculated using Eq. (3).

$$p(k) = \frac{e^{U_k}}{\sum_x e^{U_x}} \quad \ldots (3)$$

where $p(k)$ is the probability of the decision-maker choosing alternative k and U_k is the utility of alternative k.

The parameter estimation is done by maximizing the log-likelihood function. The log-likelihood can be calculated using the Eqns.(4), (5) and (6).

If a sample of N decision-makers is obtained for estimation. The probability of a person n choosing the alternative that he/she was actually observed to choose can be expressed using Eq.(4).

$$\prod_i (P_{ni})^{y_{ni}} \quad \ldots (4)$$

where $y_{ni} = 1$, if person n chooses i and zero otherwise. It simply gives the probability of the chosen alternative.

Assuming that each decision-maker's choice is independent of others, the probability of each person in the sample choosing the mode that he/sheactually using is calculated from Eq.(5).

$$L(\beta) = \prod_{n=1}^{N} \prod_i (P_{ni})^{y_{ni}} \quad \ldots (5)$$

where β is a vector containing the parameters of the model. The log-likelihood function is expressed as in Eq.(6).

$$LL(\beta) = \prod_{n=1}^{N} \prod_i y_{ni} \ln(P_{ni}) \quad \ldots (6)$$

The goodness of fit for the model is measured using the likelihood ratio index (ρ^2) value. The likelihood ratio index value is calculated using Eq.(7).

$$\rho^2 = 1 - \frac{LL(\hat{\beta})}{LL(0)} \quad \ldots (7)$$

where $LL(\hat{\beta})$ is the value of the log-likelihood function at the estimated parameters and $LL(0)$ is the value when all the parameters are set equal to zero.

The problem with the likelihood ratio index is that it improves with the increase of the variables, even though the variables do not have any relationship with the output results. Therefore, the likelihood ratio index is modified as an adjusted likelihood ratio index ($\bar{\rho}^2$) as shown in Eq.(8).

$$\bar{\rho}^2 = 1 - \frac{LL(\hat{\beta}) - k}{LL(0)} \qquad \ldots (8)$$

where k is the number of degrees of freedom (parameters) used in the model.

The validity of the estimated parameters was tested using the t - statistic value of each parameter. The t- statistic values were calculated using Eq.(9).

$$t - statistic = \frac{\hat{\beta}_k - \beta^*{}_k}{S_k} \qquad \ldots (9)$$

where $\hat{\beta}_k$ is the estimate for the k^{th} parameter. $\beta^*{}_k$ is the hypothesized value for the k^{th} parameter andS_k is the standard error of the estimate.

The null hypothesis is rejected with a higher absolute value of the t-statistic which implies that the parameter is equal to the hypothesized value. The low absolute value of the t-statistics implies that the variable does not contribute significantly to the explanatory power of the model and can be considered for exclusion.

3.6 Elasticity Analysis

Choice probabilities in logit models are a function of the values of the attributes that define the utility of the alternatives. Therefore it is useful to know the extent to which the probabilities change in response to changes in the values of associated attributes. One measure for evaluating the response to changes is to calculate the elasticity of the choice probabilities of each alternative for the variable in question.

Elasticity can be identified in two sections as (1) direct elasticity and (2) cross elasticity.

Direct elasticity measures the percentage change in the probability of choosing a particular alternative in the choice set with respect to a given percentage change in an attribute of that same alternative. The direct elasticity of a selected mode can be calculated using Eq.(10).

$$Direct\ Elasticity = \beta_k X_{ik}(1 - P_i) \qquad \ldots (10)$$

Cross elasticity measures the change in the probability of choosing a particular alternative in the choice set with respect to a given percentage change in a competing alternative. The cross elasticity of a selected mode can be calculated using Eq.(11).

$$Cross\ Elasticity = -\beta_k X_{ik} P_i \qquad \ldots (11)$$

where β_k is the parameter of the k^{th} attribute, X_{ik} is the k^{th} attribute of the alternative i and P_i is the probability of choosing the alternative i.

4. Results

4.1 Factors Influencing Mode Choice Behaviours of Commuters

The factors influencing the mode choice behaviour of the commuters are analysed using the factor analysis under two sections. The first section contains the Personal Characteristics (PC) of the commuter while the second section contains the Travel based Characteristics (TC) of the commuters. Although twelve vehicle categories were considered in the questionnaire, bus, car and motorbike show the highest percentage among all modes which is 93% of the total share. Therefore those three modes were considered for the data analysis.

The accuracy of the factor analysis is checked by using the KMO (Kaiser-Meyer-Olkin) score and Bartlett's significant score. KMO statistic is a value that measures sampling adequacy. It takes a value from zero to one. Values close to zero are considered not suitable, while values close to one are acceptable. The KMO score and Bartlett's significant score for each mode are shown in Table 1.

Table 1 – Model Estimation Results

Travel Mode	KMO and Bartlett's Test	Value for PC	Value for TC
Public Bus	Kaiser-Meyer-Olkin Measure of Sampling Adequacy.	0.494	0.676
	Approx. Chi-Square	316.267	760.137
	Bartlett's Test of Sphericity df	36	21
	sig.	0.000	0.000
Motor Bike	Kaiser-Meyer-Olkin Measure of Sampling Adequacy.	0.526	0.690
	Approx. Chi-Square	240.731	355.193
	Bartlett's Test of Sphericity df	36	15
	sig.	0.000	0.000
Car	Kaiser-Meyer-Olkin Measure of Sampling Adequacy.	0.619	0.617
	Approx. Chi-Square	264.392	436.038
	Bartlett's Test of Sphericity df	36	15
	sig.	0.000	0.000

The KMO score is almost greater than 0.5 for each travel mode which implies that the analysis can be continued for all the travel modes. Bartlett's score is 0.000 for each mode which indicates a strong correlation among the variables.

The main public transportation system inside the Kandy district is a bus-based public transportation system. Although there are train services, a very limited number of trains can be seen within the district. Therefore, only public bus transportation is considered for the analysis. The factors influencing public bus-based transportation are divided into two main segments for the analysis as PC and TC.

After the analysis, nine variables for the PC are reduced into four latent variables and eight variables for the TC are reduced into three latent variables. Tables 2 to 7 show the components which contribute a significant value of 50% for the total variance and their Eigenvalues are greater than one. Tables 2 to 7 show the final scores of each variable after the Direct Oblimin rotation.

Table 2 represents the rotated component loadings of bus transport for PC.

Table 2 – Rotated Component Loadings of Bus Transport for PC

Personal Characteristics	Component			
	1	2	3	4
Occupation	0.886			
Age of the Respondent	0.879			
Vehicle Ownership		0.771		
Licence Ownership		0.764		
Number of Family Members			0.727	
Number of Earning Members in the Family			0.711	
Gender of the Respondent				0.715
Educational Background				-0.518
Total Variance	63.55			

According to Table 2, the occupation and age of the respondent come under one factor. Most of the young people tend to use public transportation as they do not own a private vehicle or they are students. The people who owned a private vehicle and have a driving licence tend to use a private vehicle than use public transportation. Therefore, vehicle ownership and driving licence ownership come under one category. When the number of family members is increasing, although the family owns a private vehicle, some of the members have to use the public transport service to fulfil their daily travel requirements. Therefore, when the number of family members is increasing, public transport usage also increases. When the number of earning members is high, the number of members leaving the home is high. Therefore, some of the members tend to use the public transportation service. Most of the ladies are using public transportation than males and most of the highly educated people are using their private transport modes in Sri Lanka.

Table 3 represents the rotated component loadings of bus transport for TC.

Table 3 – Rotated Component Loadings of Bus Transport for TC

Travel Characteristics	Component		
	1	2	3
Trip Distance	0.969		
In-Vehicle Travel Time	0.935		
Travel Cost	0.879		
Waiting Time		0.664	
Egress Time		0.622	
Access Time		0.607	
Trip Purpose			0.879
Total Variance	69.61		

According to Table 3, most of the commuters are considering the trip distance, travel time and travel cost when selecting public transportation as the mode of transportation. Most of the people who own a motorbike or three-wheeler tend to use public transport if the trip distance is high. Since the cost of private transport is higher than public transport, most of the commuters are using public transport when the trip distance is high to reduce the total cost. Commuters consider the time reliability and the waiting time when choosing public transport. Therefore, access time, waiting time and egress time are important parameters for the mode choice variability of the commuters. The trip purpose is also a considerable factor in the mode shift of the commuters.

Table 4 and Table 5 represent the rotated component loadings of the motorbike for PC and TC, respectively.

Table 4 – Rotated Component Loadings of the Motorbike for PC

Personal Characteristics	Component			
	1	2	3	4
Licence Ownership	0.840			
Gender of the Respondent	0.776			
Vehicle Ownership	0.675			
Number of Earning Members in the Family		0.792		
Educational Background		0.703		
Age of the Respondent		-0.817		
Monthly Income			0.730	
Occupation			0.729	
Number of Family Members				0.936
Total Variance	72.44			

Table 5 – Rotated Component Loadings of the Motorbike for TC

Travel Characteristics	Component		
	1	2	3
Trip Distance	0.966		
In-Vehicle Travel Time	0.948		
Travel Cost	0.918		
Parking Cost		0.867	
Parking Mode		0.619	
Trip Purpose			0.899
Total Variance	83.82		

In Sri Lanka, most of the males tend to use the motorbike as their mode of transportation. With the lower cost and the lower travel time in motorbikes, many commuters are shifting to motorbikes instead of public transport. Majority of educated people and elderly people are not willing to use motorbikes due to low comfort level. Occupation is directly affecting the monthly income and mostly the middle-class households are using motorbikes as their mode of transportation.

Commuters are considering the trip distance and the travel time when choosing the motorbike as their mode of transport as the comfort level of the motorbike is low. Parking mode and the parking cost also significantly affect the private mode choice of the commuters. Parking facilities within the city limits are very poor. Therefore, people are thinking about the parking mode and the parking cost when choosing the motorbike as the mode of transport.

Table 6 and Table 7 represent the rotated component loadings of Car for PC and TC, respectively.

Table 6 – Rotated Component Loadings of Car for PC

Personal Characteristics	Component		
	1	2	3
Occupation	0.881		
Age of the Respondent	0.803		
Monthly Income	0.740		
Number of Family Members		0.851	
Number of Earning Members in the Family		0.833	
Licence Ownership		0.575	
Gender of the Respondent			0.763
Vehicle Ownership			0.661
Total Variance	62.22		

Table 7 – Rotated component loadings of car for TC

Travel Characteristics	Component		
	1	2	3
Trip Distance	0.975		
In-Vehicle Travel Time	0.944		
Travel Cost	0.891		
Trip Purpose		-0.827	
Parking Mode		0.729	
Parking Cost			0.908
Total Variance	83.61		

Many high-income households are using the car as their mode of transport. Therefore, occupation and income significantly affect choosing the mode of car. Main TC factors affecting choice of the car are trip distance, in-vehicle travel time and travel cost. As the comfort level of the car is high, many commuters are choosing the car for long-distance trips with a higher travel time.

Figure 2 shows the factors affecting the mode choice behaviour of the commuters for the three modes, bus, motorbike and car under the two categories PC and TC.

4.2 Parameter Estimation

A well-developed discrete choice model is used to analyse the mode choice behaviour of the commuters within the Kandy district. The parameter estimation was done using RStudio statistical software for the parameters, travel time, travel cost, access time, waiting time and egress time. Bus, car and motor bicycle modes were used for the parameter estimation as they are the governing transport modes of the city. The respective estimation results are shown in Table 8.

Table 8 – Model Estimation Results

The absolute value of the t-statistics is greater than 1.96 for each parameter other than the travel cost and that implies the parameters are significant with more than a 95% significant threshold. For the travel cost parameter, absolute value of the t-statistics is greater than 1.645 which implies that the parameter is significant with more than a 90% significant threshold. The respective sign of the parameters is also used to show the accuracy of the model along with the $\rho^2$and t-statistic values. The positive sign of a parameter implies that the option has a beneficial effect on the choice and the option is likely to be chosen. The negative sign of the parameter implies that the option is not likely to be chosen. The likelihood ratio index of the model is 0.236 and the adjusted likelihood ratio index is 0.212 which represents a decent model fit for a discrete choice model.

	Estimate	t-statistic value
Travel Time	-0.0193	-2.55
Travel Cost	-0.0012	-1.74
Access Time	-0.0741	-2.49
Waiting Time	-0.0589	-3.26
Egress Time	-0.1554	-5.53
Sample		513
Initial LL		-289.74
Final LL		-221.23
ρ^2		0.236
$\bar{\rho}^2$		0.212

Parameters, access time, waiting time, travel time, and egress time show negative signs. Commuters are always trying to reduce these parameters in their trips to save time. Therefore, when the total travel time increases, the likelihood of the choice of that mode will decrease. The next considering factor is the travel cost. Commuters are more likely to use a mode with the lowest travel cost. When the travel cost increases, the likelihood of the mode choice decreases. The negative sign of the travel cost parameter in Table 8 implies this phenomenon.

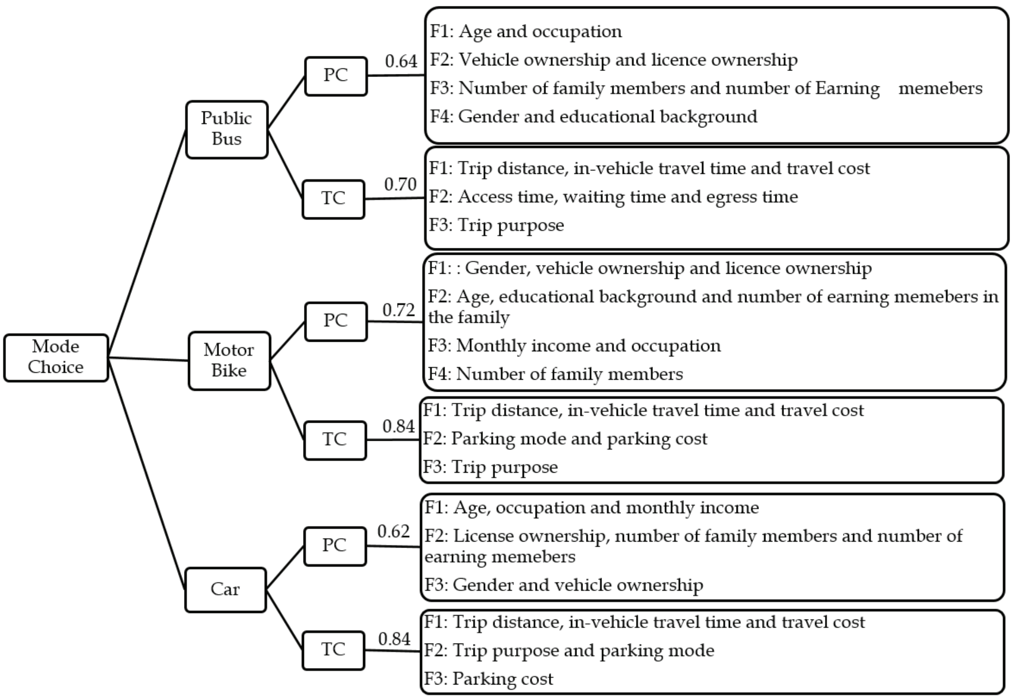

Figure 2 – Factors Influencing the Mode Choice Variability of the Commuters

The parameters, access time, waiting time and egress time are related only to public transport. But travel time and travel cost are related to both public and private transport modes. Therefore, more attention should be paid to above three parameters to attract more commuters towards public transport modes. Route coverage of public transportation can be increased to reduce the access time and egress time of the commuters. More public transport services can be implemented in rural areas to increase route coverage [1]. With that, people may get the chance to use alternative routes for their trips with public transport modes. The waiting time of the passengers can reduce by increasing the frequency of the public transport service.

4.3 Elasticity Analysis

Elasticity analysis for the choice set was performed to measure the percentage change in the probability of choosing a particular alternative with respect to a given percentage change in the same or in a competing alternative. Elasticity analysis was done for all the five attributes discussed above for the three alternative modes,bus, motorbike and car.

Table 9 shows the percentage values of direct elasticity analysis for each alternative.

Table 9 - Direct Elasticity Values

Alternative	Travel Time (%)	Travel Cost (%)	Access Time (%)	Waiting Time (%)	Egress Time (%)
Bus	-0.20	-0.01	-0.18	-0.20	-0.54
Motor Bike	-0.26	-0.05	-	-	-
Car	-0.22	-0.12	-	-	-

According to Table 9, all the elasticity values are obtained as negative values which says that the increase of each of the alternatives is reducing the attraction of the commuters to the relevant mode. The value of -0.20% for the travel time of the bus represents that for an additional one minute of travel time in bus, 0.20% of commuters are leaving the bus transport mode. The highest elasticity value for the bus-based public transport system can be seen in the egress time. 0.54% of commuters are leaving the bus transport system for an additional minute of the egress time. This implies that the route coverage within the Kandy district can be improved to attract more commuters to the public transport system. The lowest elasticity value for the bus transport system is for the travel cost where 0.01% of the commuters are leaving the bus transport system for an additional 1 LKR in bus fare. With the results, it can be seen that the commuters are considering the travel time rather than the cost when choosing the public bus-based transport system.

When considering the private transport modes which are motorbikes and cars, the highest elasticity can be seen in travel time than travel cost. 0.26% of commuters are leaving the motorbike mode for an additional minute of travel time where it is 0.22% for cars. The highest percentage of commuters, which is 0.12% of commuters, are leaving the car for an additional 1 LKR in car. This implies that most car users are willing to use buses or motorbikes with the increase in the cost.

According to the direct analysis results, it can be identified that the total travel time of the bus transport system should be reduced to attract more commuters. Route coverage can be improved to reduce access time and egress time while bus frequency can be increased to reduce the waiting time of the passengers.

Cross elasticity can be used to measure the change in the probability of choosing a particular alternative in the choice set with respect to a given percentage change in a competing alternative. Table 10 shows the cross elasticity values for each alternative.

Table 10 - Cross Elasticity Values

Alternative	Travel Time (%)	Travel cost (%)
Bus	0.65	0.04
Motor Bike	0.41	0.07
Car	0.46	0.33

According to Table 10, all the elasticity values are obtained as positive values which says that the increase of each of the alternatives in a mode is increasing the attraction of the commuters towards another mode. The highest cross elasticity value for the travel time can be seen in the mode bus which is 0.65. This indicates that, when the travel time of the motorbike or car is increased from one minute, 0.65% of more commuters are attracted to the bus-based public transport system. Therefore by reducing the total travel time of the bus transport system, more commutes can be attracted to use the public transport. When considering the travel cost, the highest elasticity value can be seen in the mode car which is 0.33%. Therefore, the increase of 1 LKR in bus fares can move some more passengers towards the private modes.

According to the results in Table 10, it can be seen that the best way to attract commuters to the public transport system is reducing the travel time of the bus transport system rather than reducing the bus fare. The travel time of the bus transport system can be done by reducing the access time, waiting time and egress time by increasing the route coverage and the bus frequency.

5. Conclusions

The study was conducted to identify the mode choice behaviour of the commuters in Kandy district, Sri Lanka. Trip data was collected by using online and face to face interviews through a structured questionnaire. According to the findings, the highest percentage of people are using buses, cars and motorbicycles as their mode of transportation. About one-third of the population is using public transport modes for their travel purposes within the district. Kandy is attracting more work and educational trips compared to other purposes. 513 respondents were selected for the study within the Kandy district.

Factor analysis was used to analyse the data. Two main categories of factors were considered as Personal Characteristics (PC) and Travel Characteristics (TC). Three vehicle categories were considered for the study as public bus, motorbike and car.

According to the results, age and occupation are the considerable factors that significantly affect the public mode choice under the PC category, while for the TC category, it is trip distance, in-vehicle travel time and travel cost. Gender, age, occupation and monthly income are significantly influencing the choice of a private transport mode under the PC category. Same as public transport, trip distance, in-vehicle travel time and travel cost are the factors that are significantly affecting the private mode choice under the TC category.

The multinomial logit model was used for the parameter estimation with the utility maximization theory. Travel time, travel cost, access time, waiting time and egress time were identified as the key parameters for the mode choice behaviour. All the estimated parameters are significant and have achieved the expected negative sign which implies that increasing the value of each parameter decreases the likelihood of choosing the relevant mode.

Elasticity analysis was done for the three modes using the estimated parameters for each attribute. From the elasticity analysis, it was identified that more commuters can be attracted towards the public transport system by reducing the total travel time of busses. Route coverage of the bus service and the frequency of the bus service can be improved to reduce the travel time of the commuters [13].

Accordingly, the relevant authorities can use these results to identify the improvements which have to be done in public transport services to attract more commuters towards public transportation. Some studies can be done to identify the service intensity of public transport service in the Kandy district and to identify the measures which can be taken to provide a better public transport service to the people. Furthermore, the results can be improved with more trips and some more modes can be used for the estimation.

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