ESTIMATION OF A MODE CHOICE MODEL FOR BOAT PASSENGER TRANSPORT FOR WORK TRIPS IN COLOMBO

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Degree of Master of Science in Transportation

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Thesis submitted in Partial fulfilment of the requirements for the Degree of Master of Science in Transportation

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DEDICATION

I dedicate this thesis to my family for helping me to complete this thesis with all their love and strength

ACKNOWLEDGEMENT

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ABSTRACT

Estimation of a Mode Choice Model for Boat Passenger Transport for Work Trips in Colombo

Public transportation service in Colombo canal network is an applicable alternative in addition to roads and railway network on Colombo Metropolitan Region (CMR) corridors. Though it is an environmentally friendly and one of the most economical mode of canal boat service, it remains largely under exploited in Sri Lanka. The prevailing public transportation modes such as bus, train and private transportation modes such as Cars, Motor bikes, Taxis play vital roles in passenger movements within the country. But with the increasing population & the land scarcity in Colombo Municipal Council (CMC) region vast traffic and congestion problems exists in prevailing conditions. Thus, introducing another transportation mode is essential for future. Lack of data availability in the transport mode choice modelling has create problems implementing passenger boat transportation in CMR that leads to do more researches in the field. This study intends to present an idea of developing suitable choice model on the basis of discrete choice modelling technique. Nested logit modelling is an improved version to Multinomial logit models due to its ability of modelling alternatives which have correlation among them. ALOGIT software has been used for model setup and data analysis process. A stated preference pilot survey has been carried out in CMR region by proposing a public boat service route from Wellawatta to Battaramulla. The estimated results of nested logit model indicated that Alternative Specific Constants (ASCs) and considered travel time attribute had significant effects on the choice of proposed public boat transport service in CMR. The coefficient value of travel time was -0.006835. Compared to the travel time attribute, the travel cost attribute coefficient value was less, -0.0003279. the estimated ASC values showed the preference of public for given alternatives as ASC2 (0.8978, Alternative 3) > ASC3 (0.8516, Alternative 4) > ASC 5 (0.8324, alternative 6) > ASC 6 (0.7385, alternative 7) > ASC 4 (0, alternative 5) from highest to lowest. According to the estimated nested logit model results people choose to use available bus mode option though it introduced new passenger boat service to the public transport system.

Key Words: Utility Theory, Discrete choice modeling, Multinomial logit model, Nested logit model, Boat passenger transportation, ALOGIT

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LIST OF ABBREVIATIONS

Abbreviation	Description
ASC	Alternative Specific constant
CMR	Colombo Metropolitan Region
CMC	Colombo Municipal Council
CM	Choice Modeling
MNL	Multinomial Logit
NL	Nested Logit
RP	Revealed preference
SP	Stated Preference
Tt	Travel Time
Tc	Travel Cost
RT	Ride Time
WT	Wait Time
TT	Transfer Time

1 INTRODUCTION

1.1 Background

Transportation is one of the primary factors for economic development of a country. This modern era people are moving to work, education, business and trade, leisure for their day today life. On the other hand, fast movement of passenger & goods save money and time. Hence rulers of the country pay special attention for introducing new technologies, strategies, modes for the prevailing system in order to gain quick economic development. Further it enhances the living standards of people by saving time and money providing quick comfortable access for work, education, health services etc. transport modes play vital role in transportation. Transportation can be classified as land born, water born, and air born based on the different modes and infrastructure used for transportation. Motor vehicles like buses, cars, motor bikes, vans, trucks, trains etc considered as land born transport modes, while boats, ships, ferries etc considered as water born transport modes.

Water born transportation is one of the oldest and cheapest transport modes used by ancient people. People used large ships to navigate from Europe to America in early nineteenth century. Still passenger navigation is done by ships in many countries in the world. Water born passenger transportation can be divided as inland water born transportation and oceanic transportation. Countries like Indonesia, Japan, Korea and archipelago countries used oceanic passenger boat transportation among their islands. Inland water born transportation considers as transportation along wide rivers, canals, streams. Ex, passenger boat transportation along river Mekong in Vietnam, boat transportation in Yellow river China, boat transportation in Venice, Netherlands, Kerala etc. Specially, considering the fact that many cities forms based on river banks, it is eventually a better option to use passenger boat transport to travel between these cities lying along the same river.

In Sri Lanka the modal shares of water born transport modes for the transport activities are lesser as per the policy report published for world bank in 2012. (Kumarage, 2012) Figure 1.1 showed the transport modal share in 2011. But with the available unitize

resources Sri Lankan transport sector can increase the modal shares of water born transportation, relieving some burden from the land transport infrastructure.

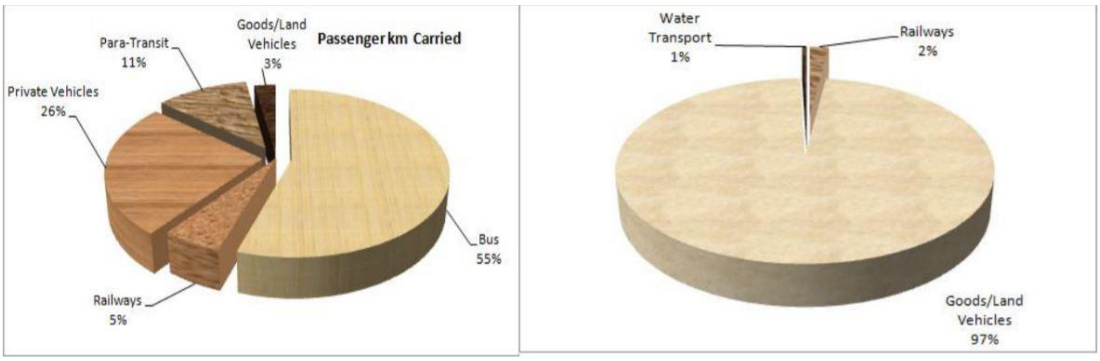

Figure 1-1 Transport modal share in 2011 (Source: Kumarage, 2012)

Considering the existing resource utilization Sri Lanka can consider Bangkok's existing commuter ferry service along chao Phraya river as an inspiration for utilizing the Colombo canal network and Kelani river for operating a water born transport service. This would start to make some impact in the prevailing congestion issue in Colombo roads.

1.1.1 Canal network system in CMR

One of the evidences for Dutch legacy in Sri Lanka, the old canal network in western region of the country is stating from Puttalam lagoon to Kaluthara. This canal network can be divided in to 3 parts, Northern CMR, Central CMR, Southern CMR. Northern CMR canal network starts from Negambo lagoon to Kelani river. Dutch canal and Hamilton canal are two of the networks belong to the northern CMR. Central CMR consist of Baire lake, St Sebastian canal and other canals connects eastern Colombo to the Colombo port. Wellawatte Kirulapona canal network also belong to central CMR network. Southern CMR consist of Bolgoda lake and canal network connects to the Kalu ganga at Kalutara (De Silva, 2003). Most of these canals have been abounded and now facilitates storm water drainage discharge in to the sea. But through the mero Colombo urban development project most of these canals will be widen and use for multipurpose network. According to the study (De Silva, 2003), it has been identified five possible routes for inland water transport system in CMR that are technically feasible. Among them most viable routes are from Wellawatta to Battaramulla via

Kirulapona canal, Kotte marsh and Diyawannawa oya and from Baire lake to union place. Figure 1.2 shows the Colombo canal network.

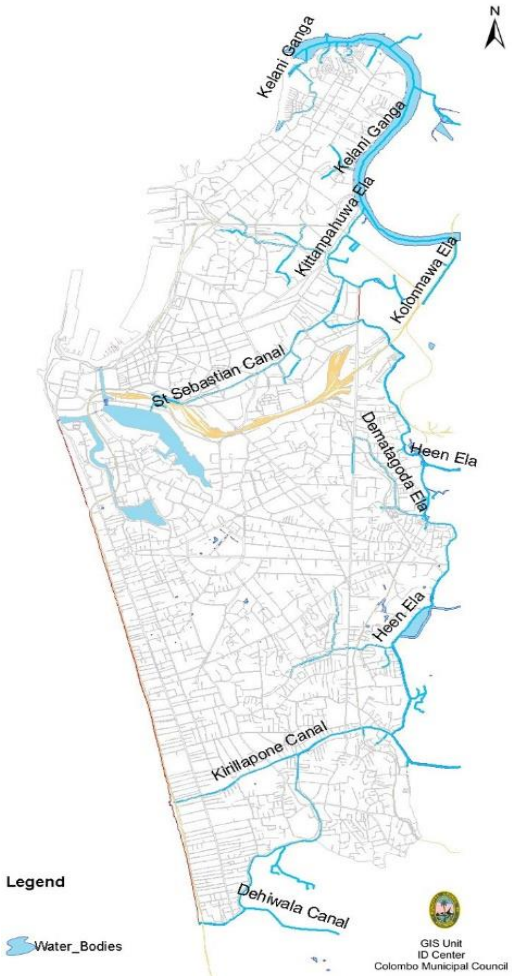

Figure 1-2 Colombo Canal Network (Source: Colombo Municipal Council)

1.2 Motivation

The traffic annual growth rate in Colombo was nearly 5.5% (Kumarage, 2012). But considering the growth rate of available public transport modes, buses were 5% and rails were 0% creating a huge growth of 60% in 2011. This showed that compared to the public transport services the private vehicle usage has increased in leaps and bounds. (Kumarage, 2012) According to the COMTRANS study by JICA in 2013, private motorized traffic has been increased in Colombo Metropolitan Region (CMR) recently.). As per their findings personal trips by car will be increased form 0.093

million per day (from 2013) to 5.5 million trips in 2035. It is almost six times compared to the study period (Agency, 2014).

Further due to its location closeness to the Colombo international sea port, Bandaranaike international airport and other several ongoing projects like Colombo port c0ity w0ill create 0more traff0ic in CMR region. Therefore, other than introducing alternative public transport options that utilize the existing road infrastructure it would be worth to introduce alternative mode options that utilize separate infrastructure networks such like Light rail transport service, Public boat transport service etc.

In order to reduce traffic congestion in urban areas improving public transport is very effective (Zhang, 2001). Therefore, improving the conditions, infrastructure, and operating characteristics in existing public transport modes, introducing public transport polices and introducing alternative public travel options are some solutions to mitigate the existing crisis in transportation sector in CMR region.

As a solution to minimize traffic congestion on roads, introducing passenger boat transport has been a widely spoken subject in Colombo Capital recently among business and administrative sector. The prevailing public transportation modes such as bus, train and private transportation modes such as car, motor bikes, taxis play vital roles in passenger movement within the country. But with the increasing population & the land scarcity in CMR region introducing another transportation mode is essential for the future. Colombo metropolitan lands consist with a historical canal network built in Dutch colonial period which has been used to transport of goods from inland to the Colombo port. After centauries that this canal network only serves as a stormwater drainage system in Colombo suburbs. Few studies have been carried out for operating passenger boat service in Colombo canal network during two decades (De.Silva, 2003) (Sutharman & Silva, 2016)

1.3 Research Problem

With the availability of different travel modes People are considering choosing of travel modes based on their trip purpose. In Sri Lanka for choosing public mode services an Individual’s travel behaviour closely related with social demographic

characteristics like age, gender, income, education etc and mode characteristics like comfort, safety, cost of the travel mode, travel time etc (Maduwanthi, 2016). with the development of transportation sector nowadays different travel modes are available and people have different options to choose. In order to have successful operation in transport business, operator must ensure their service is fit for the users. Analysing the user behaviour for choosing their transport mode is essential for adding effective attributes to transport services. It ensures the successful operation in the market. By modelling user influential factors related to the mode selection for the trip purpose, operator can change the mode designs and its operation characteristics and further make the mode operation more suitable for day today life. Such mode services will survive in the transport market for a long time. Since there were less studies done for mode choice modelling for Sri Lankan transportation market, it will be hard to analyse the mode share for proposed boat service in the industry. Thus, conducting this study is will be more influential for the long-term successful operation for the proposed public boat passenger service.

1.4 Objectives of the Study

Ultimate goal of this study is to support the idea of establishing passenger boat service along the Colombo canal network as an alternative public transport mode for reducing traffic congestion in CMR. During peak hours, Colombo centre and its suburban roads get highly congested with traffic. The proposed passenger boat service in CMR will help to reduce the traffic on roads by attracting some of public transport users and private transport users to the boat service during peak hours. objectives of this study set to be fulfilled based on the daily trips in CMR. The first objective is to identify the most influential transport system characteristics for developing a choice model for the proposed passenger boat service. The second objective for this study is to develop a choice model to estimate the proposed passenger boat service along the Colombo canal network as a public transport mode.

2 LITERATURE REVIEW

2.1 Theoretical Background of Mode Choice Modeling

Among the traditional four step transport model consist of trip generation, trip destination, transportation mode choice and route assignment mode choice is the third step **(de Dios Ortuzar.J., 2011)**. Mode choice analysis can address for forecasting demand for newly introduced modes to the system, mitigating traffic congestion, Resource allocation, examine the efficiency of travel, examine the traveler's characteristics and establishing transport policies **(Ashalatha, 2013)**. Most of mode choice modeling works are based on random utility maximization principle. Mode choice models can be categorized as aggregate discrete choice models and disaggregate discrete choice models.

2.1.1 Utility theory & discrete choice modeling

Let's assume there are J different alternatives available in a choice set. U_{ij} utility of j^{th} alternative for individual called i. each utility value consists of two components. V_{ij} called as systematic component & ε_{ij} a random component. The random component interprets the uncertainty on utility due to un observed factors. The systematic component is a linear function of alternative attributes and individual demographic characteristics.

$$U_{ij} = V_{ij} + \varepsilon_{ij}$$

$$V_{ij} = bx_{ij} + c_j z_i + d_j w_{ij} + a_j$$

Individual I will be to choose the alternative of highest utility value from the J alternatives. Categorization of discrete choice model depend on the distinct distribution assumptions for random utility component ε_{ij}. discrete choice model is categorized as aggregate and dis-aggregate models. Aggregate model interprets the market share of a particular mode based on the collective behavior of the decision makers in the market. Disaggregate model interpret the mode choice of an individual. further disaggregate model are more accurate compared to the aggregate due to its

consideration of treating each individual separately and requires many characteristics data of him.

2.1.2 Logit models

The logit model describes the probability of a certain mode choice can be taken as its proportional to e raised to the utility over the sum of e raised to the utility.

$$P_m = / \frac{e^{ui}}{\sum e^{ui}}$$

For any logit model the sum of the probability of all modes will equal to 1. There are mainly three basic categories of logit models., binary, ordinal and nominal models. Under nominal logit model most famous type of model used in transport modelling is multinomial logit models.

2.1.3 Multinomial logit models

Multinomial logit model is a most popular type choice modelling technique where it uses a linear combination of observed features & specific parameters for a problem to estimate the probability of each of values of the dependent variable. The most suitable values for each parameter for a problem are determined from some training data.

In multinomial logit models the alternatives are treated symmetrically. The basic formula for the multinomial logit model as follows,

$P_1 = \exp(V_1) / \{\exp(V_1) + \exp(V_2) + \exp(V_2) + \ldots\ldots\ldots + \exp(V_2)\}$

Specialty in MNL is it assumes proportional substitution patterns. It is called independence of irrelevant alternatives, IIA.as (de Dios Ortuzar.J., 2011) stated by tree structure model (NL) this restriction can be overcome in choice modeling.

2.1.4 Tree Structure (Nested logit Models) (Kumarage, 2012)

When analysts want to work beyond the multinomial logit models, the nested logit model is best among other discrete choice modeling options. (de Dios Ortuzar.J., 2011)

and the nested logit model is relatively easy to estimate compared to multinomial logit models. Nested logit model has the special ability to account for similarities between pairs of alternatives. Nested logit model is a tree structure with several branches which are subdivided with more alternative branches. Figure 2.1 shows an example tree structure

Probability value of each alternative in Nested logit model can be calculated using the given equations, 1,2,3,4

$P_i = \frac{e^{u_i \lambda_1}}{\sum_{i=1,2,8} e^{u_i \lambda_1}}$ for i= alternative & (dummy variable) ⟶ Eq 1

$U_{dummy} = \frac{1}{\lambda_1} \log [\sum_j e^{u_j \lambda_1}]$ for j=2,3 alternatives ⟶ Eq 2

$P_j = P_{dummy} * \mathbf{P}'_j$ for j=2,3alternatives ⟶ Eq 3

$\mathbf{P}'_j = \frac{e^{u_j \lambda_2}}{\sum_{j=3,4,5,6,7} e^{u_i \lambda_1}}$ for j=2,3 alternatives ⟶ Eq 4

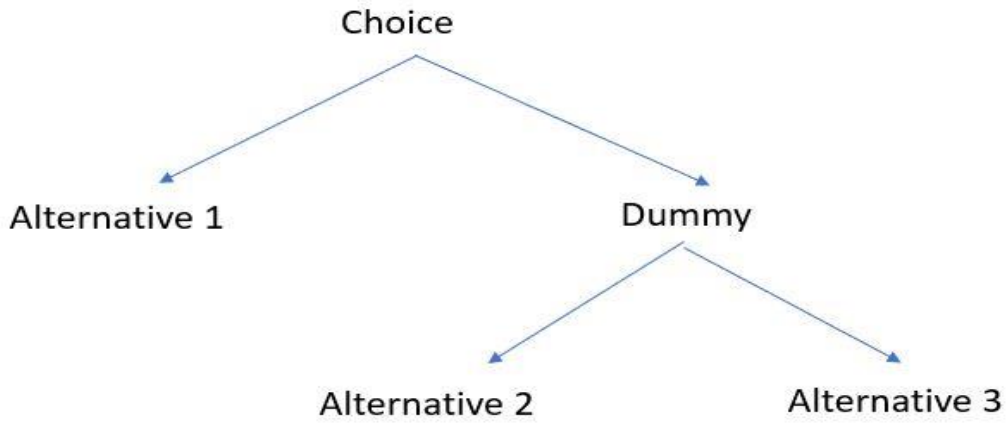

Figure 2-1 Nested tree structure

2.2 Survey Methods

In transport modelling most, used survey methods are revealed preference and stated preference models. Among them the revealed preference is widely used and well established (Moshe, 1985)

2.2.1 Revealed preference surveys (RP)

In these type of surveys for transportation modelling data are being collected directly from the public/user which are related to the characteristics of alternatives that already available to them. Ex; highway and public transport network data, demographic and socioeconomic data etc. (Bradely, 1997)

2.2.2 Stated preference surveys (SP)

Stated preference data are based on the choices to hypothetical travel situations proposed by the interviewer, analyst. This method is widely used when observed choice behaviour is not adequate to model a certain proposed of interest. For example, we can use this method to get the information of public interest of choosing a travel alternative that not yet exist among other existing alternatives. (Bradely, 1997)

For forecasting purpose many of transport modellers use SP surveys on their data collections because it can derive essential information from SP data and to incorporate it into a model. (Hunt.J & Abraham, 2007) (Sutharman & Silva, 2016)

2.3 Relevant Work on Mode Choice Analysis

Mode choice Analysis is essential to make transport planning and decision making. Mode choice behaviour influenced by many caricaturists categorized as characteristics of trip maker, characteristics of the journey, characteristics of transport modes. (Maduwanthi, 2016) The most primary mode considered as walking. Considering the mode choice analysis history analysis of walking distance is worth to consider. Next mode option is bicycle. There are many studies available on bicycle mode choice analysis. For ex: Hunt & Abraham, 2007 study showed that the purpose of cycling use (trip purpose), infrstructure facilities for cycling use, travel time, age of cyclists,

bicycle purchase cost and the level of experience and cofort cycling in mixed traffic conditions were the influential factors for choosing cycling options by an individual. They have done a logit choice model using ALOGIT software for the study..

The similar results have showed from the study done by (Arasan, 1994) for characteristics of foot trips a bicycle trips, in Tiruchirapalli, south India. As the results, home based walking and cycling trips depend by the factors like, trip length, age, sex, occupation, time of the day for travel and the trip purpose.

There are more researches done for analysing public mode choices like bus services, trains, recently, in different countries,

Findings from (Maduwanthi, 2016) study in 2016 in Sri Lanka showed that for choosing public transport mode options effected by no of earning members in the family, vehicle ownership, gender, age, education, occupation, trip distance, trip time, total cost and safety. This study used logistic regression method for analysis.

According the finding from (Ashalatha, 2013)2013 which has developed a Multinomial logit model for analysis the mode choice behaviour of commuters Thiruvananthapuram in India, showed that the choice was influenced by Age, gender, income level, vehicle ownership, travel distance, travel time and travel costs parameters.

As per the Kristian Birr's study (Birr, 2018) of mode choice modelling in polish cities, the variables that considered for mode choice modelling were divided in to three, factors describing the user, such that car availability, mobility, age, education, number of children, factors describing the journey, such that distance, travel time by bicycle, travel time by car, perceived journey time by collective transport, waiting time for public transport at the first stop of the journey, number of transfers in public transport, factors describing journey origin or destination, such that direct rail transport availability, paid parking zones, Destiney of population.

Chinese study of mode choice modelling done by (Gang.L.I.U, 2007) stated that work trip mode choice in Shanghai China influenced by factors like, income level, in vehicle time and cost for choosing bus vs taxi.

De Silva's Study (Sutharman & Silva, 2016) logit choice model for a passenger boat service in Wellawatte canal study has considered the variable factors affecting for the mode choice modelling as trip duration, waiting time, transfer time, trip cost and parking fare. But in his study, he stated that factors like comfortability also should have chosen for better results but it would be difficult to quantify. The main parameter in defining alternative solutions was operating authority like private or public. Following authority terms has been considered for the study. The considered car option mobike option bus option bus + boat option and bus + train+ boat option. for planning attributes and mode options for our study has been based on this literature.

3 METHODOLOGY

The objective of this study is to develop a choice model for the proposed public transport service. It aimed to identify the factors that contribute to the selection of proposed boat service mode in the City of Colombo. Since it is a hypothetical transport option the stated preference experiment would be sited. It can derive essential information and incorporate it into a model. Hence Stated preference survey, the technique was used to collect data for the study. MNL modelling (single level logit and Nested logit) was adopted in the study because of its ability to estimate the mode shares where multiple choice of modes of travel are available for the decision maker. The questioner covered following areas of socio economic and trip information of the traveller.

1. The choice set of the individual decision maker
2. Socio economic characteristics of the individual decision maker (age, vehicle ownership, income level.)
3. Characteristics of the transport system specific to the trip (travel time spend in particular mode, travel cost for particular mode, transfer time and waiting time the modes)

Further for this study it was not considered the access time of the traveller that spends to reach from the origin and to destination by walking or using other mode options except bus or train (such as taxi or cab services, bicycles, three wheelers etc). the data for the study were collected by directly interviewing 200 people, age above 18 years older and mostly working-class people in Colombo city.

3.1 Stated Choice Experiment Design and Data Collection

A stated preference experiment was designed and prepared as a card game with instructions and a form of application should be filled providing data of personal information before entering to play the game by the individual who play the game through the computer. The card game was about planning your journey in Colombo

city. It was a hypothetical travel scenario that consist of 6 alternative travel options as follows

A hypothetical travel Scenario

You are starting your journey from Moratuwa and your destination is Battaramulla town. You are given seven different travel options to travel.

First alternative option – Use your personnel car for the journey

Second alternative option – Use your motor bicycle for the journey

Third alternative option – Use Public bus service for the journey

Fourth alternative option – Use both public bus and train mode services only for the whole journey

Fifth alternative option – Use available public bus service and proposed public boat service only for the whole journey

Sixth alternative option – Use available train service and proposed public boat service only for the whole journey

Seventh alternative option – Use available bus, train both services and proposed public boat service only for the whole journey

(Here the access time or mode used to access haven't considered for preparation the alternative options. Access means from the origin (home) to starting point (Moratuwa main bus stop) and destination (place in Battaramulla town))

Decision maker have to select the choice alternative for his/her travel, considering following factors. ride time (for available public modes/ private modes), travel cost/fare (for available public modes/ private modes), ride time in boat, boat ticket fare, transfer time (total time taken for transferring from one public mode to another from when you start the journey to the end of the journey), waiting time (total time that you have to spend waiting for each mode option to travel).

All 5072-choice situation according to the values given for each attribute for each option. For one person three games had been played and for one game five different cards were appeared. On that game one card appears from private alternatives options and four cards from public mode alternative options. A sample of choice scenarios presented to the interviewee is shown in below Figure 3.1.

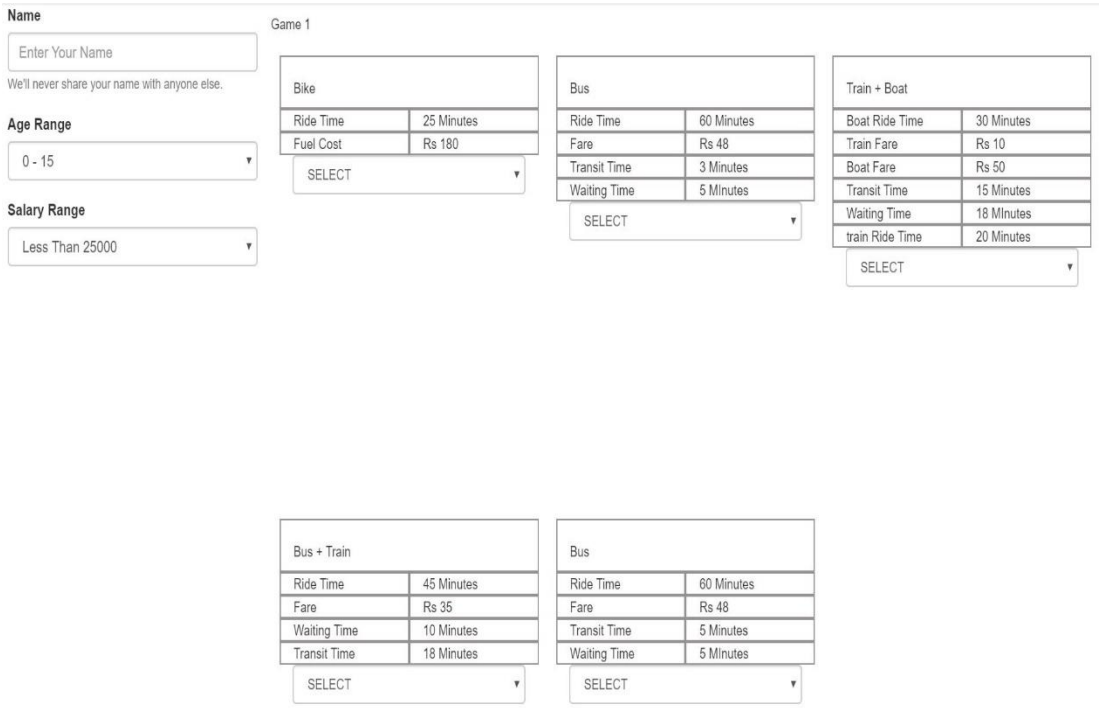

Figure 3-1 Personal interview form and card game inter-face developed as a computer-game

3.1.1 Attribute values for card game

After doing a pilot journey from the origin and destination it was identified average value for following attributes for prevailing transport modes and values for proposed transport modes.

1. Ride time (Car, motor bike, bus, train, bus and train)-
   - travel time for mobike and car modes has been considering as average values of 25 minutes and 45 minutes after personnel driving from Moratuwa (Origin) to Battaramulla (Destination).

- Average travel time via public bus service takes 60 minutes from origin to destination.
- Train mode option cannot be considered individually due to, non-availability of direct route from origin to destination. For trains, average time it takes 25 minutes to travel from Moratuwa to Wellawatte (longest travel distance) and bus service takes additional 35 minutes to reach to destination considering total travel time of 60 minutes.

2. Ride time (Boat)
   - According to Initial studies done by Sri Lanka Land Reclamation Development Corporation on operating Passenger boat service along Wellawatte-Battaramulla canal network it takes 30 minutes to travel from Wellawatte to Battaramulla (longest travel distance). Hence for this study it considered 30 minutes average travel time for a boat.

3. Travel cost (car, motor bike, bus, train, bus and train)
   - With the prevailing economy and traffic conditions in Sri Lanka a maximum consumption of fuel need for travelling 1km in CMC roads for a car 15km/l, for a bike 25km/l. these values has been taken by doing an average journey using selected car model (engine capacity 1000cc and petrol fuel) and a motorbike (100cc engine and petrol fuel), therefore averagely it costs Rs.200 for cars and Rs 120 for bikes.
   - It costs (fare) Rs 60 averagely to travel via bus from origin to destination and for train – bus option it takes Rs 75 averagely.
4. Travel cost/fare (boat)
   - For this study we introduce boat passenger service for average Rs.100 fare per person. We considered this service is semi luxury service compared to available public transport service. (providing seating and safety equipment for every passenger. Air conditioning ser ice inside etc).

5. Waiting time
   - Prevailing public transport modes have different waiting times along different routes over the country with the availability of resources. Compared to the

other region in the country CMR has least waiting time for all public transportation modes. For bus service this value ranges from 10 – 15 minutes averagely.

- During peak hours the availability of trains along the considered route ranges from 15- 30 minutes.
- The proposed boat transport service for this study we considered as 10-15 minutes.

6. Transfer time
    - here we estimated as how much time it takes to transfer form one public mode to another public mode or how long it takes to transfer from one vehicle to another in the same mode. Sri Lankan public transportation consist on two major modes. Bus service and train service. Bus service and train service have their central hub at Pettah. But different locations, that it takes averagely 10 minutes reaching from one hub to another hub. Apart from that other train stations (sub hubs) and bus stops along the considered pilot route have the distance apart from each other for 10 to 15 minutes reachable distance.

The attribute values decided were added for preparation of card game. For example, a card prepared for private mode choice were included attributes fuel cost and journey time only since doesn't require waiting time and transfer time. It was used 3-4 different values for one attribute to apply on cards for one attribute. This value was decided based on the initial average prevailing value, then when the prevailing value increased by 50% and prevailing value decreased by 25% and 50%.

3.1.2 Personal information

Socio economic characteristics of each individual who participated for the survey is very important. It can change the function coefficients significantly. Specially between private mode choice and public mode choice. For this study we considered only about the age of the person and the income level and the vehicle ownership. We categorize age in to four different levels and income range in to ten different levels as shown in below table.

Table 3.1 collected individal's personol information catogorization

Age range		**Income range**		**Vehicle ownership**
15- 30	Type1	Less than 25000	Range 1	Car ownership
30- 45	Type2	25,000-50,000	Range 2	Mobike ownership
45- 60	Type3	50,000-75,000	Range 3	No vehicle ownership
Over 60	Type4	75,000-100,000	Range 4	Both car and mobike ownership
		100,000-125,000	Range 5	
		125,000-150,000	Range 6	
		150,000-175,000	Range 7	
		175,000-200,000	Range 8	
		200,000-225,000	Range 9	
		225,000 to above	Range 10	

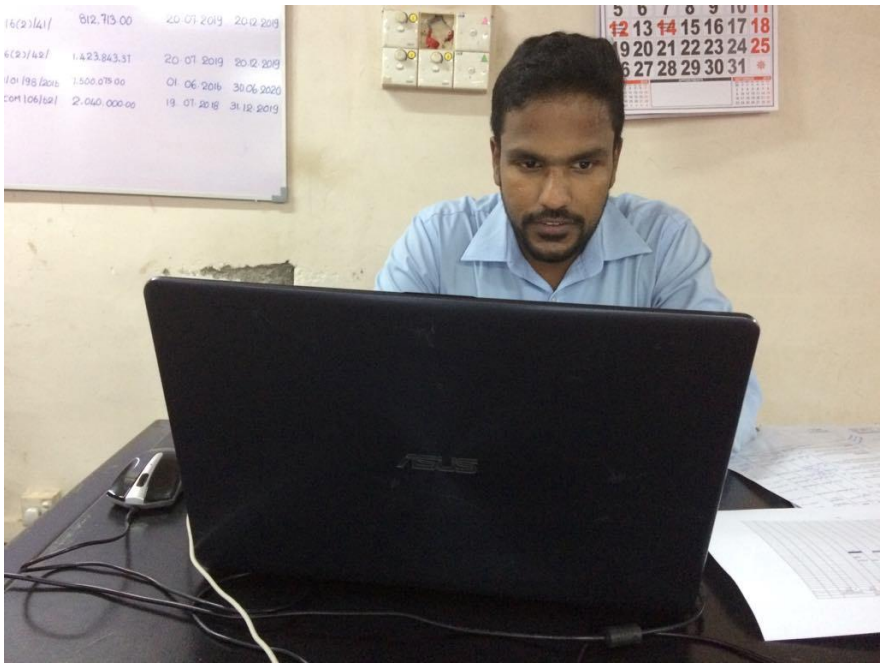

Figure 3-2 Card game and data collection in indoor locations

Designed computer game has been used for data collection. Data collection was done as a Stated preference survey because proposed boat service is a hypothetical mode to the prevailing system.

The collected data were summarised to an excel file and it is upload to the A logit software and modelling has been done as an output from the A logit software.

3.2 Data Preparation of ALOGIT Modeling

To develop a logit model using ALOGIT software user must prepare 2 files. First one base data file, next is control file. For base data file data has to be prepared and upload in to the software as a DAT file. For that first excel sheet has been prepared. All the data were entered as numerical values. Presence of options were entered as 1 and absent as -1. Attribute values of each card options entered directly. Each interview represents by one raw and it has an ID value. Personal information was categorized into value ranges and entered as a number. Choices of the cards were entered using four columns such as choice 1,2,3,4. After preparation of excel sheet the file was saved as .cvs file and then open in a notepad. Note pad file the values can be seen directly as lines and column values were separated by “commas”. Finally, this note pad has been saved as a DAT file.

Control file was used as a command file which helps user to develop the model and describe details how ALOGIT function requested to be executed. It consists of title of the model to be run, control lines that calls for specific options, specifications of the coefficients to be estimated, specifications of transformations to be made for data items in base data file, definitions of the utility functions for each alternatives and size functions for relevant alternatives etc. control file has been prepared using notepad and save as a .BIN file. When we run the model in the command prompt using a simple dialog, such as enter the control file, enter base data file, and name the output file, the software itself made a print file using the given name by us in note pad version. It gave the results of our model and accuracy of our model.

4 DATA ANALYSIS AND MODEL ESTIMATION

4.1 Characteristics of Data Sample

Total collected data of 466 has been collected from interviewing 233 people from both government and private offices around Battaramulla area. Few interviews have been taken from the students in University of Moratuwa. Following statistics shows the characteristics of the data sample.

- Age – total 233 individuals are categorized under 4 types as shown in figure 4.1

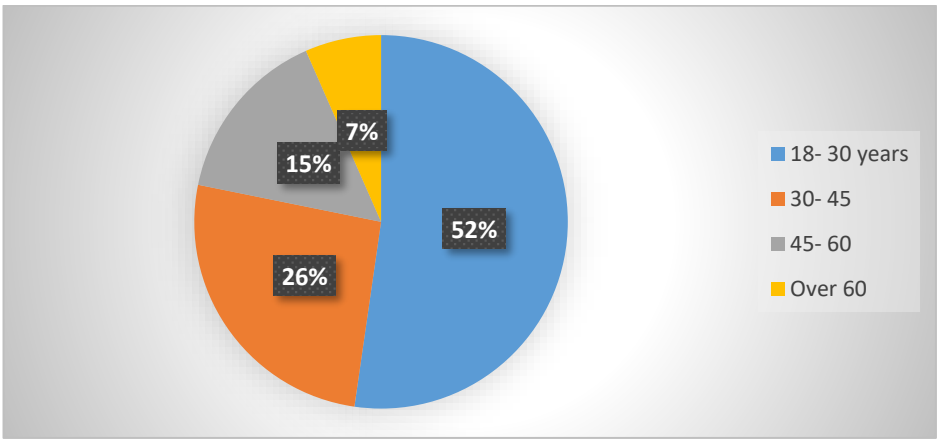

Figure 4-1 Probability of Age in data sample

- Income -total individuals have been categorized under 10 types of income ranges and their probabilities are shown in following pie chart

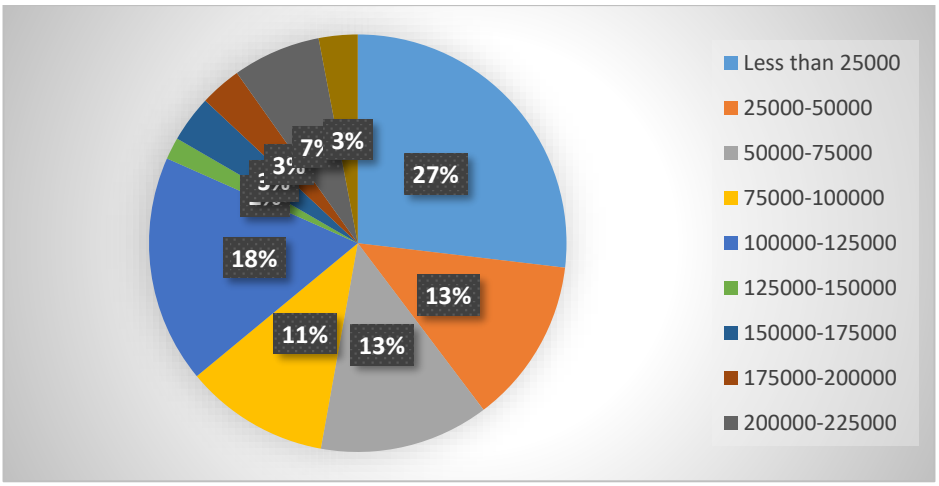

Figure 4-2 Probability of income ranges in data sample

- Vehicle ownership – vehicle ownership probability of the data sample is shown in Fig 4.3

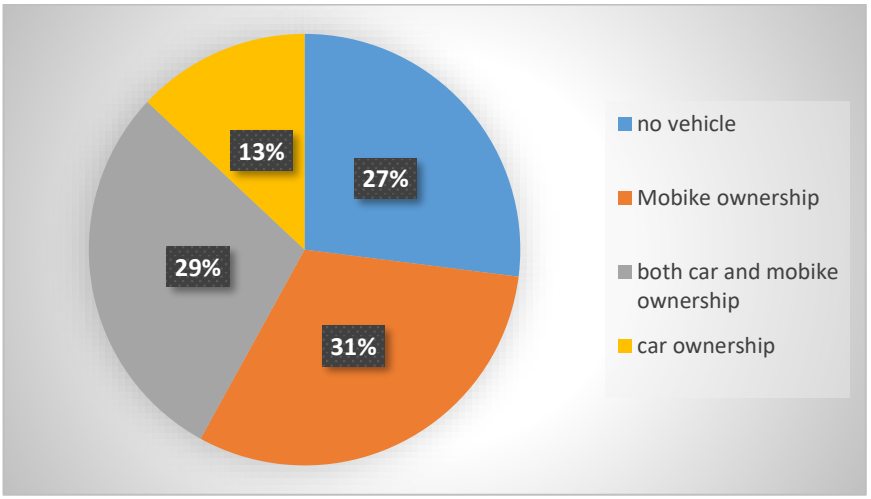

Figure 4-3 Probability of vehicle ownership in data sample

4.2 Model Estimation

4.2.1 Single logit model

Before preparation nested structure for developing the model, single level logit model has been prepared using the collected data in order to get an idea about respondents' choice for alternatives considering each attribute values.

When simulating the model, Basic processing was done at the beginning and code modifications were done by studying the t stat values from basic modeling to the codes.

The summary report showed the model accuracy by giving four key likelihood values, likelihood with zero coefficients, likelihood with constant only, initial likelihood, final value of likelihood.

In here likelihood with zero coefficient interprets the simple calculation of the likelihood model for each observation, all the available alternatives have equal probabilities. The final likelihood said the optimum value at which ALOGIT has converged.

Further report showed Rho-squared p^2 value. This means of comparing final likelihood with base likelihoods with zero coefficients and with constants.

P^2 = 1- (final likelihood / base likelihood)

It summarizes the overall quality of the model. In here 0.05 – 0.10 can be considered to be good.

- Final Likelihood= -169.0851 (Achieved in 6th iteration)

4.2.2 Utility functions of single logit model

1. Utility of car usage for journey U_1= C1* Prvt time +C2* Prvt cost
2. Utility of Mobike usage for journey U_2 =C1* Prvt time + C2 * Prvt cost +ASC1
3. Utility of bus usage for journey U_3= C3* Pub RT + C4* Pub Fare + C5*WT + C6* TT+ ASC2
4. Utility of bus and train only usage for journey U_4 = C3* Pub RT + C4* Pub Fare + C5* WT+ C6* TT +ASC3
5. Utility of bus and boat only usage for journey U_5 = C3* Pub RT + C4* Pub Fare + C5* WT+ C6* TT + C7*boat ride time + C8*boat fare + ASC4
6. Utility of train and boat only usage for journey U_6 = C3* Pub RT + C4* Pub Fare + C5* WT+ C6* TT + C7*boat ride time + C8*boat fare + ASC5
7. Utility of train and boat only usage for journey U_7= C3* Pub RT + C4* Pub Fare + C5* WT+ C6* TT + C7*boat ride time + C8*boat fare + ASC6

The estimation results of single level logit model resulted by the ALOGT consisted with the coefficient estimates for each attribute considered, their Standard error and T ratio values. Standard error gives the accuracy with which the coefficient is estimated. T ratio means coefficient divided by standard error. This statistic has been used to show the level of significant of the coefficient to the model.

By considering the t ratios of single logit model attributes it could get an idea about the significance of variable to the equation. When t-ratio is less than 2 of on variable it means less significant in the equation and less affection to stay independent in the equation.

Therefore, we combined one or more variables together at this situation by creating new variable to the equation. This can be done by combining two or more matching characteristic variables.

After analyzing the results of single logit model for the collected data for boat choice modelling, we observed following characteristics.

- Though the analyst divided the total journey time as ride time (RT), transfer time (TT) and wait time (WT), individuals (interviewees) responded to the card game concerning all together for their journey as total Travel time (Tt)
- The t ratio of transfer time (TT), wait time (WT) and Ride time (RT) are small values, less than 2.0. therefore, by combining together Travel time (Tt) attribute has been developed for nested logit model.
- For card game (stated preference survey) it has introduced boat fare and other mode travel cost (TC)as two separate attributes in order to get the public response. But evaluating single logit model the t ratios of travel cost (TC) and boat fare were lesser values, (<2.0). therefore, for nested logit model total Travel cost (Tc) attribute has been created including the boat fare.
- Further it has noticed that Travel cost (TC) of public mode choices (bus, train, boat) and private mode choices (bus, mobike) didn't have significant deviation. Hence for the nested logit model for we considered on attribute coefficient called Travel cost (Tc).
- In single logit model it has clearly indicated that mobike usage has significant value compared to the car mode.

4.2.3 Nested logit model

Following tree structure has been developed for nested logit model preparation

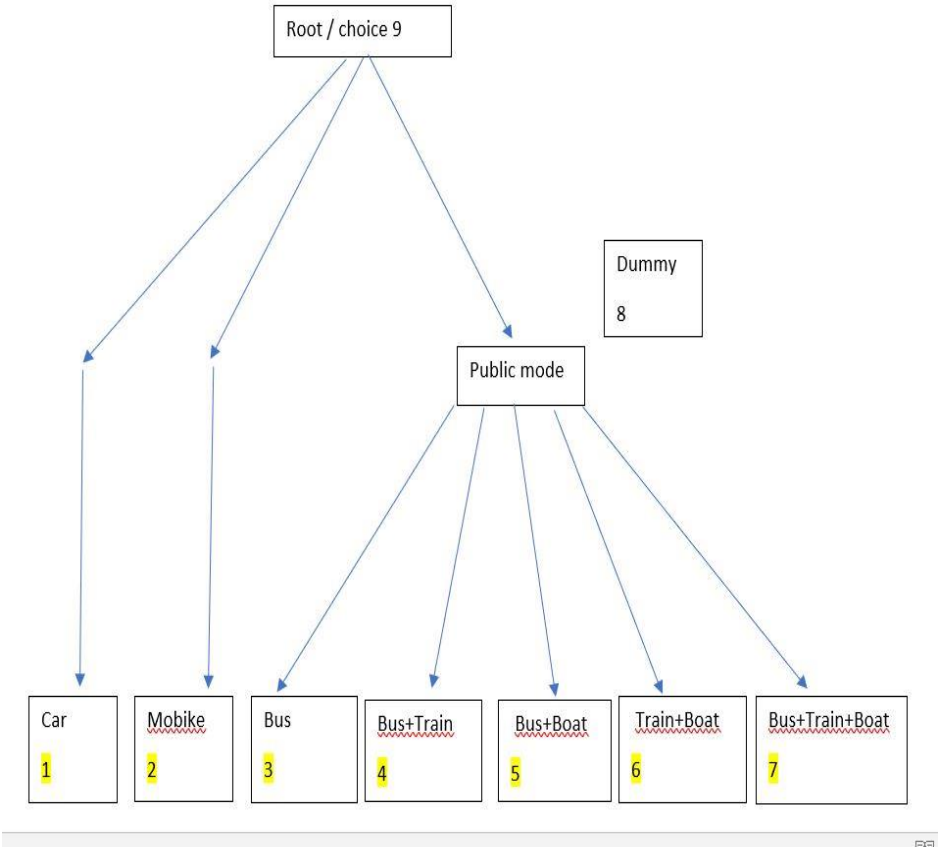

Figure 4-4 Tree structure developed for boat passenger transport modeling

4.2.4 Attributes of nested logit model

Travel time and Travel cost are most primitive attributes for all the alternatives. Boat ride time and Boat fare were other two attributes defined for alternatives include proposed boat mode option.

Travel time (Tt): For the nested logit model this attribute has denoted including total time spend for a one-way trip starting from bus stop or train station or boat station and total time taken for you to reach to Battaramulla town including transfer time (valid for public mode choices) from one mode another and waiting time (valid for public mode choices) for all given mode options.

Travel Cost (Tc): Total monetary values spend for the journey considered as journey cost. For private modes this value is the expenses for fuel. For public modes this value considered as the ticket prices for both bus mode and train mode.

Boat ride time: Total time spend for riding the boat. This attribute considered as a separate attribute since we collected data considering boat passenger service as a proposed mode option.

Boat fare: total monetary value spends to ride the boat (proposed ticket prices)

The coefficients for Journey time and Boat ride time considered as same denoted by $\boldsymbol{\alpha_1}$ because it is noticed that in single logit model t ratios of coefficients of boat ride time is not significant. Further coefficients for journey cost and boat fare have been considered as $\boldsymbol{\alpha_2}$ for the same reason.

4.2.5 Utility functions of alternative choices

Following utility functions has been derived for alternative choices

1. Utility of car $U_1 = \alpha_1 * (Tt) + \alpha_2 * (Tc)$
2. Utility of mobike $U_2 = \alpha_1 * (Tt) + \alpha_2 * (Tc) + ASC_1$
3. Utility of bus $U_3 = \alpha_1 * (Tt) + \alpha_2 * (Tc) + ASC_2$
4. Utility of bus and train only $U_4 = \alpha_1 * (Tt) + \alpha_2 * (Tc) + ASC_3$
5. Utility of bus and boat only $U_5 = \alpha_1 * (Tt) + \alpha_2 * (Tc) + \alpha_1 * (\text{Boat ride time}) + \alpha_2 * (\text{Boat fare}) + ASC_4$
6. Utility of train and boat only $U_6 = \alpha_1 * (Tt) + \alpha_2 * (Tc) + \alpha_1 * (\text{Boat ride time}) + \alpha_2 * (\text{Boat fare}) + ASC_5$
7. Utility of bus, train and boat only $U_7 = \alpha_1 * (Tt) + \alpha_2 * (Tc) + \alpha_1 * (\text{Boat ride time}) + \alpha_2 * (\text{Boat fare}) + ASC_6$

following statistics shows the nested logit model accuracy using the total data set

- Final Likelihood = -584.2881 (Achieved in 6th iteration)

Table 4.1 shows the results, obtained after analyzing the nested structure in ALOGIT software

Table 4.1 Nested logit model estimation results

Attribute coefficient	**Coefficient value**	**Standard error**	**T- ratio**
Travel time (Tt) α_1	-0.006835	0.00283	-2.4
Travel cost (Tc) α_2	-0.0003279	0.000750	-0.4
Alternative Specific Constants (ASC)			
ASC_1	0.6812	0.224	3.0
ASC_2	0.8978	0.238	3.8
ASC_3	0.8516	0.239	3.6
ASC_4	0	0	0
ASC_5	0.8324	0.236	3.5
ASC_6	0.7385	0.231	3.2
λ_1 root coefficient	1	-	-
$\lambda_{2\ branch}$ coefficient	0.5951	0.166	3.6

5 DISCUSSION

5.1 Nested Logit Model

The nested logit model was estimated using the same software ALOGIT that used for estimating single logit model. For the nested logit model development, it is assumed alternative 3,4,5,6 and 7 were correlated with each other due to being public modes with additional time consume for the journey as waiting for the particular modes and time taken for transferring among these modes. The rho squared value (p^2), indicator for overall model fit and the likelihood ratio for the model proved that nested model fit well with the choice decisions of public. When we compared the two rho squared vales of Single logit model and nest logit model, it indicated that nested logit model has significant performance compared to the single logit model. (in Nested logit model $p^2(C)$ =0.0139, and in Single logit model $p^2(C)$ =0.0606)

As per the theories nested logit model can improve the model performance over the Multinomial logit models by clustering the correlated alternatives together. The model estimation results shown in Table 5.2. We have considered car mode alternative as the reference alternative for this model too. Thus, ASC of car alternative sets for zero. According to the ASC values observed from the nested logit model most preferred alternative option was to use bus mode option to the whole journey (Alternative 3) followed by use bus and train modes only for whole journey (Alternative 4). The third most preferred alternative was use train and boat modes only for the whole journey (Alternative 6). The fourth preferred alternative was to use bus, train and boat (all three modes) for the whole journey (alternative 7). Public like to travel on motor bike (alternative 2) compared to the car due to its ASC value is 0.6812 compared to the car ASC. The ASC value of Alternative 5, (use bus and boat modes only to complete the whole journey) was zero. This means alternative 5 and Alternative 1 (car option, reference alternative) have equal preference by the people. If we Summarize the preference order as per the ASC values, ASC2 (0.8978, Alternative 3) > ASC3 (0.8516, Alternative 4) > ASC 5 (0.8324, alternative 6) > ASC 6 (0.7385, alternative 7) > ASC 4 (0, alternative 5 By considering ASC values of the nested logit model it can be said that people choose public transport modes to travel in CMR rather than private modes

with the root coefficient of public branch as 0.5951 compared to the car mode. This is different observation compared to the results of single logit model. In single logit model it indicated that public choice was to use private modes rather than public modes. The reasons may due to the data usage for model estimation. For single logit model we only used 100 data from the total observation. But for nested logit model we used total data set of 466 data. In the nested logit model estimated results it is expected to observed the negative signs for the travel time, travel cost, boat ride time, and boat fare. As expected all were negative giving the meaning when the ride time and cost per ride increases the utility of the particular alternative is going to decrease. This means people don't like to consume more time on traveling and increasing fares. It's an obvious fact in daily life scenarios too. However, it observed rather small coefficient values for both attributes (travel time coefficient = -0.006385, travel cost = -0.0003279). When considering the coefficient of two attribute values it could notice that people consider travel time mode than travel cost. They are willing to pay more for saving time while traveling by transport modes. It is observed same attribute coefficient values for the boat ride time and travel time by other modes. This means during the stated preference experiment an individual have responded to the survey considering the boat ride time and travel time on other available modes in a sequential manner. Not considered as separate attributes, they considered the time taken for the whole journey rather considering the preference on how long they would travel on each mode. The same observation noticed for travel cost of other modes and cost of boat ride.

5.2 Accuracy of The Model

As the observed results from nested logit model following equations were given for seven alternatives.

U_1 = -0.006835* (Travel time) + -0.0003279 * (Travel cost)

U_2 = -0.006835* (Travel time) + -0.0003279 * (Travel cost) + 0.6812

U_3 = -0.006835* (Travel time) + -0.0003279 * (Travel cost) + 0.8978

U_4 = -0.006835* (Travel time) + -0.0003279 * (Travel cost) + 0.8516

U_5 = -0.006835* (Travel time) + -0.0003279 * (Travel cost) -0.006835* (Boat ride time)

-0.0003279 * (Boat fare)

U_6 = -0.006835* (Travel time) + -0.0003279 * (Travel cost) -0.006835* (Boat ride time)

-0.0003279 * (Boat fare) + 0.8324

U_7 = -0.006835* (Travel time) + -0.0003279 * (Travel cost) -0.006835* (Boat ride time)

-0.0003279 * (Boat fare) + 0.7385

As a result of this model, an individual of the CMR region can be categorized that he or she has this much utility or probability for usage of proposed boat transport service. For example, let's consider an individual has started his journey from Pettah to Battaramulla, for this journey as per the Google maps directions it takes following times and fares for the journey.

Table 5.1 Example : An individual's trip detail and the estiamted Utilities Via the estimated Nested logit model

alternative	**Travel time (minutes)**	**Travel cost (Rs)**	**Boat ride time**	**Boat fare**	**Utility (Utils/persn)**
Use car mode only	33	150	NA	NA	**-0.284577**
Use mobike mode only	25	100	NA	NA	**0.477535**
Use bus mode only	45	40	NA	NA	**0.577109**
Use bus and train mode only	40	40	NA	NA	**0.565084**
Use bus and boat mode only	20	20	10	20	**-0.218166**

Use train and boat mode only	25	20	30	50	**0.467697**
Use Bus, train and boat modes only	15	30	10	20	**0.55123**

Utility values of all seven alternatives indicated that the individuals most preferred choice is to use bus mode with the existing travel conditions and fares. Next, he likes to use Alternative 4 (bus and train option) followed by alternative 7 (bus, train and boat alternative). As expected his least preference is for using car mode (alternative 1) and using bus and boat mode option (alternative 5). But it shows little controversy between the Alternative 6 and alternative 2 results. Here though ASC of train and boat mode option (alternative 6) is higher compared to the mobike alternative. Bus in this situation due to availability of existing routes it takes longer travel duration for travel from Pettah to Battaramulla using train and boat. Therefore, in that situation the preference of individual diverts from alternative 6 to alternative 2. But considering an example travel scenario, the nested logit model results can be accepted.

5.3 Comparison of model results with a previous study

Table 5. 2: Comparioson of Nested logit model coefficient of attributes with the Attribute coefficients of single logit model estimated by Sutharman & De Silva's Study,2016

Attribute	**Results of Sutharman and De silva's study (Sutharman & Silva, 2016)**		**Nested logit model developed by this study**	
	Coefficient value	T-ratio	Coefficient value	T-ratio

Travel time (Tt)	NA	NA	-0.006835	-2.4
Travel cost (Tc)			-0.0003279	-0.4
Private ride time(C1)	-0.01639	-2.6	NA	NA
Prvt cost (C2)	-0.001066	-0.8	NA	NA
Pub RT (C3)	0.03602	0.6	NA	NA
Pub Fare (C4)	-0.02941	-4.6	NA	NA
Pub WT (C5)	-0.04376	-3.8	NA	NA
Pub TT (C6)	-0.07258	-6.8	NA	NA
Boat RT (C7)	-0.008682	-1.2	-0.006835	-2.4
Boat fare (C8)	0.005796	-0.8	-0.0003279	-0.4
Mobike const (ASC1)	-0.4396	-2.4	0.6812	3.0
Bus const (ASC2)	1.207	1.7	0.8978	3.8
Bus train const (ASC3)	1.718	2.1	0.8516	3.6
Bus boat const (ASC4)	1.935	2.7	0	0
Train boat const (ASC5)	1.935	2.7	0.8324	3.5
Bus train boat const (ASC6)	2.109	2.5	0.7385	3.2

λ_1 coefficient	root	NA	1	-
λ_2 coefficient	branch	NA	0.5951	3.6

As shown the values in table 5.2 in 2016 study by Sutharman & De Silva (Sutharman & Silva, 2016), the ASCs values of boat transport alternatives, (bus and boat option, train and boat option and bus, train and boat option) had the higher values compared to the other considered options. The methodology of this study and the attributes considered for this study were similar to this study. Therefore, comparison of two models could be done.

Both studies the data collection has been done in a similar way considering similar attributes. But for this study the nested logit mode was developed considering two attributes Travel time (Tt) and Travel cost (Tc). The travel time has not been categories into different categories based on the mode. But considered total travel time traveling on each mode together including the waiting time and transfer time taken for considered trip as a one value. For Travel cost, as same for the Travel time, total fare/cost have to bare for traveling on each mode considered as a one attribute value. This was done due to the less data availability for the model estimation, considering the results of single logit model it was observed less T ratios indicating separate time attributes and cost attributes make less significant to the model.

But in 2016 study the data collection used for the model fairly large considering to this study therefore the T ratios of separate travel attributes based on mode categorization, and time separation such as travel time waiting time and transfer time for each travel option had significance to the model. Their T ratios were higher.

In 2016 study it showed that Alternative specific constant values of public mode options consisting with proposed boat mode service has higher values compared to other available options. Based on the ASC values in 2016 study it indicated their preference order as follows. If the considered attribute values for each alternative were same for a trip, for each mode option, the most preferred option is based on ASC values

such that, individual would prefer to use bus, train and boat option (considered to our option numbering system it is option 7). Second most preferences option was using either train and boat option (option 6) or use bus and boat option (option 5). As their model development, they have considered bus and boat option interprets the train and boat option too. Their third preferred option was bus and train option, followed by bus option. Compared to the car mode option mobike has least preference because it gave negative ASC value. Their preference order based on ASC values as ASC6 (2.109, option 7)>ASC5 (1.935, option 6)>ASC4 (1.935, option 5)> ASC3 (1.718, option 4)> ASC2 (1.207, option 3)> ASC=0 (car option)> ASC1(-0.4396, option2).

But in this study based on the ASCs values (for a considered trip, the same attribute values for all options) the option 7,6 and 5 that consist average preference value compared to the other options (both private and public). In this study it showed that people prefer to use mobike rather than car option. As per this study people preferred to use existing mode options like bus and train are most rather than proposed one. As per this study based on the ASCs value (for a considered trip, the same attribute values for all options) most preferred option was using bus option followed by bus and train option.

Comparing the two model results based on the ASC values 2016 model gives strong recommendation supporting to start the proposed boat service rather this study.

In general, the attribute coefficient values of 2016 study (Silva.G, 2016) were higher compared to this study. (travel time and travel cost coefficient values were compared) as shown in table 5.3. this is due to the total data used for model estimation is rather less compared to the 2016 study (Sutharman & Silva, 2016).

Further considering the attribute coefficient values of 2016 study it showed that pub ride time and boat fare had positive coefficient value meaning people like to spend more for travel on the boat service. the positive value of pub rt means people would like to spend on more time on public mode options. It can be said in other words that it the journey time is longer people would like to use available public modes more rather than using private modes. Further in 2016 model indicated that highest negative T ratio for transfer time. This means people dislike transferring from one mode to

another. But when considering that opinion it is rather surprising that people like to use bus, train and boat option together for their journey as indicating by the ASC value.

According to the 2016 study (Silva.G, 2016)people did not like waiting for the public transport modes. Waiting time was a significant factor for the model as indicated by the T ratio. As indicated by the model the attribute coefficient value of public ride time was much higher compared to private ride time attribute. So as the same for public fare and the private cost attributes also. This means people don't like to use private mode options compared to the public mode options as per the 2016 study. But as per our study (this study) an individual's dislike of using private mode option is comparatively lesser to the 2016 study (Silva.G, 2016). Even the utility of using mobike is rather higher. It is more preferred compared to the car option.

For the attention, the attribute values used for the stated preference survey were different from each other and people make their preference order based on the attribute values that they were given. Anyhow both studies indicated that compared to the travel fare attributes people considered for travel time attributes more. The attribute coefficient values of travel time are rather higher compared to the cost/fare attributes.

As a summary two models that develop for the proposed public boat transportation service indicated that the utility of using the proposed mode is higher compared to the private mode options. Both models showed that still there is a higher utility for using available public modes due to their mode characteristics while 2016 study (Sutharman & Silva, 2016) emphasize that reducing transfer time and waiting time for the particular public modes will enhance the individual's utility for that mode option.

6 CONCLUSION AND RECOMMENDATIONS

In this study it is expected to develop a suitable logit choice model to evaluate individual's choice behavior for proposed boat passenger service with selected alternative private and public choice alternatives and compare them. Further one of the objectives were to identify the influential factors for individual's choice.

The data set used for modeling was obtained from a stated preference survey conducted among daily travelers in CMR. Nested logit model was established to capture public behavior of decision making on proposed boat transport service in CMR canal network for their daily travels. The proposed model was suitable identifying the utility of people on proposed public boat passenger service among the other available public mode options.

The estimated results of nested logit model indicated that ASCs (Alternative Specific Constants) and considered travel time attribute had significant effects on the choice of proposed public boat transport service in CMR. People considered travel time of the journey by each mode options compared to the travel cost they have to bear for it. This means they are willing to pay more for their traveling if the travel time could be reduced by a certain mode. According to the estimated model results people choose to use available bus mode option though it introduced new passenger boat service to the public transport system. But compared to the choice of private mode usage for their traveling in CMR, the utility of choosing boat passenger service is higher. According to the observed alternative specific constant values the highest utility is for existing public bus service option followed by the available bus and train service option for traveling CMR region. People did not like use bus and boat service together for traveling. As per the initial estimation using single logit modeling people showed negative attitude on transferring from one to another in public transportation network. Therefore, in the considered boat option they showed moderate utility due to its combination travel characteristics with other modes. (Due to the limited availability of canals in CMR the proposed boat transport service cannot operate independently.). The results of nested

logit model showed general choice preference of public for introduction of boat passenger transport mode considering the total travel time and total monetary value they have to bear. Therefore, it recommends develop the nested logit model with other influential travel characteristics factors like travel distance, travel time spend on each mode options, transferring and waiting time for each mode, fare values of each modes. Further for future studies it will be worth to consider how the model will change due to considering socio economic factors like age, gender, income level, occupation etc. for future studies it also enhances the model considering more alternative options with more modes like taxis, three wheelers etc. finally, it can conclude that as expected the developed Nested logit model acts well for when there are correlated alternatives presence in the model.

In summary the developed nested logit model showed only two significant attributes travel time and travel cost were effect on individual's utility for selecting proposed boat service among the other alternatives. Though it considered separate travel time factors for private modes, available public modes and boat mode, the mode didn't showed significance in separate travel times but total travel time for the particular trip. The coefficient value of travel time was -0.006835. Compared to the travel time attribute, the travel cost attribute coefficient value was less, -0.0003279. the estimated ASC values showed the preference of public for given alternatives as ASC2 (0.8978, Alternative 3) > ASC3 (0.8516, Alternative 4) > ASC 5 (0.8324, alternative 6) > ASC 6 (0.7385, alternative 7) > ASC 4 (0, alternative 5) from highest to lowest. By considering ASC values of the nested logit model it can be said that people choose public transport modes to travel in CMR rather than private modes with the root coefficient of public branch as 0.5951 compared to the car mode.

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Appendix A: Nested logit Function

- Input file : BT1.BIN

- Output file : BTOU.OUT

- Base data file new 1.DAT

- Date : September 2019

----------Control Lines----------

-data

- Explanation to data items

-D01 ID

-D02 age

-D03 income

-D04 choice 1

-D05 choice 2

-D06 choice 3

-D07 choice 4

-D08 car available

-D09 Mobike available

-D10 bus available

-D11 bus + train available

-D12 bus + boat available

-D13 train + boat availabe

-D14 bus + train + boat availabe

-D15 car time

-D16 car cost

-D17 Mobike time

-D18 Mobike cost

-D19 Bus time

-D20 Bus fare

-D21 B Waiting Time

-D22 B transfer time

-D23 BTBus + train time

-D24 BTBus + train fare

-D25 BTBus + train waiting time

-D26 BTBus + train transfer time

-D27 BBBus + boat boat time

-D28 BBBus + boat boat fare

-D29 BBBus + boat bus time

-D30 BBBus + boat bus fare

-D31 BBBus + boat transfer time

-D32 BBBus + boat waiting time

-D33 BTtrain + boat train time

-D34 BTtrain + boat train fare

-D35 BTtrain + boat boat time

-D36 BTtrain + boat boat fare

-D37 BTtrain + boat transfer time

-D38 BTtrain + boat waiting time

-D39 BTBbus + train + boat bus time

-D40 BTBbus + train + boat bus fare

-D41 BTBbus + train + boat boat time

-D42 BTBbus + train + boat boat fare

-D43 BTBbus + train + boat transfer time

-D44 BTBbus + train + boat waiting time

-Non availability alternatives

-Car not available if no car rank

Nonav 1,8

-Mobike not available if no mobike rank

Nonav 2,9

-Bus not available if no bus rank

Nonav 3,10

-Bus + train not available if no bus + train rank

Nonav 4,11

-Bus + boat not available if no bus + boat rank

Nonav 5,12

-train + boat not available if no train + boat rank

Nonav 6,13

-Bus +train + boat not available if no bus + train + boat rank

Nonav 7,14

-Nesting Structure

Tree 9 9 8 8 8 8 8 9

Theta 7*0 91

END

---------- Coefficient specificationS----------

- Car specific terms

01 trvel time

02 cost

- Mobike specific terms

01 trvel time

02 cost

- Bus only specific term

01 trvel time

02 cost

- Bus + boat only specific term

01 trvel time

02 cost

- Train + boat only specific term

01 trvel time

02 cost

- Bus + train + boat only specific term

01 trvel time

02 cost

- Alternavie specific constants

32 Mobike

33 bus

34 bustrain

-35 Busboat

36 trainboatconst

37 bustrainboatconst

-nest

91 pub

---------- transformations----------

-creating compound identification observations

-id1 = D01

choice=D04

-ndata = 44

-exclusions:

-exclude = ifeq(D04,0)

----------Utility functions----------

-for car only alternative

U01 = p01*d15

+ p02*d16

-for Mobike only alternative

U02 = p01*d17

+ p02*d18

+ p32

-For bus only alternative

U03 = p01*(d19+d21+d22)

+ p02*d20

-For bus + train only alternative

U04 = p01*(d23+d25+d26)

+ p02*d24

-For bus + boat only alternative

U05 = p01*d27

+ p02*(d28+d30)

+ p01*(d29+d31+d32)

-For train + boat only alternative

U06= p01*(d33+d37+d38)

+ p02*(d34+d36)

+ p01*d35

-For bus+ train + boat alternative

U07= p01*(d39+d43+d44)

+ p02*(d40+d42)

+ p01*d41

Appendix B: Nested logit model results

Convergence achieved after 5 iterations

Analysis is based on 444 observations

Likelihood with Zero Coefficients = -614.3640

Likelihood with Constants only = -592.5139

Initial Likelihood = -614.3640

Final value of Likelihood = -584.2881

"Rho-Squared" w.r.t. Zero = .0490

"Rho-Squared" w.r.t. Constants = .0139

ESTIMATES OBTAINED AT ITERATION 5

Likelihood = -584.2881

	PrvRT	cost	Mobike	bus	bustrain	trainboatc
Estimate	-.6835E-02	-.3279E-03	.6812	.8978	.8516	.8324
Std. Error	.283E-02	.750E-03	.224	.238	.239	.236
"T" Ratio	-2.4	-.4	3.0	3.8	3.6	3.5

	bustrainbo	pub
Estimate	.7385	.5951
Std. Error	.231	.166
"T" Ratio	3.2	3.6

Correlation of Estimates (multiplied by 1000)

	1	2	32	33	34	36	37
cost	2	-355					
Mobike	32	41	367				
bus	33	-69	220	85			
bustrain	34	-130	245	91	690		
trainboatc	36	52	75	47	672	650	
bustrainbo	37	7	111	81	654	641	648
pub	91	-207	607	655	-263	-232	-348	-288