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School for Transportation Sciences

Master of Transportation Sciences

Masterthesis

Multi-stage trips: Factors influencing mode combination choice of travelers

Muhammad Aamir Basheer

Thesis presented in fulfillment of the requirements for the degree of Master of Transportation Sciences, specialization Mobility Management

SUPERVISOR :
Prof.dr.ir Tom BELLEMANS

MENTOR :
dr. ing. Petrus VAN DER WAERDEN

CO-SUPERVISOR :
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PREFACE

The decline in use of public transport is one of the major problem nowadays. The consideration of different stages in public transport trip makes the choice behavior more complicated. My experience in Lahore Development Authority (LDA), Pakistan, and at Hasselt University, has equipped me with many tools and techniques which have enhanced my abilities as a transportation researcher. On a broader level, infrastructure investment is not usually possible so, the emerging need of mobility management in cities is required which can help to strengthen this weak link for implementation of efficient transportation system.

The improvement in public transport system helps to reduce the load of private vehicles on roads and assists in creating a social. In Belgium, I usually use walking as a mode to reach bus stops or railway station which is extremely inconvenient for me. As an observer, this practice gave me a new way of thinking and made me realize about the attributes of a trip which hinders the use of public transport. While going through literature, I have noticed many research studies are being carried out to identify the problems in public transport trips. I felt that there is a need of more research to identify the problem of multi-stage trips, as a little effort has been done till date to integrate the different stages of a trip. The importance of first and last mile in a multi-stage trip deduced from literature indeed provoked me to conduct research on multi-stage trip for my master's dissertation. I hope this research will fill the existing gap in mobility management research and will bring improvement in the public transport sector as well as multi-stage trips. This research will insist concerned authorities to take these factors into consideration while improving public transport services. Lastly, I would like to thank my teachers Dr.ing. Peter van der Waerden who guided me at every step and made this research possible.

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SUMMARY

An increase in mobility patterns has been observed worldwide and most dominantly this increasing trend is observed in the use of personal vehicles. Such increasing trend of car use may induce problems like congestion, travel delays, and environmental pollution. Different steps have been taken by the authorities to reduce the use of private vehicles. Congestion charging and improvement of public transport infrastructure are among these steps. Multi-stage trips are recognized as an alternative for private vehicle use. These trips involve different stages in which different modes of transport are used to reach to the destination. Few efforts have been made to explore the mode choice behavior in different segments of the multi-stage trip.

A multi-stage trip mainly consists of three or more stages (first mile, main mode and last mile). A multi-stage trip has many advantages like reduce cost, congestion reduction and many environmental benefits. On the other hand, private car trips are encouraged because of its comfort, flexibility and travel time. So, mode choice behavior is not the function of a single attribute rather it is a complex task. Mainly transportation mode choice is dependent on different attributes like trip distance, trip purpose, trip travel time, age, gender, individual income, education, Income, household structure, number of people in household, access to car, number of vehicles in household and availability of driving license. As seen in a multi-stage trip these factors have more implications. Typically, individual do not prefer to take public transport because of its long travel time and reliability issues.

A two-stage methodology is used to check the influence of trip, stage, household, individual and vehicle related variables on mode choice. In the first stage, the influence of indicated variables on mode choice of solo-car-only and multi-stage trip are analyzed using binary logistic regression. In the second stage of the analysis, to know the impact of different variables on selection of different mode combinations of a multi-stage trip a multinomial logistic regression is conducted.

The results of the binary logistic regression analysis show that transportation mode choice between solo-car-only and multi-stage trip is a function of trip purpose, trip distance, age, gender, household income, household structure and access to car. These factors do influence the choice people make. There is a need to focus on these factors if want to shift people from private vehicles to public transport.

The multinomial logistic regression for mode combination selection of a multi-stage trip reveals that trip purpose, stage distance for main stage of trip, age, gender, household income and household structure significantly influence the choice of specific mode combination. In order to encourage specific modes combinations like walk + public transport + walk we will need to focus on these attributes. The findings can help to improve the situation of transportation systems and to influence the choices of people so that they can use green modes of transport like walk, bicycle and public transport.

1.0. INTRODUCTION

This chapter explains the recent problems being faced due to the increase of private car use and factors which affect the execution of Multi-stage trips. The problem statement gives an overview of the problems being faced in Multi-stage trips. It provides the basis for the development of research questions and research objectives. The practical and theoretical relevance has been explained under the heading of Justification. Finally, the chapter ends with the explanation and illustration of the Research Design.

1.1. Background

In recent years, an exponential growth has been observed in private car use. In Europe, the mobility level has also increased but the major increase can be observed in car use which ultimately results in congestion and pollution (Beirão & Cabral, 2007). Motorized vehicles have increased from 75 million to about 675 million in the period of 1950-1990. Most of them are used for personal transportation. As a result, the kilometers travelled by private car per capita have also increased by 90% in Western Europe (1970-1990) (STEG, 2003). In Europe 80-90% of passenger kilometers are travelled by car (Van Exel & Rietveld, 2009). This increase in private car use has engendered various problems like environmental, economic and social problems (STEG, 2003). Transport is considered as one of the key contributors toward air pollution (Redman, Friman, Gärling, & Hartig, 2013). Among European countries, Germany is with the highest rate of motorization even though in Germany 40% of the trips are made by green modes like foot, bicycle and public transport (Buehler, 2011). Whereas, second highest car sales were observed in United Kingdom (U.K) which is the leading cause of traffic congestion (Pitas, 2015). In the U.K., the vehicles miles travelled has increased over ten times from 1949 to 2015 (DoT, 2016). Moreover, 64 % of all the trips and 78% of total distance travelled is based on car and van (NSR, 2013).

Increase in travel demand is the result of a rapid growth in vehicle ownership and population growth. This rapid growth results into congestion on the urban road network which ultimately affects travel time, traffic congestion, travel cost and air pollution (Aftabuzzaman, Currie, & Sarvi, 2010; Javid, Okamura, Nakamura, Tanaka, & Wang, 2016; Redman et al., 2013; Van Exel & Rietveld, 2009). The traveler's dependency on cars contributes to degradation of environmental conditions (Buehler, 2011). So, there is a need to reduce the dependency on private vehicle and to shift people towards green modes like public transport which can contribute to reduce travel time and congestion on the roads.

The availability of a well-articulated public transportation system is the need of the hour. Road transport significantly contributes toward climate transformation. The use of private vehicles has been recognized as main source of greenhouse gas emission. The other problems like traffic congestion and noise pollution is also linked with high reliance on private cars. This congestion also costs billions of dollars each year. The Intergovernmental Panel on Climate Change (IPCC) recommended to promote modal shift from personal vehicles to public transport to mitigate the problem of climate change (Chowdhury & Ceder, 2016). Public transport is an important mean to alleviate the problems of congestion and environment (Brands, de Romph, Veitch, & Cook, 2014). All these wider and immediate impacts on climate push governments to device policies for sustainable transportation system (Dell'Olio, Ibeas, & Cecin, 2011). The figure 1 below depicts the emission of greenhouse gas per person for different mode of transport. The emission from a solo-car-only trip is much higher compared to multi-stage trips. The combination of different modes can give environmental benefits of reduce emissions.

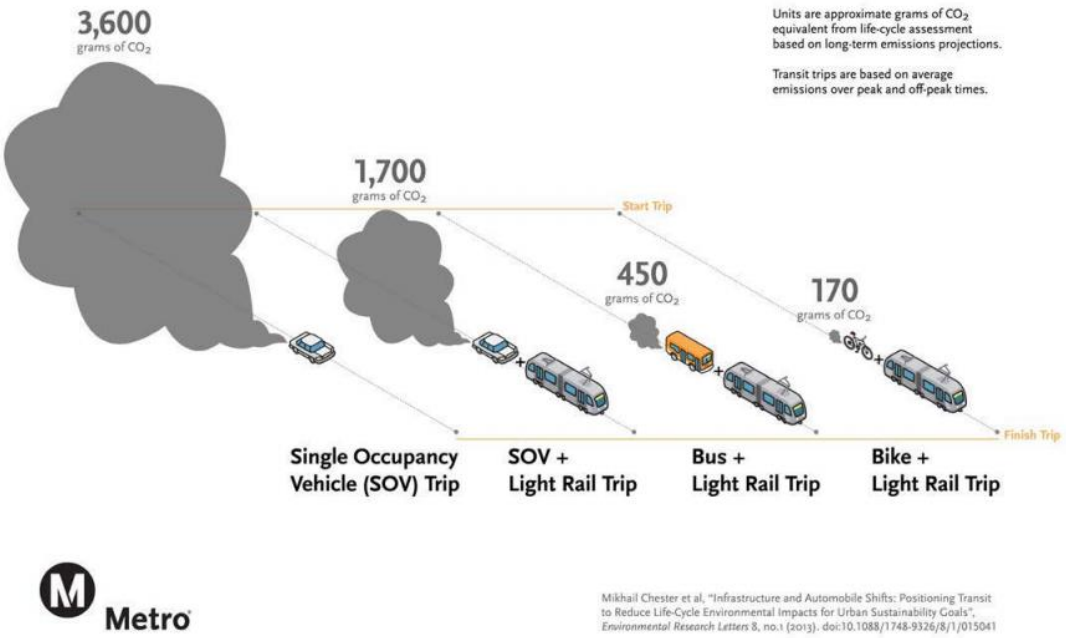

FIGURE 1. Greenhouse Gas Emission Per Person Per Trip (Linton, 2014).

A multi-Stage trip is the alternative of the so called solo-car-only trip which can help to mitigate the problems of congestion, long delay and environmental degradation. A multi-stage trip uses more than one mean of transport to complete the whole journey. The main part of the trip is being carried out by train, tram, or bus. Therefore, a transfer between different points is required in case of multi-stage trips. On the other hand, solo-car-only trips do not require any transfer point to reach a destination. Globally, solo-car-only trips are preferred because of flexibility and comfort provided by the private vehicle (Chowdhury & Ceder, 2016). A multi-stage trip provides the benefit of system optimization and user equilibrium. It provides a planned and coordinated execution of trip which reduces the time and money loss (Hamdouch, Florian, Hearn, & Lawphongpanich, 2007). There are different factors related to trip characteristics (trip travel time, trip purpose, trip distance) and individual characteristics (age, income, gender, vehicle ownership) that influence the choice of travel mode (Cho, 2013). Other influential factors include convenience, comfort, speed, and individual freedom behind the preference of people to travel by car (Beirão & Cabral, 2007; STEG, 2003). The choice between different transport modes like private car and public transport is influenced by several factors and it is a complex task to choose between available transport options (Chowdhury & Ceder, 2016). According to Hoogendoorn-Lanser, van Nes, and Hoogendoorn (2006), the number of transfers in a trip influences the choice of travel mode. So, all these factors contribute towards the exponential increase in private car use (Beirão & Cabral, 2007).

1.2. Problem Statement

It is clear from the above discussion that the increase of car use is not only a matter of choice but there are different attributes like trip purpose, travel time, trip distance, age, gender, income etc. attached to this mode choice process. Therefore, it is necessary to highlight the most important factors which lead people to choose the private car as their mode of transport. The factors like access to public transport terminal (Chowdhury & Ceder, 2016), increase in access and egress (distance and time) and distance of transfer location from bus/transit stop influence the choice of people for public transportation (Krygsman, Dijst, & Arentze, 2004). The effect of these access and egress stages can be seen as minimal for longer distance multi-stage trips whereas, the effect is higher for shorter distance trips (Rietveld, 2000). According to Keijer and Rietveld (1999) as the distance between railway station

and residential area tends to increase, the frequency of railway use declines. Moreover, one individual link is not enough to evaluate the quality of the transport network, but this can be described in term of the connectivity of these links with each other for a multi-stage trip (Keijer & Rietveld, 1999). In U.K., the bus use has declined by 46.7% in a period of 20 years (1995-2015). Whereas, in the same period the use of car has increased by 19.4% (DoT, 2014a). Following the traffic scenario of U.K., there is a need to investigate the reason behind this decline of bus use. Most of the studies only focus on the attributes of public transport which affects the choices of people but few have discussed about organization of first mile, main trip and last mile. According to Rietveld (2000), entry and exit mode used in combination with train trip is mostly ignored in analysis of modal choice. So, this research will focus on the attributes which influence the choices between a solo-car-only and a multi-stage trip. This research will also try to figure out the organization of multi-stage trips and factor affecting these combination for a multi-stage trip. It is important to investigate these elements in order to encourage multi-stage trips and to reduce the solo-car-only trips.

1.3. Research Question

The primary research question of this dissertation is 'which factors affect the choice between solo-car-only and multi-stage trips?' Moreover, how are multi-stage trips organized in terms of the first mile, the main trip, and the last mile, and is this organization related to characteristics of household, individuals, environment, trip and its different stages?

The further research questions are as follows:

- Which attributes affect the choice for a certain combination of transportation modes?
- How are modes organized in a multi-stage trip?
- What are the dependent and independent variables can be identified in the context of a multi-stage trip?

1.4. Problem Analysis & Research Objectives

The following are the objectives for carrying out this research:

1. To have deep understanding of the size of solo-car-only and multi-stage trips;
2. To investigate different modes being used for first and last mile;
3. To investigate different attributes that affects the choice for solo-car-only and multi-stage trip.

1.5. Research Plan

To carry out the research in an appropriate way different steps have been identified to meet the research objective (see figure 2). The work is divided into two portions. In first part, the major work is related to literature review. The second portion deal with the data collection, preparation, analysis and model development.

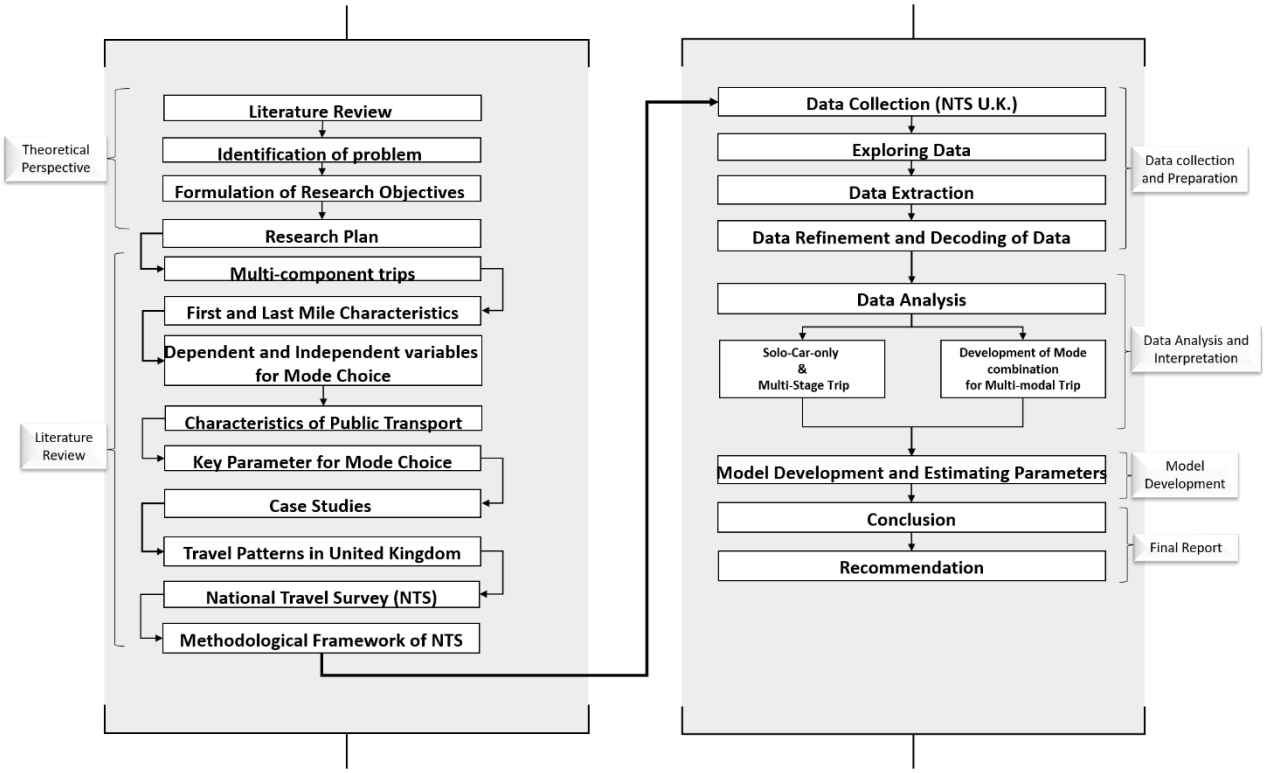

FIGURE 2. Research plan.

1.6. Justification of the Study

The increase in private vehicle use is one of the main issues being confronted by many governments. This is one of the main reasons for traffic congestion, travel time delays and degradation of environment. The inefficiency in public transportation system is main reasons behind the use of private vehicles. On the other hand, comfort and flexibility provided by private cars also prompt people to choose car as mode of transport and aggravate the situation. Following the high rate of motorization in Europe and a decline of public transport use in U.K., there is a need to investigate the characteristics of a trip, individual, household, and vehicle for U.K. which trigger people to choose their own vehicle. The first and last miles in a multi-stage trip are a major source of discomfort for the travelers. So, it is necessary to identify the main variables influencing the mode choice in first and last mile and the elements which force people not to travel by public transport. This research will help to improve the efficiency of public transport. Moreover, this will also help to bring the integration between different transportation mode in order to encourage multi-stage trips. This research will be helpful for the transport operator as well as for the local and regional government to improve their efficiency. The finding can be used to improve the public transportation system and to promote multi-stage trips.

1.7. Limitation of Study

The study will be focused on revealed preference approach and secondary data available from National Transport Survey of U.K. will be used. The full data includes the survey responses from 1995-2014 which is too large to analyze. Therefore, latest data of 2014 will be used for this study.

2.0. LITERATURE REVIEW

2.1. Introduction

This chapter starts with a brief introduction of solo-car-only trip and includes growing trends of solo-car-only trips in different countries. Then chapter outline the description of multi-stage trips and the how these trips are being carried out in the world. This part also outlines the advantages and disadvantages of a multi-stage trip. This is then followed by the identification of factors which influences the mode choice of travelers. A distinction between first-last mile as well as between access-egress point has been made in the later part of this chapter which is then followed by different a brief description of different mode being used for first and last mile. The mode choice behavior for first and last mile is supplemented by case studies. Based on the literature review an effort is made to find the gap in the current research. At the end, a conclusion has been inferences from the different researches.

2.2. Solo-car only trip

Solo-car only (unimodal) trip is a trip in which only one mode of transport is used for the whole trip. The second half of 20th century is characterized by upsurge of private car use. A considerable mode shift was observed as result of motorization at the expense of public transport. In Germany, almost 75% of the trips are carried out by car (Scheiner, 2010) whereas, in Porto, Portugal the car use for the journey to work or school has increase from 23% to 50% (1991-2001) similar, situation is observed in U.S. where the proportion of people driving alone in car has increased from 73% to 76% in just 10 years whereas, the transit ridership remains very low which was about 5%. Despite the benefits provided by private vehicle, it is responsible for many serious environmental problems. The use of automobile contributes 70% of CO2, 45% of NOx and 33% of hydrocarbon emission is major cities of U.S. (Katzev, 2003). The growth in private car use is alarming and cities will go in a situation of immense look down if same situation prevails. Therefore, there is a need to device a policy which helps to control the growth of private vehicle use and at the same time encouraging people to use public transport. The use of multi-stage trips can help to reduce the use of private vehicle which will ultimately help to reduce the environmental and congestion problems.

2.3. Multi-stage Trip

Multi-stage trip is one in which two or more than two modes are used to complete the trip. In such trips transfer between different points is necessary (Bovy & Hoogendoorn-Lanser, 2005; Nes, 2002). According to Carlier, Catalano, Schrijver, and Van Nes (2005), a super network is used to represent a multi-stage transport system in which unimodal networks (bicycle, car, bus, metro, tram, train etc.) are connected through different transfer points (Carlier et al., 2005). Multi-stage trip provides an opportunity of combining private and public transport mode to execute a trip. A multi-stage transport system is a complex system which involves phenomena of transfers and timetables. The dissemination of information is an essential part to carry out a multi-stage trip (Nes, 2002). Figure 3. depicts a simple form three stage (multi-stage) trip. Figure 4. represents the different trip alternatives for a multi-stage trip.

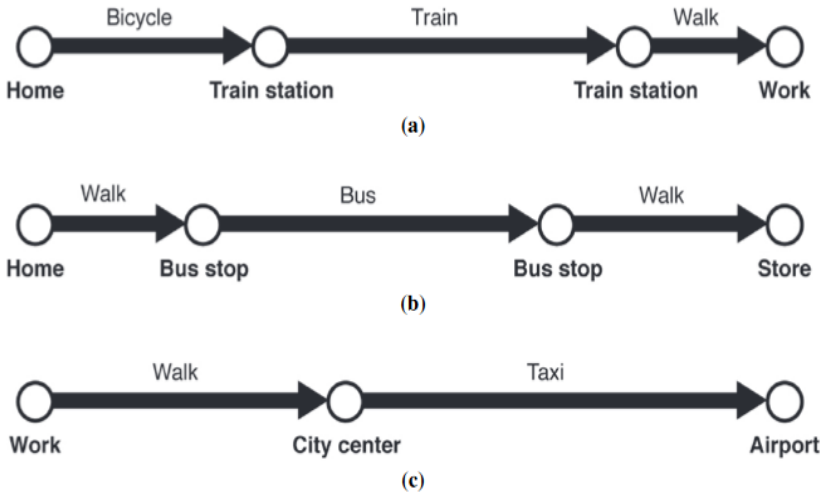

FIGURE 3. Multi-stage Trip (Clifton & Muhs, 2012).

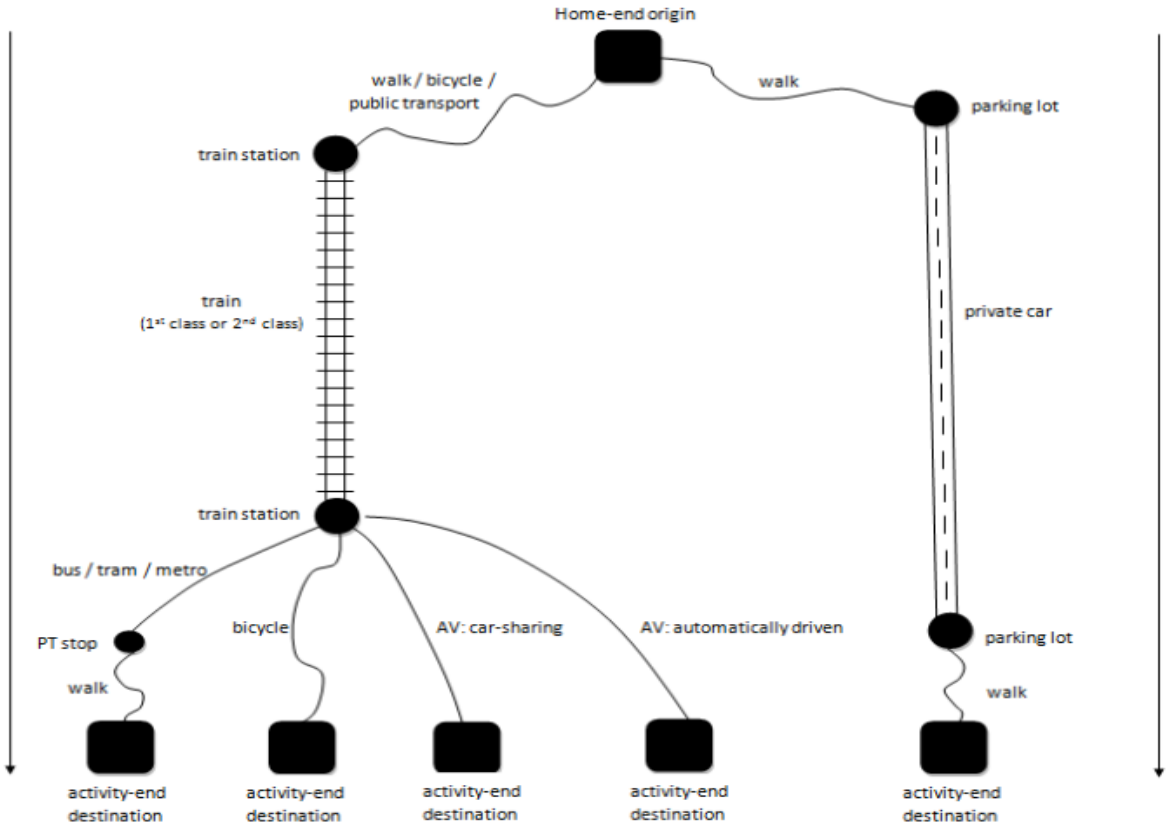

FIGURE 4. Overview of trip alternatives (Yap, Correia, & van Arem, 2015).

A multi-stage trip time can be split up into following components.

- Travel time from origin to transit stop (Access time).
- Time at first transit stop (waiting time).
- Time inside vehicle.
- Travel time from landing transit station to destination (Egress time).

The table 1 explains the advantages and disadvantages of a multi-stage trip:

TABLE 1. Advantages and disadvantages of Multi-stage trip (Keijer & Rietveld, 1999).

Advantages	Disadvantages

• A multi-stage trip provides better energy performance and environment as compare to unimodal trip
• Multi-stage trip provides the opportunity of freedom by providing more transfer point
• Multi-stage trip is cheaper and faster as you do not need to travel through the congested urban centers
	• There are two major disadvantage of a multi-stage trip
	  ○ Detours (its follow specific route)
	  ○ Waiting and Rescheduling (more waiting time is required)

The problem of rescheduling and waiting time can be resolved by introducing coordinated timetable for the entire transportation network. This is a complex task and required great efforts. It is very difficult to establish system where public transportation service is reliable (Keijer & Rietveld, 1999).

In Netherlands 20% of all the trips are multi-stage trips. In most of the cases (e.g. 50%) the major distance (main stage) is covered by the train (Keijer & Rietveld, 1999). The table 2 below shows the result for National Travel Survey (NTS 1995-1997) for Netherlands. The findings of NTS depict that the share of multi-stage trip has increased by 25%. The basis of this increase can be based on the initiative of Students Public Transport Card (PTC) introduced in 1990. Despite of this increase multi-stage only account for 2.9% of all the trips. In these multi-stage trips 72% of the trips are those which contain two vehicles (two legs), 26% of the trips involve three vehicles (three legs) whereas; only 2% contain four or more vehicles. In most of the multi-stage trips train is the main mode of travel (59.2%) which is then followed by bus (14.5%), car passenger (7.3%), metro/tram (6.4%) and car drivers (6.2%) (Nes, 2002).

TABLE 2. Model Split for Uni-stage and Multi-Stage Trips (NTS 1995-1997) (Nes, 2002).

Main Mode	All trips [%]	Uni-stage [%]	Multi-stage [%]	Percentage Multi-stage
Car driver	36.2	36.0	0.2	0.5
Car passenger	13.1	12.9	0.2	1.6
Train	2.1	0.4	1.7	80.5
Tram/Metro	0.9	0.7	0.2	20.4
Bus	2.0	1.6	0.4	21.2
Bicycle	27.6	27.5	0.0	0.1
Walking	16.0	15.9	0.1	0.7
Other	2.1	2.1	0.0	1.7
All modes	100.0	97.1	2.9	2.9

It is clear from the table that train is the major mode for multi-stage trips as it accounts for 80% of all the trips which is then followed by metro/tram and bus. So, the integration of these services with other modes should be improved to promote multi-stage trips. The optimal combination of different transport mode in a trip provides a way towards sustainability in urban transportation system. The core of multi-stage trip is to combine the public transport with different modes (motorized and non-motorized). The new concept of mode sharing like bike-sharing, car sharing and ride sharing can help to alleviate the problem of vehicle ownership and to encourage multi-stage trips (Klug, 2013).

2.4. Transportation Mode Choice

According to Chowdhury and Ceder (2016), modes choice is not the function of one or two factors rather it is a complex. So, there are many attributes of transportation system which affect the mode choice of travelers. Generally, the car is chosen as a mode of transport because of its speed, comfort, convenience and flexibility (Beirão & Cabral, 2007). Despite these factors mode choice is also the function of status and affection (driving is pleasurable) (Chowdhury & Ceder, 2016). Transport mode choice behavior is also influenced by the situational factors and individual's characteristics. The person travelling with family prefer to take private vehicle instead of public transport (Javid et al., 2016). Traveler's mode choice behavior for solo-car-only and multi-stage trip can be influenced by the factors represented as travel/trip characteristic (travel time, travel distance, trip origin and destination, trip purpose) and individual/traveler characteristics (gender, income, age, availability of personal vehicle, access to alternative modes) (Cho, 2013; Nes, 2002; Racca & Ratledge, 2003). Among these variables related to trip; trip distance, type of destination and trip purpose seems to effect multi-stage trip the most. Almost 83% of the multi-stage trips can correctly be classified based on these three variables (Nes, 2002).

Travel time reliability, waiting time, bad connection and low speed of entry modes are the reason of choosing car as a travel mode (Chowdhury & Ceder, 2016; Rietveld, 2000). Factors like distance, cost and operating streetscape also influence the travel mode choice (Meng, Koh, & Wong, 2016). The service quality factors like walking distance/time, waiting time, travel time and number of transfer is a multidimensional problem of transit connectivity (Mishra, Welch, & Jha, 2012). The other factors related to mode choice includes number of travelers/persons on same trip (Cho, 2013; Koppelman & Sethi, 2000; LaMondia, Snell, & Bhat, 2010; Swait, 2001). The different factors/attributes which effect the mode choice of people will be discussed in detail in this section.

2.4.1. Trip Characteristics

The factors related to trip characteristics like trip travel time, type of trip, time of day, trip purpose and waiting time affect the choice for transportation mode (Almasri & Alraee, 2013). The choice between transit facility and car is mostly being effect by relative time between transit and private vehicle trip time (Racca & Ratledge, 2003).

2.4.1.1. Trip Purpose

There exit a strong association between trip purpose and mode choice (Limtanakool, Dijst, & Schwanen, 2006). Since preferences for mode choice differ with purpose of trip. So, different trip purposes show varying mode splits. The trip related to work generally shows dominant use of public transport and carpooling. Walking mostly depend on trip distance and show a significant relation with trip purpose as well (Racca & Ratledge, 2003). The studies also reveal that leisure and business trips are expected to have different modes because of their different sensitivity to travel time (Cho, 2013). Whereas, study conducted by Kim, Ulfarsson, and Hennessy (2007) also indicated that trip purpose is not significantly associated with LRT mode choice between stations and homes.

The table 3 shows the relationship between trip purpose and corresponding people choices for multi-stage trips in Netherlands (Nes, 2002). Work trips are of most important as highest share of multi-stage trip can be witnessed. Most work trips are oriented toward city centers and this high value for multi- stage trips is again linked to the availability of different modes for first and last mile.

TABLE 3. Trip Purpose (Nes, 2002).

	All tips [%]	Multi- stage [%]	Percentage [%]
Work	17.7	31.4	5.3
Social	15.6	14.8	2.8
Education	4.6	21.4	14.0
Shopping	24.5	9.4	1.1
Business, private	2.2	1.0	1.3
Business, work	3.1	2.4	2.3
Recreation	12.4	11.2	2.7
Touring	4.3	1.4	10
Personal care	3.1	1.3	1.2
Pick-up/drop-off	6.9	0.9	0.4
Other	5.6	4.8	2.6
Total	100.0	100.0	3.0

2.4.1.2. Travel Time

Travel time is one of the major attribute of mode choice. According to Mohammed and Shakir (2013) the reduction of travel time by 70% can diminish the private car use by 84%. Travel time does not only account for in-vehicle time rather it also includes the access and egress time. Access and egress time are not just related to entering a bus station or de-boarding from a train rather these are more complex. The access time also comprises the time taken by the commuter to reach the bus/rail platform from station entry. Similarly, egress time also has many implications. After entering a bus/train station the additional access time is the result of:

a. Time required to walk up and down stairs
b. Time spend in the queue for buying ticket
c. Time spend at fare gates (particularly for metro)

In addition time required for interchange at transfer points is also included in travel time (Goel & Tiwari, 2016). Moreover, access and egress time can be divided into transit and private mode access time. The first one account for the time spend in the main mode like tram/bus/train/metro. Whereas, private access mode time contains walking, cycling and the time spend in personal car (Bovy & Hoogendoorn-Lanser, 2005). It is evident that travelers are sensitive toward private mode access time as compare to transit access time (Bovy & Hoogendoorn-Lanser, 2005). Travel time needed to access the railway station are weighted more heavily than in-vehicle time similarly, time between interchange is valued equal to 6 minutes of in vehicle time (Keijer & Rietveld, 1999). In the same way waiting and walking time are of inconvenience for people in a multi-stage trip as they do not want to stay for a long time at bus station waiting for bus (Schakenbos, La Paix, Nijenstein, & Geurs, 2016).

In a study in UK it was observed that waiting time is valued 1.7 times more than in vehicle time similarly, walking time is valued 1.65 times more than in vehicle time (Schakenbos et al., 2016). Therefore, it is necessary to integrate such elements in overall journey time while planning for multi-stage trip network (Chowdhury & Ceder, 2016). So, special attention should be given to travel time particularly for first and last mile to eliminate the discrepancies in current transport system.

2.4.1.3. Trip Length/Distance

The travel distance is an important factor in mode choice as its effect the unobserved perception of people about convenience and comfort (Ashiabor, Baik, & Trani, 2007; Cho, 2013; Koppelman & Sethi, 2000). Trip distance is a main factor for trip mode choice particularly for bicycling and walking

(Racca & Ratledge, 2003). The choice between one-stage and multi-stage trip depends on the length of trip. The analysis of NTS 1995-1997 data revealed that 45 kilometers is the average trip length for multi- stage trips which is 4.5 times more than the average for unimodal trips (Nes, 2002). So, it can be inferences that most of the longer trips are carried out as multi-stage trips and for most of the shorter trips are unimodal trips. The figure 5 shows the comparison of multi-stage trips with all the trips made in Netherlands.

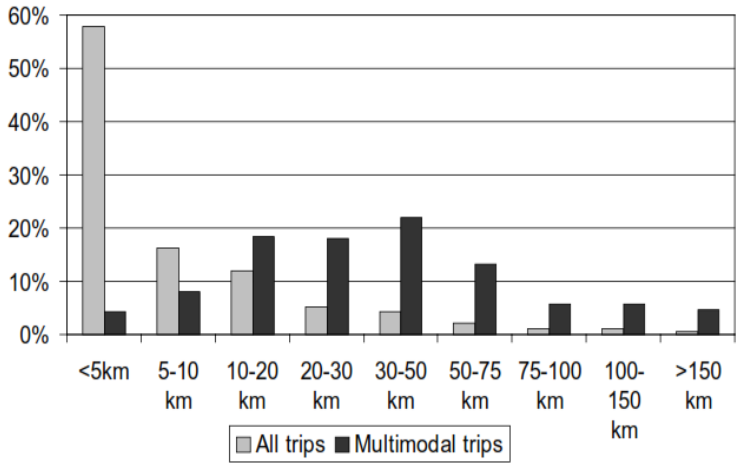

FIGURE 5. Trip length distribution for all trips and Multi-stage trips (Nes, 2002).

2.4.1.4. Accessibility

Accessibility to public transport system is the focal service issue. The access is influenced by many factors like environment, infrastructure provision and street connectivity. Most of the people avoid to choose rail because the poor quality of station and it accessibility (Givoni & Rietveld, 2007). Moreover, ease of access has an effect over the satisfaction of travelers (Chowdhury & Ceder, 2016). In second half of the 20th century a decline in the use of railway was observed as result of accessibility problem. Accessibility to railway is most important as railway station are located far away from each other so, reaching these stations required great efforts even in major cities. Therefore, accessibility determines whether railway will be used as an alternative or not. It is also evident that improving access to railways station and a slight decline in distance from the station can help to increase the rail ridership (Givoni & Rietveld, 2007).

The reason not to choose the train as travel alternative often depends upon the accessibility to railway stations. Traveler face problems both at home and activity end to access the railway station. The quality and capacity of feeding transport for first and last mile (e.g. feeder bus, bicycle, walking, car pool) is critical factor for the accessibility of transfer point. There is a need to increase coordination between access modes and transfer point in order to enhance accessibility. This will help to increase the share of multi-stage trips compared to unimodal trips (Vork, 1999). The accessibility can be enhanced by providing proper places for parking of access modes and by established infrastructure which give direct access to transport terminals.

2.4.1.5. Trip Destination

The variable which affects the choice of multi- stage trip is the type of destination area. The figure 6 shows the share of unimodal and multi- stage trip for specific destination area. There are two type of destination area home based (departure) and activity based (arrival). It can be seen that multi-stage trips generally have their last mile in city centers or large city centers. Whereas, to travel villages and rural areas unimodal trips are preferred (Nes, 2002). This trend can be explained by the fact that in most dense urban centers there is always availability of different modes for first and last mile. Therefore, people prefer to execute multi- stage trips in such situation. Furthermore, the high parking prices and congestion in large city centers can be linked to this phenomenon as well. On the other hand, the poor connection of different modes in the countryside and villages leads people to execute their trip using private vehicle (unimodal trip).

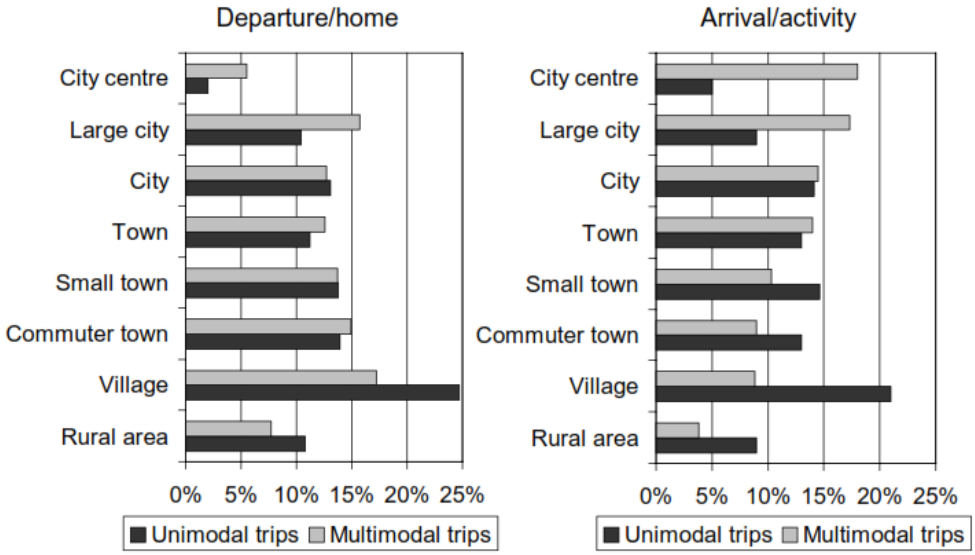

FIGURE 6. Distribution of Unimodal and Multi-stage trips for different departure areas (Nes, 2002).

2.4.1.6. Trip Cost

Travel cost plays an important role in mode choice behavior of traveler. A high travel cost will not encourage people to choose multi-stage trip to reach to their destination. In a multi-stage trip the unavailability of integrated ticketing system create problem for the user as each mode in a multi-stage trip calculate its own fare. This fare pricing at every interchange enhance the cost of overall trip for a traveler as they need to pay a basic fare as well as a variable fare depending on the trip distance (Schakenbos et al., 2016). Travel cost not only includes the cost being paid to the transport operator. In a multi-stage trip, extensive part of cost depends on non-monetary elements. This non-monetary cost can be taken in term of time lost, cost related to unreliability (risk of delay), and low comfort (Keijer & Rietveld, 1999). It is difficult of measure the monetary value of a transfer but these transfers also account for some cost at customer end (Schakenbos et al., 2016). In case of an interchange the low comfort, cost will be quite high (Keijer & Rietveld, 1999).

Cost and time are substantial factors which influence the transport mode choice. The reduction in cost and travel time will encourage people to choose private vehicles as their mode of travel (Ganji, Eftekhar, Shokri, Ismail, & Atiq, 2013). Therefore, it is necessary to include these components as well while calculating cost of a multi-stage trip and these costs should be reduced to promote people to execute multi-stage trips.

2.4.1.7. Comfort and Flexibility

Comfort and flexibility is the key reason of choosing car as a mode of transport. The car provides the opportunity of flexible schedules as compare to public transport. Moreover, private car provides their users with the chance to move to infinite number of destination. One the other hand, public transport users can only enter and exit at limited origins and destinations. The freedom to choose a specific route is also linked to private vehicle use whereas; public transport mainly operates in a closed system with fixed route. The level of comfort decline at interchange/ transfer points which worth more for transport (Keijer & Rietveld, 1999). So, comfort and flexibility provided by private vehicle also leads people not to choose public transport as their mode of travel.

2.4.2. Individual and Household Characteristics

In a cross-sectional study on transit use in 265 urbanized areas of US by Taylor, Miller, Iseki, and Fink (2009) divulges that characteristics of traveler is one of the main factor affecting transit ridership. The population characteristic which affect the mode choice of travelers include gender, age, income, household structure, education, vehicle availability, number of household vehicles and number of persons in household with full car license (Bhat, 1997; Cho, 2013; Koppelman & Sethi, 2000; Li, Song, Cheng, & Yu, 2015; Racca & Ratledge, 2003). Limtanakool et al. (2006) inspected the influence of gender, age, household type, education, and car availability on traveler mode choice decision. Employment is an imperative predictor of transportation mode choice. The transit boarding can be increased up to 1.6% by increasing employment rate to 1% (Liu, Erdogan, Ma, & Ducca, 2014). The factors related to household structure are importance for modeling travel mode choice. The household with or without children have different choices for travel mode (Racca & Ratledge, 2003).

2.4.2.1. Age

Age is a major factor affecting mode choice of individual (Almasri & Alraee, 2013; Racca & Ratledge, 2003). In a study by Tyrinopoulos and Antoniou (2013) reveals that respondent between age of 35-44 years indicate a higher preference for car. The younger riders (less than 25 years) are mostly being picked-up or dropped off at station. This effect is large for individual younger than 19 years. The individual between age of 25-34 has less probability to use walk as mode of transport (Kim et al., 2007). The results of study in Portland indicate that population under age of 17 show a positive relationship with transit ridership (Dill, Schlossberg, Ma, & Meyer, 2013). These results are contradictory with the study of Chu (2004) who found that in Jacksonville, Florida, the rail ridership is negatively associated with age (under 18) of population (Liu et al., 2014).

2.4.2.2. Gender

Senbil, Kitamura, and Mohamad (2009) indicate that gender is a significant factor for automobile use. Kim et al. (2007) indicates that females are more attracted toward bus compared to other modes. But the results are different for the females having access to private vehicle. The study by Tyrinopoulos and Antoniou (2013) also reveals the preference of female toward public transport. The result are not consistent as studies also indicate that gender is not significantly associated with mode choice (Almasri & Alraee, 2013; Racca & Ratledge, 2003). So, there is a need to know the impact of gender on mode choice behavior of individuals.

2.4.2.3. Individual and Household Income

Income is an important factor for modelling mode choice as low incomes tends to have more share of public transport whereas, higher incomes have reduced share of public transport compared to other modes (Kim et al., 2007). Racca and Ratledge (2003) also indicate that individual with lowest income tend to use bicycle and walk more. This is not related to the fact that people like to walk but in

fact people do not have access to car. According to De Jong and Van de Riet (2008) household income is a crucial determinant for mode choice travelers. The importance of income lays in the fact that future growth in private vehicle is directly related to income growth (Tyrinopoulos & Antoniou, 2013). Household income is one of the major factors influencing vehicle ownership (Senbil et al., 2009). They study by Chu (2004) indicated that in Jacksonville, Florida, household income is negatively related to the choice of rail ridership (Liu et al., 2014).

2.4.2.4. Vehicle Ownership

The vehicle ownership is related to every aspect of daily travel (Senbil et al., 2009). Chu (2004) found that in Florida most of the household without car tends to board transit facilities more compared to other modes (Liu et al., 2014). Private vehicle ownership complies for reduction in share of other modes of transport. People having access to car and driving license has greater preference for choosing private car as mode of transport (Kim et al., 2007). Whereas, people with no vehicle mostly uses walk and bicycle as mode of transport (Racca & Ratledge, 2003). According to Li et al. (2015) vehicle ownership has stronger impact compare to other factors like age, gender and income. A positive correlation between travel mode and vehicle ownership is observed by (Dupuy, 1999; Golob, 1990; Senbil et al., 2009).

These all factors listed above are important for mode choice of travelers whereas, besides these factors there are also some advantage and disadvantages being offered by private vehicle and public transport itself which influence the people mode choices. These advantages and disadvantages are as follow:

2.5. A comparison of private vehicle and public transport

In this section, the benefits and constraints of public transport will be discussed which promote/restrict people to use public transport. The factors like travel behavior, time, cost and type of journey influence the choice people make for mode choice. In a study carried out by Hagman in 2003 the perceived advantages and disadvantages of private care use were identified. The research shows that most of the advantages offered by car are personal like freedom, saving time and flexibility whereas, the disadvantages (like environmental impact) are related to public discourse. There are very few disadvantages like cost which are related to personal experience of people.

No doubt, people are aware of the fact that excessive car use is creating problem for the people but they are not ready to reduce their car use (Beirão & Cabral, 2007). It is supposed that public transport is not a good alternative for private car. Results of the study by (STEG, 2003), revealed that the frequent car users think of public transport negatively as compare to the people with infrequent car use. The infrequent car users evaluate the car positive but they have less negative behavior toward public transport as a result they are more open to use public transport (STEG, 2003). The table 4 presents the advantages as well as disadvantages for using public and private transport.

TABLE 4. Perceived advantages and disadvantages of Private and Public Vehicle (Beirão & Cabral, 2007).

Advantages	Disadvantages
Private Car	
Flexibility/freedom Speed Convenience Comfort Safety Private Space	Fuel and Parking cost Parking issues Traffic problems/congestion Driving Stress Isolation Accidents Pollution Time waste in congestion

Public Transport	
Less Stress	Time waste
No driving stress	Lack of Comfort
Low cost	Crowded
To be able to relax	Unreliability
Bus priority	Lack of Control
Less pollution	Long waiting times
To be able to rest and read	Transfer points
Lower travel time	Lower flexibility
Socialization	Walking Time
	Security

Generally, in a public transport trip people do not want a transfer unless it is easy and fast. To have a seat and a comfortable journey is the priority of the traveler. Journey time is one of the main reasons to choose private car as mean of travel by many people. The policies improving the operational aspect of public transport should also focus to improve the image of public transport. The system of public transport should be competitive and market-oriented. The decision should be made keeping in view the travel behavior and expectations of travelers. The choice of transport mode can change over the time and with type of journey. So, public transport performance measure should be improved in order to attract more people (Beirão & Cabral, 2007). The low waiting time, cleanness and comfort are the measures which can help to attract more people to use public transport (Dell'Olio et al., 2011).

2.6. First Mile and Last Mile

The first mile is the journey from origin (home) to a transit station whereas, last mile account for the journey from a transit station to destination (workplace). No doubt public transportation provides a way to diminish traffic congestion and environmental problems. The accessibility to public transport is essential particularly for first and last mile to promote sustainable transportation. Door-to-door and cost effective public transport can be realize when a transit system is coupled with first and last mile (Chong et al., 2011). The provision of service from a transit station to home or office is referred as Last Mile Problem (LMP). The absence of such services is the major deterrents to use public transport particularly for demographic groups like disabled, senior and school going children (Wang, 2015). The figure 7 explains the different stages of multi-stage trip with regards to first and last mile.

FIGURE 7. First and Last Mile ("Projects First Last Mile Strategic Plan Path Planning Guidelines | | IBI Group Inc.," n.d.).

When anyone commute from home to transit station the following questions come into mind. How I will get there? Parking will be available or not if I travelled by car? Is it safer, easier and convenient to use bike or walk? Most of the people use car as it is the most convenient way to travel. These differences regard as problem of "First and Last Mile". So, it is viable to provide accessible, safer and convenient options at first and last mile in order to promote multi-stage trips (McLeod, 2014).

Traveler consider last mile as the longest mile. The journey before and after a transit ride, has sufficient impact to encourage or discourage an individual to ride in a transit facility again. Therefore, first and last mile is the special area of concern for city governments and transit agencies and they are developing strategies to provide convenient ride. Despite of typical solution (increase route coverage) to increase transit ridership there is a need to develop and implement the strategies to expand first and last mile connectivity to transit services (Nashville, 2015). First and last mile can be seen as crucial component in a multi-stage trip (McLeod, 2014).

Access and egress are the terms alternative used for first and last mile. Access and egress is the part of a trip involved in getting people to and from a public transit facility (Clifton & Muhs, 2012). In a chain trip of public transport access and egress considered as weakest link and they determine the convenience and efficiency of public transport. The inexpensive and significant improvements can be witnessed by improving these links. Access and egress improvements are inexpensive compared to the provision of expensive infrastructure and other options (Krygsman et al., 2004).

According to Blumenberg and Pierce (2014), public transport use typically demands a multi-stage trip; for example, walking to bus stop (access/first-mile) and walking from bus stop (egress/last-mile) to final destination is involved in a single transport trip. The time disutility linked with first and last mile stages makes a solo-car-only trip more attractive. When access and egress distance make up 15% when compared with the total distance of the trip (Krygsman et al., 2004). The term access point and egress point in multi-stage trip are used for the points where an individual enters or exit a public transport terminal/station.

The different component related to multi-stage trip particularly for first and last mile has been explained. There are different factors related to multi-stage trips which have an impact on the transportation mode choice. These factors will be explained in the following section.

2.7. Transportation Mode Choice in First and Last Mile

There is a need to identify the mode mostly being used in first and last mile as the coordination of these modes with main travel mode can help to promote multi-stage trips. Moreover, this can also help to identify the problems being faced in first and last mile. According to Givoni and Rietveld (2007), the share of access-egress modes decline as the trip length increases. Improving access of these modes to transit station can help to increase public transport use. In general, it is observed that people can wait for longer time at access points as compare to egress points. Different modes are being used at home and activity end. Different stage of trip also influences the mode choice of people as in a study conducted by Zhao, Chow, Li, Ubaka, and Gan (2003) concluded that transit use decline exponentially as walking distance increase from transit stop (Gutiérrez, Cardozo, & García-Palomares, 2011). This difference can be explained by the availability of private modes at both ends (Givoni & Rietveld, 2007). Figures 8 and 9 show the different mode being used for first and last mile.

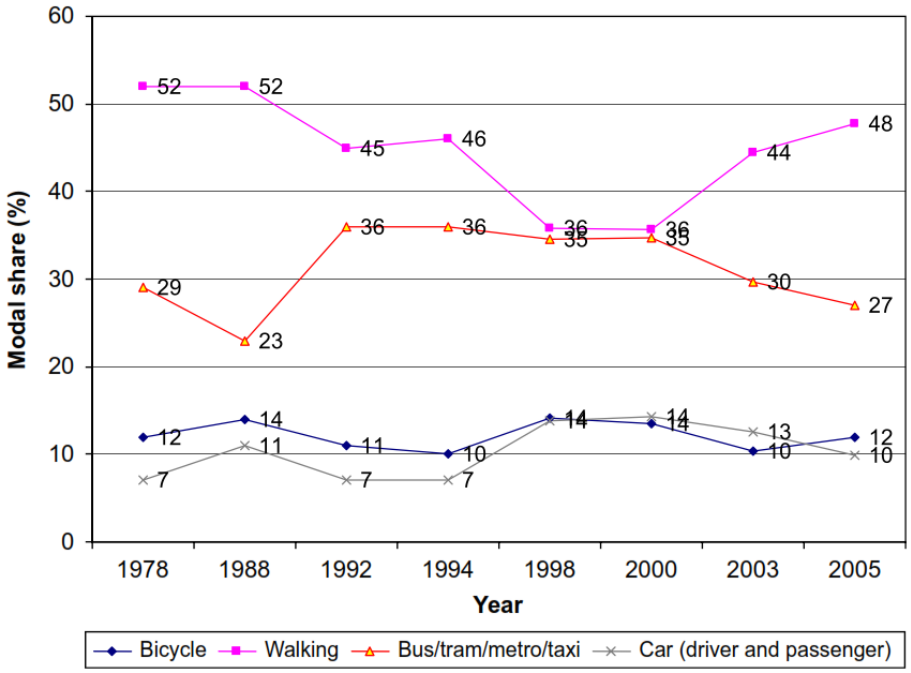

FIGURE 9. Access mode at activity end (1978-2005) (Givoni & Rietveld, 2007).

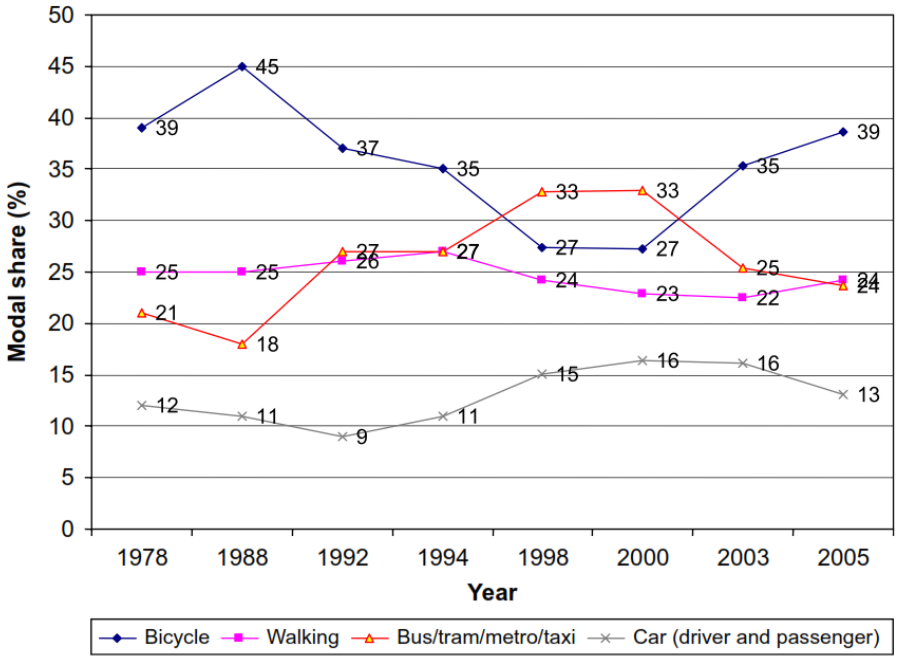

FIGURE 8. Access mode at home end (1978-2005) (Givoni & Rietveld, 2007).

The results show that walking, bicycle and public transport is the dominant used mode of transport for first and last mile. At home end bicycle is mostly been used because of its availability. Walking is dominant at the activity end. These modes can contribute to mitigate the problem of environmental pollution. There is a need to improve the access of these mode to the railway station. According to Nashville (2015), the following are the mode mostly being used for first and last mile.

- Walking
- Bicycling

- Shuttles service (Public and Private)
- Private car
- Taxi service like Uber
- Shared vehicles

Whereas the main trip is carried out by public transport like bus/tram/metro/train (Nashville, 2015). Non-motorized modes are predominantly being used for both home as well as for activity end. Bicycle is mostly being used as access mode for home. At activity end the share of bicycle is rather small and walking is mostly being used. This difference can be explained by the irregularity in supply of bicycle at home and activity end (Keijer & Rietveld, 1999). According to Blumenberg and Pierce (2014), walking is used to access bus stop and final destination but in Netherlands the trend is different where bicycle is mostly being used to access the transit stop. The convenience at first and last mile depends on these factors:

a) **Distance:** Distance between origin/destination and transit service;
b) **Modal Integration:** how different modes like walking, bicycling and private car are integrated with transit facility? Parking facility is available on station or not?
c) **Network Quality:** how the infrastructure is being provided for specific mode between origin, destination and transit facility?

(Nashville, 2015)

The table 5 shows the different modes being used in different countries for first (access) and last (egress) mile. It is clear from the table that in most of the countries walking is mostly being used to access/egress the railway station. In addition, the share of bus is also high in India and China as a mode to access the transit station.

TABLE 5. Access and egress mode for rail-systems (Goel & Tiwari, 2016).

Setting of metro network	Reference	Access/egress	Walk	Cycle	Bus	Private motorized	Motorized para-transit
Delhi, India	Goel and Tiwari (2016)	Both	44	1	11	13	22
Mumbai, India	Rastogi (2010)	Access	49	6	30	4	10
Nanjing, China	Zhao et al. (2013)	Access	59	3	26	3	3
Nanjing, China	Zhao et al. (2013)	Egress	76	1	17	1	2
Manila, Philippines	Fillone et al. (2008)	Access	50	–	–	–	41
Santiago, Chile	Bianchi et al. (1998)	Access	47	–	31	11	10
Athens, Greece	Tsamboulas et al. (1992)	Access	62	–	18	16	3.5

The walking and bicycle is used as mode when it is quick and affordable. According to the report of American Public Transportation Association (APTA) (2007) almost 60% of the passenger use waking as mode for first and last mile to reach transit station. In Bay Area, people living within a distance of half mile from the station tend to walk more compared to the people living away from station. Similarly, studies in Washington, DC, reveals that people living near to the railway stations use walking as a mode to access railway station (McLeod, 2014).

It is evident from the discussion that most of the people use walking and bicycle as their mode for first and last mile. It is necessity of the hour to promote non-motorized mode of transport and

encourage people to carry out multi-stage trips. A safer, convenient, reliable and comfortable environment in the vehicle as well as at access and egress point is the basic requirement to promote public transport use.

2.8. Statistical Modelling for Mode Choice Analysis

Statistical model gives a way to generate interrelationship of mode choice with other attributes like comfort, travel time, cost etc. The different models being used by researchers for mode choice analysis is shown in the table 6. The selection of these models depends on the different variables being identified and their correlations.

TABLE 6. Mode Choice Analysis

Sr. No.	Reference	Place	Statistical Model
1	Arasan, Rengaraju, and Rao (1996)	India	Binary logit model
2	De Palma and Rochat (2000)	Geneva, Switzerland	Nested logit approach
3	Badoe and Wadhawan (2002)	Toronto Canada	Disaggregated logit mode choice models
4	Nurdeen, Rahmat, and Ismail (2007)	Kuala Lumpur	Binary logit model
5	Gang (2007)	Shanghai, China	Multinomial choice model
6	Spurr and Chapleau (2007)	Montreal	Multinomial logit model and a confusion matrix
7	Buehler (2011)	Germany and USA (comparison study)	Multinomial logit model
8	Miskeen, Alhodairi, and Rahmat (2013)	Libya	Multinomial logit model
9	Chiu Chuen, Karim, and Yusoff (2014)	Malaysia	Logistic regression
10	Ding and Zhang (2016)	Nanjing, Chine	Multinomial logit model

The relevant studies on mode choice behavior reveals that the mode choice is the function of socioeconomic and travel characteristics of traveler. The modelling of mode choice behavior is a useful tool for decision makers and planners to shift the people from private vehicle to public transport. Multinomial logit model (MNL) and binary logistic regression are mostly used in different countries and recognized as good technique for mode choice modeling of traveler.

2.9. Case Studies

First and last mile are the weakest link in a multi-stage trip hence they contribute toward increase in travel discomfort and travel time (Rietveld, 2000). Most often cycling, walking, car commuting (kiss-and-ride, park-and-ride) and feeder bus are the modes which are being used at these stages. Universally, walking is mostly used mode of transport for first/last mile. In recent years cycling, has also emerged as an alternative mode for these two stages. The share of car for first/last mile changes with the provision of parking facilities.

In developed countries like Canada and U.S. share of car is expanding, particularly for first mile (Meng et al., 2016). Results have shown that non-motorized modes (walk and bicycle) are preferred for both home and activity end. A high share of bicycle is being observed; as out of three more than one person uses this for first mile (home to station). Whereas, the share of walking is higher at activity end (Keijer & Rietveld, 1999). In North Rhine, Germany it is observed that the dependency on car is slightly lower for the people living within radius of one kilometer around a railway station. In U.K. 76% of trips within the distance of 1 mile are covered by foot. Whereas, in Germany this figure is 60% for the distance of 1Km and in Norway walking account for 53% of the trips (Scheiner, 2010).

The choice of these modes is influenced by different factors in which distance from the railway station is of main importance at both ends (first/last-mile) of a multi-stage trip.

2.9.1. The Dutch Experience

In a study carried out by Keijer and Rietveld (2000) the mode choice behavior in a multi-stage for first and last mile was observed. The mode choice behavior for these stages of a multi-stage trip was linked with distance from railway station. In this study, a simple example of multi-stage transport chain linking *home* with *railway stations* (R_1, R_2) and *activity* has been used. Whereas, the walk trips carried out in order to reach to the public transportation has been ignored. The figure 10 below explains the multi-stage transport chain used for this research.

FIGURE 10. Multi stage transport chain consist of three elements (Keijer & Rietveld, 2000).

One of the disadvantage of multi-stage trip results in detours problem which correspond to the discontinuity in space. The figure 11 explains the detours problem as a result of multi-stage trip where chain between home and activity implies a longer distance compare to the actual distance.

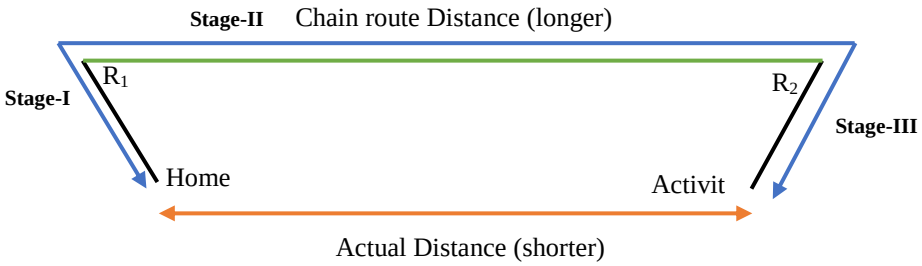

FIGURE 11. Detours problem in Multi-stage trips (Keijer & Rietveld, 2000).

The results show that the influence of distance from the railway station is closely related to the mode choice. The figure 12 and 13 represents how choices for home and activity end changes with the distance from the station. It has been witnessed that for short distance trips people prefer to take bike or walk whereas, public transport is mostly used to cover large distance at home and activity end.

Moreover, when the distance from a rail station was compared with the use of rail as mode of transport, it delineated that people living within 500 meters from railways station uses 20% more rail as mode of transport compared to the people living within 500-1000 meter (Keijer & Rietveld, 2000).

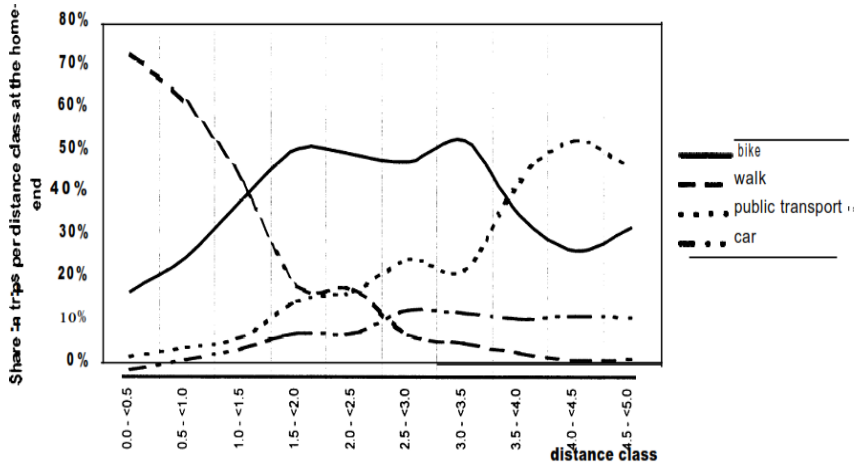

FIGURE 12. Share of Transport Mode per distance class at home (Keijer & Rietveld, 2000).

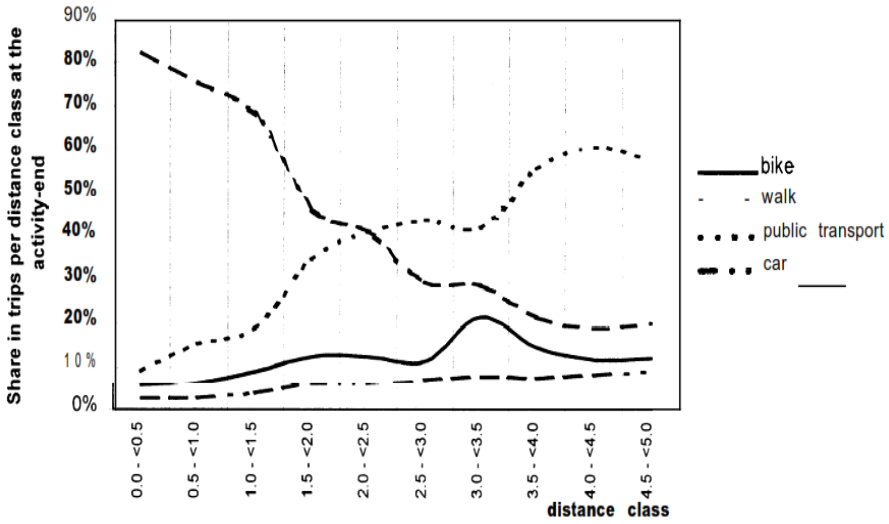

FIGURE 13. Share of Transport Mode per distance class at activity end (Keijer & Rietveld, 2000).

2.9.2. The Case of Netherlands

In order to study the important role of walking, bicycle and other modes in a multi-stage trip (home and activity end) a study was carried out in Netherlands by Rietveld (2000). In the analysis of a multi-stage trip entry and exist modes (walking and bicycle) are mostly being neglected. This has following implications:

- **Mode of transport:** This leads to underestimation of other modes needed to carry out a multi-stage trip as in many countries. Walking and bicycling are underestimated which influences the use of train.
- **Attractiveness:** Attractiveness for the train is overestimated when compared to the car. Entry and exist are the weakest parts in a multi-stage. So, their contribution will be highest when estimating discomfort, etc.
- **Long-distance trips:** For long distance trips, the train gets more weightage compared to other modes and disadvantages of multi-stage trips are underestimated.
- **Environmental Impact:** The environmental impact of multi-stage trips is over estimated when car is neglected. As mentioned above the detour problem may increase the travel distance for an individual. If emission of trains is 20% less than car, then environmental benefits may be negligible particularly when using a motorized mode for the entry and exit stage.

The finding of this study shows that bicycling and walking is a feasible alternative for origin and destination closer to the railway station. Bicycling is predominantly used at home end, whereas at activity end walking is preferable mode. The table 7 depicts the findings of this study. An increasing trend can be observed in the use of bicycle at home end in the period of 1975-1994. At the activity end, the same increasing trend is being observed for walking and bus. Moreover, as the distance increase between railway station and residence increase the tendency to use railway decline (Rietveld, 2000).

TABLE 7. Mode Choice in access to railway station at home and activity end (%) (Rietveld, 2000).

Home End	1975	1978	1988	1992	1994
Bicycle	30	39	45	37	35
Walking	35	25	25	26	27
Bus/tram/metro/taxi	20	21	18	27	27
Car (driver and passenger)	15	12	11	9	11
Other	0	3	1	1	0
Activity End	**1975**	**1978**	**1988**	**1992**	**1994**
Bicycle	5	12	14	11	10
Walking	55	52	52	45	46
Bus/tram/metro/taxi	30	29	23	36	36
Car (driver and passenger)	10	7	11	7	7
Other	0	0	1	1	1

2.9.3. The Case of Germany

The study was carried out to examine the association between travel mode choice and travel distance particularly in the context of multi-stage trips. Moreover, the influence of a geographical area as well the availability of car in each geographical category was analyzed. The results of the study revealed that:

- **Distance base travel mode choice categorization:** Walking outweighs the other modes of transport in some distance categories. The share of the bicycle shows irregular behavior for different distance categories.
- **City size based modal split:** It is evident that most short and medium trips are covered by walk or bicycle in urban area as compare to other spatial settings.
- **Comparing city size category (trend over time):** The availability different modes of transport like car and bicycle also effect the mode choice of individuals. The culture, social and geographical setting and awareness for health benefits also have implication for walking and use of bicycle.

The study of Berlin revealed motorized household that for a distance exceeding 670 meters hardly any mode of transport is used other than car. Same trend is being observed for a distance 325 meters or greater. In contrast individuals with no access to car use the bicycle as their mode of transport for the same distance of 325 meters. Walking is seen as the most convenient mode of transport for short distance but this is not true in case of Germany where most of the shorter trips are undertaken by bicycle. The use of bicycle for short distance trip can be explained by the provision of parking for bikes at major points (Scheiner, 2010). Similarly, for the first and last mile the bicycle is also used as one of the major mode of travel. The figure 14 depicts the parking facilities available for cyclist at station in Germany. Such arrangement encourages people to use cycle as first or last mile of transport.

FIGURE 14. Combination of long distance and short distance trips in Germany (Klug, 2013).

The table 8 below shows the model split by trip distance in Germany. It can be seen that share of walk and bicycle is increasing for a distance up-to 200-400 meters and starts to decline after reaching maximum distance of 600-800 meters. So, the model shift toward car is the result of increasing distance from a destination.

TABLE 8. Model split by trip distance Germany 1976-2002 (Scheiner, 2010).

Km	1976				1982				1989				2002			
	On foot	Bicycle	PT	Car	On foot	Bicycle	PT	Car	On foot	Bicycle	PT	Car	On foot	Bicycle	PT	Car
≤0.2	96	3	0	1	92	5	0	3	95	3	0	2	94	5	0	1
0.2-0.4	90	7	0	3	84	10	0	5	89	7	0	3	81	11	0	7
0.4-0.6	81	12	0	7	76	15	1	8	76	12	0	11	64	19	0	17
0.6-0.8	73	14	1	13	66	19	0	14	74	14	2	10	56	21	1	21
0.8-1.0	64	15	2	19	53	23	1	22	58	20	1	20	38	19	1	40
1.0-1.5	51	19	3	26	44	24	2	29	48	24	3	24	25	19	3	53
1.5-2.0	39	17	8	36	30	23	6	41	32	22	5	41	18	17	5	60
2-3	24	15	14	46	20	20	13	46	19	20	10	50	10	14	7	68
3-5	10	11	26	53	10	12	21	57	8	14	17	61	4	9	10	77
5-7	3	7	30	59	3	7	25	64	2	7	21	69	1	6	11	81
7-10	1	4	28	66	2	5	26	67	1	5	19	74	1	4	12	82
10-20	1	2	29	68	0	3	23	73	1	3	16	80	0	2	10	87
>20	0	0	25	74	0	1	23	75	0	1	12	86	1	1	13	85
Total	37	10	14	39	29	13	13	44	29	13	10	48	21	10	7	62

2.9.4. The United Kingdom Experience

In United Kingdom (U.K.) to offset the increased trend private vehicle use a number of policies has been introduced like Green Paper 1996 and White Paper 1998. The objective of these policies is to establish a sustainable and integrated system of transport across the country. The ro le of public transport is key to achieve such objectives which can help to transfer people from private car to bus thus reducing congestion on the roads (Lyons & Harman, 2002). In U.K., the share of multi-stage trip has increased from 6% to 8% (2002-2014) of all the trips recorded in National Travel Survey (NTS). Whereas, 27% of walking trips are executed to reach another mode of transport (DoT, 2014c). Generally, walking mostly used to access surface or underground train service and this distance changes as the distance from the railway station increases. The figure 15 below shows the contribution of walking in relation to distance from railway station. The other mode of transport being used for first and last mile includes bike, bus, car and taxi.

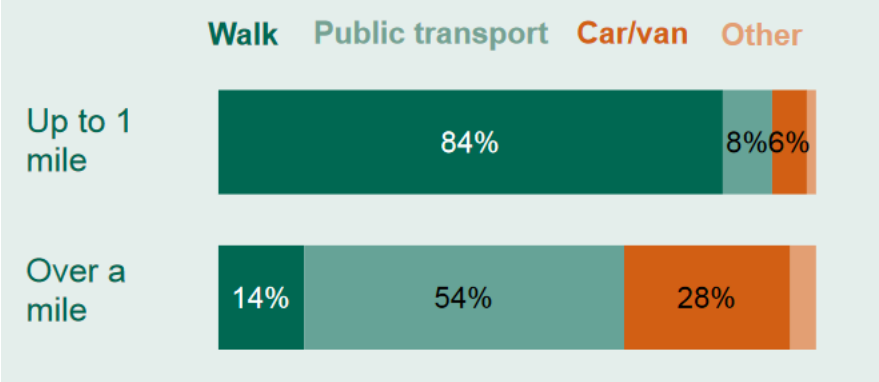

FIGURE 15. Walking Trips to reach to Railway Station **(DoT, 2014c).**

2.10. Finding the Gaps

Multi-stage trips are the need of the hour because of growing trends of congestion, travel time delays, travel costs and environmental problems. These all problems are the result of tremendous growth in private vehicle use. The knowledge of multi-stage trips is necessary to shift people from personal vehicles to public transport. In the literature review an effort has been made in order to find out the different factors affecting the choice between solo-car-only and multi-stage trips. There are different factors mentioned in the literature which affect the choice of multi-stage trips. Narrowing down the criteria when talking about factors affecting the mode choice behavior of traveler's trip length, trip purpose, trip travel time as well as personal and household recognized as factors playing decisional role. These factors differentiate the mode choice between public transport and private vehicle. A lot studies have been carried out to know the factors affecting mode choice behavior but very limited studies focus on the selection of competitive modes like solo-car-only and multi-stage trips. Moreover, organization of modes for first, main and last mile of multi-stage trip is phenomenon in these studies which need more studies although different researches tried to find out the mode choice behavior for first and last mile like in Netherlands and Germany but their scope is rather limited. Whereas, there is a need to find out factors which influence the mode choice for first, main and last mile. The interaction between first mile, main mode and last mile is of critical importance as disturbance at one end can change the whole trip chain. The relationship between first mile, main mode and last mile is still needed to be explored and research is need in this regard. Most of the organizations working for the improvement of public transportation often do not consider organization of first-last mile and integration of different transportation facilities in their service performance criteria. These factors play an important role for efficient working of public transport. A well-articulated public transport system can help to elevate the problem of congestion, increased travel cost and time by shifting people to public transport. The organization of first, main and last mile for a multi-stage is not the area of interest in current research which need attention as the choice behavior or available resources at one end of the trip influences the whole trip. Lastly there is need to establish a model which can predict the mode choice behavior for solo-car-only and multi-stage trip. A model predicting the mode choice of travelers can help transport organization and operators to improve their efficiency and to reduce the load of private vehicle from the roads.

2.11. Conclusion

Transportation mode choice is a difficult decision and complex decision which is influenced by many attributes. Some attributes are related to overall cycle of multi-stage trip like travel time, transfer, reliability whereas, some attributes particularly related to the efficiency of public transport has also been discussed. The key to analysis the decision making for mode choice is to study these attributes. Travel time is considered as main variable which influence mode choice. The time lost in transfers and waiting time is closely related to total travel time of the journey and hence affect the choice for a multi-stage trip. Reliability is also an issue being faced by the travel of public transport as rescheduling is difficult and the chance to miss a connection force people to choose private vehicle. Similarly, comfort and flexibility provided by private vehicle decrease is chance of a multi-stage trip which requires transfers and accessibility problem. Accessibility to transit station also impact the choices people made. These variables are also related to the mode choice people made for first and last mile as accessibility to transit station lead people to choose walking as their most common mode of travel for first and last mile.

Different modes of transport are being used to access or egress the transit station. The accessibility to transit station leads people to choose walking as their most common mode of travel for first and last mile. Moreover, availability of infrastructure at transit station leads people to choose to different mode of transport. In Netherlands, most of these trips are carried out by bicycle where the facility of bicycle parking is highly encouraged and provided. The mode choice between first and last mile also differ as it is not possible to have a bicycle for last mile especially for the destination people occasionally visit. So, walking is predominantly used for last mile. Distance of origin and destination from transit station also influence these choices. As the distance increase from transit station a mode shift toward motorized transport is being observed. In most of the case explained above as the distance from the transit station increase the probability to use public transport also decline. The mode share of walking and bicycling for first and last mile is higher for places near to transit station. So, there is a need to put these elements in place for establishing an integrated transportation system. The understanding of mode choice for first-last mile and the factor influencing these choices are necessary to identify in order to encourage multi-stage trips.

3.0. NATIONAL TRAVEL SURVEY (U.K.)

3.1. Introduction

This chapter outlines the different aspects of National Travel Survey conducted in the U.K. since1965. In the first part of the chapter travel patterns being observed in U.K. have been explained followed by a brief description of National Travel Survey (NTS). NTS is carried out periodically in the U.K. to know the travel behavior of people. Different methodological steps involved in this survey have been discussed. Different symbols and conventions used in NTD have also been included in annexure. Moreover, some definitions being used in NTS are listed in annexure.

3.2. Travel Patterns in United Kingdom (U.K.)

Travel patterns in United Kingdom (U.K.) have changed after world-war II tremendously. The post-industrialization era has witnessed an increase in automobile ownership. In Great Britain, the number of cars per 1000 persons has increased from 210 to 500 in a period from 1970 to 2005. This increase results in additional number of kilometers travelled from 30 Km per day per person to 40 Km (1970-1990). A change in travel mode use was also observed, as trips made by young people on foot received a decline from 20% in 1975 to 16% in 1999. A positive change in walking was observed when in 2005 it again rose to 18%. This change is the result of the decline in vehicle ownership and the increase in the share of multi-stage trip for long distance trips. The National Travel Survey (NTS) is the major source of capturing such travel behavior information (Kuhnimhof, Buehler, & Dargay, 2011).

A number of steps have been taken in the U.K. in order to manage the travel demand. An association with the name of “Association for Commuter Transport” came into existence on 1997. Moreover, Minister for Transport in U.K. also introduces a national guide on workplace travel plans. The purpose of these enactments was to change the work-related travel behavior as 38% of the all miles travelled were those for business purpose or commuting. Significant changes related to tax system were observed in the budget of 1999 to encourage the employers to formulate measures which would help to manage sustainability in travel patterns of employees. Furthermore, more benefits for employers were also introduced in 2002 budget. Similarly many other measures were introduced to manage the travel pattern in Great Britain (Cairns, Newson, & Davis, 2010)**.** These policy decisions are based on the statistical figures provided by the National Travel Survey. More information about NTS will be discussed in later part of this chapter.

3.3. National Travel Survey

National Travel Survey (NTS) is carried out in the United Kingdom (U.K.) is a way to monitor changes in travel patterns of people and provide an understanding of how people use transport facility throughout the U.K. In the survey, detailed information is collected about characteristics of household and its members. Moreover, data about vehicle access and travel log for one week are collected. The NTS 2014 is the latest one and is the part of periodic survey which was started in 1965 by the Ministry of Transport. Several methodological differences have been observed which helped to improve the data quality as well as the response rate. The data is used to monitor variations in travel patterns and to device policy based on these findings. The data is also used by different organization like Department of Environment, Universities, Government departments, transport consultants, and local authorities. In the studies carried out before 2001 sample size of 5,040 addresses was used and it was increased to 5,796 in 2001. The size was again increased to 15,048 addresses in 2002. In the lastest survey of 2014, 6,900 household fully participated in the survey. Furthermore, an independent research institute (Natcen Social Research) was hired by the Department of Transport (Dft) to carry out this research. The

development of questionnaire, selection of sample, data collection, and database development is the responsibility of Natcen (Abeywardana et al., 2006).

3.3.1. Geographical Coverage

The data from the private households within the geographical boundary of England is collected and people living in other places like student hostels, tourist etc. are excluded from this survey. Since 2013, people living in Wales and Scotland are not included in the sample and travel within the boundary of Great Britain is catered (DoT, 2014b).

3.3.2. Methodology for National Travel Survey

The following framework is used to carry out the NTS tasks.

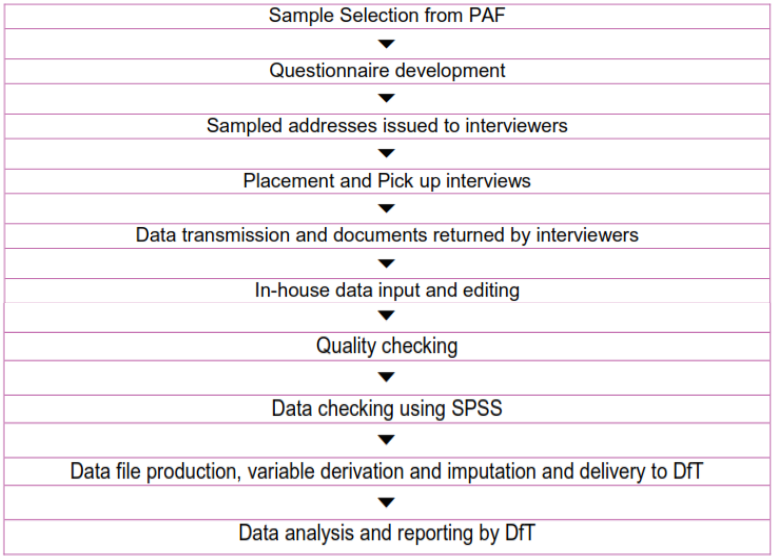

FIGURE 16. NTS Tasks Sequence (Abeywardana, Christophersen, & Tipping, 2006).

3.3.2.1. Sample Selection

The sample in NTS is selected based on random sampling of households drawn from Postcode Address File (PAF). The sample size has been reduced proportionally compare to previous survey as Scotland and Wales have been removed from this survey (Abeywardana et al., 2006).

3.3.2.2. Data Collection

In NTS data collection is done using two methods. In the first method face to face interviews are done using computer assisted personal interviewing (CAPI) and in the second method a seven-days travel record is completed by respondents (Abeywardana et al., 2006).

3.3.2.3. Dairy coding and Editing

The data collected from the seven-days travel diaries is entered into the Diary Entry System (DES). The data is checked for errors before entering. If any data is missing or there is inconsistency in the data, then respondent is contacted through phone. The coding is done for different attributes like origin, destination, journey purpose, mode of travel, and type of ticket etc. (Abeywardana et al., 2006).

3.3.2.4. Data Input and Editing

The data collected using computer assisted personal interviewing (CAPI) technique is transmitted to operational department of NatCen and travel record for whole week is received via post.

Then coding and editing of data is done at this level to produce error free data. In case of any query, respondents can be re-contacted to resolve the issues (DoT, 2014c).

3.3.2.5. Checking the travel record data

In order to check the validity of travel record data two extensive checks are run. In the first-place checks are applied at DES level when the data is entered. The second check is run to compare the inconsistency between CAPI and data collected through travel diaries.

3.3.2.6. Data Type

The data consist on several levels in a hierarchical order. Most significant data include the data about households, individuals, vehicles, trip and different stages of trip. Data is organized in a way to do cross-level analysis (DoT, 2014c). The figure 17 shows the different level of data in NTS.

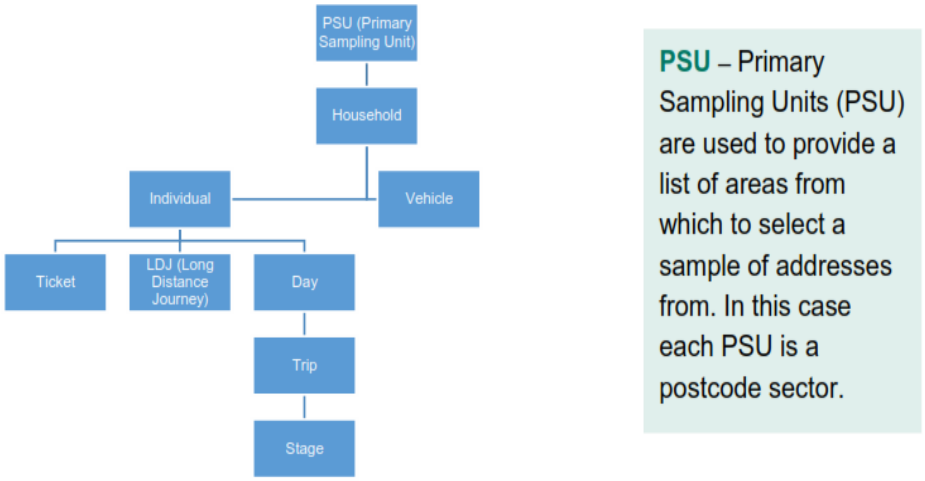

FIGURE 17. Levels in NTS Database (DoT, 2014c).

3.4. Conclusion

Travel patterns in the United Kingdom (U.K.) have changed tremendously. A shift towards private vehicle use has been observed which resulted into an increase in number of kilometers travelled. The National travel survey (NTS) is the key to calculate changes in travel patterns of individual. It helps to identify the long-term travel changes and helps to device policies for sustainable mobility. NTS is a periodic survey which was started in 1965 by department of transport. The latest update of NTS is available for the year 2014. In NTS data is collected about households, individuals, trips and different stages of trips. All the data sources help to identify the changes in travel preference of travelers. The methodological framework used for the collection and interpretation of data has also changed from 1965-2014. Initially the data was collected by the Department of Transport. Then this responsibility was handed over to a private research institute named NetCen. The geographical boundary has also changed and now that data is only collected in the geographical limits of England. No data is collected for Wales and Scotland. The data in NTS is collected in two phases. In the first phase, face-to-face interviews are conducted whereas in the second phase self-administered seven days' travel record is filled out by the respondents. The data is then coded, refined and interpreted. The final outcomes of this survey are used by different organization like Department of Environment, Universities, Government departments, transport consultants and local authorities. The different symbols, weighting procedure and terms used in NTS have been added to the annexure.

4.0. METHODOLOGICAL FRAMEWORK

4.1. Introduction

A systematic approach is essential to carry out any research work and to increase the reliability and validity of findings. This chapter explains the methodological framework that is used to carry out the research. The work is divided into two portion in first part the major work is related to literature review whereas, second portion deal with the data collection, analysis and model development. The figure 18 and figure 19 shows the methodological framework that will be used to carry out this research.

4.2. Literature Review

Literature review is the mandatory part in any research work as it gives an in-depth knowledge about the topic and highlights the major milestones being achieved in the relevant research topic. It typically includes the information available on the topic being chosen for study. Literature review is done to identify the main reasons behind mode choice. Also, the reasons for the fact that "people do or do not use public transport" have been identified. The problem being faced in a multi-stage trip and the role of first and last mile in multi-stage trip has also been analyzed. Chapter 2 of this thesis gives detail description of different aspects of multi-stage trips. Moreover, it also includes a detail description of first and last mile. The different aspects which influence the mode choice of people has been discussed and this chapter end with the mode choice behavior particularly for first and last mile. Last part of literature review includes a brief description of National Travel Survey (NTS) U.K. as the data from NTS will be used for this study. This step helps to identify the variables that will be used for this study.

4.3. Method

In this research revealed preference will be used to find the mode choice of people for first and last mile. For this purpose, data from National Travel Survey of U.K. for a 2014 will be used. The figure 18 and 19 gives detail methodology used to carry out this research. Two different models and different set of dependent and independent variables are used as shown in the figure below. First methodology is adopted to know the influence of different variables on choice of solo-car-only and multi-stage trips. In second methodology, influence of independent variables extracted from literature is evaluated on the choice of different mode combination of a multi-stage trip.

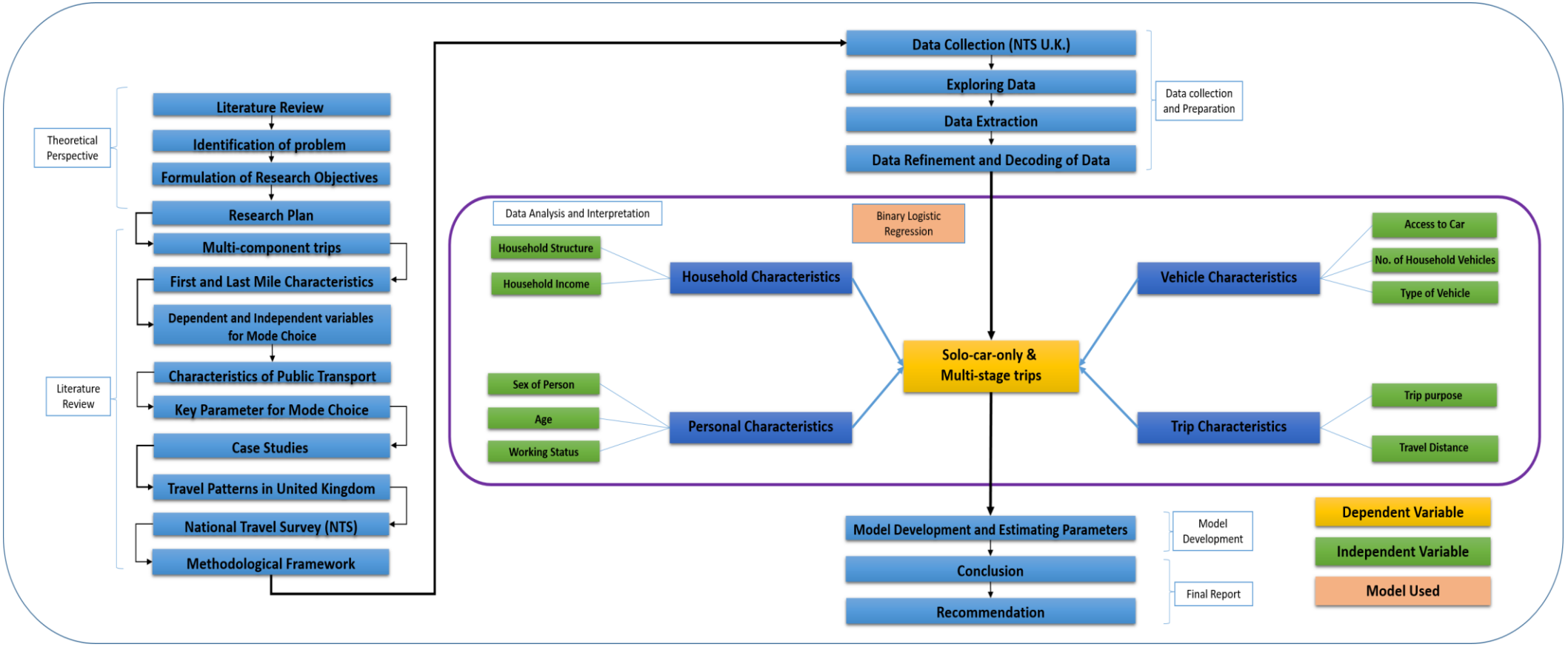

FIGURE 18. Methodological Framework (Analysis-1).

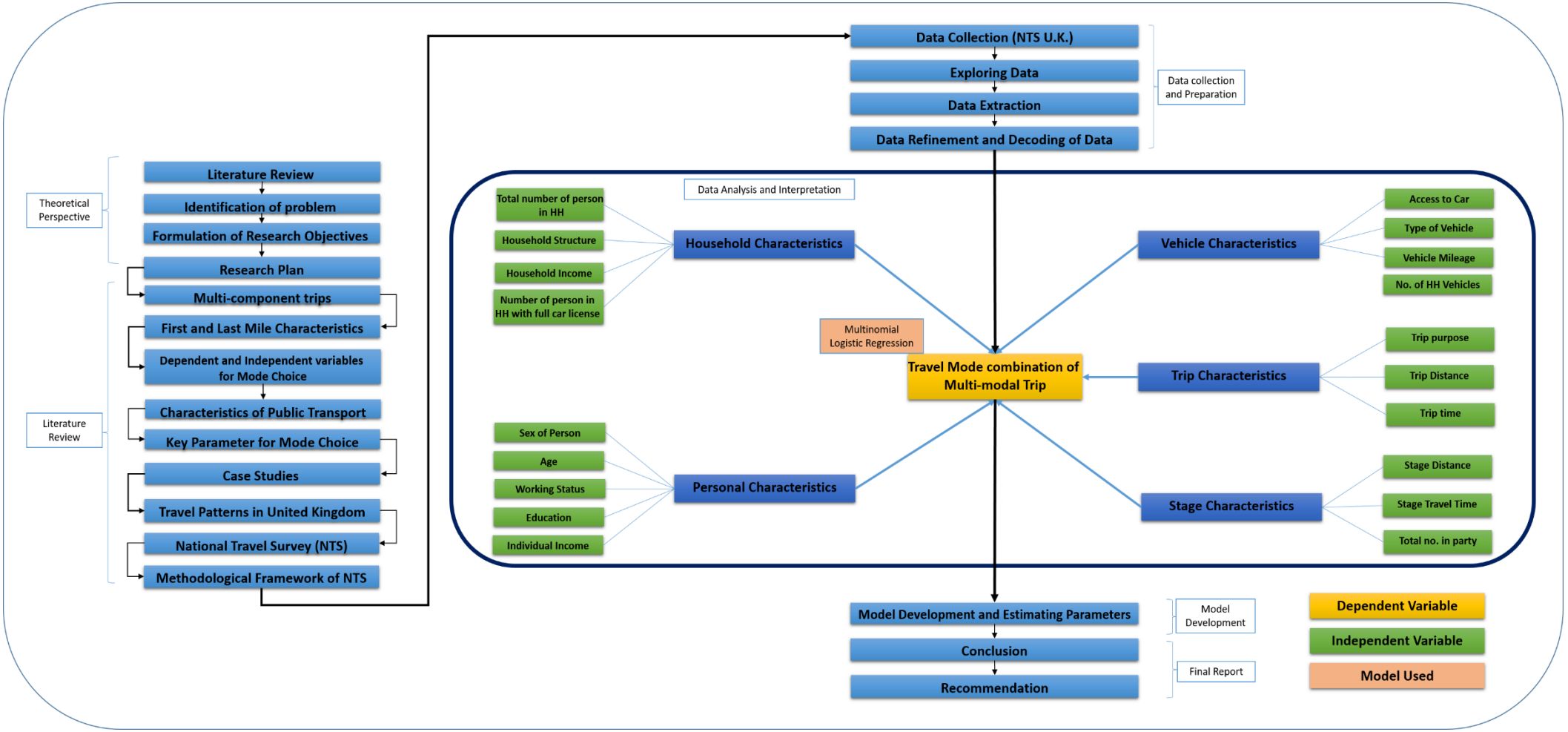

FIGURE 19. Methodological Framework (Analysis-2).

4.4. Data Collection and preparation

In the first step data, will be collected which then will be followed by data exploration/mining. This stage is necessary to have clear understanding of the terms and symbols being used in the National Travel Survey (NTS) data. In the later stage data for 2014 survey will be extracted as data file from NTS includes data for the survey from 2002-2014. This data then will be recoded to obtain result in the next section of this research work.

4.5. Analysis of Data and Interpretation

The data obtained after preparation will be used to draw inferences. The variables for the analysis include trip characteristic, stage characteristics, household characteristic, individual characteristics and vehicle characteristics. First analysis will be done to know the choice between solo-car-only and multi-stage trips. In the second analysis, organization of different transportation modes will be analyzed. This analysis will also help to analyze the influence of different variables on different mode combination for three stage trips (multi-stage trips). impact. The data will be analyzed using SPSS software.

4.6. Model Development

Models of mode decision by and large fall into two classifications; total discrete decision models and disaggregate discrete decision models. The two sorts have a similar general idea that travelers will boost their utility by picking the mode that offers them the best bundle of properties, for example, travel time, cost, flexibility and comfort and which matches their demographic characteristics. The distinction is that aggregate models foresee the mode choice from the collective behavior of individual whereas, disaggregate models inspect the mode decision of an individual or household unit. The application of aggregated model is appropriate for a larger scale where displaying individual conduct is unrealistic e.g. for the improvement public transportation the view of whole population weighted more compare to one individual. The disadvantage of these models is that individual behavioral nuances are lost at the total level. Disaggregate models treat every individual or family unit independently, and require information on numerous attributes of every traveler. These models can give more precise evaluations of the flexibility of interest for modular qualities, and they relate singular attributes to mode decision all the more successfully (Koppelman & Bhat, 2006). As evident from the literature review that binary and multinomial logistic regression is mostly being used for the analysis of mode choice.

Binary logistic regression will be used to know the choice of people between solo-car-only and multi-stage trips and influence of different variables on mode choice behavior of travelers. whereas, multinomial logistic regression will be implied to know the effect of variables on mode combination of multi-stage trips.

4.7. Discussion, Conclusion and Recommendation

The Discussion and conclusion outlines the findings of the research process. In this part, the result of this study will be discussed and mode choice behavior for a multi-stage trip will be discussed. In the last part, which is related to recommendation, ways to improve the efficiency of multi-stage trips as well as for first mile, main mode and last mile will be discussed. Recommendations will give a route of actions for the concerned authorities to improve the transportation system.

5.0. DATA ANALYSIS AND RESULTS

This chapter gives a detail description of steps followed for collection and preparation of data. The first part of this chapter focuses on data collection source and process. Whereas, second part of the chapter focus on data preparation process. Data preparation stage has three different steps. Preliminary data preparation focuses on general steps being used for data cleaning and data preparation whereas, different steps also being followed to prepare file according to the analysis type. This chapter also outline the descriptive analysis and include results of binary and multinomial logistic regression.

5.1. Data Collection and Preparation

5.1.1. Data Collection

National travel survey data is used to carry out this research work. Data about travel survey is collected from gov.UK. The data include information about household, individuals, vehicles, trips and stage of trips.

5.1.2. Data Preparation

5.1.2.1. Data Extraction

Data collected at first step includes information about travel from 2002-2014. This study only analysis travel information for the year 2014 so, that is extracted for this year.

5.1.2.2. Data Mining and Attribute selection

Data mining is done which is necessary part for data preparation. To start the data preparation process data file is refined in a way to retain only those variables required for the analysis. The following table 9 gives the list of variables being used:

TABLE 9. Data Variables.

Category	Variables
Trip Characteristics	Trip purpose to
	Trip distance
	Total trip time
Stage Characteristics	Stage distance
	Stage travel time
	Total number in party
Individual Characteristics	Age of person
	Working Status of Individual
	Individual Income
	Certified Qualification
	Sex
Household Characteristics	Total number of people in household
	Household Structure
	Person in household with full car license

	Household Income
Vehicle Characteristics	Access to Car
	Number of household vehicles
	Type of vehicle
	Vehicle's total mileage

5.1.2.3. Data Reclassification and Recoding

In this step data obtained is reclassified and recoded for analysis using SPSS. For list of reclassifications see (See Annexure-D).

5.1.2.4. Data preparation for Analysis-1 (Solo-car-only and Multi-stage trips)

In order to carry out analysis on the data prepared in pervious step is joined into one single file based on trip characteristics. This file gives an information against each trip of household, individual and vehicle characteristics.

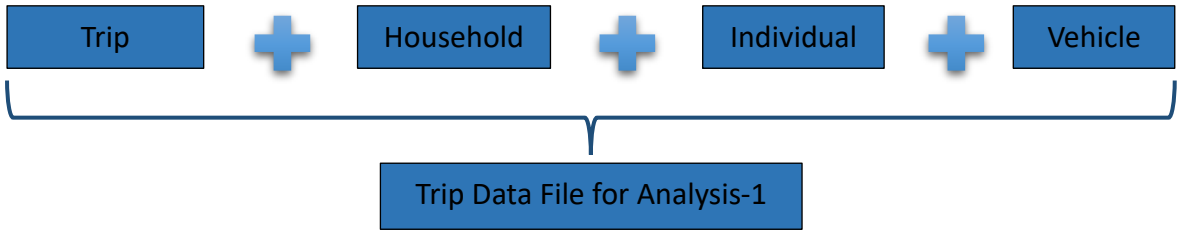

FIGURE 20. Data file preparation for Analysis-1.

For the purpose of analysis; one stage trips having car as their mode of travel and multi-stage trips with all modes of transport are retained. A new variable showing solo-car-only and multi-stage trip is generated. The following table 10 gives the information about frequency of solo-car-only and multi-stage trips. whereas table 11 gives information about modes being used at different stages of multi-stage trips.

TABLE 10. Solo-car-only and Multi-stage trips.

Solo-Car-only and Multi stage trips		
	Frequency	Percent
Multi-stage trips	9490	5.0
Solo-car-only trips	179628	95.0

TABLE 11.Number of Stages and Stage Mode of Travel.

Number of Stages * Stage Mode of Travel Crosstabulation				
Number of Stages	Stage Mode of Travel			
	Walk	Bicycle/Motorcycle	Car/van driver	Public Transport
One	0	0	179628	0
Two	1320	99	1780	3774
Three	847	63	461	796
Four	152	2	55	91
Five and More	24	0	12	14

5.1.2.5. Data preparation for Analysis-2 (First and Lat mile)

For analyzing organization of multi-stage trips and impacts of different variables on this organization data is extracted for only multi-stage trips having 3 stages from the data prepared in previous analysis. Stage data also merged with data based on trip characteristics. Data is organized in a way that each row of the data gives information about trip, three stages of trip, household, individual and vehicle characteristics.

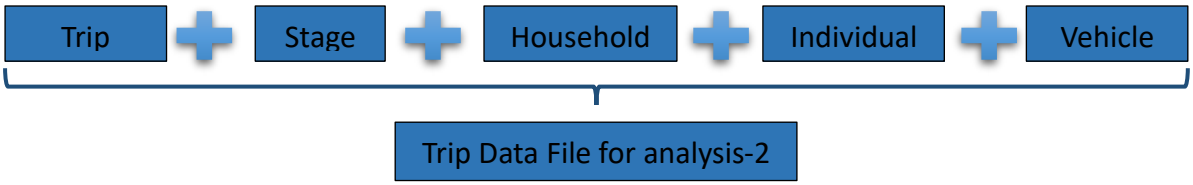

FIGURE 21. Data File preparation for Analysis-2.

A new variable showing different mode combinations for first, main and last mile is generated. The trips having public transport as main mode of travel (2nd stage of trip) are retained whereas, trips having other modes on stage-two of multi-stage trip are removed from the data set. The following mode combinations are generated for the trips having public transport for second stage of travel.

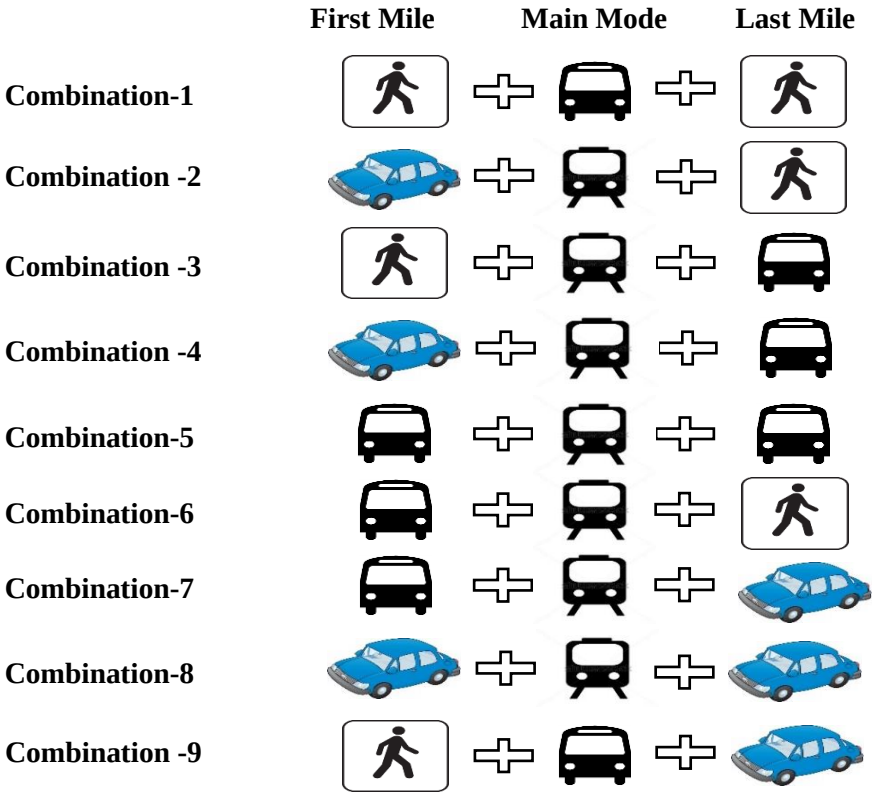

FIGURE 22. Mode Combinations (a).

Whereas, mode combination having frequency of less than 50 are joined into one category of other.

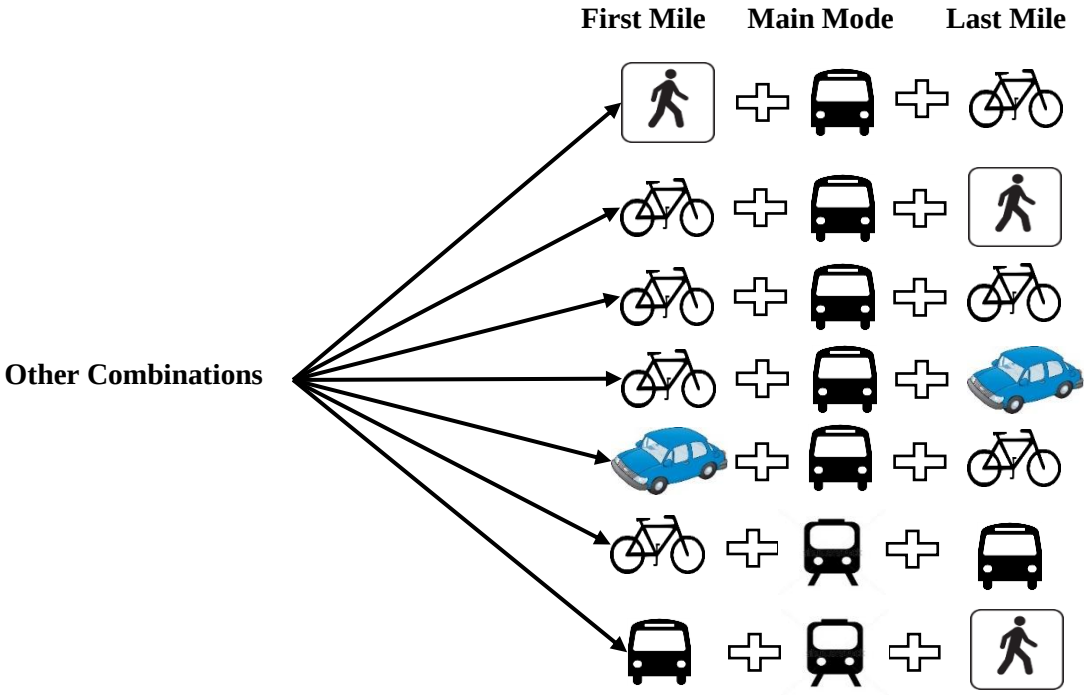

FIGURE 23. Mode Combinations (b).

The table 12 gives descriptive statistics of different mode combinations:

TABLE 12. Descriptive for Mode Combination.

Mode Combination	Frequency	Percent
W + P.T. + W	594	28.9
C + P.T. + W	130	6.3
W + P.T. + P.T.	132	6.4
C + P.T. + P.T.	197	9.6
P.T. + P.T. + P.T.	423	20.6
P.T. + P.T. + W	129	6.3
P.T. + P.T. + C	182	8.9
C + P.T. + C	99	4.8
W + P.T. + C	87	4.2
Others	269	4.0

5.2. Descriptive Analysis

Descriptive analysis helps to present extensive amount of data into a simple and sensible way. This is usually presented in form of tables and graphs. Moreover, descriptive analysis helps to understand data and paved a way for more widespread statistical analysis. This step gives information about trips, stage, individual, household, and vehicle characteristics. As information of NTS is collected through face-to-face interview and from travel-log of one week. So, data also include some missing information. DNA in the data indicates that specific category is “not application” for the respondent.

NA indicated that respondent did not response, do not know or refused to respond. Missing values in the data indicate that information provided by respondent on specific issue is not complete therefore, cannot be used.

5.2.1. Basic Statistics

The graph presented below provides information about different variables of trip, stage, individual, household and vehicles. This section only gives information about nineteen variables (see table 9) selected from NTS dataset.

a) Trip Characteristics

The graph below shows three variables from trip characteristics. Graph shows that most people execute trip to reach their home (43%) whereas, leisure (27%) is the second highest purpose for trip execution. Most of these trips have a trip distance of under 3 miles (56%). Moreover, most of the people travel 15 minutes to under 1 hour (52%) to complete their trip. Car is used as main mode of travel (96%). Moreover, public transport is second highest mode (3.9%) of transport used for travel.

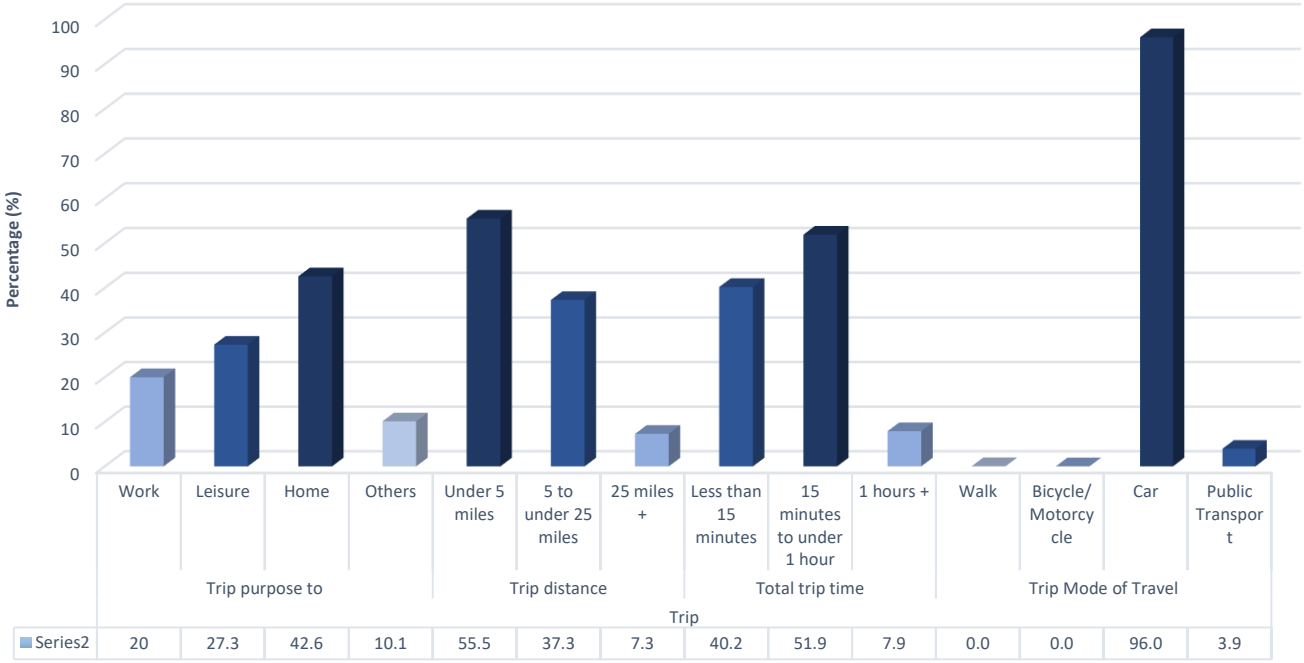

FIGURE 24. Trip Characteristics.

b) Stage Characteristics

The graph below shows percentage for four stage related variables. In stage distance, most of the stage distances belong to category of under 5 miles (58%) whereas, 5 to under 25 miles (36%) is the second highest category in stage distance. For stage travel time, most of the stages have travel time of 15 to fewer than 1 hour (51%) and most of the people have at least one person (40%) as travel party.

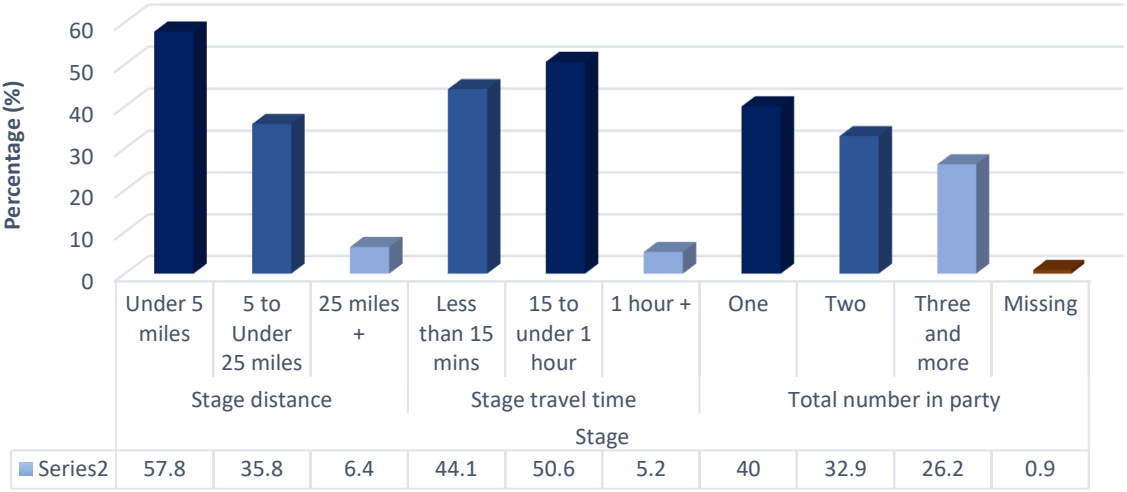

FIGURE 25. Stage Characteristics.

c) Individual Characteristics

The graph below shows percentage for five variables of individual characteristics. In age, most of the people have an age of 50 years (40%) and above whereas; middle age persons (30-49) have the second highest percentage (32%). Highest percentage (41%) of people is full time employees and most of them (70%) are educated. The percentage of people belongs to lower income (less than £25,000) group is 57%.

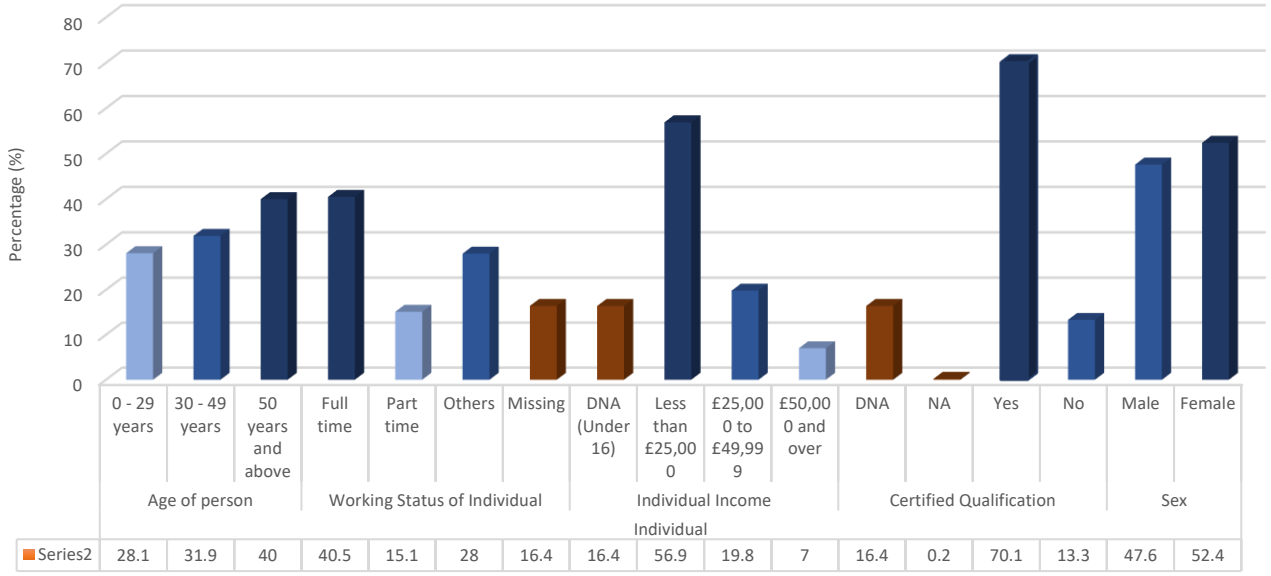

FIGURE 26. Individual Characteristics.

d) Household Characteristics

The graph below shows four variables for household characteristics. The number of household with 3 or more members is the highest (59%) where most of these households are without children (58%). The percentage of household with 2 or more people with full car license is 71%. The household income of £50,000 and over is 36%.

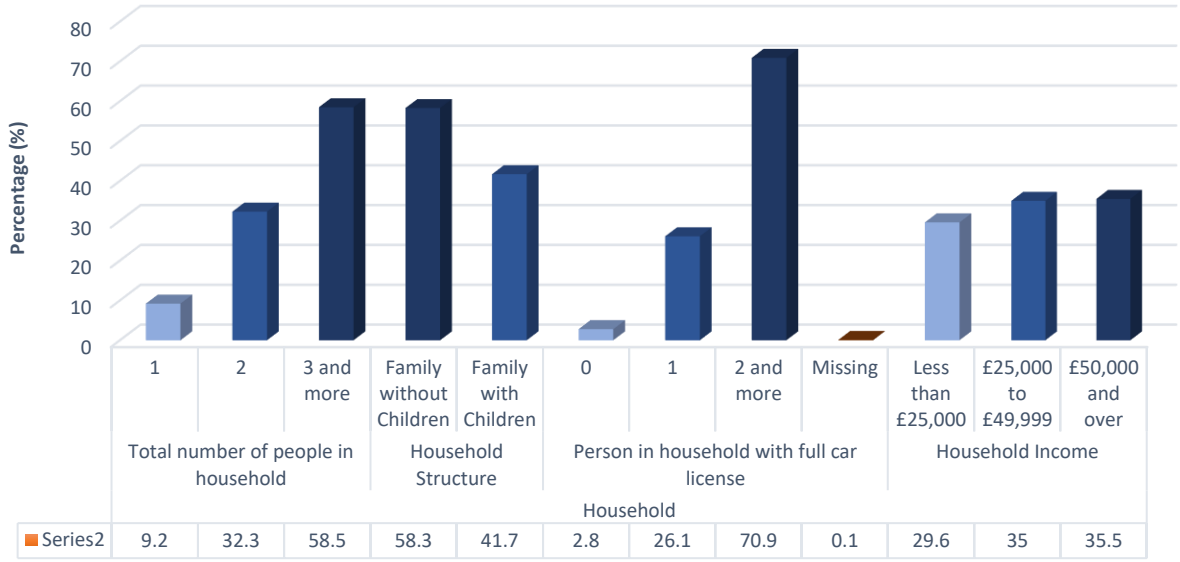

FIGURE 27. Household Characteristics.

e) Vehicle Characteristics

The table 13 shows the descriptive statistics for vehicle variables. In the target population, most people (96%) have access to car. The percentage of household with 2 or more vehicles is 54%. There are only few households (4%) that have no vehicle. The percentage of car is higher (3.6%).

TABLE 13. Vehicle Characteristics.

Variables	Variable Level	Percentage
Access to Car	Yes Access	95.7
	No Access	4.2
	Missing	0.0
Number of household vehicles	0	4.2
	1	41.5
	2 and more	54.3
Type of vehicle	Car	3.6
	Motorcycle/scooter/moped	0.1
	Other	0.1
	Missing	96.3
Vehicle's total mileage	0 - 15000 miles	0.6
	15001- 60000 miles	1.2
	60001 miles and above	1.4
	Missing	96.8

5.2.2. Interaction between Variables

a) Trip purpose and Total trip time

The cross tabulation between trip purpose and total trip time reveals that to execute home, leisure and work based trips mostly its take 15 minutes to 1 hour. Whereas, other trips like escort and non-work trips its take less than 15 minutes for people to reach their destination. Moreover, percentage of trips having trip time of 1 hour and above is higher for home, leisure and work based trips.

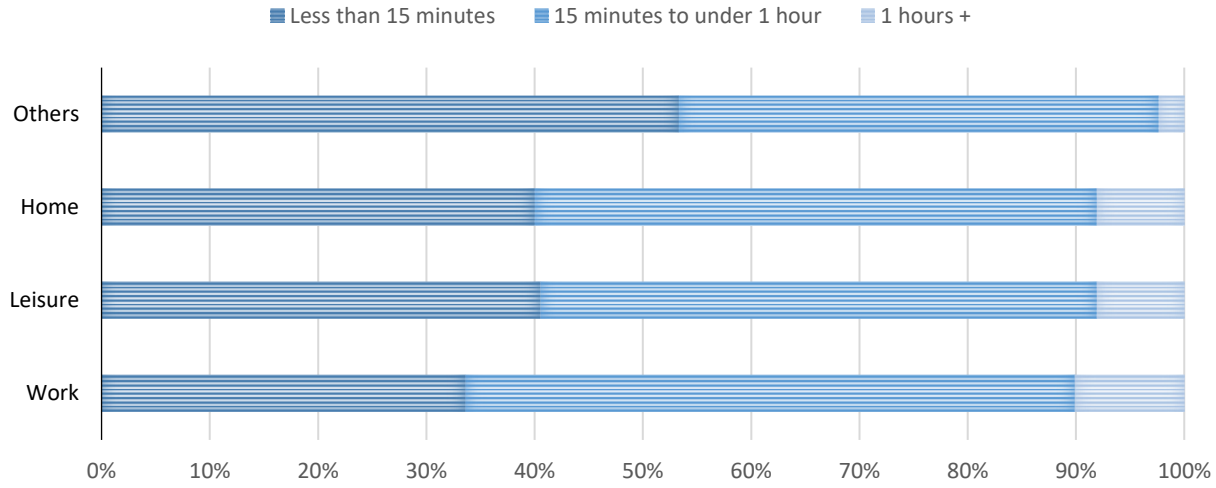

FIGURE 28. Trip purpose and Total trip time.

b) Trip Distance and Total trip time

The descriptive analysis between trip distance and trip time shows that as distance increase the total trip time also increases. Most of the trips having travel distance of under 3 miles are covered within a travel time of less than 15 minutes. Moreover, travel distances of 25 miles and above takes 1 hour plus to complete the trip.

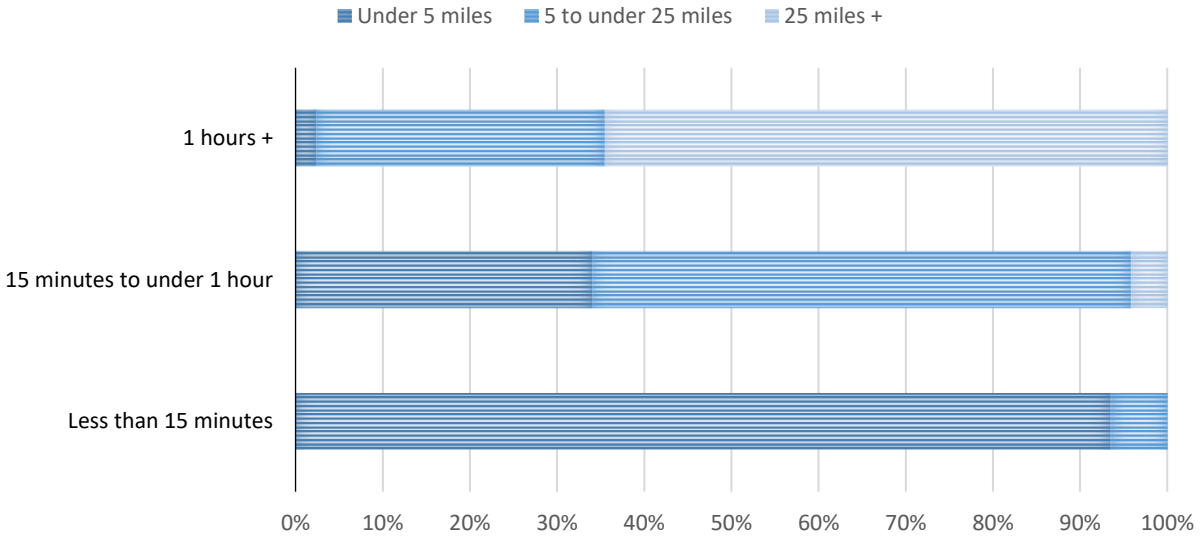

FIGURE 29. Trip Distance and Total Trip Time.

c) Trip purpose and Trip distance

The cross tabulation between trip purpose and trip distance depicts that the trip distance is higher for work related trips compared to other purposes. The percentage of trips having 25 miles and more travel distance is lower for others (Escort, non-work) trips whereas this percentage is highest for work related trips.

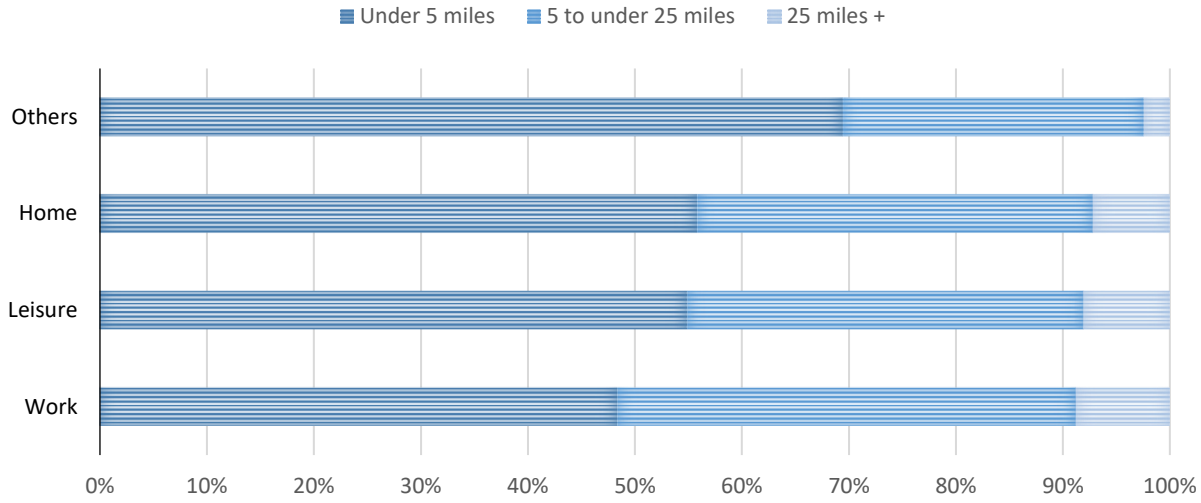

FIGURE 30. Trip purpose and Trip distance.

d) Trip purpose and Trip main mode of travel

The crosstabulation analysis between trip purpose and trip mode of travel reveals that public transport is mostly used for work and home-based trips. The use of car is higher for home-based trips compare to rest of the purposes. Walk as mode of transport is mostly used for leisure related trips. the percentage of walk as mode of transport is also higher for home-based trips.

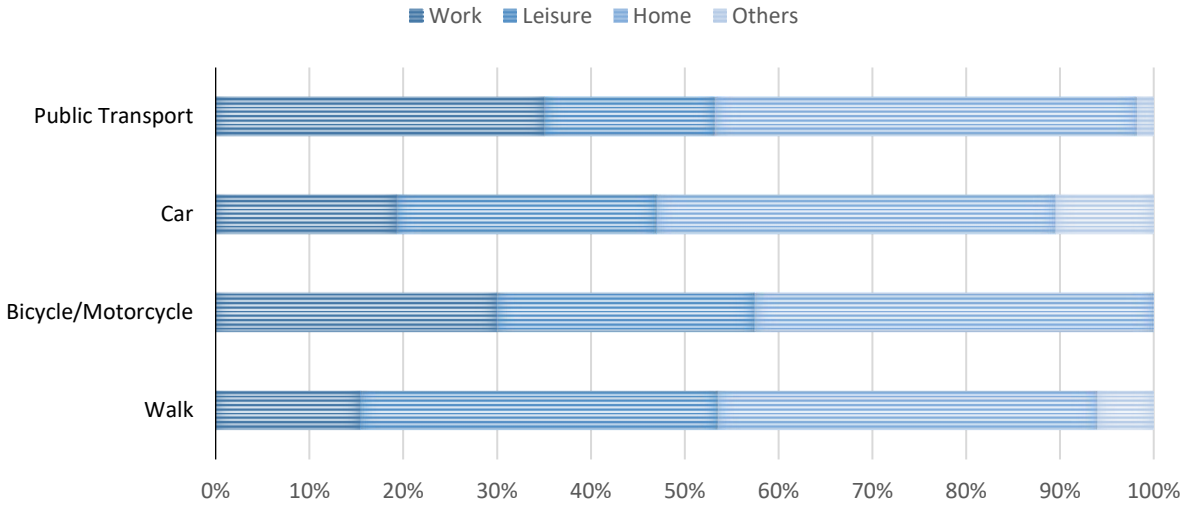

FIGURE 31. Trip purpose and Trip mode of travel.

e) Stage Distance and Stage travel time

The cross tabulation between stage distance and stage travel time reveals that short distances like under 5 miles are covered within a time of less than 15 minutes whereas, 5 to under 5 miles are mostly covered within a time frame of 1 hour and greater distances like 25 miles and above have travel time of 1 hour and above.

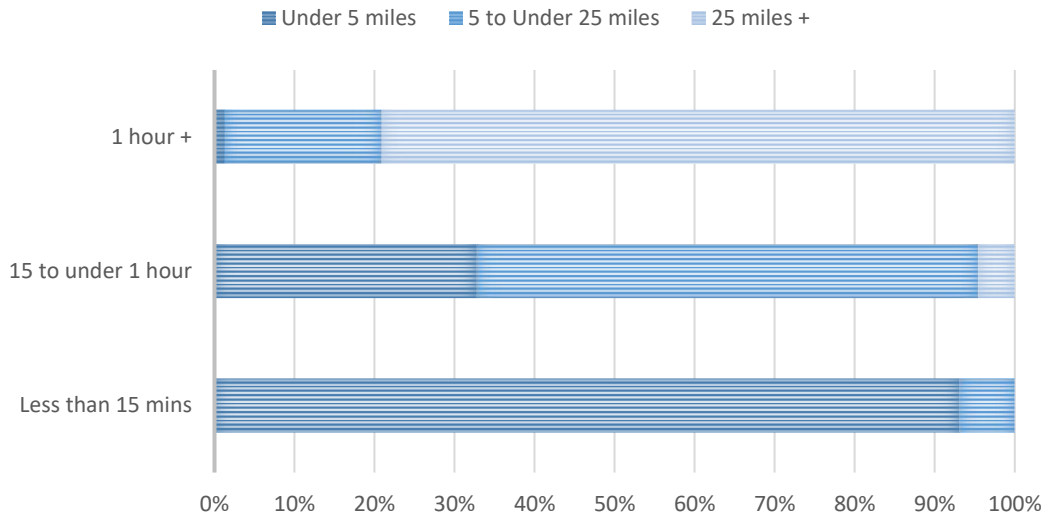

FIGURE 32. Stage Distance Stage travel time.

f) Main mode of travel and total number in party

The cross tabulation between stage mode of travel and total number in party reveals that the choice of modes like walk, bicycle and public transport is high when there is only one person in travel party but as number of person in travel party increases the shift in mode choice take place and the percentage of car use increases.

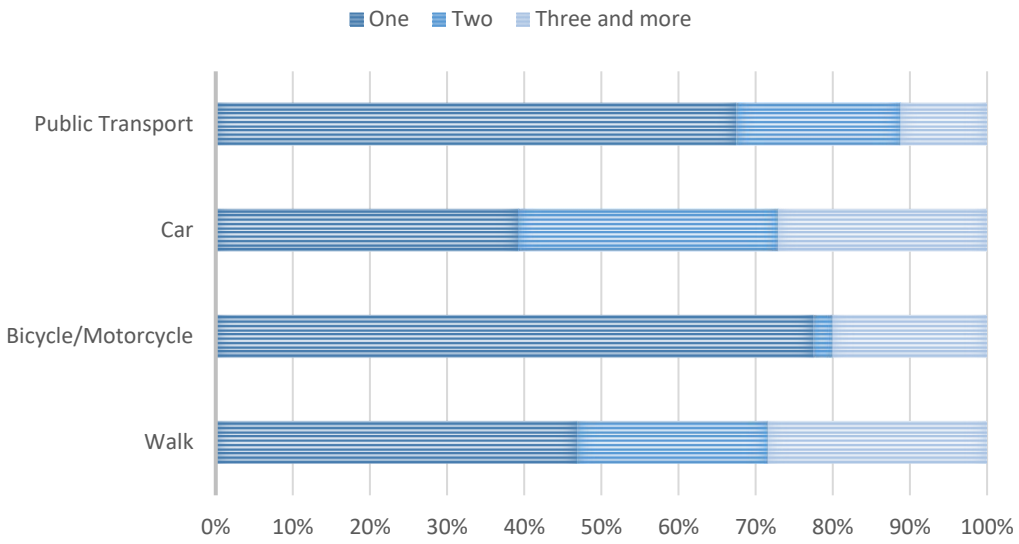

FIGURE 33. Mode of travel and Total number in Party.

g) Household structure and Number of household vehicles

The graph below shows that as percentage of families with children increases the number of household vehicles also increases. The percentage of families with children is highest for household having number of vehicles 2 and more.

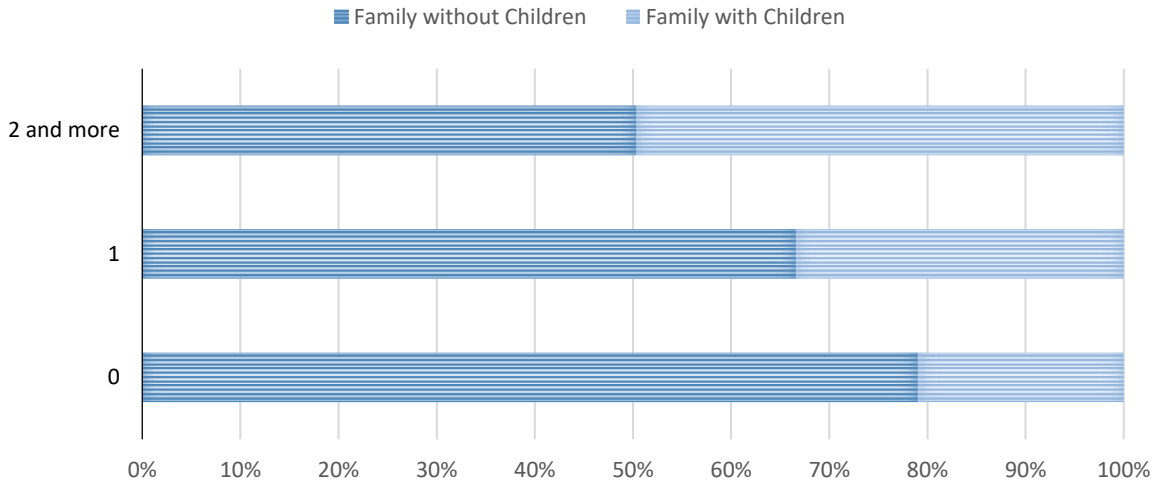

FIGURE 34. Household Structure and Number of household Vehicles.

h) Working status of individual, Individual income and Access to car

The results of cross tabulation among working status, Income and access to car reveals that car access is lower for people having full time job and individual income of less than £25,000. For people having part time working status or others type of working status have more access to car even if they have individual income of less than £25,000. For the people who do not have access to car are those which have part time or others working status and have income of less than £25,000. So, it can be concluded as working status become full time and individual income increase the access to car also upsurges.

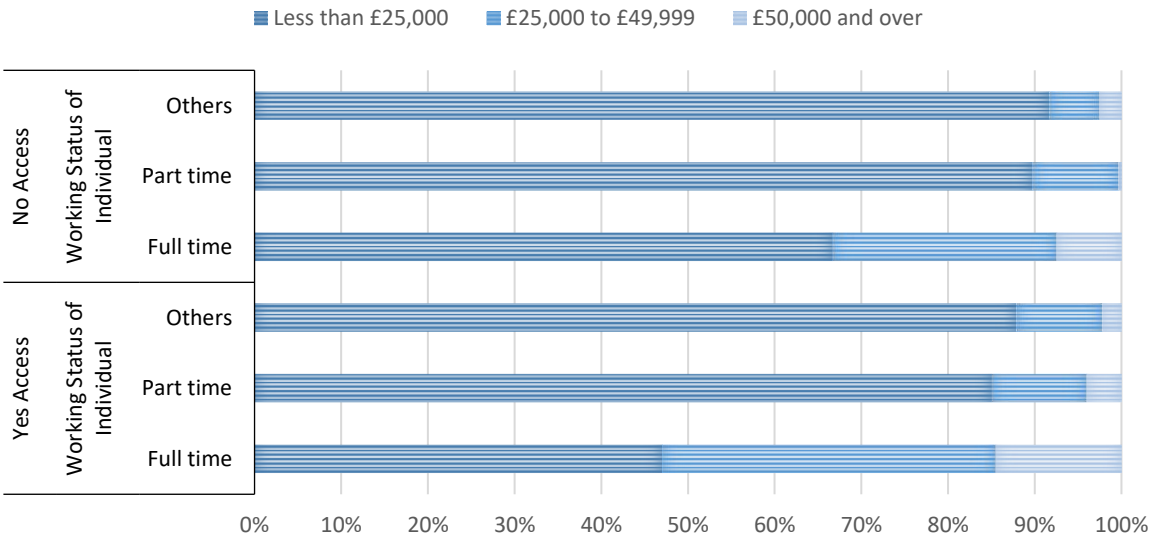

FIGURE 35. Working status, Individual income and Access to car.

5.3. Model Estimation

Statistical modelling helps to identify the relationship between dependent and explanatory variables (Lee, Ihaka, & Triggs, 2012). Moreover, it helps in development and testing of theories using causal relationship. An excellent prediction can be obtained from a well fitted model (Shmueli, 2010).

5.3.1. Binary Logistic Regression

Binary logistic regression is used to know the dependence between dependent variable (Y) and a set of explanatory variables (X) (Harrell Jr, 2015; Tranmer & Elliot, 2008). In the given analysis mode choice between solo-car-only and multi-stage trip is taken as dependent variables whereas, trip, household, individual and vehicle characteristics are taken as explanatory variables. The response of a binary logistic regression can be Y=0 or 1, with Y=1 denote that an individual chooses solo-car-only trip whereas, Y=0 denote that an individual will choose multi-stage trip. The following table 14 present the coding of dependent variable used to carry out the analysis.

TABLE 14. Dependent Variable Coding.

Dependent Variable Encoding	
Original Value	Internal Value
Multi-stage trips	0
Solo-car-only trips	1

The binary logistic regression has the form of:

$$\ln\left(\frac{P}{1-P}\right) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\beta_n x_n$$

Where P is the probability of selecting solo-car-only trip for travel, β_0 is the intercept for the logistic regression and $\beta_1 x_1$ give information about certain characteristic of a trip along with its associated parameter estimate. The variables showing significance association for choice of given alternatives are included in the model. The value of β in the model fives information about the weight of categories in independent variable. In binary logistic regression if a category has a β of less than 0.5 it's mean that individual falling in that category will choose option encoded as "0" which is multi-stage trips in the following case. If value of β exceed 0.5 value then option encoded as "1" will be chosen which is solo-car-only trip in present case.

The chi-square test is performed to know the dependencies between different variables of trips, household, vehicles and individual. The results of chi-square test reveal that following variables have strong relationship with other variables so, they are removed from final binary logistic regression.

- Trip travel time
- Age of person
- Individual income
- Education qualification
- No. of person in household with full car license
- Total number of persons in household
- Vehicle's total mileage

5.3.2. Final Model for Analysis-1

The table 15 shows the results of binary logistic regression. The first left column of the table shows the independent variables used for the analysis. One of the category of independent variable is taken as reference. The column two of the table shows the weight for each category of independent variable. Last column of the table depicts the significance of variables.

TABLE 15. Final Model for Analysis-1.

Variables	B	Sig.
Trip Purpose to (Other)[ref]		0.000
Trip Purpose to (Work)	-2.517	0.000***
Trip Purpose to (Leisure)	-1.971	0.006***
Trip Purpose to (Home)	-1.390	0.062*
Trip Distance (25 miles+) [ref]		0.000
Trip Distance (Under 5 miles)	3.200	0.000***
Trip Distance (5 to under 25 miles)	1.155	0.000***
Age of person (50 years and above) [ref]		0.385
Age of person (0 - 29 years)	0.025	0.935
Age of person (30 - 49 years)	-0.223	0.202
Sex of person (Male)	0.205	0.165
Access to Car (Yes Access)	2.261	0.099*
Working Status of Individual (Other) [ref]		0.413
Working Status of Individual (Full time)	0.019	0.928
Working Status of Individual (Part time)	-0.246	0.307
Household Structure (Family without Children)	-0.349	0.060*
Number of household vehicles (2 and more) [ref]		0.000
Number of household vehicles (0)	0.359	0.835
Number of household vehicles (1)	-1.222	0.000***
Household Income (£50,000 and over) [ref]		0.000
Household Income (Less than £25,000)	0.850	0.000***
Household Income (£25,000 to £49,999)	0.655	0.000***
Type of vehicle (Other) [ref]		0.773
Type of vehicle (Car)	-0.528	0.479
Type of vehicle (Motorcycle/scooter/moped)	-0.412	0.675
Constant	2.588	0.117

Number of Observation = 189,118
-2 Log Likelihood = 1649.531
Nagelkerke R Square = 0.224
ref = reference category
*** p < 0.01
** p < 0.05
* p < 0.10

5.3.3. Multinomial Logistic Regression

The multinomial calculated (MNL) display structure has been broadly utilized for both urban and intercity mode decision models basically because of its straightforward numerical frame, simplicity

of estimation and translation, and the capacity to include or expel decision choices. The MNL show gives the decision probabilities of every option as an element of the orderly part of the utility of the considerable number of choices. Multinomial logit (MNL) is used to estimate the probable likelihood that an individual will choose a certain mode combination. The combination can differ for each individual based on the choices of travelers made for first mile, main mode and last mile. The combination observed from Nation Travel Survey has been presented in the above figure 22 and 23.

The basic theory behind MNL is that each traveler (n) has a set of mode choice combination and each mode combination has its own utility U_{in} which is the utility of i^{th} mode combination for n^{th} traveler. Moreover, the utility of each traveler is linked to observed component V_{in} and an unobserved error. The observed component V is the function of a constant for i^{th} mode combination, beta parameter estimates, household characteristics, personal characteristics, trip characteristics, vehicle characteristics, environmental characteristics and stage characteristics for n^{th} traveler (Appleyard, 2014). The following model will be used to determine the probability of a person choosing a specific combination to execute a multi-stage trip.

Utility (mode combination C1) = function (household, personal, trip, vehicle, environmental and stage characteristics) + Error

$$\text{Utility (mode combination C1)} = V_{in} + Є$$

$$\text{Where } V_{in} = \Sigma_n \beta_i * X_{in}$$

$$P\ (Cn) = \frac{e^{Vcn}}{e^{Vc1} + e^{Vc2} + e^{Vc3} + \cdots e^{Vcn}}$$

In the final model of multinomial logistic regression analysis trip purpose is reclassified as some of the combination were missing trip purpose of "Other" as shown in table 16. So, category "Other" is merged with category of "home" for this specific analysis. Same problem is faced for the stage distance and this variable is also not included in the model. The chi-square test is performed to know the dependencies between different variables of trips, stage household, vehicles and individual. The results of chi-square test reveal that following variables have strong relationship with other variables so, they are removed from final binary logistic regression.

- Trip travel time
- Trip Distance
- Stage Travel time
- Individual income
- Education qualification
- No. of person in household with full car license
- Total number of persons in household
- Number of people in household
- Vehicle's total mileage

TABLE 16. Mode combination and Trip purpose

Mode Combination * Trip Purpose Crosstabulation					
		Trip Purpose to			
		Work	Leisure	Home	Others
Mode Combination	Others	38	6	39	0
	W + P.T. + W	216	98	262	18
	C + P.T. + W	85	25	20	0
	W + P.T. + P.T	61	25	43	3

	C + P.T. + P.T.	121	53	21	2
	P.T. + P.T. + P.T.	159	59	203	2
	P.T. + P.T. + W	29	13	87	0
	P.T. + P.T. + C	8	16	151	7
	C + P.T. + C	32	25	39	3
	W + P.T. + C	8	8	68	3

5.3.4. Final Model for Analysis-2

The table 17 gives information about model fit of multinomial logistic regression analysis. The intercept depicts the results of model when it is run without including any independent variable. The final shows the results of model including independent variables and significance of model.

TABLE 17. Model Fit Analysis-2.

Model Fitting Information				
Model	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	5885.398			
Final	4179.594	1705.804	126	0.000

The following table 18 show information about R-square values of model. SPSS gives three different values for R-square. The detail of these values is described in discussion part of this dissertation.

TABLE 18. Pseudo R-Square Analysis-2.

Pseudo-R-Square	
Cox and Snell	0.590
Nagelkerke	0.600
McFadden	0.214

The table 19 shows the results of multinomial logistic regression. First column (left) of the table shows the different combination of multi-stage trip. This is taken as dependent variables. There are 10 different combination that are extracted from the data and the influence of independent variables is evaluated on the choice of these combinations. The second column of the table gives information of independent variables. Last, two columns of the table depict the value of β and significance of each independent variables.

TABLE 19. Final Model for Analysis-2.

Parameter Estimates			
Mode Combinations		β	Sig.
W + P.T. + W	Intercept	2.696	0.005
	[Trip Purpose =Work]	-0.119	0.659
	[Trip Purpose =Leisure]	0.824	0.092*
	[Trip Purpose =Home]	0b	.
	[Trip Distance = Under 5 miles]	1.929	0.000***

	[Trip Distance =5 to Under 25 miles]	2.980	0.000***
	[Trip Distance = 25 miles +]	0b	.
	[Household Income = Less than £25,000]	0.006	0.989
	[Household Income =£25,000 to £49,999]	0.006	0.986
	[Household Income =£50,000 and over]	0b	.
	[Household Structure= Family without Children]	0.426	0.136
	[Household Structure= Family with Children]	0b	.
	[Age of person=0 - 29 years]	-0.796	0.029**
	[Age of person=30-49 years]	0.472	0.181
	[Age of person=50 years and above]	0b	.
	[Sex of person=Male]	-1.161	0.000***
	[Sex of person=Female]	0b	.
	[Access to Car=Yes Access]	-1.568	0.000***
	[Access to Car=No Access]	0b	.
	[Working Status of Individual=Full time]	-2.260	0.000***
	[Working Status of Individual=Part time]	-2.133	0.001***
	[Working Status of Individual=Others]	0b	.
	[Any certificated educational qualifications=Yes]	1.118	0.016**
	[Any certificated educational qualifications=No]	0b	.
C + P.T. + W	Intercept	-0.224	0.853
	[Trip Purpose =Work]	1.715	0.000***
	[Trip Purpose =Leisure]	2.083	0.000***
	[Trip Purpose =Home]	0b	.
	[Trip Distance = Under 5 miles]	-2.819	0.001***
	[Trip Distance =5 to Under 25 miles]	1.049	0.004***
	[Trip Distance = 25 miles +]	0b	.
	[Household Income = Less than £25,000]	-0.734	0.189
	[Household Income =£25,000 to £49,999]	0.719	0.068*
	[Household Income =£50,000 and over]	0b	.
	[Household Structure= Family without Children]	0.759	0.030**
	[Household Structure= Family with Children]	0b	.
	[Age of person=0 - 29 years]	-1.429	0.001***
	[Age of person=30-49 years]	-0.466	0.247
	[Age of person=50 years and above]	0b	.
	[Sex of person=Male]	-2.244	0.000***
	[Sex of person=Female]	0b	.

	[Access to Car=Yes Access]	0.595	0.311
	[Access to Car=No Access]	0b	.
	[Working Status of Individual=Full time]	-1.687	0.013**
	[Working Status of Individual=Part time]	-1.796	0.015**
	[Working Status of Individual=Others]	0b	.
	[Any certificated educational qualifications=Yes]	1.656	0.020**
	[Any certificated educational qualifications=No]	0b	.
W + P.T. + P.T.	Intercept	2.085	0.057
	[Trip Purpose =Work]	0.379	0.237
	[Trip Purpose =Leisure]	1.275	0.017**
	[Trip Purpose =Home]	0b	.
	[Trip Distance = Under 5 miles]	-1.906	0.003***
	[Trip Distance =5 to Under 25 miles]	1.475	0.000***
	[Trip Distance = 25 miles +]	0b	.
	[Household Income = Less than £25,000]	-0.213	0.664
	[Household Income =£25,000 to £49,999]	0.027	0.947
	[Household Income =£50,000 and over]	0b	.
	[Household Structure= Family without Children]	0.759	0.028**
	[Household Structure= Family with Children]	0b	.
	[Age of person=0 - 29 years]	-1.444	0.001***
	[Age of person=30-49 years]	0.312	0.436
	[Age of person=50 years and above]	0b	.
	[Sex of person=Male]	-1.215	0.001***
	[Sex of person=Female]	0b	.
	[Access to Car=Yes Access]	-1.444	0.003***
	[Access to Car=No Access]	0b	.
	[Working Status of Individual=Full time]	-2.362	0.000***
	[Working Status of Individual=Part time]	-2.649	0.000***
	[Working Status of Individual=Others]	0b	.
	[Any certificated educational qualifications=Yes]	1.707	0.007***
	[Any certificated educational qualifications=No]	0b	.
C + P.T. + P.T.	Intercept	2.694	0.010
	[Trip Purpose =Work]	1.922	0.000***
	[Trip Purpose =Leisure]	2.497	0.000***
	[Trip Purpose =Home]	0b	.
	[Trip Distance = Under 5 miles]	-4.312	0.000***

	[Trip Distance =5 to Under 25 miles]	0.314	0.375
	[Trip Distance = 25 miles +]	0b	.
	[Household Income = Less than £25,000]	-0.221	0.648
	[Household Income =£25,000 to £49,999]	-0.105	0.792
	[Household Income =£50,000 and over]	0b	.
	[Household Structure= Family without Children]	0.355	0.265
	[Household Structure= Family with Children]	0b	.
	[Age of person=0 - 29 years]	-1.829	0.000***
	[Age of person=30-49 years]	0.181	0.634
	[Age of person=50 years and above]	0b	.
	[Sex of person=Male]	-1.357	0.000***
	[Sex of person=Female]	0b	.
	[Access to Car=Yes Access]	-0.056	0.916
	[Access to Car=No Access]	0b	.
	[Working Status of Individual=Full time]	-2.546	0.000***
	[Working Status of Individual=Part time]	-2.138	0.002***
	[Working Status of Individual=Others]	0b	.
	[Any certificated educational qualifications=Yes]	0.193	0.721
	[Any certificated educational qualifications=No]	0b	.
P.T. + P.T. + P.T.	Intercept	4.616	0.000
	[Trip Purpose =Work]	-0.210	0.447
	[Trip Purpose =Leisure]	0.632	0.204
	[Trip Purpose =Home]	0b	.
	[Trip Distance = Under 5 miles]	-2.890	0.000***
	[Trip Distance =5 to Under 25 miles]	1.997	0.000***
	[Trip Distance = 25 miles +]	0b	.
	[Household Income = Less than £25,000]	-0.912	0.041**
	[Household Income =£25,000 to £49,999]	-0.190	0.598
	[Household Income =£50,000 and over]	0b	.
	[Household Structure= Family without Children]	0.328	0.264
	[Household Structure= Family with Children]	0b	.
	[Age of person=0 - 29 years]	-1.635	0.000***
	[Age of person=30-49 years]	0.166	0.641
	[Age of person=50 years and above]	0b	.
	[Sex of person=Male]	-1.283	0.000***
	[Sex of person=Female]	0b	.

	[Access to Car=Yes Access]	-2.338	0.000***
	[Access to Car=No Access]	0b	.
	[Working Status of Individual=Full time]	-2.749	0.000***
	[Working Status of Individual=Part time]	-2.879	0.000***
	[Working Status of Individual=Others]	0b	.
	[Any certificated educational qualifications=Yes]	1.887	0.000***
	[Any certificated educational qualifications=No]	0b	.
P.T. + P.T. + W	Intercept	1.647	0.159
	[Trip Purpose =Work]	-1.048	0.002***
	[Trip Purpose =Leisure]	0.161	0.774
	[Trip Purpose =Home]	0b	.
	[Trip Distance = Under 5 miles]	-1.016	0.065*
	[Trip Distance =5 to Under 25 miles]	1.830	0.000***
	[Trip Distance = 25 miles +]	0b	.
	[Household Income = Less than £25,000]	-0.300	0.549
	[Household Income =£25,000 to £49,999]	0.135	0.738
	[Household Income =£50,000 and over]	0b	.
	[Household Structure= Family without Children]	0.584	0.084*
	[Household Structure= Family with Children]	0b	.
	[Age of person=0 - 29 years]	-1.438	0.001***
	[Age of person=30-49 years]	0.818	0.045**
	[Age of person=50 years and above]	0b	.
	[Sex of person=Male]	-0.849	0.020**
	[Sex of person=Female]	0b	.
	[Access to Car=Yes Access]	-1.540	0.002***
	[Access to Car=No Access]	0b	.
	[Working Status of Individual=Full time]	-2.519	0.000***
	[Working Status of Individual=Part time]	-3.748	0.000***
	[Working Status of Individual=Others]	0b	.
	[Any certificated educational qualifications=Yes]	2.479	0.001***
	[Any certificated educational qualifications=No]	0b	.
P.T. + P.T. + C	Intercept	3.719	0.000
	[Trip Purpose =Work]	-2.839	0.000***
	[Trip Purpose =Leisure]	-0.639	0.244
	[Trip Purpose =Home]	0b	.
	[Trip Distance = Under 5 miles]	-2.614	0.000***

	[Trip Distance =5 to Under 25 miles]	0.119	0.741
	[Trip Distance = 25 miles +]	0b	.
	[Household Income = Less than £25,000]	0.167	0.729
	[Household Income =£25,000 to £49,999]	-0.479	0.245
	[Household Income =£50,000 and over]	0b	.
	[Household Structure= Family without Children]	0.277	0.390
	[Household Structure= Family with Children]	0b	.
	[Age of person=0 - 29 years]	-1.855	0.000***
	[Age of person=30-49 years]	0.144	0.709
	[Age of person=50 years and above]	0b	.
	[Sex of person=Male]	-1.420	0.000***
	[Sex of person=Female]	0b	.
	[Access to Car=Yes Access]	0.301	0.587
	[Access to Car=No Access]	0b	.
	[Working Status of Individual=Full time]	-1.876	0.004***
	[Working Status of Individual=Part time]	-1.884	0.008***
	[Working Status of Individual=Others]	0b	.
	[Any certificated educational qualifications=Yes]	0.509	0.354
	[Any certificated educational qualifications=No]	0b	.
C + P.T. + C	Intercept	0.443	0.706
	[Trip Purpose =Work]	0.004	0.990
	[Trip Purpose =Leisure]	1.260	0.021**
	[Trip Purpose =Home]	0b	.
	[Trip Distance = Under 5 miles]	0.140	0.759
	[Trip Distance =5 to Under 25 miles]	1.019	0.013**
	[Trip Distance = 25 miles +]	0b	.
	[Household Income = Less than £25,000]	1.701	0.001***
	[Household Income =£25,000 to £49,999]	1.741	0.000***
	[Household Income =£50,000 and over]	0b	.
	[Household Structure= Family without Children]	-0.705	0.061*
	[Household Structure= Family with Children]	0b	.
	[Age of person=0 - 29 years]	-2.440	0.000***
	[Age of person=30-49 years]	-1.255	0.004***
	[Age of person=50 years and above]	0b	.
	[Sex of person=Male]	-2.112	0.000***
	[Sex of person=Female]	0b	.

	[Access to Car=Yes Access]	0.749	0.202
	[Access to Car=No Access]	0b	.
	[Working Status of Individual=Full time]	-2.189	0.001***
	[Working Status of Individual=Part time]	-2.400	0.001***
	[Working Status of Individual=Others]	0b	.
	[Any certificated educational qualifications=Yes]	2.153	0.001***
	[Any certificated educational qualifications=No]	0b	.
W + P.T. + C	Intercept	2.369	0.054
	[Trip Purpose =Work]	-2.069	0.000***
	[Trip Purpose =Leisure]	-0.291	0.629
	[Trip Purpose =Home]	0b	.
	[Trip Distance = Under 5 miles]	-2.375	0.004***
	[Trip Distance =5 to Under 25 miles]	0.956	0.013**
	[Trip Distance = 25 miles +]	0b	.
	[Household Income = Less than £25,000]	-1.043	0.098*
	[Household Income =£25,000 to £49,999]	0.359	0.389
	[Household Income =£50,000 and over]	0b	.
	[Household Structure= Family without Children]	0.525	0.165
	[Household Structure= Family with Children]	0b	.
	[Age of person=0 - 29 years]	-2.084	0.000***
	[Age of person=30-49 years]	-0.426	0.314
	[Age of person=50 years and above]	0b	.
	[Sex of person=Male]	-2.091	0.000***
	[Sex of person=Female]	0b	.
	[Access to Car=Yes Access]	-0.422	0.462
	[Access to Car=No Access]	0b	.
	[Working Status of Individual=Full time]	-1.653	0.017**
	[Working Status of Individual=Part time]	-2.174	0.005***
	[Working Status of Individual=Others]	0b	.
	[Any certificated educational qualifications=Yes]	1.818	0.017**
	[Any certificated educational qualifications=No]	0b	.

a. The reference category is Others
b. reference category
c. *** p-value<0.01
d. ** p-value<0.05
e. * p-value<0.10

6.0. DISCUSSION

6.1. Solo-car-only and Multi-Stage Trip (Analysis-1)

The results of binary logistic regression for trip purpose reveal that it is significantly associated with choice of solo-car-only trip. Trip purpose for work (β = -2.52, p-value = 0.000), leisure (β = -1.97, p-value = 0.006) are negative associated at a significance level of 0.05 whereas, home related trips (β = -1.39, p-value = 0.062) are negative associated with choice of solo-car-only trips at significance level of 0.1 with reference to trip bonding other purposes. The trip distance is significantly associated with choice of solo-car trips. The probability to choose solo-car-only trip increase as distance trip distance decreases. The probability to use car as mode of transport is high for distance under 5 miles (β = 3.20, p-value = 0.000) and for distance between 5 to under 25 miles (β = 1.16, p-value = 0.000) compare to the distance above 25 miles. The analysis of data reveals that age of respondent and sex of person are not associated with choice of solo-car-only trips or multi-stage trips.

The access to car is significantly associated with choice of solo-car-only trip. The probability to use car as mode of transport is high (β = 2.26, p-value = 0.099) for the people having access to car at a significant level of 0.10. The analysis also depicts that working status of individual is not associated with mode choice. The household structure is significantly associated with mode choice. The probability to use car as mode of transport is low (β = -0.36, p-value = 0.060) for the families without children compared to families with children at a significant level of 0.10.

Binary logistic regression result shows that for household having 1 or more vehicles, mode choice is significantly associated with number of household vehicles. As number of household vehicles increases the probability to use car as mode also increases. The probability to use car as mode for household having only 1 vehicle is low (β = -1.22, p-value = 0.000) compared to household having 2 or more vehicles. For household having no vehicle mode choice is not associated with number of household vehicles. Household income is also positively associated with mode choice behavior. The probability to travel by car is lowest (β = 0.66, p-value = 0.000) for household with an income of £25,000 to £49,999 whereas this probability is a little bit lower (β = 0.85, p-value = 0.000) for household with an income of Less than £25,000 compared to household having income of £50,000 and over. Type of vehicle is not associated with mode choice behavior.

The following model describes the choice for solo-car-only and multi-stage trips based on stage characteristics.

$$\ln\left(\frac{P}{1-P}\right) = 2.59 - 2.52x_{1st\ purpose} - 1.97x_{2nd\ purpose} - 1.39x_{3rd\ purpose} + 3.20x_{1st\ Distance} + 1.16x_{2nd\ Distance} + 2.26x_{1st\ access} - 0.35x_{1st\ hh\ structure} - 1.22x_{1nd\ hh\ Vehicles} + 0.85x_{1st\ hh\ Income} + 0.66x_{2nd\ hh\ Income}$$

$x_{1st\ purpose}$ = Work, $x_{2nd\ purpose}$ = Leisure, $x_{3rd\ purpose}$ = Home, $x_{1st\ Distance}$ = Under 5 miles, $x_{2nd\ Distance}$ = 5 to under 25 miles, $x_{1st\ access}$ = Yes Access, $x_{1st\ hh\ structure}$ = Family without children, $x_{1st\ hh\ vechicles}$ = 1, $x_{1st\ hh\ Income}$ = Less than £25,000, $x_{2nd\ hh\ Income}$ = £25,000 to £49,999.

6.2. Multi-Stage Trip (Analysis-2)

6.2.1. Model

The model fitting gives information about the parameter of which model fitness is calculated. The "Intercept Only" describes the fitness of model without control of any other predictor variables and fits an intercept for prediction of outcome variables (UCLA, 2017). The final value in the model indicates the fitness of the model in the presence of other predictor variables. This value is achieved through an iterative process which maximizes the log likelihood of outcome variables. The Chi-square value under Log likelihood Ratio Statistic Test (LRS) indicates that one of the predictors' regression

coefficient is non-zero in the final model (UCLA, 2017). The LRS can be calculated using following formula:

$$LRS = -2*[L \text{ null model} – L \text{ fitted model}] = 6716.177– 4629.212= 2086.965$$

where L (null model) is the value of log likelihood for response variable/Intercept only and L (fitted model) shows the value of log likelihood for final iteration including all parameters.

Significance gives information about the probability of getting LRS test values as extreme as possible, then observed value under the null hypothesis (UCLA, 2017). The value of p is compared to significance level which is our willingness to accept a type I error, which is typically taken as 0.05 or 0.01 (UCLA, 2017). So, here it shows a a value of significance ($p<0.05$).

6.2.2. Pseudo R-Square

Pseudo R-square value is used to evaluate the model strength. Logistic regression does not have a value equivalent to R^2 as found in OLS regression (Field, 2013; Salkind, 2007). So, it presents three pseudo-R-square values. The large R^2 value indicates that most of the variation in the data is explained by the model, to a maximum of value 1 (Field, 2013; Salkind, 2007). It is not possible to have one single R^2 for a regression model with categorical variables. Therefore, three different methods are used for estimation of the coefficient of determination. In Cox and Snell's R^2, 1 is based on log-likelihood for the model compared to the baseline model. However, the outcomes with categorizing have theoretically maximum value which is less than 1 (Field, 2013; Salkind, 2007). The value of Cox and Snell's R^2 for given model is 0.590 which is a good value. Nagelkerke's R^2 is another version of Cox & Snell R^2 with certain adjustment to cover the full range between 0 and 1 (Field, 2013; Salkind, 2007). In given case this value is 0.600 which is a good value as well. McFadden's R^2 is a version of Cox & Snell's, having log-likelihood kernels null model and for fitted model. A good R^2 for this version varies according to its application (Field, 2013; Salkind, 2007). This is most useful for comparison of competing models of same data. The model with highest R^2 is considered as the best model. The value of McFadden of this model is 0.214.

An important aspect of the multinomial logit model is that it estimates k-1 models, where k is the levels of the outcome variable. At present, SPSS is treating Trip Purpose for Others as the referent group and therefore estimated a model for the trip purpose of Work, Leisure and Home relative to Others. In stage distance, the distance of 25 miles and above is taken as the reference category. In household income, the income of £50,000 and above and for household structure family with children is treated as the reference category. In the age of the individual, the age of 50 years and above and for sex of person male is taken as the reference category. The category of others and no access is treated as the reference category for the working status of individual and access to car respectively. The relative log odds of being in different combination versus in other combination is explained as follows:

6.2.3. Walk + Public Transport + Walk (Combination-1)

The trip purpose is significantly associated (p-value<0.05) with the choice of combination-1 for trips carried out for leisure. Leisure ($\beta = 0.824$) related trips have less weight compare to home based trip hence they have less probability to influence the choice of combination-1. The trip distance is significantly associated (p-value<0.01) with the choice of combination-1 relative to other combination. In comparison to trip having a travel distance of 25 miles and above; the trips having a distance of fewer than 5 miles ($\beta = 1.929$), and 5 to under 25 miles ($\beta = 2.980$) have more contribution to the choice of combination-1. The results of the analysis reveal that Household Income and Household structure do not influence the choice of this combination. The multinomial regression analysis reveals that as the age of a person increases the choice for the combination-1 decreases. Age is an influencing factor (p-

value<0.05) for the choice of combination-1 only for the individual having age less than 29 years. The persons having an age between 0-29 years have less weight to choose the combination-1 (β = -0.796) compared to an individual having an age of 50 years and above. The gender of the individual has a significant influence on the choice of combination-1. The results show that male weight (β = -1.161, p-value<0.01) less for the choice of combination-1 compared to female. Access to car is also associated with the choice of combination-1. People having access to a car have a lower probability (β = -1.568, p-value<0.05) of choosing combination-1 for their trips in comparison with people having no access to car. This show that people with access to the car do not have a preference for a combination including walk as a mode of transport. The results of the multinomial regression analysis reveal that working status of an individual is significantly associated with the choice of combination-1. The probability to choose combination-1 for travel is lowest for individual doing a full-time job (β = -2.260, p-value<0.01). The probability is a little bit higher for people having part time job (β = -2.133, p-value<0.01), but this is still less compared to the people having other jobs. The individual's education level is also an influential factor (p-value<0.05) for the choice of combination-1. Individual's with certified education qualification (β = 1.118) have more probability to choose combination-1 compared to a person with no education.

6.2.4. Car + Public Transport + Walk (Combination-2)

The trip purpose is significantly associated (p-value<0.01) with the choice of combination-2. Work related (β = 1.715) and leisure (β = 2.083) trips have more weight as compared to home-based trips hence they have more probability to influence the choice of combination-2. The trip distance is significantly associated (p<0.01) with the choice of combination-2 relative to other combination. The trips having a distance between 5 to under 25 miles (β = 1.049) have more probability to adopt combination-2, moreover for trips having trip distance less than 5 miles (β = -2.819) the probability to choose combination-2 is less in comparison with trips having a distance of 25 miles and above. The result of the analysis reveals that only household with an income of £25,000 to £49,999 has the significant association (p-value<0.10) with choice of combination-2. The household with income £25,000 to £49,999 has less weight (β = 0.719) for the choice of combination-2 compared to a household with an income of £50,000 and more. Household structure is significantly associated (p<0.05) with choice of combination-2. The probability to choose this combination is lower for families with children (β = 0.759) compare to families having children. Age is an influencing factor (p<0.01) for the choice of combination-2 only for the individual having age less than 29 years. The persons having an age between 0-29 years have less probability to choose the combination-2 (β = -1.429) as compared to an individual having an age of 50 years and above. The gender of the individual has a significant influence on the choice of combination-2. The results show that male have less probability (β = -2.244, p-value<0.01) to choose combination-2 compared to female. Access to car is not significantly associated with the choice of combination-2. Working status of an individual is significantly associated (p-value<0.05) with choice of combination-2. The probability to choose combination-2 for travel is lowest for individual doing a part-time job (β = -1.796). The probability is a little bit high for people having a full-time job (β = -1.687), but this is still small compared to the people having other jobs. The individual education is also an influential factor (p-value<0.05) for the choice of combination-2. Individual with some education qualification (β = 1.656) have more probability to choose combination-2 compared to a person with no education.

6.2.5. Walk + Public Transport + Public Transport (Combination-3)

The trip purpose is significantly associated (p-value<0.05) with the choice of combination-3 for trips carried in course of leisure. Leisure (β = 1.275) related trips have more weight for the choice of combination-3 compared to the home-based trip. The trip related to leisure will have more probability

to choose combination-3. The trip distance is significantly associated ($p<0.01$) with the choice of combination-3. The trips having distance between 5 to under 25 miles ($\beta = 1.475$) have more probability to choose the combination-3, moreover, for trips having trip distance less than 5 miles ($\beta = -1.906$) the probability to choose combination-3 is less compared to trips having a distance of 25 miles and above. Household income is not significantly associated with the choice of combination-3. Household structure is significantly associated ($p<0.05$) with the choice of combination-3. The probability to choose combination-3 is lower for families with children ($\beta = 0.759$) compare to families having children. Age is an influencing factor ($p<0.01$) for the choice of combination-3 only for the individual having age less than 29 years. The persons having age between 0-29 years have less probability to choose the combination-3 ($\beta = -1.444$) compared to an individual having an age of 50 years and above. The gender of the individual is significantly associated (p-value<0.01) with the choice of combination-3. The results show that male have fewer weights ($\beta = -1.215$) for choose combination-3 compared to female. The multinomial logistic regression results show that access to car is significantly associated (p-value<0.01) with the choice of combination-3. A household with access to car has less probability ($\beta = -1.444$) to choose combination-3 compared to a household with access to a vehicle. Working status of an individual is significantly associated (p-value<0.01) with the choice of combination-3. The individuals having a full time ($\beta = -2.362$), and part time ($\beta = -2.649$) have less weight for the choice of combination-3 compare to persons having other jobs. The individual education is significantly associated (p-value<0.01) with a choice of combination-3. Individual with education qualification ($\beta = 1.707$) have more probability to choose combination-3 compared to a person with no education.

6.2.6. Car + Public Transport + Public Transport (Combination-4)

The multinomial logistic regression results show that trip purpose is significantly associated (p-value<0.01) with the choice of combination-4. Work related ($\beta = 1.922$) and leisure ($\beta = 2.497$) trips have more weight compared to trip with a home purpose. Therefore, the choice combination will be high for work and leisure related trips. The trip distance is significantly associated (p-value<0.01) with the choice of combination-4 for distance under 5 miles. The trips having distance under 5 miles ($\beta = -4.312$) have less probability to choose combination-4 compared to trips having a distance of 25 miles and above. Household income and household structure are not significantly associated with the choice of combination-4. The results of the analysis show that only person having age between 0-29 years have a significant association (p-value<0.01) for the choice of combination-4. The person with age of 0-29 years has less weight ($\beta = -1.829$) for the choice of combination-4 compare to an individual with age 50 years and above. Sex of person is associated (p-value<0.01) with the choice of combination-4. The results show that male have less probability to choose combination-4 ($\beta = -1.357$) compared to female. Access to car is not significantly associated with the choice of combination-4. Working status of an individual is significantly associated (p-value<0.01) with the choice of combination-4. The results show that full time ($\beta = -2.546$) and part time ($\beta = -2.138$) worker has less weight for the choice of combination-4 compare to an individual with other working status. Education is not significantly associated with the choice of combination-4.

6.2.7. Public Transport + Public Transport + Public Transport (Combination-5)

The trip purpose is not significantly associated with the choice of combination-5. The trip distance is significantly associated ($p<0.01$) with the choice of combination-5. The trips having distance between 5 to under 25 miles ($\beta = 1.997$) have more probability to choose combination-5 compared to trips having a distance of 25 miles and above. For trips having a trip distance less than 5 miles ($\beta = -2.890$) the probability to choose combination-5 is less compared to trips having a distance of 25 miles and above. Household income is significantly associated (p-value<0.05) with the choice of combination-5 for income less than £25,000. Household having income less than £25,000 have less

weight (β = -0.912) to choose combination-5 compared to household having income £50,000 and above. Household structure is not significantly associated with the choice of combination-5. Age is significantly associated with (p<0.01) choice of combination-5 only for the individual having age less than 29 years. The persons having age between 0-29 years have less weight (β = -1.635) for selection of combination-5 compared to an individual having an age of 50 years and above. The gender of the individual is significantly associated (p-value<0.01) with the choice of combination-5. The results show that male have fewer weights (β = -1.283) for choose combination-5 compared to female. The multinomial logistic regression results show that access to car is significantly associated (p-value<0.01) with a choice of combination-5. A household with access to car has less probability (β = -2.338) to choose combination-5 compared to a household with access to vehicle. Working status of an individual is significantly associated (p-value<0.01) with a choice of combination-5. The individuals having a full time (β = -2.749), and part time (β = -2.879) have less weight for the choice of combination-5 compare to persons having other jobs. The individual education is significantly associated (p-value<0.01) with a choice of combination-5. Individual with education qualification (β = 1.887) have more probability to choose combination-5 compared to a person with no education.

6.2.8. Public Transport + Public Transport + Walk (Combination-6)

The trip purpose is significantly associated (p-value<0.01) with the choice of combination-6 for trips carried out for work. Work (β = -1.048) related trips have less weight for the choice of combination-6 compared to the home-based trip. Therefore, trips related to work will have less probability to choose combination-6. The trip distance is significantly associated with the choice of combination-6. The trips having distance between 5 to under 25 miles (β = 1.830, p-value<0.01) have more probability for the choice of combination-6. For trips having a trip distance less than 5 miles (β = -1.016, p-value<0.10) the probability for the choice of combination-6 is less compared to trips having a distance of 25 miles and above. Household income is not significantly associated with the choice of combination-6. Household structure is significantly associated (p<0.10) with a choice of combination-6. The probability to choose combination-6 is lower for families with children (β = 0.584) compare to families having children. Age is an influencing factor for the choice of combination-6. The persons having age between 0-29 years (β = -1.438) and age between 30-49 years (β = 0.818) have less probability to choose the combination-6 compared to an individual having an age of 50 years and above. The gender of the individual is significantly associated (p-value<0.05) with the choice of combination-6. The results show that male have fewer weights (β = -0.849) for choose combination-6 compared to female. The multinomial logistic regression results show that access to car is significantly associated (p-value<0.01) with the choice of combination-6. A household with access to car has less probability (β = -1.540) to choose combination-6 compared to a household with access to vehicle. Working status of an individual is significantly associated (p-value<0.01) with the choice of combination-6. The individuals having a full time (β = -2.519), and part time (β = -3.748) have less weight for the choice of combination-6 compare to persons having other jobs. The individual education is significantly associated (p-value<0.01) with the choice of combination-6. An individual with education qualification (β = 2.479) has more probability to choose given combination compared to a person with no education.

6.2.9. Public Transport + Public Transport + Car (Combination-7)

The trip purpose is significantly associated (p-value<0.01) with the choice of combination-7 for trips carried out for work. Work (β = -2.839) related trips have less weight for the choice of combination-7 compared to the home-based trip. So, trips related to work will have less probability to choose combination-7. The trip distance is significantly associated (p-value<0.01) with the choice of combination-7 for distance under 5 miles. The trips having distance under 5 miles (β = -2.614) have less probability to choose combination-7 compared to trips having a distance of 25 miles and above.

Household income and household structure are not significantly associated with the choice of combination-7. Age is associated (p-value<0.01) with the choice of combination-7 for the individual having age between 0-29 years. The persons having age between 0-29 years (β = -1.855) have less probability to choose the combination-7 compared to an individual having an age of 50 years and above. The gender of the individual is significantly associated (p-value<0.01) with the choice of combination-7. The results show that male have fewer weights (β = -1.420) for choose combination-7 compared to female. The results show that access to car is not significantly associated with the choice of combination-7. Working status of an individual is significantly associated (p-value<0.01) with the choice of combination-7. The individuals having a full time (β = -1.876), and part time (β = -1.884) have less weight for the choice of combination-7 compare to persons having other jobs. The individual education is not significantly associated with the choice of combination-7.

6.2.10. Car + Public Transport + Car (Combination-8)

The trip purpose is significantly associated (p-value<0.05) with the choice of combination-8 for trips carried out for leisure. Leisure (β = 1.260) related trips have more weight for the choice of combination-8 compared to the home-based trip. The trip distance is significantly associated (p-value<0.01) with the choice of combination-8 for distance 5 to under 25 miles. The trips having distance 5 to under 25 miles (β = 1.019) have more weight for selection of combination-8 compared to trips having a distance of 25 miles and above. Household income is significantly associated (p-value<0.01) with the choice of combination-8. Household having income less than £25,000 (β = 1.701) and between £25,000 to £49,999 (β = 1.741) have more weight for selection of combination-8 compared to household having income £50,000 and above. Household Structure is significantly associated (p-value<0.10) with the choice of combination-8. Families without children (β = -0.705) have less probability to choose given combination compare to families with children. Age of person is significantly associated (p-value<0.01) with the selection of combination-8. The individual with age between 0-29 years (β = -2.440) and 30-49 years (β = -1.255) have fewer weights for the choice of combination-8 compare to persons having age 50 years and above. Gender also influence (p-value<0.01) the choice for combination-8. Results show that male has less weight (β = -2.112) for the choice of combination-8 compared to female. Access to car is not significantly associated with the choice of combination-8. Working status of an individual is a significant predictor (p-value<0.01) of choice for combination-8. Individual having a full time (β = -2.189) and part time jobs (β = -2.400) have fewer weights for the choice of given combination compare to an individual having others job. Education is also one factor affecting (p-value<0.01) choice for the combination-8. People having education has more probability (β = 2.153) to choose given combination compare to an individual without any education.

6.2.11. Walk + Public Transport + Car (Combination-9)

The results of the analysis reveal that trip purpose is significantly associated (p-value<0.01) with the choice of combination-9 for trips carried out for work. Work related trips have less weight (β = -2.069) for the choice of combination-9 compared to the home-based trip. The trip distance is significantly associated with the choice of combination-9. The trips having distance under 5 miles (β = -2.375, p-value<0.01) and 5 to under 25 miles (β = 0.956, p-value<0.05) have less weight for the choice of combination-9 compared to trips having a distance of 25 miles and above. Household income is significantly associated (p-value<0.10) with a selection of combination-9 for household having income less than £25,000. Household having income less than £25,000 (β = -1.043) have less weight for selection of combination-9 compared to household having income £50,000 and above. Household Structure is not significantly associated with the choice of combination-9. Age of person is significantly associated (p-value<0.01) with the choice of combination-9 for the individual having age between 0-29 years. The individual with age between 0-29 years (β = -2.084) has fewer weights for the choice of

combination-9 compare to persons having age 50 years and above. Gender also influences (p-value<0.01) the choice for combination-9. Results show that male has less weight (β = -2.091) for the choice of combination-9 compared to female. Access to car is not significantly associated with the choice of combination-9. Working status of an individual is a significant predictor of choice for combination-9. Individual having full time (β = -1.653, p-value<0.05) and part time jobs (β = -2.174, p-value<0.01) have less weights for choice of given combination compare to individual having others job. Education is also one factor affecting (p-value<0.05) choice for the combination-9. People having education has more probability (β = 1.818) to choose given combination compare to an individual without any education.

The figure … gives an overview of the multinomial logistic regression.

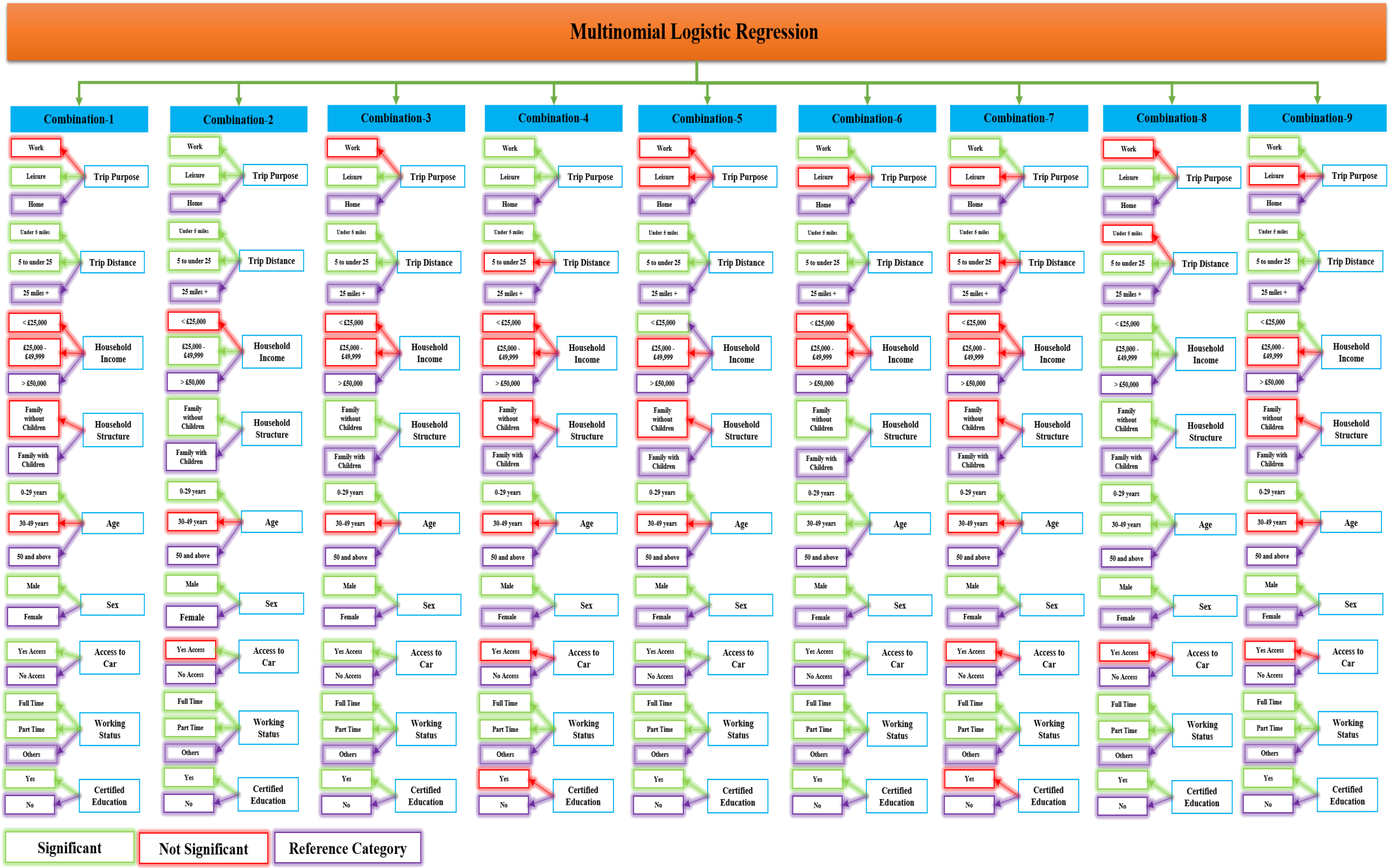

Figure 36. Overview of Multinomial Logistic Regression Analysis

7.0. CONCLUSION AND RECOMMENDATION

7.1. Conclusion

The growing trend to use private vehicles is one of the key problems in achieving sustainable mobility. In the past few decades there has been a lot of debate to reduce the use of private vehicles. However, only in U.S., the proportion of people driving alone has increase from 73% to 76% in just 10 years (Katzev, 2003). Multi-stage trips are seen as one way to reduce the use of personal vehicles. However, multi-stage trip planning is a complex task as it involves combination of modes. A multi-stage trip provides the advantages of freedom by providing different transfer points and better energy performance. Though, at the same time these transfer points also discourage the traveler. Multi-stage trips provide a cheaper and fast way to reach the destination and time is not wasted in congested urban environment. Long waiting time particularly at the transit station is one of the key disadvantage of multi-stage trip which might influence the choice of people. The literature shows that there are three major factors related to a trip which can influence the choice of people regarding multi-stage trip. These factors include trip purpose, trip length and type of destination. There are also other socio-economic and individual factors which influence the mode choice of travelers. The stages in a multi-stage trip can be characterized into first mile, main trip and last mile. Generally, first and last miles are the most inconvenient part of the trip in a multi-stage trip. First and last mile are most important part of trip as they are the primary means of access to different facilities. It is evident from different researches that first and last mile are weighted more as compare to in-vehicle time. Ergo, there is a need to improve the connectivity of first and last mile to enhance the performance of current public transportation system. This study tries to find out the fact that why people choose between solo-car-only and multi-stage trips. Moreover, the study also focuses on the characteristics of trips, stage of trips, individuals, vehicles and households, that influence the mode combination in a multi-stage trip.

The binary logistic regression for choice between solo-car-only and multi-stage trips reveals that trip purpose and trip distance are significantly associated, the result which consistent with the findings of (Limtanakool et al., 2006). The probability of choosing solo-car trips increases as distance of trips decreases. It means for longer distance, people prefer to choose multi stage trips. These results are same as that of (Nes, 2002). Access to car has a significant relation with mode choose and the probability to choose solo-car-trip increase with access to car. The results reveal that probability to choose car as mode of transport is high for the families with children. This show that people have a behavior influence when they are travelling with car may be due the inconvenience and safety issues at transit stations. These results are consistent with the findings of Racca and Ratledge (2003) inferring that the choice of mode for household with or without children differ. The choice for solo-car-only trip also increase as number of household vehicles increases. The household having 1 or more car has more chance to adopt car as their primary mode of transport. Household income is also associated with choice of solo-car-only trips. An increase in household income is associated with increase in probability to choose solo-car-trip.

The multinomial logistic regression is used to know the choice between different mode combinations. A mode combination gives the mode choice between different stages of multi-stage trip. For most of the combinations (C1, C2, C3, C4, C6, C7, C8, C9) trip purpose is significantly associated with trip purpose. The home-based trips have the highest probability to choose the given combination whereas work related trip has less probability to choose the combinations of multi-stage trips. It is clear from the results that for work related trips people do not prefer to take multi-stage trips. This behavior may be the effect of time pressure which is critical to work related trips. The trip distance has significant association for the choice of mode at each stage of multi-stage trip. As trip distance increase the utility of combination involving car at any stage of multi-stage trip also increase.

Household income and household structure shows mixed results of multinomial logistic regression for mode combination. Household income has influence on choice of specific mode involving public transport or car for first and last mile. The families with children prefer to take combination involving car or public transport at first or last mile. The utility of using multi-stage trip combination including walk at first or last mile is less attractive for the families having children. Age is a significant factor for choice of mode combination. The individual with an age between 0-29 years has less probability to choose any of the mode combination. The gender of an individual also influences the choice of a mode combination. Males have less probability to select any mode combination of a multi-stage trips compared to females. For most of the combinations working status of individual also influence the choice of a mode combination. Full time and part time employees have less probability to choose given combination compared to individuals having other jobs (retired etc.). In most of mode combination access to car is significantly associated with choice of a mode combination. In most of the cases, access to car results in decline of probability for choosing a combination involving walk. The education of an individual is also associated with choice of given combinations. The education status of an individual also affects the choice of mode combination, for example, an educated person is an indicator of the fact that the individual will choose the modes involving walk at first or last mile of the trip.

7.2. Recommendations

- In U.K. during 2014, 95% of trips were solo-car-only trips. The companies and organization can play a role to reduce the share of solo-car-only trip by introducing schemes for promotion of green modes of transport. Companies can also give seasonal tickets to their employees to shift their mode of transport. In this way organizations do not need to provide wider parking lots.
- In order to make a model shift from solo-car-only to public transport the target population should be the people having car access. As this target group has more probability to use solo-car trips so, policies should focus to reduce their car use. Insurance benefits can be introduced for the household with less vehicle mileage. Moreover, benefits for using green mode of transport (walk, bicycle) can also be adapted.
- Young people with age less than 29 years should be focused on to initiate car use reduction schemes. Free tickets at universities and reduce fare cost for people of an age of less than 29 years can help to shift individual from solo-car-only trips to multi-stage trips. Moreover, for more specific policies males may be focused for the aforementioned techniques.
- In trips, executed in course of work; the car is mostly used in combination with public transport and people prefer to take car at first and last mile for these trips. This may be due to the fact that for trip purpose like work sensitivity of time is high. The share of car can be reduced at activity end (last-mile) by promoting use of services like blue-bike. The commuter using such combinations can be informed and promoted to use green mode of transport for first and last mile.
- For trips having larger distances people can be promoted to use public transport for first and last mile instead of car. People can be informed about environmental benefits they can achieve using combination without car. The information can be disseminated using electronic media and other sources.
- It is observed from the analysis that mostly bicycle is not used in conjunction with public transport. The unavailability of bicycle parking and security at station exacerbate this situation. Therefore, improving parking facilities and security for bicyclist can help to increase the share of bicycle use in multi-stage trips.
- The multi-stage trips having three stages are the focus of this research work. More work can also be done for the multi-stage trips having more than three stages.
- In the present data used for the study there is a large share of solo-car-only trips (95%) so, a more detail and generic study can be executed by taking equal number of solo-car-only and multi-stage trips.
- In the present study stage characteristics being omitted from the data because of short time frame and data issues. Therefore, a further study focusing on “effect of stage characteristics on mode combination” can be promulgated. A study covering only first and last mile and their impacts on mode combination can be of interest for researchers.

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ANNEXURE-A National Travel Survey (Symbol, Variables and Response rate)

Symbols and Conventions used in NTS

In NTS data used following symbols:

TABLE 20. Symbols and Conventions used in NTS (Abeywardana et al., 2006).

..	Not available
.	Not applicable
-	Negligible (less than half the final digit)
0	Nil

Identifying Variables

Attribute in each data files are attached with identifier variables which make possible to link the data from every level of hierarchy. The following variable identifier are used in NTS.

TABLE 21. Key Identifier variables.

PSU	PSUID
Household	HouseholdID
Vehicle	VehicleID
Individual	IndividualID
LDJ	LDJID
Day	DayID
Trip	TripID
Stage	StageID
Ticket	IndTicketID

These identifiers are unique IDs allowing linkage between different level of dat.

Missing Values

Three minus values being used to express missing values in the data.

- -10 is used for questions which were not asked in the survey
- -9 applies for the ‘not applicable’
- -8 is used for ‘non-response’. This may include ‘don’t know’ and ‘refused’ response

Response Rate

The households which fully cooperate are included in the response calculations. A response rate of 59% was observed in 2014.

ANNEXURE-B National Travel Survey (Weighting)

Weighting

In response to the recommendation of quality review of NTS in 2000 a weighting strategy was introduced to reduce the impact of non-response bias. In 2002 the analysis result for weighted and unweighted was presented. The weighting strategy was also applied on the number of trips to adjust the drop-off by respondent. The review of this weighting strategy was done in 2013(Abeywardana et al., 2006). This weighting is applied at different level of the data.

The Interview Sample Weights

The interview sample weights are used to analysis all household with complete individual interviews. The approach used for generating the weights for interview sample is to:

- Generate weights for the selection of household /dwelling unit at the sample address (W_1)
- Producing weights non-participants at household level (W_2)
- Weights generation for the excluding participants did not completed interview (W_3)
- Compute composite weights ($W5= W_1 \times W_2 \times W_3$)
- Calibration weights generation (wt_int) adjust the interview sample of individual/household to known population estimate for age/sex and region. For this purpose, composite weights are used.

(Abeywardana et al., 2006)

Weights for multiple dwelling units and households

This weighting procedure is used for the addresses one which more than one household and dwelling unit reside. One dwelling unit is randomly selected of these units but the figure for such address is relatively low (<1%). As at this level dwelling units are selected randomly so an appropriate weight is applied to under-representation of dwelling units at split address. Similar procedure is repeated for the households and weights is applied to these households. The dwelling unit weight (wDU) is identical to number of dwelling units exist at certain address. Similarly, weight of household (wHH) is identical to households identified at a particular address. The composite household/dwelling unit selection weight can be given as (w = wDU x wHH) (Abeywardana et al., 2006).

Weighting for household Participation

The purpose of this weight is to decrease the bias produced by systematic variation between household interviewed and those that did not take part in survey. A logistic regression model is used for the generation of non-response weights. The model is fitted on the basis whether an eligible household has participated or not and terms related to household participation as covariates. This model is used to predicted the tendency for each household to participate. The household participation weights are calculated as reciprocal of these tendencies (Abeywardana et al., 2006).

Weighting for missing individual Interview removal

This weighting is done to reduce bias by removing the households for which individuals did not completed the survey. This weight is solely depending on the size of the household. A logistic regression model is fitted in which size of the household is taken as covariate. Similar reciprocal procedure is used to calculate the weights (Abeywardana et al., 2006).

Weighting Calibration

In the final weighting procedure of interview sample the weights are adjusted using calibration weighting. Calibration weighting is used to adjusts the weights so that the characteristics of weighted achieved sample correspond the population estimates. This help to reduce non-response bias and impact of sampling and coverage error. The calibration weight is based on characteristics of the members of household (Abeywardana et al., 2006).

Fully Responding Sample Weights

In NTS weights are also produce for analysis of the fully responding sample. In 2014, there were 6,900 households which cooperate fully and completed their interviews as well as travel diaries for 16,646 household members. The approach for generating weights for fully responding sample is to:

- Generate weights for selection of dwelling unit/household at sampled address (W_1)
- Produce weights for non-participants at household level (W_2)
- Generate weights for dropping household in which individual did not completed the interview (W_3)
- Generate weights for dropping household did not respond completely (W_4)
- Compute the composite weights ($W_6 = W_1 \times W_2 \times W_3 \times W_4$)
- Generating calibration weights (wt_fully) adjust the individuals/household to know household population estimate for age/sex and region. For this purpose, final composite weights are used.

A non-response model is fitted for which household full responds are taken as response variable and pre-determined measures taken as covariates. These measures include region, number of adults, tenure, married couple, use of vehicle, youngest household member age category, household members ethnic group, rural/urban measure. The weights are calculated with the similar procedure as mentioned above by taking the reciprocal of the tendency to fully respond estimated from this model (Abeywardana et al., 2006).

Weighting Travel Data

The figure 37 below reflects the number of journey recorded in the travel diary week. A gradual decline has been observed in these values from 2.14 to 1.96 in seven days. These weights are established to reduce the biases from under-reporting of journeys in travel diary week.

	Average number of journeys:	
	Weighted	Unweighted
Day of travel diary:		
1st day	2.14	2.14
2nd day	2.12	2.12
3rd day	2.09	2.09
4th day	2.05	2.05
5th day	2.03	2.02
6th day	2.00	1.99
7th day	1.96	1.96
Base: Individuals	*16,624*	*16,491*

FIGURE 37. Average number of Journeys recorded in travel diary for whole week (Abeywardana et al., 2006).

The weights are generated in such a way that number of journeys made on a particular day is equaled to the journeys reported for the first day of travel diary. This is done separately for each journey purpose. The figure 38 below shows the number of journey executed with the purpose of that journey. In this approach, it is assumed that reporting on first day is more accurate than rest of the week and this decline in number of trip is the result of drop-off. As the journey reported for business and holiday purpose does not change much for the whole week so weights were set to 1 for these journey purpose in 2014 NTS. Similarly, for trips related to education on weekend depict the real situation so, weights were also set to 1 for these journey purpose as well (Abeywardana et al., 2006).

	Average number of journeys:							
	Commuting	Business	Education	Escort Education	Shopping	Other	Social	Holiday
Day of travel diary:								
1st day	0.38	0.08	0.12	0.10	0.40	0.43	0.48	0.14
2nd day	0.37	0.08	0.12	0.09	0.39	0.41	0.51	0.15
3rd day	0.36	0.09	0.12	0.09	0.38	0.40	0.50	0.14
4th day	0.37	0.08	0.12	0.09	0.34	0.40	0.49	0.16
5th day	0.36	0.09	0.12	0.09	0.34	0.39	0.48	0.16
6th day	0.35	0.09	0.12	0.09	0.34	0.37	0.48	0.16
7th day	0.35	0.08	0.12	0.10	0.33	0.36	0.44	0.17
Bases (individuals):								
Weighted	*16,624*							
Unweighted	*16,491*							

FIGURE 38. Average number of journeys by purpose of journey (Abeywardana et al., 2006).

Short Walks

Short walks are recorded only for the seventh day of travel diary in NTS. Aggregated information is formulated for short walks and analysis is not done on individual level. The information on short walks for different people at different days should be averaged for aggregate estimates, assuming that collected information is distributed evenly for the seven days but in reality, it is not accurate. Weights were generated in 2014 survey to adjust the short walks for each day equal to the weighted mean. These adjustments are shown in the following figure:

Day of the week	Information collected	Percentage	Adjustment	Weight
Sunday	2,333	14.0	1.018	7.125
Monday	2,506	15.1	0.948	6.633
Tuesday	2,370	14.3	1.002	7.013
Wednesday	2,457	14.8	0.967	6.767
Thursday	2,319	13.9	1.024	7.170
Friday	2,376	14.3	0.999	6.995
Saturday	2,262	13.6	1.050	7.349
Bases (individuals):				
Total (weighted)	*16,624*			
Total (unweighted)	*16,491*			

FIGURE 39. Weighting for Short Walks (Abeywardana et al., 2006).

Long Distance Travel Records

The additional information about long distance trip (more than 50 miles) is also collected in NTS prior to travel diary week. The number of long distance trip reported was lower compare to the trip reported in travel diary of 2014 survey. The information obtained from travel diary is likely to be more accurate so long distance trips are weight so, that long distance trip reported on week days equaled the average number of trips reported in travel diary. The long-distance trips are separated based on journey length as 50-75 miles, 75-100 miles and 100 miles or more. The figure below shows the different weights based on these distances.

	Long distance journeys reported:		Weight
	Travel Diary	LDJs	
Journeys: 50 to 75 miles			
1st day	348	159	2.38
2nd day	363	224	1.69
3rd day	383	235	1.61
4th day	397	248	1.53
5th day	404	291	1.30
6th day	348	248	1.53
7th day	407	225	1.68
Average	379		
Journeys: 75 to 100 miles			
1st day	156	95	1.79
2nd day	153	99	1.72
3rd day	159	151	1.13
4th day	171	180	.95
5th day	197	119	1.43
6th day	207	151	1.13
7th day	148	100	1.71
Average	170		
Journeys: 100 miles or more			
1st day	302	206	1.42
2nd day	300	230	1.27
3rd day	295	332	.88
4th day	235	338	.86
5th day	320	294	.99
6th day	286	238	1.22
7th day	302	241	1.21
Average	292		

FIGURE 40. Number of long distance journey made during the Travel week (Abeywardana et al., 2006).

ANNEXURE-C National Travel Survey (Terms)

Terms used in NTS

Trip

In NTS trip is defined as one-way path of travel with only one main purpose. Whereas, return and outward are treated as separate trips. If a trip involves change in purpose in the middle of the trip this will be split into two trips.

Stage

A trip may consist of one or more stages. A stage in NTS is alternatively used for transfer. This involve the change in mode of transport or change in vehicle.

Series of calls trips

The travel which has a main purpose but involve a number of stops as well as the same transport is used for the whole trip is treated as one continuous series of call trips.

Trips in course of work

Trips made specially for work purpose are included in NTS with the provision that the trip is to reach a specific destination. Trip made to deliver goods, drop off a passenger (taxi driver/bus driver) is not included in this survey. Similarly, the trip executed in order to fulfil the course of work like police patrolling, traffic wardens are not included in this analysis.

Main mode of travel

A mode is regard as main mode of travel if it is used for longest distance of the journey.

Walking

Walking for a distance of less than 50 yards is excluded.

ANNEXURE-D Recoding Attributes

DNA = Not Applicable (When Conditions are not met)

NA = No Response, Don't Know, and Refused to Respond

Household Characteristics

Total number of people in household - actual number			
	Frequency	Percent	New Category
1	2022	27.2	1
2	2718	36.5	2
3	1134	15.2	3 and more
4	1042	14.0	
5	354	4.8	
6	107	1.4	
7	43	.6	
8	9	.1	
9	4	.1	
10	6	.1	
Household structure - 6 categories			
	Frequency	Percent	New Category
Single adult	2022	27.2	Family without Children
2 adults	2547	34.2	
3 adults or more	782	10.5	
Single parent family	346	4.7	
2 adults, 1 child or more	1331	17.9	Family with children
3 adults or more, 1 child or more	411	5.5	

Number of persons in household with full car license - actual number			
	Frequency	Percent	New Category
0	1257	16.9	0
1	2670	35.9	1
2	3000	40.3	2 or more
3	390	5.2	
4	98	1.3	
5	9	.1	
6	4	.1	
7	1	.0	
Number of household vehicles - actual number			
	Frequency	Percent	New Category
0	1737	23.3	0

1	3187	42.8	1
2	1987	26.7	2 and more
3	398	5.4	
4	92	1.2	
5	20	.3	
6	10	.1	
7	4	.1	
10	1	.0	

Household Income bands - 2002 bandings - 3 categories			
	Frequency	Percent	New Category
Less than £25,000	3417	45.9	Less than £25,000
£25,000 to £49,999	2227	29.9	£25,000 to £49,999
£50,000 and over	1795	24.1	£50,000 and over

Individual Characteristics

Sex of person			
	Frequency	Percent	New Category
Male	8670	48.4	Male
Female	9239	51.6	Female
Age of person - banded age - Band D - All ages - 9 categories			
	Frequency	Percent	New Category
0 - 4 years	1176	6.6	0-29 Years
5 - 10 years	1373	7.7	
11 - 16 years	1379	7.7	
17 - 20 years	760	4.2	
21 - 29 years	1742	9.7	
30 - 39 years	2257	12.6	30-49
40 - 49 years	2432	13.6	
50 - 59 years	2304	12.9	50 and above
60 years +	4486	25.0	
Access to car			
	Frequency	Percent	New Category
NA	28	.2	NA
Main driver of company car	384	2.1	Yes Access
Other main driver	7700	43.0	No Access
Not main driver of household car	1627	9.1	Yes Access

Household car but non-driver	4878	27.2	
Driver but no car	607	3.4	No Access
Non-driver and no car	2685	15.0	
Working status of individual - Summary - 4 categories			
	Frequency	Percent	New Category
DNA	3699	20.7	DNA
Full time	6106	34.1	Full Time
Part time	2000	11.2	Part Time
Retired/permanently sick	4102	22.9	Others
Other non-work	2002	11.2	

Individual Income - 2002 bandings - 3 categories			
	Frequency	Percent	New Category
DNA (under 16)	3699	20.7	DNA (under 16)
Less than £25,000	10388	58.0	Less than £25,000
£25,000 to £49,999	2786	15.6	£25,000 to £49,999
£50,000 and over	1036	5.8	£50,000 and over

Vehicle Characteristics

Type of vehicle - 5 categories			
	Frequency	Percent	New Category
NA	3	.0	
Car	7756	86.6	Car
Motorcycle/scooter/moped	208	2.3	Motorcycle/Scooter/moped
Landrover/Jeep	541	6.0	Car
Light van	314	3.5	
Other	135	1.5	Others

Vehicle's total mileage - banded mileage - from mileage card			
	Frequency	Percent	New Category
NA	1994	22.3	NA
0 - 2000 miles	334	3.7	0-15000
2001 - 4000 miles	146	1.6	
4001 - 6000 miles	145	1.6	
6001 - 8000 miles	165	1.8	
8001 - 10000 miles	144	1.6	
10001- 15000 miles	349	3.9	

15001- 20000 miles	325	3.6	15001-60000
20001- 25000 miles	324	3.6	
25001- 30000 miles	312	3.5	
30001- 40000 miles	583	6.5	
40001- 50000 miles	575	6.4	
50001- 60000 miles	576	6.4	
60001- 75000 miles	809	9.0	60001 and above
75001- 100000 miles	1002	11.2	
100000 miles +	1174	13.1	

Trip Characteristics

Number of stages - banded number			
	Frequency	Percent	New Category
One	233955	96.1	1
Two	6973	2.9	2
Three	2167	.9	3
Four	300	.1	4
Five	41	.0	5 and above
Six	4	.0	
Seven or more	5	.0	
Trip purpose from - 23 categories			
	Frequency	Percent	New Category
Work	22895	9.4	Work
In course of work	5658	2.3	
Education	8356	3.4	
Food shopping	11919	4.9	Leisure
Non food shopping	12458	5.1	
Personal business medical	3177	1.3	Work
Personal business eat/drink	54	.0	
Personal business other	9100	3.7	
Eat/drink with friends	4603	1.9	Leisure
Visit friends	15045	6.2	
Other social	2310	.9	
Entertain/ public activity	8159	3.4	
Sport: participate	2175	.9	
Holiday: base	2016	.8	
Day trip/just walk	9188	3.8	
Other non-escort	41	.0	Others
Escort home	1423	.6	
Escort work	2130	.9	
Escort in course of work	157	.1	

Escort education	7062	2.9	
Escort shopping/personal business	5382	2.2	
Other escort	5011	2.1	
Home	105126	43.2	Home

Trip purpose to - 23 categories			
	Frequency	Percent	New Category
Work	22987	9.4	Work
In course of work	5666	2.3	
Education	8384	3.4	
Food shopping	11893	4.9	Leisure
Non food shopping	12429	5.1	
Personal business medical	3192	1.3	Work
Personal business eat/drink	54	.0	
Personal business other	9112	3.7	
Eat/drink with friends	4604	1.9	Leisure
Visit friends	15098	6.2	
Other social	2359	1.0	
Entertain/ public activity	8192	3.4	
Sport: participate	2176	.9	
Holiday: base	2202	.9	
Day trip/just walk	9176	3.8	
Other non-escort	40	.0	Others
Escort home	1426	.6	
Escort work	2143	.9	
Escort in course of work	151	.1	
Escort education	7051	2.9	
Escort shopping/personal business	5402	2.2	
Other escort	4997	2.1	
Home	104711	43.0	Home

Total trip time - minutes - banded time			
	Frequency	Percent	New Category
Less than 3 minutes	1791	.7	Less than 15 minutes
3 minutes to under 8 minutes	34307	14.1	
8 minutes to under 15 minutes	48833	20.1	
15 minutes to under 30 minutes	84356	34.7	15 minutes to under 1 hour
30 minutes to under 45 minutes	40743	16.7	
45 minutes to under 1 hour	13391	5.5	
1 hour to under 1.5 hours	12205	5.0	1 hour +

1.5 hours to under 2 hours	3767	1.5	
2 hours to under 2.5 hours	1744	.7	
2.5 hours to under 3 hours	758	.3	
3 hours to under 4 hours	789	.3	
4 hours to under 5 hours	418	.2	
5 hours to under 6 hours	171	.1	
6 hours +	172	.1	

Main mode of travel - publication table breakdown - 13 categories			
	Frequency	Percent	New Category
Walk	26265	10.8	Walk
Bicycle	4889	2.0	Bicycle/motorcycle
Car/van driver	115825	47.6	Car
Car/van passenger	63752	26.2	
Motorcycle	910	.4	Bicycle/motorcycle
Other private transport	1962	.8	
Bus in London	5564	2.3	Public Transport
Other local bus	12045	4.9	
Non-local bus	231	.1	
London Underground	2499	1.0	
Surface Rail	5764	2.4	
Taxi/minicab (need explanation)	3052	1.3	
Other public transport	687	.3	

Trip distance - including short walk - miles - banded distance - 12 categories			
	Frequency	Percent	New Category
Under 1 mile, including 0 distance	19036	7.8	Under 5 miles
1 to under 2 miles	53206	21.9	
2 to under 3 miles	33970	14.0	
3 to under 5 miles	43148	17.7	
5 to under 10 miles	46764	19.2	5 to under 25 miles
10 to under 15 miles	18960	7.8	
15 to under 25 miles	14107	5.8	
25 to under 35 miles	5259	2.2	25 +
35 to under 50 miles	3353	1.4	
50 to under 100 miles	3689	1.5	
100 to under 200 miles	1471	.6	
200 miles +	482	.2	

Stage Characteristics

Stage Distance - miles - banded distance			
	Frequency	Percent	New Category
Under 1 mile	22510	8.8	Under 5 miles
1 to under 2 miles	57657	22.5	
2 to under 3 miles	35749	14.0	
3 to under 5 miles	45034	17.6	
5 to under 10 miles	47855	18.7	5 to under 25 miles
10 to under 15 miles	19049	7.4	
15 to under 25 miles	13957	5.5	
25 to under 35 miles	5122	2.0	25 miles +
35 to under 50 miles	3355	1.3	
50 to under 75 miles	2582	1.0	
75 to under 100 miles	1086	.4	
100 to under 150 miles	1062	.4	
150 to under 200 miles	393	.2	
200 miles +	459	.2	

Stage travel time - minutes - banded time			
	Frequency	Percent	New Category
Less than 3 mins	2800	1.1	Less than 15 mins
3 under 8 mins	39910	15.6	
8 under 15 mins	55398	21.7	
15 under 30 mins	91179	35.6	15 to under 1hours
30 under 45 mins	39732	15.5	
45 mins under 1 hour	11934	4.7	
1 under 1.5 hours	9135	3.6	1 hours +
1.5 under 2 hours	2698	1.1	
2 under 2.5 hours	1379	.5	
2.5 under 3 hours	571	.2	
3 under 4 hours	625	.2	
4 under 5 hours	285	.1	
5 under 6 hours	117	.0	
6 hours +	107	.0	

Total number in party - banded number			
	Frequency	Percent	New Category
NA	3385	1.3	NA
One	113909	44.5	One
Two	77479	30.3	Two
Three	33406	13.1	Three and more
Four	18317	7.2	
Five	6434	2.5	
Six	1273	.5	
Seven or more	1667	.7	

Stage mode of travel - publication table breakdown - 13 categories			
	Frequency	Percent	New Category
Walk	31194	12.2	Walk
Bicycle	5154	2.0	Bicycle/motorcycle
Car/van driver	117007	45.7	Car
Car/van passenger	65068	25.4	
Motorcycle	931	.4	Bicycle/motorcycle
Other private transport	2050	.8	Car
Bus in London	7057	2.8	Public Transport
Other local bus	12783	5.0	
Non-local bus	240	.1	
London Underground	3782	1.5	
Surface Rail	6151	2.4	
Taxi/minicab	3397	1.3	
Other public transport	1056	.4	

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Multi-stage trips: Factors influencing mode combination choice of travelers

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Jaar: **2017**

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