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Modeling of commuters' route choice behavior

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Anirban Pal

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An Abstract of

MODELING OF COMMUTERS' ROUTE CHOICE BEHAVIOR

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The purpose of this research is to investigate the approach of a driver in choosing a particular route from various available routes while making a road trip. Route choice depends on individual characteristics, route features, trip purpose and various other attributes involved in trip making. Route choice behavior is studied through a means of questionnaire circulated amongst the faculty, staff and students at The University of Toledo. Socio-demographic information, trip characteristics and commuters' attitude in selecting a particular route are studied through the responses from the survey. Statistical analysis is carried out to determine the effects of such attributes as the route choice behavior and the way they differ with the purpose of the trip. This study adopts the method of principle component analysis in order to group certain attributes measuring same underlying values. Mann-Whitney Test, correlation analysis, binary logistics regression and grouping techniques are used to analyze the commuter route choice behavior in detail. It is concluded from this study that individual characteristics, purpose of the trip and route attributes are the factors that affect the route choice of commuters.

Dedicated to

My Parents

whatever I am today is because of them.

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CHAPTER 1: INTRODUCTION

1.1 Motivation

For the last few decades, transportation engineers have been pursuing the large number of individuals in trip participations to understand the individual behavior in route choice. The aggregate behavior depends on the individual decisions. Each and every individual decision ultimately creates an impact on the traffic system. Thus, each traffic behavior is in the core of all predictive traffic forecasting and assignment. Incidentally, there isn't any universally accepted single model which is capable of predicting the behavior of the traveler. Different researchers have focused on the behavior of the route choice of the trip makers and expanded effort to analyze this -by developing the stochastic or probabilistic model. This study emphasizes the prediction of the traffic based on an individual behavior, taking into account recent developments in choice behavior and decision making in economics and psychology.

The elementary traffic assignment procedure is a model for the traveler's decision about which route to take. The model deals with the commuter's "best" route choice analysis, keeping the origin, destination, departure time, mode and purpose fixed. To choose the best possible route is to minimize the travel disutility (1). The procedure is quite complex because there isn't any single measure of travel disutility and the complex pattern overlap between travel attributes. Creating a mathematical representation and a realistic replication of the human decision process with synthesizing of many factors about possible route choice is complex. Researchers primarily deal with the thought process of the individual. A trip maker has to choose a route after a process of sequential decision making based on a set of different routes (alternatives) depending upon the conditions (commuter's attributes and traffic attributes). Before starting to build up models by creating a unique choice set, it is necessary to discuss the necessity, underlying process of decision making, potential application and the contribution of the route choice behavior analysis approach.

This choice behavior analysis is necessary because:

1. It can be used as an useful tool in traffic assignment model to redirect the existing traffic in the most efficient way by considering a sophisticated, logical and real time data model
2. It can be used to evaluate the usage of the existing infrastructure and the need of the further infrastructure.

With the advancement of the transportation system, mathematical models are developed to simulate how various parameters impact the operational characteristics of the system. A properly analyzed model is required to provide an accurate real time commuter information system. For the Intelligent Vehicle Highway System (IVHS) to function, it is crucial to feed the real time traffic information to the database of the Advanced Traveler Information System (ATIS) [(2)]. Therefore the analytical models that provide information to the real time route choice model should be accurate. This has developed as the area of interest in the 'Intelligent Transportation System'. Thus researchers are concentrating on additional parameters to generate a higher resolution on the past model and trying to build up a choice set which was not included in the past. A lot of attributes are now drawing the attention to researchers.

Most of the past models basically developed with the travel time as a main function of the average usage of a facility over period. In a recent study [3] shows that this function is not adequate to build up a model to analyze the behavior of the trip maker. A great deal of attention has been devoted to incorporate the attributes, which can alone or by the interaction with other attributes can explicitly affect travel time and ultimately lead to change in behavior.

1.2 Basic Definitions

Transport routes can be defined as "*…being typified by several linkages interconnected by means of nodes. As a result there are usually a number of possible routes between two points, which overlap to varying degrees due to common road segments and nodes.*" [4]. Bovey & Stern (1990) [5] defined a route as; "*a route is a chain of consecutive road segments connected by nodes. Such chains connect trip origins and destinations*."

The knowledge of psychological basis of behavior is necessary for this research. The basic definitions of some terms that are repeated in the discussion are follows:

'Behavior' signifies the relation and/or movement of a system (in this case the organism, the human body, the person) because of its possibilities of reaction, towards conditions in the environment.

'Action' is a behavior which is reflected by a person in his environment and / or which has an aspired objection or intension. Action is the behavior with human consciousness. Action includes behavior plus planning.

‘Choice’ is the action by which a person selects the best possible option(s) from a set of alternatives.

1.3 The Choice Behavior

1.3.1. Overview

The need for realistic representation of decision-making behavior is acute as this is a conceptual and mathematical representation of the human thought process. The realistic behavioral decision modeling related to commuter’s behavior should be capable of analyzing the complex nature of responses. Modeling the route choice characteristics is needed for transportation planning purposes. The modeling can be achieved by incorporating realistic representations of commuter’s behavior considering substantial shifts in household structures, individual and household socio-demographics, alternative choices and attributes of the commuter. Behavioral representation also provides a clear picture of the functioning of urban areas. It has the potential to identify the differential natures of route selection among different segments of the population.

1.3.1.1 Influence of Individual Choice Behavior

Individual choice behavior is getting priority in travel demand model in urban areas. Particularly, the travel demand model continues to use individual trip as the unit of analysis. Sometimes for a multi-stop tour from home consisting of grocery, shopping and social visit, the traditional approach fails to recognize selections of the route for all trips (home to shop, shop to visit, and visit to home). The chosen travel route depends on various characteristics of all three trips (and not any one single trip) and consequently, these trips can not be studied independently. Similarly, the location of a stop in a multi-stop tour is likely to be affected by the location of other stops on the tour. Such multi-stop tours are becoming increasingly prevalent. We can not ignore these individual behaviors in travel analysis because these can eliminate critical elements in the individual's organization of time and space.

1.3.1.2 Recent Scenario

A more realistic model of people's adaptation to changing travel environment can address congestion-management issues through examination of how people modify their route patterns. Some Metropolitan Planning Organizations (MPOs) are embracing this new approach and the efforts to develop comprehensive individual route choice based model. Although, it is beyond the scope of the research to review these developments and efforts, there is no question that individual route choice based methods are gaining momentum in the transportation modeling profession. There are already several applications of these methods to develop travel patterns for forecasting and to assess the impact of Traffic Control Measures (TCMs) on traffic congestion. Much of this transition toward model has occurred within the last few decades, and the stage is set for further development and implementation of such method [(6)]. This is an assessment of the implementation and the performance aspect of route choice behavior study.

1.3.2 Decision Process

According to Moshe Ben-Akiva [(7)], definition of the choice problem is generation of the set of alternatives considering the objective of the trip-makers and evaluation of the each and every attribute of the alternatives by setting a weight parameter on the each parameter ultimately guides to the selection of choice. A typical theory of choice consists of the following elements:

1. Decision maker.
2. Alternatives.
3. Route Attributes.
4. Commuter's Attributes.
5. Decision Rules.

1.3.3 Decision Maker

The decision maker can be an individual person or an organization or a group of person. Though generally it is particularly refers to an individual, but sometimes to abstract the complexity of the aggregate behavior it is taken an "actor" in a more general case. The outcome of the choice depends on the household behavior. Selecting the route may be the outcome of the dominant single member of the household whenever they are together on a trip, otherwise may be a complex intra-household decision process.

1.3.4 Alternatives

To build up the choice set the alternatives play an important role. The decision maker first selects the alternatives of the traffic system. The alternatives here in this study are different route available to the trip makers to complete the trip purpose from origin to destination. The choice set includes the entire feasible routes available to the decision maker. The term "available" here can only be emphasized by physical availability. The global choice set of alternatives consists of alternative routes irrespective of monetary availability, time availability, and informational constraints and so on.

1.3.5 Attributes

To formulate the route, the commuter uses a number of numerous criteria on route choice. Though, it is not possible to consider all the criteria in a specific situation. The degree of importance for each criterion varies from situation to situation. The degree of importance imposed by the commuter on the criteria (attributes) dynamically changes. In this study, an effort to develop an individual behavior-based mechanism for determining the influential attributes for route choice decision making.

1.3.5.1 Commuter attributes

1. Commuters' Socio-demographic attribute: Drivers' age, sex, education and income play important roles in route choice. Recent surveys revealed the influence of socio-demographic factors on choice behavior.
2. Value of time: The value of time in connection to decision maker put an important role to the decision making process. Individual value of time varies from person to person. Individual can allot different weights on the time constraint in different time period of the day, or in different situation.
3. Past Experience: Most of the time the commuter influenced by the perception that he/she had last time when he/she visited the route. Last trip experience creates a lot of impact to the commuter's mind. Even a last time better experience can get prioritized over a long time preferred route.

4. Purpose of the Trip: Commuter put a priority over the purpose of the trip. Travel time, importance on the cost of the travel all depend explicitly on the trip purpose. Commuter imposes an extra privilege to the purpose of the trip. The importance of the trip purpose leads the commuter to choose the route after interacting with the other attribute. Commuters try to negotiate with the cost of travel with the time of travel if the purpose is important to them.

5. Familiarity with the route: It is known that that commuter familiarity with network orientation and travel conditions influence how commuters make route choices. On a given day it may be expected that commuters who are more familiar (who performed more trip participations before that) with network conditions and layout should be able to make more efficient pre-trip initial choice set as well as be able to better adjust their travel pattern in the presence of severe congestion. Alternatively, commuters with limited experience should, on average, perform worse than experienced commuters. They are expected to select initial route choices that are inferior and while en-route is less equipped to make adjustments in response to adverse traffic condition.

6. Information supply: Increasing attention has are important to the travel's information system as real time traffic information can influence the commuters' decision. Understanding of real-time travel information, like link travel times (Adler and Blue 1998) [8] on individual route choice behavior is essential. Though sometimes commuters confronted with too much information. Ultimately it may lead to over-saturation of information processing and users develop simple heuristics to solve the problem (Gigerenzer *et al.* 1999) [9]. Commuters may also overreact to information

and thereby cause additional fluctuations. The weight of this information depend upon the reliability of the source of the information such as traffic information broadcasting service, radio, telephonic information, in-vehicle navigation, variable message sign, route guiding information. Types of travel information influence the commuter to choose the route in different manner.

a) Pre-trip traffic information: Leads to pre-trip route choice.

b) En-route traffic information: En-route switching decision.

7. Commuter's habits: Commuters usually try to follow the same habitual route. When they go out for the workplace or school or other institution in the morning peak hours they do not want to be adventurous to explore a new route. They are in hurry to reach the destination early. A habitual route assured the travel time. But on the return trip sometimes they try it, as they have flexibility in term of time to reach home. For the recreational or shopping trip people can explore a new route rather than a habitual one, where they also have the flexibility.

1.3.5.2 Route Attributes

1. Travel Time Reliability: Travel route reliability effects in the choice of route. A route having a less congestion, time taken to travel the route is on an average is very good gets priority to the commuter. The reliability is particular to specific commuter.
2. Path Length: The length of the path determines the cost incurred for the travel and the time. Apparently, the shortest distance travel route will take less time and less cost. But practically all the commuter's do not choose it for their travel because the shortest route will attract more traffic and the road will get congested ultimately it

will leads to more time and more fuel for extra stoppage and less speed. To balance in the network, the trip maker always dispersed through all the routes of the network.

3. Congestion: Congestion plays a special role in the choosing of the route. Obviously the more congested route has been avoided by the decision maker. Decision maker more often try to avoid the longer distance travel path over the shorter distance travel route because of the congestion.
4. Safety: Route condition, speed of the vehicle, age of the decision maker, chances and numbers of accidents, characteristics of other trip makers speed and safety behavior determines the safety to the individual. The degree of safety determined by the trip maker is very specific to the decision maker.
5. Number of Signals: The more the number of signals in the route; the more will be the stopping time. As a result people experience more delay. People tend to avoid important intersections, where stopping time could me more. Commuters take freeways for work-trip to avoid stopping at the signals although the distance could me more in case of freeways rather than local routes.
6. Number of Turns: Commuters general tendency is to dislike the breaking action. Turns causes reduction in speed and hamper the flow of the commuter. Ultimate this will increase the travel time.
7. Cost of Travel: People have an interest during the travel on the cost of the travel. Commuters traveling in network are from different economic levels. A percentage of the people like to travel the route that is economical for them. A longer route is expensive in terms of gas usage; a toll-way may be expensive in comparison to other

routes connecting the same origin and destination. People consider the total cost of the in terms of money.

8. Time of the day: Congestion, safety, time of the travel, fuel consumption changes depending upon the time of the day. In the morning and evening peak hours particular route gets very congested, whereas other period of the day it may not be so congested. The commuter, who is familiar with the route, has the perception of system behavior selects their route accordingly.
9. Traffic comfort: A number factors is responsible for the traffic comfort. The condition of the road, stopping, turns, steady flow all are related with the traffic comfort. Traffic comfort should be considered in thee model before checking the correlation with other attributes.
10. Roadway characteristics: A number of load link attributes such as width of the road, number of lanes average speed of the road, scenic beauty, zoning type of the adjacent land have a impact on the commuter. So, it is useful to describe the network data available for the study.

1.4 Modeling the Route Choice Behavior

The construction of models based on the concept of utility maximization, neglecting substantial evidence relative to alternate decision strategies involving household variables, information levels, choice complexity, discontinuous specifications, and habit formation. Misspecification of individual choice sets resulting from the inability to establish distinct choice alternatives available to the decision maker has to be treated carefully. Several interrelated themes characterize these approaches; methods and models generally reflect one or more of these themes. (10)

1. Route selection is derived from the demand for trip maker's participation in the urban area.
2. Sequences or patterns of behavior, and not individual trips, are relevant unit of analysis.
3. Household and other social structures influence route selection behavior.
4. Spatial, temporal, transportation, and interpersonal interdependencies constrain travel behavior.

1.5 Research Goals

1. To identify the patterns of commuter's travel behavior.
2. To study commuter's attitude towards his/her route choice for commuting to work and shop.
3. To analyze relationships between attributes and the choice behavior and developing Route Choice Model for Travel Demand Forecasting.

1.6 Objective

1. To analyze the importance of the different attributes received by commuter survey.
2. To determine the correlations between commuters' route choice and choice (personal and route) attributes.

3. To analyze the impact of socio-demographic factors and travel characteristics over commuter's attitude in choosing the route during travel.

1.7 Research Questions

1. What characteristics other than minimum distance, minimum time influence selection for route choice?
2. Can the route and personal attributes as independent variables significantly explain the route choice behavior of the commuters?
3. Do the socio-demographic variables like age and sex significantly explain route choice behavior?
4. What proportion of people actually switches their routes to and from any given origin-destination?
5. Is there any significant difference in commuters' attitude for work and shopping trip?
6. What are the factors that initiate the commuter to switch the route?

1.8 Thesis Outline

This study compares analytically several models for a simple route choice problem and analytical comparison of several models trying to access the relations of the attributes with the route choice. This paper is organized as follows:

1. Understanding the route choice behavior.
2. Related works on route choice.
3. An analytical procedure for specifying the changes in influential criteria.

4. A procedure for assessing weight of the criteria.
5. An empirical study of commuters' route choice behavior on intra-city trips is undertaken.
6. Finally, the conclusions are presented.

This thesis is made of 6 Chapters. The next chapter is on the literature review including recent works in the field of route choice and route switching behavior and discussions on the major finding. Chapter 3 provides the general framework of route choice behavior. The basic flow diagrams are presented. Chapter 4 presents the instrumentation, data collection method, methodology of the data analysis. The data analysis and the results are described on Chapter 5. Chapter 6 provides findings, some concluding remarks and suggestions for further research.

CHAPTER 2: LITERATURE REVIEW

2.1 Earlier Works

In 1841, J.E. Kohl a German mathematician realized that people actually follow the shortest path when they travel between cities. That was the first step to shortest route concept. After that, in 1920, A.C. Pigou, a British economist, realized the concept of traffic system equilibrium. He revealed the idea of forced "artificial" situation over the "natural" one by introducing the differential taxation for different routes. Due to the shifting from the 'artificially superior' route to 'natural' route, a balance in the road network will be established according to the driver's route choice pattern. *(From M. Patriksson, Algorithms for Urban Traffic Network Equilibrium, Linkoping, Sweden, 1991)* [36]

2.2 User Equilibrium Models

User equilibrium (UE) models are deterministic. It is assumed that all drivers are rational, have complete and perfect information regarding network conditions, and behave identically. In these models, congestion is represented by means of a capacity restraint. However, in 1952, Wardrop [11], a British engineer, with the well known User Equilibrium and System Optimum conditions stated that: *"The travel times on all used paths between an origin and a destination point are equal, and less than those which would be experienced by a single vehicle on any unused path" or "No traveler can* *improve his travel time by unilaterally changing routes" or "Every traveler follows the minimum travel time path".*

Further Wardrop developed System Optimum Principle and it states as: *"The travel times on all used paths between an origin and a destination point are of equal marginal travel time, and less than those which would be experienced by a single vehicle on any unused path" or "Every traveler follows the minimum marginal travel time path".* (4)

In fact, the above conditions were numbered by Wardrop as 1st and 2nd principles. Later it was realized that his principles were quite similar to Nash's (1951) equilibrium point of a non-cooperative game among various trip takers.

Most of these calculations were made manually, for instance least cost paths based on the link costs were found out from the average traveler. For the two-route or diversion problem a graphic approach is used.

In 1952, M.E. Campel commented on the techniques by calling these techniques as "*art more than science*". [36] These techniques began to change in the beginning of 1960s, due to:

- Dijkastra in 1959 introduced an efficient algorithm for the shortest path problem.
- The two-route or diversion problem became a corridor, and the corridor became a large network problem

- The attempts to connect the traffic pattern prediction with land use approaches.
- The application of computers increased which need ALGORITHMS and in turns requires mathematical formulation. (12)

Samuelson (1952) (12) was the first to formulate, what he called "the transportation market equilibrium" as a mathematical program. That formulation, however, was effectively *"all or nothing"* assignment and did not consider congestion effects.

In equilibrium (UE) models, congestion is represented by means of a capacity restraint, and the user equilibrium is found in accordance with Wardrops' first principle (Wardrop, 1952) (13). In this model, all drivers choose the route with the shortest travel time or the lowest travel cost, and equilibrium is reached where no driver can unilaterally achieve a reduction in time or cost by changing route.

Though UE models are the most widely used models in practical assignment, but have limitations due to.

'Empirical studies of route choice demonstrate that the capacity restraint mechanism in such models is insufficient to explain the variety of routes chosen, especially in more lightly-loaded inter-urban networks' (14)

More fundamentally, Gliebe *et*. *al*., 1999 (15) argued that the assumptions of UE are unrealistic and states *'Deterministic assignment is unrealistic since route choice decisions are based on perceived travel times or costs, which may vary across individuals. Further, some drivers do not know or judge incorrectly the shortest-travel-time or least-cost path, or choose a path for reasons not captured by the time and cost* *functions'*. Van Vuren [16] furthermore also states that *'…a deterministic (Wardrop) equilibrium is an unrealistic representation of the state of most urban networks. This is caused by variations in network conditions (e.g. the effect of weather and unexpected incidents on capacity) and variations in demand'*.

2.3 Different Concepts other than Shortest Route

Different approaches rather than the shorter shortest route concept started in the 1960's. Wachs (1967) [17] supported the following hypothesis for route preference by conducting a home-based survey in Chicago Metropolitan Area:

- Various route characteristics influence the people's route preferences. Preferences can vary with the characteristics of the people, their trips and the routes to which they have been exposed.
- Commuters who express preferences for many route characteristics actually tend to travel on the routes which possess them, whereas drivers who express little preference for such characteristics tend to drive on routes which do not possess them.
- For the work trip the length of the route is very important factor for choosing the route.
- Responses to the attitudinal statements about the reasons for route choice do not vary greatly with the type of trip.
- Commuter have to an inclination to choose the safer route (in terms of vehicle conflict)

- Instead of shorter distance he pointed out shorter travel time, which achieved by higher average speed.
- Time of the day is an importance function for the choice. In the peak hours, the tendency of route switching is increased. Routes having less congestion like freeways are preferred by the commuters.
- A decreased in tendency to drive through the commercial or the industrial area in the peak hours has been observed.

Benshoof (1970) [18] concentrated at how the route selection process was influenced by personal and trip-making characteristics such as:

a) Personal characteristics; Gender and age

b) Trip-making characteristics: Trip purpose and trip frequency.

The study also found that in the trip to work most of the drivers tended to decide their routes before getting into their cars, which later on defined by ‘Simultaneous Choice’ by Bovey and Stern (1990) [5]. Benshoof found that younger males tended to select their route later than older men do.

Ueberschaer M.H. (1971) [6] administered a survey based on a questionnaire which reflected that commuters having different motivations over route choice in Germany. 13000 commuters traveling from home to work were interviewed for their daily routes on the highway network and their motivation for choosing these routes. Travel time distance, number of possible stops, and maximum lane volume on a link between the points of choice are important criteria for selecting the route. These figured out factors were used to develop a trip-diversion model. It was found that the parameter values of this model depend on the route characteristics route distance and driving time and the type of town district traverse. They obtained a formula for the optimal routes in highway networks, contains travel time, length, and the lane volume of the link as important factors.

He found the following important points:

- Factors affecting trip patterns from home to work during the morning peak are homogeneous.
- The drivers coming from the same residential area going to the same industrial area, do not all take the same route.
- The freeways were the most preferred and reduced number of routes used when compared to an area where there were no freeways available.
- Route switching increased with distance.
- Travel time itself is a very good criterion for finding the optimum route because shortest route in time is most frequent one.
- Driver determines the total resistance of a route by weighting and summarizing the factors of resistance in particular sections and points of the highway network in the direction of his destination.
- The commuter tried to find out the hypothetical trade-off of the commuter to drive maximum distance along the freeway to reach the destination.

In 1972 by Ratcliff and in 1978 by Outram [(4)] and Thomson started concentrating on the travel cost as a parameter in the choice. They thought that the drivers' perceive cost is lower than the actual cost and defined it as “the cost the user thinks reflects the cost to him of making a trip. Due to ignorance, optimism or self-deception on the part of the user, the perceived cost is often less than the total cost.” [4]

Ulrich (1974) [19] also classified reasons for route choices for all trips into two groups:

- Road characteristics; Route length, road width, number of lanes, pavement conditions, geometric design, traffic control, speed limits, obstructions and scenery
- Traffic Conditions; travel time, waiting time, speed, commercial traffic, public transit in street and pedestrian control.

Shewey (1982) [4] found a significance variation in route change with the commuting distance. His found that drivers do not seek shorter routes if the savings in distance amount to less than 5 miles on journeys up to 25 miles and if the time difference was less than 5 minutes.

Vaziri and Lam (1983) [20] study based on a questionnaire which reflected that commuters having different preferences over criteria. They found that most respondents used the same route to work and back. Commuters used different weighting and ranking for the route attributes. The Study highlighted other parameters other than cost, travel time and distance. But the study did not consider the other parameter into any mathematical model or check any significance difference in importance of the criteria for choosing the route. Most of the studies still considered the shortest travel time as the dominant criterion for commuters' choice.

Bonsall & May (1986) [21] made an effort to correlate between the travel time and travel distant with the route choice. They used a sample of their study to check the accuracy of assignment models such as CONTRAM and SATURN to predict the route drivers would use, based on an equilibrium assignment model. They found that there was no clear relationship between the numbers of alternative routes a driver had tried or the length of time or the precise origin and destination of their journeys have no effect. They concluded that the propensity to use a variety of routes is very dependent on personal characteristics. Their models tended to predict paths along shorter but congested paths. Furthermore, the results of the model using minimum time as a criterion was only 35 percent successful comparing the paths from the drivers that selected routes on the basis of minimum journey time. The reasoning of this finding was not clearly stated, as this could either be due to inaccuracies in the model, its network or flow matrix, or the incomplete knowledge of the drivers.

Though most other studies have indicated a list of route choice factors found to be relevant, but many of these are applicable to inter-urban travel as opposed to intra-urban travel and the transferability of results of these studies are not always clear (Antonisse, Daly & Ben-Akiva, 1989) [1].

2.4 Behavioral Models of Drivers' Route Choice

Robert Antonisse *et al.*, in 1989 [1] defined the 'Route Choice' as the characteristics of choosing the best route through the transportation network considering the purpose, origin, network` condition, destination and mode which is thought of as the one that minimizes travel disutility. Though there are complex patterns of overlapping of network and driver's alternatives, their effort to simplify and improve the understanding of the driver's preferences and a traffic assignment model depending upon the behaviors. They concentrated on one of the important factor here; i.e. driver's knowledge regarding the network. Ben-Akiva *et al.* (1984) [22] also put an idea regarding this issue. R. Antonisse et al. focused on the following criteria for their analysis:

- Travel Time
- Distance
- Number of Traffic Signals
- Scenic Beauty(for non-obligatory trips)
- Time or distance on limited-access highways
- Commercial Development
- Congestion
- Road Quality
- Road Signing
- Number of Signals and Stops

Commuters from two different corridors with a number of viable routes in Nederland have been surveyed. The questionnaire included about the trip and personal characteristics, purpose of the trip, destination and the origin, frequency of the trip and driver's information and network data. The commuters have been asked to fill the all the attribute that effected the choice behavior. From a vast number of choice set the researchers selected their narrowed down set depending upon the attractiveness to remove out the complexities. The technique adopted in their analysis is "leveling" approach as descriptive levels are attached to the selected route candidates. Leveled paths are defined by the impedance function depending upon the one or more route attributes. Executing a minimum path algorithm level path for a particular criterion is determined. Observed chosen route data are required to select the most reasonable set to level to apply for forecasting in route choice. Primarily following 10 labels were selected for the application.

- Minimize Time.
- Minimize Distance
- Minimize number of Traffic Signals.
- Maximize Travel on Scenic Roads.
- Minimize Travel on Congested Roads.
- Maximize use of Expressway.
- Minimize Travel on High Capacity Roads.
- Maximize Travel in Commercial Area.
- Maximize Road Quality.
- Hierarchical Level.

A utility function is applied for each of the attribute. The maximum likelihood method is used to values of the utility function parameters. A computer network analysis package, SATURN, was used as to tool to generate the levels between all chosen origin-destination pair in study region. After putting positive and negative weightage on the different attributes a six-level model has been generated using both initial and final label co-efficient value. A significant effect of geographic area was found which could not be explained in terms of the trip purpose, length or frequency. Minimum travel time, minimum distance, maximum scenic route, minimum signal route, maximum capacity route, hierarchical travel route are the label-specific variables in the model.

Their analysis was matched with the collected surveyed data. But from the survey data it was possible to collect information on the "value of time", "importance of trip". They calculated the value of time by determining the ration between time and the distance co-efficient and factoring in an assumed operating cost per unit distance. A household survey was missing to categorize the data on the basis of economic level and work profile, which could approximately calculate a weight on the "value of time". The speed information for the road side was not there. The numbers of road and the speed regulation of the network in Nederland will vary from other parts of the world. In the study, the restricted speed zone is not been taken into consideration. Another important factor "cost" was not considered as a constraint in the route choice. "Cost" can be a directly or indirectly related to distance travel, no. of stops, speed, fuel efficiency of the vehicle etc. In the Questionnaire there was not any information about the number of passengers in the vehicle every time. It has been assumed that all vehicles were single occupancy vehicle. Though, this study was a remarkable step in this field.

Bovey and Stern (1990) [5] categorized the simulators for the driver which influenced to choose the route into three different categories.

1. Simultaneous Choice: For this case, the commuter chooses the entire route before the commencement of the trip. The changing behaviors of the road network do not influence the pre-determined route.
2. Sequential Choice: The commuter chooses at each alternative at common nodes of link but which is independent of the preceding route.
3. Hierarchical Choice: The commuter chooses at each alternative at common nodes of link but which is independent of the preceding route

The study stated that "It is our belief that travelers' use abstract concepts in evaluating their alternatives, including, for example; time, effort, comfort, safety and predictability. A remarkable fact is that no attempts have been made so far to identify route choice factors within a framework of more general choice behavior or needs satisfaction." (19)

They indicated 4 attributes as important in route choice:

a) The available routes

b) The character of the traveler

c) The trip that is to be made

d) Circumstantial instances (previous day's experience, information received etc.

A study by Watling (1992) (23) made an effort to summarize previous route choice studies and concludes that the following are considered prime route choice factors.

a) Direct (operating) cost as opposed to generalized cost

b) Perceived cost (Subjective combination of direct and generalized costs)

c) Physiological factors i.e. age, gender, etc.

d) Sociological factors such as income, status etc.

e) Habit of the driver

f) Network knowledge; driver experience

g) Traffic factors; delay, congestion, route characteristics

2.5 Route Diversion Behavior in Response to Delay

To correlate the drivers' route choice decision with the design strategies for the traffic congestion, Khattak *et al.*, in 1992 [20] performed a study in Chicago automobile commuter. The observed the route choice behavior pattern for the in response to incident-induced congestion.

The effects of following factors were explored:

a) Source of congestion information.
b) Incident characteristics (e.g. length of delay).
c) Trip origin and destination and other available route and other trip characteristics.
d) Attributes of the all available routes.
e) Environmental factors.
f) Driver characteristics (age, attitude, personality, safety measures etc).
g) Work rules (e.g. Flexibility of the delay).
h) Situational constraints (e.g. remaining trip length).

They stressed the attention onto individual threshold limit. Commuters set their individual threshold limit according to them and try to compare the perceived travel time and congestion to their expectation. When the frustration or the threshold limit exceeds, the commuters may be prompted to make a diverse route. As the threshold limit is specific to the driver, so it is almost impossible to set a standard limit.

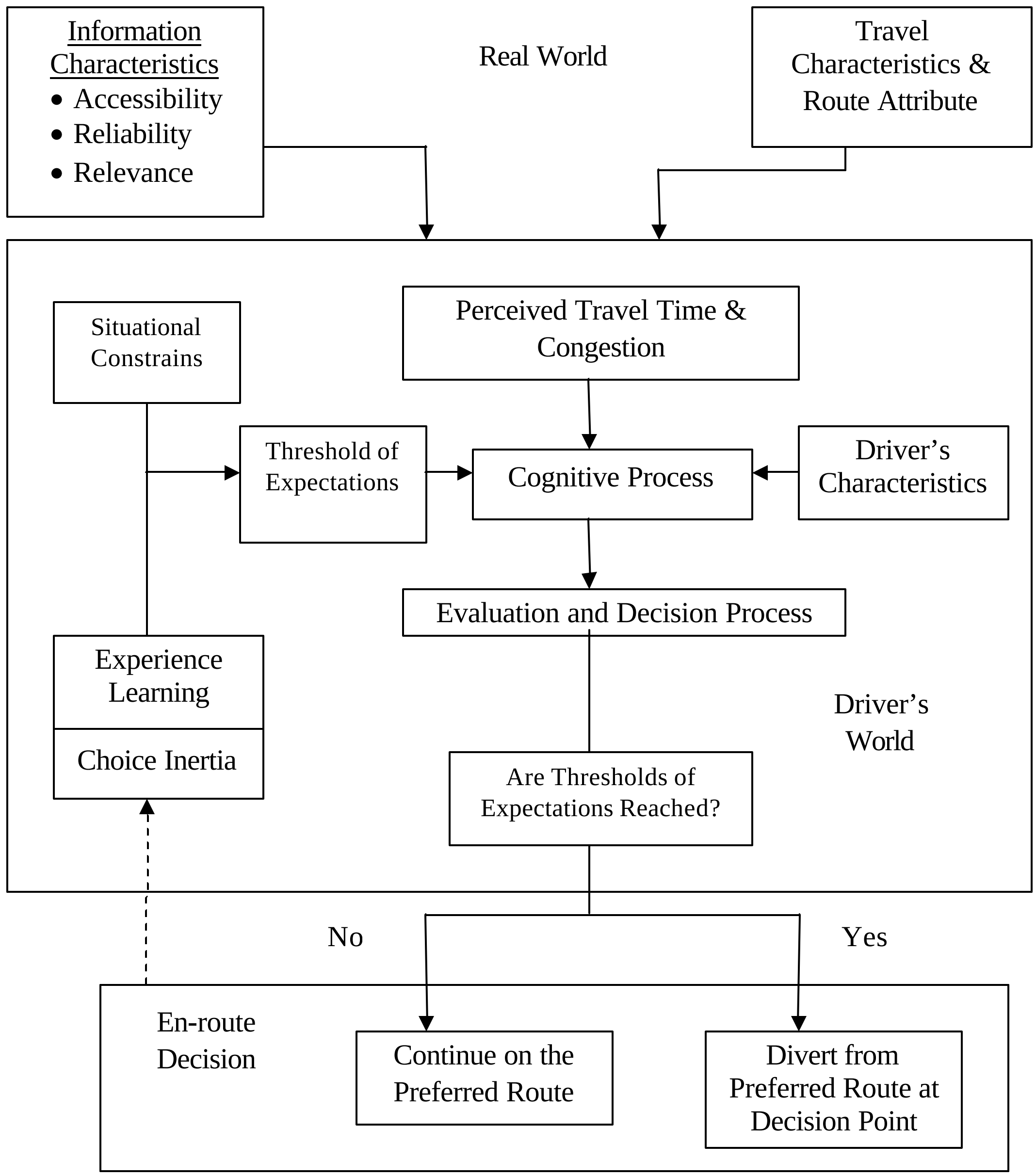

Fig 2.1: Conceptualization of En-route Decision making (Ref. Khattak *et al*., 1992) [20]

The collective report of the survey showed that 85 percent of the people experienced delay of about 15 to 30 minutes. The majority (60.8 percent of total) of the respondent experienced delay on to-work trip. Among them, 42 percent changed their route to avoid the delay. Several personality factors were identified. Almost 80 percent of them don't change their route for 1 year and 70 percent of them change their route occasionally. A relation between the length of expected delay and the diversion to an alternative route has been observed. Almost 61 percent of the drivers didn't change their route when the delay is around 10-20 minutes at the time of work trip. On the other hand, if the delay is greater than 20 minute almost 50 percent drivers changed their route. The diverter and the non-diverter have been asked to give an idea of the travel time either by changing route or not changing route that they saved by diverting or by non- diverting. More than 76 percent of the driver saved time by diverting.

To building up modeling driver response to delay effect of the variables such as delay, weather, trip direction, and information source, attributes of the usual and alternative routes, socioeconomic attributes, driver's age and personality have been explored. Statistical stets were used to choose model. Travel time, length, location had a short time travel had a low t-test statistics. The drivers are more likely to take the alternative route if they receive radio traffic report than the visual observation. A logarithmic transformation of delay is found, which is superior to linear delay. That explains that 5 minutes delay for 10 minutes travel time is same as the 30 minutes delay with 1 jour travel time. More knowledge for the alternative routes is very necessary for choosing the route for the driver. Drivers are generally skeptical to choose the alternative without being informed about it.

The individual attributes to choose the route are socioeconomic and demographic characteristics, personality and the attitude towards diversion. The attributes of the route has been chosen from congestion, roadside scenic beauty, reliability, number of stop signs, drivers' experience, stress experience during driving, and overall evaluation of the route by the driver. The main conclusion of this study driver chose the route on the basis of the radio information they get before the travel or at the time of travel.

2.6 Influence of Information on Route Choice

The route choice faced by the driver is much more complex because of large number of alternative routes and complex nature of overlap between the various routes. On route, the commuters sometimes fail to decide which route to take in case of any abnormal route network activity. In recent year a number study focus on the how the real time traffic information affects the driver's choice behavior. These studies mostly deal with the two parts of it. First of all how the driver responds when the information might not be reliable and secondly the objective of the developing redefined route including the effect of the traffic information. Most of the researchers have done on the basis of the telephonic or mail-in / mail-out survey. On the basis of the surveys of commuter in Austin, Texas Mahmassani *et. al.* (1990) [24] depicted the behavior of the commuter and their choice of route during morning and the evening peak hour. The model developed for switching propensity to switch the choices for both a.m. and p.m. commuters. The models related switching propensity in each case to four types of factors: geographic and network condition variables, workplace characteristics, individual attributes, and the use of information.

- They observed the tendency of the commuter to switch between the route mostly in the morning and the evening peak hour. The result provides the insight of the relative behavioral mechanism underlying the a.m. and p.m. traffic. A morning route choice and the evening route choice have been analyzed separately.

- Most of the commuters change their route in the way to work-to-home whereas, a significant number of commuter are willing to delay the departure time from home-to-work trip. At the same time only a few percent of the commuter appear to willing to delay the departure time from work-to-home trip. It was specifically mentioned in the survey that if they changed their routes which conditions they specifically considered to take a decision.
- Other than travel time, characteristics of roads and commuters, information use; the model for the a.m. and p.m. peak hour has been calibrated based on the "work rule". This means the flexibility that workers use as a tolerance limit to reach at office. Rather than the trip time, congestion variables, one of most important variable in this study was availability of the meaningful route alternatives to the commuter. A high statistical significance, the higher the number of alternatives increases the number of switching in the network.
- In the socioeconomic attribute, this study consider the "age" of the driver as an influencing factor. Though it had a lowest statistical important as compared to other variables in the model, though it had significance level of important to include in the model. Young aged drivers have a tendency to change the route whereas the old aged people are more skeptical about the habitual route and less inclined to switch it. In fact the young drivers prefer most often to go for the interstate and freeway for the route. They prioritize more on the speed of the vehicle and the travel time rather than traveling in shortest distance route and with more congestion.

- The use of route alternatives is more in the evening peak hour than the morning, and it is because of the fact that, drivers want to capture more geographical characteristics and to take advantage of the ability to leave earlier. Rules of the workplace take an important role in choosing the timing and more alternatives for driver. Mainly the a.m. route choice is guided by geographic considerations, network characteristics rather than social-demographic characteristics (other than age), or rules at the time place. On the contrary, evening peak hour route choice behavior is mostly motivated by the degree of congestion in the alternative routes. Due to the limitation of the data and the study area it is not a universally accepted generalized model for the study of the commuter behavior.

Although this study was not able to differentiate between the characteristics of the behavioral causes and pattern of the route choice. No doubt this early study opened an insight of the interaction between the choices.

A. Polydoropoulou *et. al.* [(25)] conducted a diary survey of Massachusetts Institute of Technology commuters conducted in the spring of 1991. They tried to reflect on the impact of factors such as driver's socioeconomic characteristics, travel characteristics and information characteristics on the following decisions.

- Pre-trip traffic information
- Pre-trip route choice
- En-route traffic information
- En-route switching decisions.

Before starting the trip the driver relies on the information acquired. If the driver does not acquire any information he/she relies on historical perceptions, experiences and starts their trip following the habitual route. For the en-route condition the driver can get the information passively or whenever expected level of service in not matched with the level of service what was expected he seeks for the real time traffic information. The perceived behavior can affect the updating of the driver's attitude towards the acquisition of and response to the real time traffic information and the future travel route choice. The acquisition of pre-trip and en-route traffic information is influenced by the perception of the driver in terms of reliability and relevance of the traffic information. More efficient and precise route guidance and information system (ATIS), capable of focusing the actual traffic will be more suffice in gaining driver confidence in following its route choice behavior.

Janssen and Horst in 1993, (26) concentrate their study on the impact of the information on the driver. Depending upon the type and presentation information on road congestion, it is driver's choice to diverge and driver's capability to find the user-optimal decision strategy. Driver always appreciates the freedom of own choice of route selection. Before their work, Heathington *et. al.* (27) and Dudek *et. al.* (28) presented their study on the change of driver's behavior under descriptive information modes. But their studies were hypothetical and did not involve any actual behavior and based only about preferred information on a single route. In Heathington study, was shown that the probability of diversion of the commuter is a function of delay at a certain monetary cost. However, he did not consider the inherent unreliability of the information. Janssen and

Horst sought to determine the pattern of the diversion form the normal route behavior encountered by the information of different reliability in terms of the varying degree of actual travel time. They choose variable message signing (VMS) as a means for diverging traffic from an original normal route towards a reasonable alternatives. Three modes of variable information presentation were compared

a) Length of congestion.

b) Delay relative to normal travel time.

c) Travel times.

With the experimental process, they found a correlation between the inclinations to diverge when the information is in terms of congestion length. When congestion length is concerned, the percentage of diversion reaches very fast to 100 percent with the increase of the reliability of the information, and on the other hand does not even approaches 100 percent under most extreme conditions of congestion if the information is less reliable. Whenever travel time or delay is concerned, the divergence is not so affected by the reliability of the information as it reaches slowly to 100 percent as the reliability increases. In case of travel time and the delay the diversion rate is not affected for the most reliable information also as the driver depends more to their past experiences, but in case of congestion, the diversion rate is much higher even for the most unreliable source. A significant increased in driving speed had been observed from the point of VMS and up-to the decision point with the increased of the length of the congestion. The driving speed in also intended to increase with the severity of the congestion. That indicate the length of congestion affects significantly to the behavior of the driver. A tendency to diverge from the normal route had been observed whenever the detailed information with indication of the worse condition of congestion in the normal route. Driver's behavior to diverge is sensitive to certain particular types of information in conjunction of the particular level of reliability in terms of length of congestion. This is because the driver's perception of the relationship between the actual and expected travel time is much stronger than the length and the severity of the congestion. The driver is more capable of discerning relationship between of these variables. But in case of congestion, driver's perception easily affected when sufficient unreliability is added.

2.7 Travel Time Uncertainty as a Contributing Factor to Route Choice

Travel time is one of the important factors to the route choice. In 1950 to 1990, a number of research works examined the factor affecting the commuters' choice. Some researchers concluded that travel time is the most dominant, where as some researchers indicated travel distance is predominant factor. Simultaneously, researchers also noted the importance of other factors as road type [17, 7], avoidance of congestion [17], and avoidance of stops and signals [29]. In 1995, M. A. Abdel-Aty *et. al.* [30] conducted study to determine how reliability (in terms of travel time) affects the choice behavior of the driver. Travel could suffer the disutility of the route because of the uncertainty or unreliability in travel times. In a survey based study, M. A. Abdel-Aty *et. al.* found 54 percent of respondents in a route choice survey indicating that travel time reliability is either the most important or the second most important reason for choosing their primary routes. A Computer Aided Telephonic Interview (CATI) of Los Angeles area morning commuters were surveyed in the summer of 1992. The similar study in the similar area is done in the next 1993 summer to investigate the commuters' attitude and the perceptions about the several route characteristics and to understand the effect of the travel time variation on the route choice. The model they used for their experiment showed:

- Commuters' perceptions and attitude have important effects on their choice behavior. If respondents perceive shorter travel distances as being important then they choose the route which they d as a shorter travel time with a significant reliability.
- Receiving traffic information is a very significant variable in this model. Information is more likely to influence the degree of uncertainty which ultimately directs the route choice behavior. The study revealed an interesting observation. Commuters who regularly listen to pre-trip information are more likely to choose the uncertain route. An explanation of the fact could be because of they have the idea about the delay on a route and try to avoid that route.
- Gender also had a significant effect on route choice. Males are more likely to choose the uncertain route in trying to minimize the travel time.

The models estimated the tradeoff involved in the choice between a longer reliable route and a shorter route with uncertain travel time. The impact of the travel time variability differs in individuals. The idea of the risk aversion and risk prone could be the extension of the study.

2.8 Route Choice Behavior Study by GPS Data

Federal Highway Administration studied with the GPS (Global Positioning System) vehicle location data from Lexington, Kentucky (1997) [14] to determine whether these data are helpful in analyzing path choice assumption in assignment model. An effort to match between the trips of same origin and destination has done. The method adopted an automated data collection device that incorporated commuters' reported information and Global Positioning System (GPS) information for the collection of personal travel data. This device offers a robust data source for defining personal travel. By observing the same vehicle movement over the network and plotted into the GIS along with the drivers' feedback, the characteristics of the driver became more clear.

The user-optimal equilibrium assignment or the stochastic multi-path traffic assignment is mostly used by transportation planners. But the underlying assumption and the theoretical approach still have not received desired degree of validation and reliability. The objective of the study was to differentiate between actual travel behavior and traffic assignment. The data set consists of Kentucky household and driver survey over 1-week period time. Two path times have been calculated; one is network path time and other is GPS path time. The former one is the sum of all links identified as being in the actual path from the trip's origin and destination. GPS time is the sun of the actual time on the each link between the trip's origin and destination. Numerous paths from the same origin and destination set have been observed from the GIS. It has been observed that variation of GPS path time for the same trip at different times is very small. Shortest path are almost different from the actual paths. More travelers made major difference from the shortest route. The GPS data represented a picture which does not support the Wardrops' principle. GPS data can reveal the some of the missing information which can not be interpreted from the traditional theoretical route-choice model. Travel behavior information, individual travel tracking is almost impossible to discern from the interviews, respondent-administered questionnaire or driver simulators. GPS data can tract all the positioning of the vehicle over time but it is unable to gain any information regarding the underlying cause of the driver decision. A post experiment survey is very necessary for this data for the analysis. Most important observation found from the experiment from it is, the driver changes the route whenever the route distance is short. As the distance of the route increases, the tendency of the changing the route increases. This GPS data could be important for the design of the path-finding algorithm in travel demand forecasting model.

2.9 Other Recent Studies

Peter Shen Chen *et. al.* in 1999 [2] examined the driver behavior on the basis of the information acquired based on the survey conducted at University of Texas, Austin. The nature and the quality of the information and the feedback from the drivers have been studied. Trip-time information is based on reliable prediction, prevailing condition, differential predicted, differential prevailing, or random. Reliability measures are calculated at each decision node for each user as the fraction of the prior experience with absolute value of the reliability falling below a threshold. Increasing reliability of information was found to result in higher compliance. Particular interested was drawn into possible difference in the influence of experience between pre-trip decision and en-route decision. Commuter are more inclined to comply with real time traffic information when

- It is associated with a greater number of departure switches to later time
- Commuter has not experienced significant congestion recently.

- Experiencing high variability in trip time or arriving destination earlier than expected.
- Commuters are provided with prescriptive or normative information than when they are provided with descriptive description.

To investigate the drivers' variance route choice between the Home and Work Trip a study was took place in Metropolitan Transport Area of East London, South Africa in June 2000 [(4)]. The survey was based on a questionnaire to determine the variance amongst driver route choice by comparing the AM and PM Home and Work commute trip. The objective of the study was to determine this variance by measurement of the spatial variance and the variance in route choice factors, which drivers apply when making these two types of trip. The target sample was the commuters who made regular trip from the outlying residential suburbs along the busiest private mode travel corridor to places of employment in the central business district or commercial area. The study hypothesis was that congestion, personal characteristics, suburb location, experience, network knowledge and trip purpose can influence spatial variance. This could also be influenced by external factors such as the need to stop en-route or drop-off/pick-up. Another purpose for this study to observe the deviation pattern of the commuters' compared from the most direct route pattern. The objective could possibly lead to a clearer understanding of how to model traffic, as well as what the effect of alternative diversion routes would have on the behavior of drivers, and hence traffic flows. This study also included the parameter mentioned by Watling (1992) [(23)] into consideration.

Metropolitan Transport Area of East London conducted a self administered constrained-response questions. 250 questionnaires were distributed to motorists in East London that were resident in any of the suburbs.

The findings are summarized below:

- No significance difference in trip length between the Am and PM for the typical and alternative routes.
- The difference in trip length was unaffected by the socio-demographic characteristics of the sample. The average has been found only 5 percent longer than the shortest route. Gender, age, journey time, departure time, fixed or flexible working condition or car age did not reflect any significance effect for route switching.
- A significance difference in route switching with the income of the commuter has been observed.
- At least 45 percent of the drivers use a different route for at least part of their journey to work and back with 25 percent of drivers using a substantially different route (>50 percent) for the AM and the PM. For this case he accepted the null hypothesis and rejected the alternative hypothesis.
- There is no significant difference in lateral separation between the AM and PM for the typical and alternative routes.
- There is no significant difference in lateral separation between the AM and PM for the typical and alternative routes.
- The route that differs by more than 50 percent between the AM and the PM, the separation is greater (1.57 km) than those that are less than 50 percent different.

- Higher income earners have lower journey times for the “quickest” PM trips.
- The majority of the drivers have been found who choose the route before commencing the trip.
- The most popular reason for selecting a route is that “it is the quickest” followed by “it is the most convenient” and thirdly “it is the shortest”. The popularity of the reasons is the same for the AM and the PM.

The study was actually based on the modeling of the AM flows and reversing the flows for the PM journey. But a significance difference could be there in the AM and PM traffic. Correlation studies of the underlying factors related to route choice would be necessary to explain some of the spatial differences found in this study.

Table 2.1 shows the works of previous researchers and their attribute set.

Table 2.1: Attributes in Route Choice Observed by different Research Worker

Researchers(s)	Year	Traffic Information	Time of day	Travel Time	Minimum Distance	Scenic Beauty	Capacity of road	Weather	Traffic Lights	Habit	Delay on route	Congestion	Familiarity with route	Driver's factor	Location of Study
Mahamassani *et. al.*	1990	X	X									X		X	Austin, TX
Polydoropoulu *et. al.*	1991	X	X	X				X	X	X	X	X			MIT, MA
Heathington *et. al.*	1970	X									X				Chicago, IL
Khattak *et. al.*	1990			X				X			X	X		X	Chicago, IL
Dudek *et. al.*	1970	X										X			Houston & Dallas, TX
Dudek *et. al.*	1978	X													Dallas,TX
R. Antonisse *et. al.*	1980			X	X	X	X		X						Netherlands
Daniels *et. al.*	1976	X													Chicago, IL
Huchingson & Dudek	1979	X									X				Multistate in U.S.A.
Huchingson *et. al.*	1977	X		X							X	X	X		Dallas, TX
Huchingson *et. al.*	1984	X									X				Houston, TX
Haefner & Dickson	1974			X											Baltimore-Washington
Richards *et. al.*	1978	X									X		X		Dallas, TX
Tumer *et. al.*	1978	X													Chicago, IL
Dudek *et. al.*	1982	X									X	X			San Antonio, TX
Roper *et. al.*	1984	X													Los Angles, CA
Shirazi *et. al.*	1988	X									X				Multistate
Stephandes *et. al.*	1989			X							X				Twin Cities, MN
Mannering	1989			X								X			Seattle, WA
Haselkorn *et. al.*	1989	X									X	X	X		Seattle, WA

CHAPTER 3: FRAMEWORK FOR ROUTE CHOICE BEHAVIOR

This chapter presents the general framework of the route choice behavior. The nature of the attitude, perception, pre-trip and en-route impact, and dynamic aspects of route choice behavior are explored. The factors for the well understanding of the choice behavior are as follows:

- Origin and the destination should be well defined.
- Driver's have an adequate knowledge about the network.

3.1 Basic Flow Diagram of Route Choice Behavior

The route choice of the traveler depends on their socioeconomic characteristics such as age, genre, income, as well as their personality, habits, preference, driving experiences and familiarity with the transportation network.

The purpose of the trip, flexibility in arrival time, availability of the alternatives and traffic conditions affect strongly in the choice. These vary from person to person. The characteristics of each alternative route do not have the same importance for driver's final decisions. Effect of alternatives counter balance one another and attribute a high value or positive or negative weightage. The decision making process has a dynamic character due to feedback from each trip made, acquiring new experience on each trip. The learning process is involved in the perception and the cognition of the driver and the information acquired through the past experience is processed in the next step. Moreover, inertia also plays a role; certain thresholds need to be crossed before changing the habitual route.

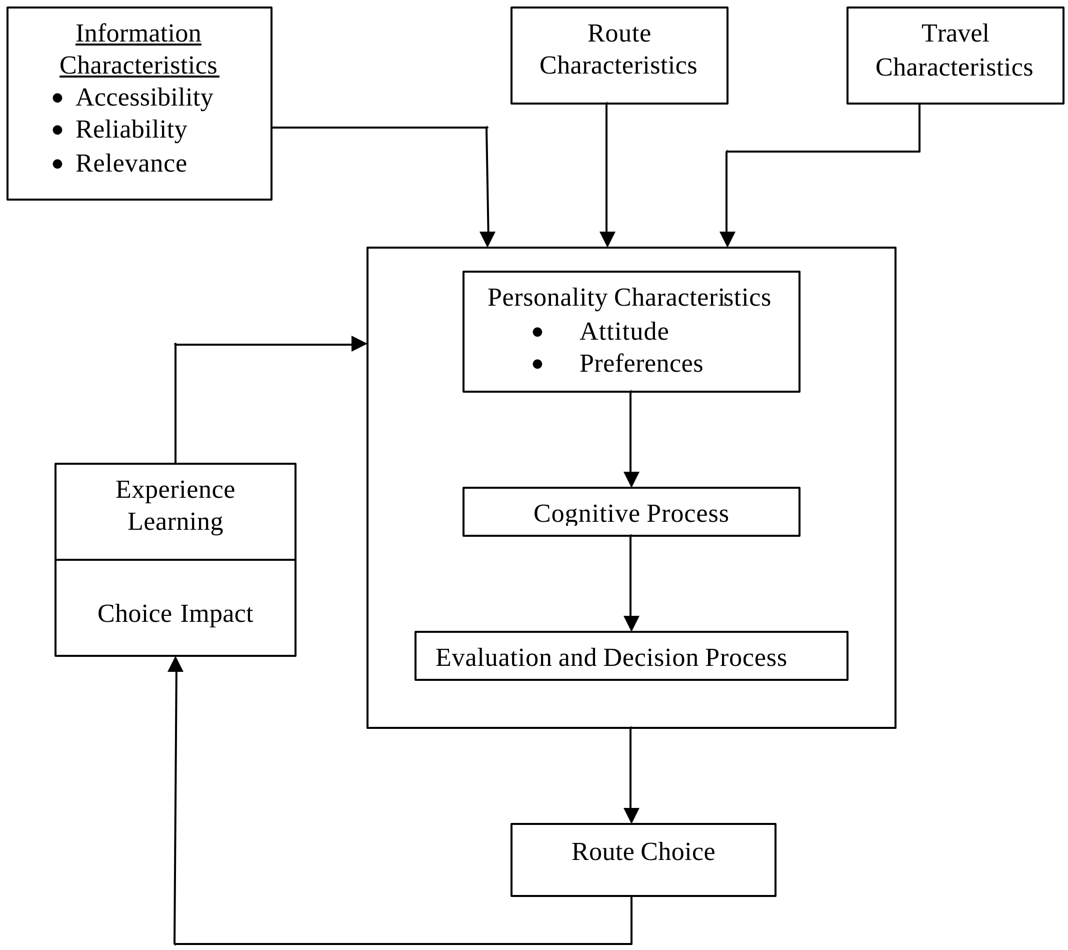

Fig 3.1: Framework for Route Choice (Ref. Polydoropoulou, A. *et. al*.) [31]

The route attributes and the personal characteristics of the traveler guide the choice behavior. These factors are summarized in the following table. [6]

Table 3.1 Table of Attributes in Route Choice

Driver's Attribute	Age
	Sex
	Income Level
	Education
	Value of Time
	Experience
	Level of Comfort
	Habituation
	Number of Passenger Traveling
Route Attribute	Distance
	Road Condition
	Capacity
	Congestion Index
	Road Width
	Number of lanes
	Number of Turns
	Number of Traffic Lights
	Number of Stops
	Traffic Volume
	Average Speed of the Vehicle
	Slope
	Reliability
	Land use along the Route
	Scenic Beauty
	Road Construction
	Safety
	Weather
	Pre-Trip and En-Route Traffic Information
Trip Attribute	Purpose
	Travel Time
	Cost of the Travel

Most of the researchers worked previously with this topic could not get sufficient data on some of the attributes of the model. Sometimes it is impossible to analyze from the available data traffic survey data conducted for some different purpose. The basic model development criteria are based on the principle how the commuter creates the rule to choose the route. It is true that every commuter chooses the route by different processes. There is no certain rule for a particular route choice. The thought process underlying the choice of the route in commuter's mind is called the "Route Choice Rule". The analysis of this study categorized the route choice rule into different types. The intention of the commuter is to shorten the travel time, and to take a shortest path. But the commuter neither can succeeds to choose it precisely every time nor can rationalize to select the route without considering the other criteria. Every rule instructs the commuter to a route and the commuter chooses it initiated by the rule. At the first stage of this procedure, the commuter chooses the rule and the choice set and in the second stage the commuter chooses which route to take. It is an effort to explain and build up the model how the rule is being created [16].

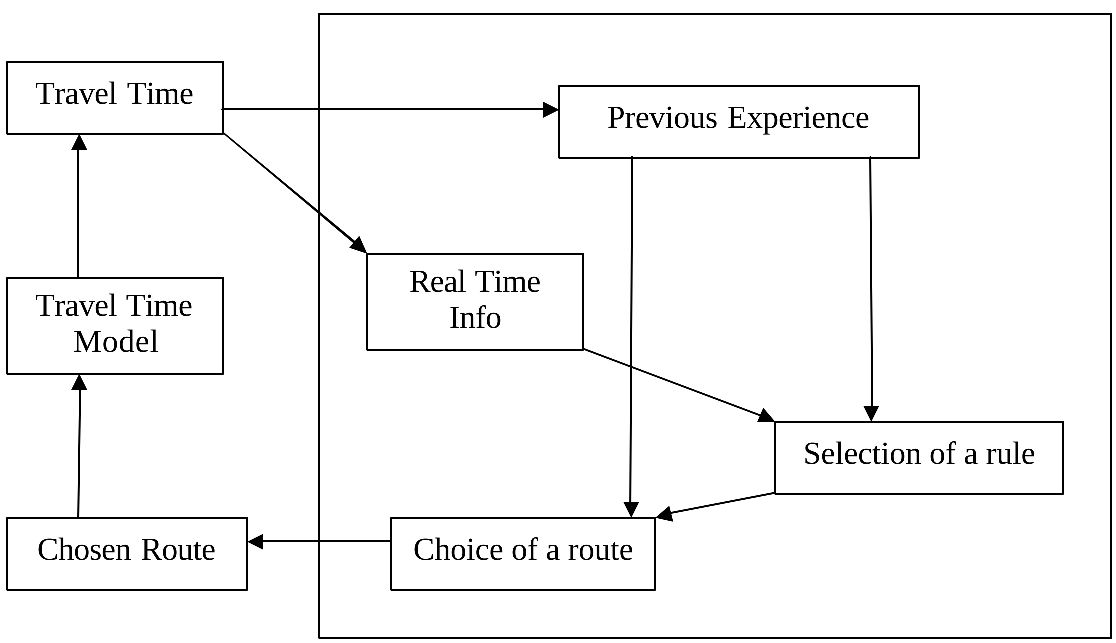

Fig 3.2: Outline of Travel Time Based Model (Ref. Nakayama, S. *et. al*., 2001) [3]

3.2 Route Choice Rule

The flow diagram of the rule processing is shown in the Fig 3.3. When the commuter drives on the road network between an origin-destination pair, he can choose any significant different route to reach the same destination point if options are available. Not all commuters for the same origin-destination pair choose the same route for the trip. Otherwise the particular shortest time or shortest distance route would have been congested. They rationalize with the availability and their preferences [3].

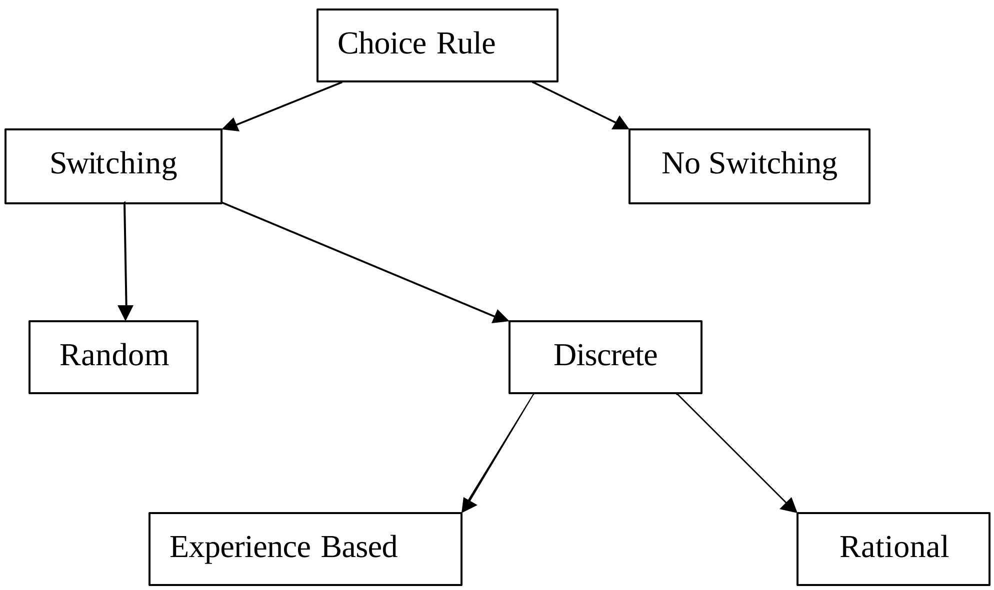

Fig 3.3: Flow Diagram of Choice Rule

The commuter selects the route by following different procedures [3].

a) No Switching Criterion

In this case commuter decides not to switch and continues along the habitual route. The commuter adopting a no-switching rule does not change the rule until a new set of rules guides the commuter to select another route. The commuter can choose the no switching criterion through experience.

b) Random Switching

In which commuter chooses the route almost randomly. Mostly, commuters who are not so habituated with the network do this. The commuter chooses the route without paying much attention to choose but rather makes the decision impromptu.

c) Experienced Based Choice

The commuter adopts the rule-set and selects the rule based on his experience and chooses the route accordingly. The experienced commuters who are habituated with the network choose the route on the basis of their expected cost as well as average of the most recent travel times experienced on the route. They are well aware of the network characteristics. The experienced based traveler is expected to choose the route from the network to minimize the expected cost and travel time. In experience based choice, the uncertainty of the route and the day of travel are viewed as the commuter's attitude towards risk in the travel. This is a bounded ratio nality in decision making where they formulate and select the route based on the experience.

d) Rational Choice

This process is done by minimizing the average travel time. Based on the all information the commuter takes the decision by taking consideratio n all travel times that he/she has experienced in past. Where in the experienced based switching the commuter only consider a subset of the all travel times he/she has experienced. The expected travel time calculated by the rational commuter is the average of all the travel time that the commuter has experienced.

Probably it is true that these four types of route choice do not include all types of choice behavior. Attempts are made here to study the overall characteristics of all commuters by developing the rational rule to choose the route. The primary assumption is that all commuters are homogenous and rational. Otherwise it would be difficult to analyze due to insufficient data. The commuter will choose the route rationally depending upon the information she/he has. This assumption implies that if all commuters are rational and homogeneous they should use rational rule even if they have the limited set of rule and, if some of them do not follow the rule at the beginning due to small set of rule, will also adopt a rational rule with a more comprehensive set of rules after a substantial amount of time passed in the network.

In this study several survey data has been analyzed to build up a set of attributes which guide the commuter to select the route. Depending upon the factor analysis, attributes have been grouped. From the survey responses, route switching model has been developed.

CHAPTER 4: METHODOLOGY

4.1 Procedure

In the context of commuter's route choices, there is a lack of consistency between the behavioral mechanisms assumed implicitly by the models used in practical scheme assessments, and those observed on-street. This study attempts to address this issue by collecting a large volume of route choice data and applying this to appropriate models. The methodology is divided into four main sections:

- Sample selection
- Instrumentation
- Data collection
- Data analysis

The methodology is based on the objectives of the study. The research performed will be an exploratory study focused on analyzing the commuters' attitude related to their choice of route during their work and shopping trips. This study will further identify the impact of commuters' perception about the choice of alternate routes on travel behavior.

4.2 Sample Selection

The subjects of interest for this study are students, faculty, and staff in University of Toledo using cars for coming to school and shopping purposes. The inclusion criteria of this study are:

- Adults - male and female, greater than or equal to 18 years of age

- People who regularly drive the car to workplace or shopping place

Regular Travelers are significant in the collected sample, as their regular travel behavior tends to change with different attributes considered. People who do not drive regularly would not be considered in the study, since their choice set of route is a subset of that of the regular commuters.

4.3 Instrumentation

A self-administered questionnaire designed was the instrumentation for the survey. The instrument was designed after reviewing relevant literature. The questionnaire contains 20 items divided into 3 parts.

Part I of the questionnaire is designed to collect socio-demographic information of the respondents. This data was used to analyze the relation between the choice behavior and age, sex and car possessions.

In Part II, an effort was made to seek information from the respondents about the regular travel information for the work-trip. These questions are related with commute time, travel time flexibility and travel habits. Moreover, the respondents were asked to give their responses on a 5-point Likert scale according to the importance of various factors that alter the route choice. The 5-point Likert scale ranges from 1(strongly disagree) to 5 (strongly agree). The respondents were asked to select only one response that they believe provides the best answer. All factors are considered as the independent variables in the study.

Part III of the questionnaire focuses on collecting responses for shopping trips so one question wais based on the shopping route choice on the same 5-point Likert scale. A cover letter explaining the nature and purpose of the study and its importance is attached with the questionnaire. This cover letter mentions the name of the institution, i.e. University of Toledo as the study area. It also requests respondents to remain anonymous and assures them of confidentiality. A contact email ID was mentioned for the use of those respondents who have further questions or comment regarding the survey.

4.4 Method Hypothesis

The focus of the work is the investigation of the criteria on commuters' route choice behavior. The underlying hypothesis is that the route selection and switching are influenced by the following factors:

1. Driver's socio-economic characteristics.
2. Trip characteristics.
3. Route characteristics.

The above factors are basic inputs for route choice behavior. The choice process is not a direct derivative of exogenous variables [11]. Bovey and Stern 1990 [5] explained this as a black box procedure, where an individual uses a system of perception and evaluation filters to make his/her final choice.

Survey was proposed to be conducted from faculty, staff and students of The University of Toledo. The assumptions made for the survey are summarized below:

1. The set of commuters selected for the survey will significantly represent the general category of people in terms of age, sex and their economic status. No discrimination of age, sex is made.
2. All commuters surveyed are homogenous and rational.

3. University of Toledo is the one of the important organizations which attracts trip in Toledo area, so the target sample includes faculty, staff and students at the University of Toledo represent the characteristics of the commuters in the City of Toledo. The trip to school is work trip for the faculty and staff. Though, for analysis purpose the trip to school for the student also taken as ‘work trip’.

4.5 Data Collection

Human subjects are utilized for this study as the data is collected by using a self-administered questionnaire filled in by the people. The approval of Human Subjects Research and Review Committee (HSRRC) of The University of Toledo was necessary to conduct this study.

The questionnaire was pre-tested for validity and reliability. Testing of validity is carried out to determine if the questionnaire contains any unclear questions or any missing terms, and to quantify the time required to complete the questionnaire. The respondents were asked to evaluate if there are any unclear questions or missing terms present in the questionnaire. The final version of the questionnaire was completed based on the recommendations from HSRRC and committee members.

The survey was online, where the respondents filled in the questionnaire posted on a survey web-casting agent. The web-casting agent is contacted to upload the survey on the web. The website took responsibilities to collect the information from the respondents. Every filled up questionnaire received through the web site was anonymous. The www.surveymonkey.com took the responsibility for collecting, storing and sending information. The responses are considered for further analyses.

4.6 Data Analysis Procedure

Data was entered into the SPSS (Statistical Package for the Social Sciences) version 12 in The University of Toledo. Reliability of the questionnaire was calculated by using Cronbach's coefficient alpha. Frequency distribution will be used to analyze the responses. A regression analysis on the information obtained will also be conducted to achieve the research objectives.

CHAPTER 5: DATA ANALYSIS

5.1 Results from Conducted Survey

A total of 787 individuals responded to the survey questionnaire. The first part of the survey reflects commuter's socio-demographic information. The responses for this part of the survey are summarized in Table 5.1 to 5.5. Table 5.1 reports that, of the respondents, 43.9 percent were males while 55.7 percent were females. 62.1 percent of the commuters were married and 36.6 percent were single. Table 5.4 represents the different categories of age of the respondents. Table 5.5 reports the auto ownership of the respondents. 91.4 percent have cars and 83.8 percent drive their cars regularly to school.

Table 5.1: Summary of Survey- Part I

		Sex	Marital Status	Age	Having Car
N	Valid	781	777	781	779
	Missing	6	10	6	8

Table 5.2: Summary Statistics based on Sex

	Sex	Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	343	43.6	43.9	43.9
	Female	438	55.7	56.1	100.0
	Total	781	99.2	100.0	
Missing	System	6	.8		
Total		787	100.0		

Table 5.3: Summary Statistics based on Marital Status

Marital Status		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Single	489	62.1	62.9	62.9
	Married	288	36.6	37.1	100.0
	Total	777	98.7	100.0	
Missing	System	10	1.3		
Total		787	100.0		

Table 5.4: Summary Statistics based on Age

Age		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	20 years or less	93	11.8	11.9	11.9
	21-30 years	339	43.1	43.4	55.3
	31-40 years	80	10.2	10.2	65.6
	41-50 years	131	16.6	16.8	82.3
	51-64 years	128	16.3	16.4	98.7
	65 years and older	10	1.3	1.3	100.0
	Total	781	99.2	100.0	
Missing	System	6	.8		
Total		787	100.0		

Table 5.5: Summary Statistics based on Auto Ownership

Automobile Ownership		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	712	90.5	91.4	91.4
	No	67	8.5	8.6	100.0
	Total	779	99.0	100.0	
Missing	System	8	1.0		
Total		787	100.0		

Table 5.6: Drive Car to School

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	653	83.0	83.8	83.8
	No	126	16.0	16.2	100.0
	Total	779	99.0	100.0	
Missing	System	8	1.0		
Total		787	100.0		

Table 5.7: Number of Days Coming to School

No. of Days Coming to School		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	4	.5	.7	.7
	2	25	3.2	4.2	4.8
	3	29	3.7	4.8	9.7
	4	83	10.5	13.8	23.5
	5	384	48.8	64.0	87.5
	6	32	4.1	5.3	92.8
	7	43	5.5	7.2	100.0
	Total	600	76.2	100.0	
Missing	System	187	23.8		
Total		787	100.0		

Table 5.8: Respondents' Commuting Time

		Home to School Commute Time	School to Home Commute Time
N	Valid	600	601
	Missing	187	186
Mean		18.56 min	19.43 min
Median		15.00 min	15.00 min

Table 5.9: Respondents' Shortest Commuting Time

		Shortest Commute Time from Home to School	Shortest Commute Time from School to Home
N	Valid	567	566
	Missing	220	221
Mean		14.76	15.31
Median		12.00	12.00

Table 5.10 Respondents' Longest Commuting Time

		Longest Commute Time from Home to School	Longest Commute Time from School to Home
N	Valid	567	566
	Missing	220	221
Mean		28.38	31.70
Median		22.00	25.00

Table 5.11: Route Change Behavior from Home to School

Changing route during last 3 months		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	195	24.8	34.4	34.4
	No	372	47.3	65.6	100.0
	Total	567	72.0	100.0	
Missing	System	220	28.0		
Total		787	100.0		

Table 5.12: Route Change Behavior from School to Home

Changing route during last 3 months		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	188	23.9	33.3	33.3
	No	377	47.9	66.7	100.0
	Total	565	71.8	100.0	
Missing	System	222	28.2		
Total		787	100.0		

Table 5.13: Number of Times Changed Route during past 3 months

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	140	17.8	30.1	30.1
	2	147	18.7	31.6	61.7
	3	122	15.5	26.2	88.0
	4	35	4.4	7.5	95.5
	5 or More	21	2.7	4.5	100.0
	Total	465	59.1	100.0	
Missing	System	322	40.9		
Total		787	100.0		

5.2 Differences in Attitude with Trips

17 attribute-response questions were given to each respondent to determine what criteria were important to his/her choice of a route for school trip. The same questions were repeated for getting information on shopping trip. Table 5.14 and 5.15 give the summary of respondents' results. The respondent circled number 5 if the attribute represented a very important factor for his/her choice of route, 1 if the factor was very unimportant, and a number between the extremes if his/her feelings were better represented by such a response. The distributions of the data collected from Question no. 13 and Question no. 18 were not normal. Hence non-parametric tests have been selected to analyze these data. Non-parametric Mann-Whitney two-sample test was employed to determine whether responses to each of the attribute about route choice were distributed similarly or differently for different trip types.

Table 5.16 and Table 5.17 show the results of the Mann-Whitney test on 17 attitude variables. The null hypothesis that 'there is no difference between the contribution of attribute variables for selecting the route for different trip types' could not be rejected at the 95 percent level of confidence. Commute Time, Traffic Congestion, Habituation of Route, Number of Traffic Lights, Risk of Delay were significantly more skewed towards the important end of the scale of route choice for the work/school trip than that for the shopping trip. Commuters indicated more importance on Weather, Cost of Travel and Number of passengers traveling for the route choice for shopping trip than that for the school trip. For these variables the null hypothesis is rejected and alternative hypothesis is accepted at 95 percent confidence interval. This perhaps indicates the business nature and the importance of time for the school trip as compared to the more leisurely nature of the shopping trip. Reaching the destination promptly is the most important criterion for the work (here school) trip whereas commuters consider other factors like comfort and pleasure of driving as important for shopping trip. For example, Weather and Number of Passengers with the commuter are related to the pleasure of driving. The commuters also seem to detract from the habitual route more for the shopping trip than the school trip. En-route Real Time Traffic Info is also an important criterion in cities where commuters get En-route traffic information. In Toledo, this did not show a considerable effect as this facility is available only in some portions.

Table 5.14: Importance of factors for work trip affecting route choice

Attributes	1 Not Important at all (%)	2 (%)	3 (%)	4 (%)	5 Very Important (%)
Time of the day when you travel	22	8	19	20	31
Commute Time	7	4	14	29	46
Habituation of Route	13	12	29	27	19
Traffic Congestions	5	3	9	35	48
Number of Traffic Lights	8	10	23	32	27
Traffic Forecasting Reports	29	18	24	17	12
Risk of Delay	10	13	23	32	23
Weather	28	21	20	18	13
Condition of Roads	15	15	25	27	18
Scenic Beauty of Road	48	21	17	9	4
Number of Turns	51	19	19	8	3
Shortest Distance	9	7	20	29	35
Number of Passenger Traveling	69	11	10	6	3
Purpose of the Trip	27	11	21	22	19
Cost of the Travel	35	16	19	18	12
Safe Route	16	9	26	27	22
En-route Real Time Traffic Info	35	18	23	15	9

Table 5.15: Importance of factors for shopping trip affecting route choice

Attributes	1 Not Important at all (%)	2 (%)	3 (%)	4 (%)	5 Very Important (%)
Time of the day when you travel	18	10	22	27	23
Commute Time	10	9	26	30	25
Habituation of Route	18	15	34	22	11
Traffic Congestions	4	3	18	38	35
Number of Traffic Lights	14	17	29	25	15
Traffic Forecasting Reports	31	19	27	14	8
Risk of Delay	14	17	28	29	12
Weather	19	20	26	21	13
Condition of Roads	11	14	31	29	15
Scenic Beauty of Road	44	24	20	9	3
Number of Turns	46	23	21	9	1
Shortest Distance	6	7	24	33	30
Number of Passenger Traveling	49	20	18	9	4
Purpose of the Trip	14	9	25	30	23
Cost of the Travel	27	17	25	18	13
Safe Route	15	11	26	27	21
En-route Real Time Traffic Info	32	20	25	16	8

Table 5.16 Results of Mann-Whitney Test of Significance between work and shopping trips

Attributes affecting route choice	Significance
Time of the day when you travel	No
Commute Time	Yes
Habituation of Route	Yes
Traffic Congestions	Yes
Number of Traffic Lights	Yes
Traffic Forecasting Reports	No
Risk of Delay	Yes
Weather	Yes
Condition of Roads	No
Scenic Beauty of Road	No
Number of Turns	No
Shortest Distance	No
Number of Passenger Traveling	Yes
Purpose of the Trip	No
Cost of the Travel	Yes
Safe Route	No
En-route Real Time Traffic Info	No

(Yes indicates significant difference. No indicates no significant difference, level of significance= 95 percent.)

Table 5.17: Analysis of attributes for different trips (Work and Shopping)

Attributes	Mann-Whitney U	Wilcoxon W	Z	Asymp. Sig. (2-tailed)
Commute time	108697	260773	-7.7111	0.0000
Habituation of route	124875	279165	-4.4248	0.0000
Traffic Congestion	125310	277386	-4.4137	0.0000
Number of traffic lights	113176	266911	-6.6639	0.0000
Risk of delay	122831	277121	-4.8319	0.0000
Weather	133851	275629	-2.7234	0.0065
Number of passengers traveling	117867	258052	-6.1843	0.0000
Cost of the travel	136194	276379	-2.0645	0.0390

5.3 Factor Analysis for School and Shopping Trip

The list of the characteristics which were considered and rated by the respondents contains some attributes that are redundant and overlapping with others on the list. For example, "Traffic Congestion" and "Risk of Delay" may lead to the same conclusion to those drivers who perceive congestion as increases the chance of delay on their way. It was not quite possible to eliminate the redundancy before the questionnaire was administered because commuter's perceptions about the inter-relationship of the attributes were not known at that time. Some of the attributes may measure the similar or the underlying value of the other attributes.

Factor Analysis is a tool to reduce the redundancy in the matrix of measurements. A rotated principle component factor analysis procedure has been adopted on the matrix of scaled responses to the statement [(20)]. This technique identifies the independent attribute toward route choice by isolating and grouping them. The factor loading obtained by performing the test is instructive and enables one to examine the interrelationships among the responses to the 17 attributes. The grouping of the attributes made the total data set more manageable and interpretable. The analysis along with statistical explanation of attribute was performed for school and shopping trips separately. The factor analysis resulted in reduction of the 17 attitudinal variables for school trip to 5 orthogonal factors, which account for 60.23 percent of the variance in the original variables. Whereas, for the shopping trip the attitudinal variables it has been reduced to 4 factors which account for 54.97 percent variance of the original variables. Table 5.20 gives the 5 factors along with the variables which load heavily upon them and factor loading for school trip. For school trip, commuters travel to school more than 4 days in a week has been considered. It is supposed that they are familiar with all alternative routes and routes' characteristics. Table 5.21 presents the factor loading for shopping trip. All respondents are considered in this analysis. Table 5.21 gives the 4 factors along with the variable and factor loading for shopping trip. An independent nomenclature assigned for the new factor grouping one or more variables which can interpret of the meaning of the common nature of all the variables loaded heavily on each factors. Variables in a particular group are in order of their variances. The 5 factors for school trip and 4 factors for shopping trip have been treated as representatives of the entire matrix. The validity of the factors is subject to judge. For the school trip, Number of Turns attribute came into the forth factor. But it supposed to be a route attribute factor. But commuters' responses were spatially grouped with other attributes of personal comfort factor. Number of turns increases the discomfort of the commuters.

Table 5.18: Rotated Component Matrix for School Trip [a, b]

Attributes	Component				
	1	2	3	4	5
Time of day when you travel	.177	.678	.133	.044	-.135
Commute time	-.032	.611	.074	.004	.503
Habituation of route	-.051	.177	.009	.578	.327
Traffic Congestion	.233	.787	.014	.124	.070
Number of traffic lights	.141	.669	.044	.323	.110
Traffic forecasting reports	.672	.337	-.033	-.127	.000
Risk of delay	.525	.598	-.053	-.074	.106
Weather	.792	.071	.052	.201	-.005
Condition of road	.724	.150	.147	.318	-.025
Scenic Beauty of road	.184	.058	.173	.670	-.263
Number of turns	.269	.074	.052	.698	.143
Shortest distance	.135	.026	.017	.108	.834
Number of passengers traveling	.081	-.038	.771	.156	-.174
Purpose of trip	.087	.121	.791	.023	.104
Cost of the travel	.394	.080	.567	.000	.403
Safe route	5.522	.207	.318	.184	.179
En-route real time traffic info (e.g. display signs on roads)	.542	.113	.258	.122	.146

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 7 iterations.

b. Only cases for which Trip Type = School are used in the analysis phase.

Table 5.19: Rotated Component Matrix for Shopping Trip [a, b]

Attributes	Component			
	1	2	3	4
Time of day when you travel	-.064	.732	.268	.075
Commute time	.059	.682	-.010	.480
Habituation of route	.171	.144	.081	.529
Traffic Congestion	.217	.772	.030	.131
Number of traffic lights	.229	.652	.174	.055
Traffic forecasting reports	.642	.326	.099	.038
Risk of delay	.422	.561	.013	.145
Weather	.768	.092	.165	-.044
Condition of road	.738	.238	.218	-.048
Scenic Beauty of road	.279	.069	.660	-.038
Number of turns	.228	.105	.694	.061
Shortest distance	-.051	.167	.074	.747
Number of passengers traveling	.090	.041	.737	.098
Purpose of trip	.057	.191	.501	.230
Cost of the travel	.453	.109	.288	.445
Safe route	.697	.078	.183	.286
En-route real time traffic info (e.g. display signs on roads)	.582	-.045	.169	.395

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 6 iterations.
b. Only cases for which Trip Type = Shop are used in the analysis phase.

Table 5.20: School Trip Choice Attribute Factors and Factor Loadings

Factor Number	Parcent of Variance	Loading	Factor Name and Variable Names
1	16.754		Route Attribute
		0.672	Traffic Forecasting Report
		0.792	Weather
		0.724	Condition of Road
		0.522	Safe Route
		0.542	En-route Real Time Traffic Information
2	14.805		Importance for Time
		0.678	Time of the day
		0.611	Commute Time
		0.787	Traffic Congestion
		0.669	Number of Traffic Lights
		0.598	Risk of Delay
3	10.56		Commuters' Personal Attribute
		0.771	Number of Passengers Travelling
		0.791	Purpose of Trip
		0.567	Cost of Travel
4	9.65		Commuters Comfort on Route
		0.578	Habituation of Route
		0.67	Scenic Beauty of Route
		0.698	Number of Turns
5	8.529		Distance factor
		0.834	Shortest Distance

Table 5.21: Shopping Trip Choice Attribute Factors and Factor Loadings

Factor Number	Parcent of Variance	Loading	Factor Name and Variable Names
1	17.856		Route Attribute
		0.642	Traffic Forecasting Report
		0.768	Weather
		0.738	Condition of Road
		0.453	Cost of Travel
		0.697	Safe Route
		0.582	En-route Real Time Traffic Information
2	15.467		Importance for Time
		0.732	Time of the day
		0.682	Commute Time
		0.772	Traffic Congestion
		0.652	Number of Traffic Lights
		0.561	Risk of Delay
3	12.097		Commuters' comfort and Personal Attribute
		0.660	Scenic Beauty of Route
		0.694	Number of Turns
		0.737	Number of Passengers Travelling
		0.567	Purpose of the Trip
4	9.552		Distance and Habituation of Route
		0.578	Habituation of Route
		0.834	Shortest Distance

A typical factor analysis has been done taking both shopping and school trip into a single group. The rotated component matrix is shown on Table 5.22. From the table the grouping is done and shown in Table 5.23. This factor grouping is same as the School trip but with slightly different percent of variation. This is taken as the final factor loading for the attribute in route choice analysis. It has been grouped into 5 different factors. To check the variation of the factor among trip types, Mann-Whitney analysis is done. Table

5.17 reflected the differences of the individual attributes among trip types. From Table 5.24, it is observed that for Factor 2, 3, 4 (i.e. Important of time Factor, Commuters Personal Attribute Factor and Commuters' Comfort on Route Factor) have significant difference between different type of trips. Commuters have an importance of time when they go to school, but this is significantly different from the shopping, where they have the flexibility on time. For commuter's personal attributes and commuters' comfort attribute factors are concerned, it is observed that for shopping trip that the mean value is significantly above from the school trip.

Table 5.22: Rotated Component Matrix for School Trip [a]

Attributes	Component				
	1	2	3	4	5
Time of day when you travel	0.039	0.717	0.276	0.068	-0.079
Commute time	0.034	0.666	0.071	-0.063	0.471
Habituation of route	0.042	0.173	-0.086	0.478	0.417
Traffic Congestion	0.236	0.772	0.016	0.067	0.086
Number of traffic lights	0.173	0.669	-0.037	0.286	0.127
Traffic forecasting reports	0.636	0.362	-0.019	-0.011	-0.011
Risk of delay	0.473	0.586	-0.082	-0.012	0.098
Weather	0.771	0.071	0.075	0.174	-0.089
Condition of road	0.719	0.201	0.099	0.276	-0.076
Scenic Beauty of road	0.199	0.065	0.161	0.735	-0.086
Number of turns	0.210	0.091	0.115	0.743	0.160
Shortest distance	0.078	0.090	0.068	0.003	0.806
Number of passengers traveling	0.100	-0.008	0.747	0.291	-0.084
Purpose of trip	0.160	0.129	0.770	-0.006	0.097
Cost of the travel	0.465	0.084	0.496	-0.002	0.373
Safe route	0.659	0.133	0.194	0.149	0.210
En-route real time traffic info (e.g. display signs on roads)	0.584	0.031	0.186	0.134	0.238

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 7 iterations.

Table 5.23 Trip Choice Attribute Factors and Factor Loadings (both for school and shopping trip)

Factor Number	Parcent of Variance	Loading	Factor Name and Variable Names
1	17.502		Route Attribute
		0.636	Traffic Forecasting Report
		0.771	Weather
		0.719	Condition of Road
		0.659	Safe Route
		0.584	En-route Real Time Traffic Information
2	15.379		Importance for Time
		0.717	Time of the day
		0.666	Commute Time
		0.772	Traffic Congestion
		0.669	Number of Traffic Lights
		0.586	Risk of Delay
3	9.397		Commuters' Personal Attribute
		0.747	Number of Passengers Travelling
		0.77	Purpose of Trip
		0.496	Cost of Travel
4	9.363		Commuters Comfort on Route
		0.478	Habituation of Route
		0.735	Scenic Beauty of Route
		0.743	Number of Turns
5	8.486		Distance factor
		0.806	Shortest Distance

Table 5.24: Factor Attributes Analysis of different trips (School and Shopping)

Attribute	Mann-Whitney U	Wilcoxon W	Z	Asymp. Sig. (2-tailed)
Route Factor	121690	245443	-1.353	0.1762
Importance of Time Factor	96668	229538	-6.736	0.0000
Commuters' Personal Attribute Factor	90776	214529	-8.003	0.0000
Commuters' Comfort Factor	127776	260646	-0.043	0.9654
Distance Factor	111312	244182	-3.585	0.0003

Table 5.25: Correlation coefficient for the Factors

Spearman's rho		Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Factor 1	Correlation Coefficient	1.00	-0.01	0.05	0.02	0.01
	Sig. (2-tailed)	0.00	0.77	0.15	0.46	0.86
	N	1014	1014	1014	1014	1014
Factor 2	Correlation Coefficient	-0.01	1.00	0.00	-0.03	-0.01
	Sig. (2-tailed)	0.77	0.00	0.93	0.30	0.80
	N	1014	1014	1014	1014	1014
Factor 3	Correlation Coefficient	0.05	0.00	1.00	0.00	0.00
	Sig. (2-tailed)	0.15	0.93	0.00	0.93	0.98
	N	1014	1014	1014	1014	1014
Factor 4	Correlation Coefficient	0.02	-0.03	0.00	1.00	-0.01
	Sig. (2-tailed)	0.46	0.30	0.93	0.00	0.67
	N	1014	1014	1014	1014	1014
Factor 5	Correlation Coefficient	0.01	-0.01	0.00	-0.01	1.00
	Sig. (2-tailed)	0.86	0.80	0.98	0.67	0.00
	N	1014	1014	1014	1014	1014

5.4 Relationship between Attitudes towards Route Choice and the Characteristics of the Respondents and their trip

It has been hypothesized that the selection of route depends on the commuters' personal characteristics, nature of the trip, route characteristics and the available alternatives routes. In this section, this hypothesis is tested. Attempts have been made to test the functional relationship between driver socioeconomic characteristics and the nature of the trip with the choice.

It also hypothesized that commute time is an important factor for the route choice and route switching. Difference between the shortest commute time and longest commute time leads to the unreliability of the route. So there could be a tendency of switching the route when the difference between shortest and longest commute time increases. Significant relation has been observed between these two variables.

No significant differences found either between home to school and school to home commute time or between change of route preference for going to school and coming back to home.

The literature searches tell that socio-demographic characteristics sometimes plays role for the route choice and route switching. From bivariate correlation analysis (Spearman's rho), there is not any significant correlation found with Gender, Age, Marital Status with route attribute factor or the route choice.

5.5 Reliability

Reliability was used for the analysis having variables developed from summated scales are used as predictor components in objective models. For question number 13 and 18 in the survey, the attitude of the respondents towards the route choice are measured. The options for the answer were in the Likert Scale. Since Likert scales are an assembly of interrelated items designed to measure underlying constructs, it was important to know whether the same set of items would bring out the same responses if the same questions are recast and re-administered to the same respondents. To check the reliability of the question sets, this study used Cronbach's Alpha. The Cronbach's Alpha was calculated for the set of questions in Q.13 and Q.18 as a whole and for variables in the factors that were achieved by factor analysis. Variables derived from test instruments are declared to be reliable as they provide stable and reliable responses over a repeated administration of the test. The Cronbach's Alpha value for Q.13 and Q.18 (commuter's perceptions related questions towards route choice for school and shopping trip) are above 0.8. For factor no. 1 and 2, the value is well above 0.7. For Factor 3, the value is closer to 0.7 which is acceptable. But the low reliability of the factor no.5 has been achieved (0.58). This may be accounted by the differences in people's perception about 'scenic beauty', a subjective parameter considered in this factor. The term "scenic beauty" has a wider scope, and is difficult to rate on a Likert Scale. It might have been difficult for the people to rate this particular parameter, since it depends on what kind of route the commuter follows. For a person, scenic beauty might be the surroundings in the form of mountains, trees, parks, fountains etc., while for some other commuters, this might be in terms of materialistic things around in form of malls, banners etc. There might be a case when a commuter admires scenic beauty, but it is not relevant for his usual travel. The question, though clearly formed might have been difficult for people to perceive. Hence this question was not very consistent with the other parameters in this factor, which were quite straightforward to answer. The distance factor (factor no. 5) consists of only one variable. So no reliability analysis was done. The results of the Cronbach's Alpha are follows:

Table 5.26: Reliability Statistics of Answers set of Question no. 13

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.846	.848	17

Table 5.27: Reliability Statistics of Answers set of Question no. 18

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.826	.827	17

Table 5.28: Reliability Statistics of Factor no. 1 (Route Attribute Factor)

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.762	.772	5

Table 5.29: Reliability Statistics of Factor no. 2 (Importance of Time factor)

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.773	.774	5

Table 5.30: Reliability Statistics of Factor no. 3 (Commuter's Personal Attribute Factor)

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.614	.687	3

Table 5.31: Reliability Statistics of Factor no. 4 (Commuter's Comfort Attribute factor)

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.577	.578	2

5.6 Route Switching

Route Switching is an important issue in route choice behavior. Commuters switch from their habitual route depending on the roadway condition and their personal characteristics. For demand management strategies which are designed to modify the driver behavior by encouraging drivers to change their route is a way to ameliorate the traffic congestion. To understand the diversion behavior, it is important to know the relationship between the diversion with commuters' socio-demographic and the trip characteristics. The following tables are the results of cross tabulation with the socio-demographic characteristics with the route switching.

Table 5.32: Gender and Route Change Cross Tabulation

		Change Route		Total
		No	Yes	
Gender	Male	69	402	471
	Female	57	596	653
Total		126	998	1,124

Table 5.33: Age and Change Route Cross Tabulation

		Change Route		Total
		No	Yes	
Age	20 or less	10	100	110
	21-30	83	360	443
	31-40	15	106	121
	41-50	17	194	211
	51-60	1	222	223
	65 and old	0	18	18
Total		126	1,000	1,126

Table 5.34: Marital Status and Change Route Cross Tabulation

		Change Route		Total
		No	Yes	
Marital Status	Single	88	564	652
	Married	38	432	470
Total		126	996	1,122

From the Table 5.33, it can be perceived that age is a criterion for switching the route. Older people are most likely to change the route. Males also change their route more than female commuters. Commuters with single marital status also have more tendencies to switch the route than that of married commuters. To check the significance difference of switching route among the groups, Mann-Whitney test is performed (Table 5.35). All three socio-demographic factors are significant in switching the route with a confidence interval of 99 percent.

Table 5.35: Mann-Whitney test for socio-demographic factor in Route Switching

	Mann-Whitney U	Wilcoxon W	Z	Asymp. Sig. (2-tailed)
Sex	53769	61770	-3.103	0.002
Marital Status	54456	62457	-2.831	0.005
Age	43577	51578	-5.878	0
Grouping Variable: Change Route				

To model the commuter's switching decision, this study incorporated the binary logit regression model. In the model, the dependent variable (switching of routing) was 1 for who switches and 0 otherwise. Logistic regression can be used to predict a dependent variable on the basis of independents and to determine the percent of variance in the dependent variable explained by the independents; to rank the relative importance of independents; to assess interaction effects; and to understand the impact of covariate control variables. Logistic regression applied maximum likelihood estimation after transforming the dependent into a logit variable (the natural log of the odds of the dependent occurring or not) (Table 5.36). In the set of the independent variable, gender, age, marital status, difference in time between the longest and the shortest commuting time to come to school (keeping in assumption that if the variance is more the tendency of switching the route will be more), Home to school commute time and all the factors got from factor analysis. But after repetitive model run, only the independent variables with significant contribution toward the switching have been considered. The R^2 value turned out low. All the questions set here based on the human attitude over route choice. So in this model, it was not possible to consider all the parameters that affect the dependent variable. Sometime, it happens in the human subject related survey. These attitude based questions somewhat did not carry the high R^2 value, though we can consider the model is good because the independent variables in the model are within the significant level. More researches are necessary to incorporated more variable in the considering more sample size, because more independent variables and more the data could lead to high R^2 value. Observing the odd ratio in Table 5.38, it is found that there is a significant relation between the gender and the age of the commuter with the route switching. Gender, age, home to school average commute time, difference between the shortest and the longest commute time (Independent variable) have the effect of increasing the odds that the dependent variable equals 1.

Table 5.36: Binary Logit Model Summary

tep	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	540.020(a)	.083	.160

a) Estimation terminated at iteration number 6 because parameter estimates changed by less than .001.
b) Method= Enter

Table 5.37: Classification Table (a) for Regression Model

	Observed		Predicted		
			Change Route		Percentage Correct
			No	Yes	
Step 1	Change Route	No	0	100	.0
		Yes	3	734	99.6
	Overall Percentage				87.7

(a) The cut value is .500

Table 5.38: Variables in the Equation in the Regression Model

	B	S.E.	d.f.	Sig.	Exp(B)
Gender	.555	.225	1	.014	1.742
Age	.400	.096	1	.000	1.492
Difference in longest and shortest commute time from home to school	.030	.016	1	.051	1.031
Home to school average commute time	.040	.014	1	.003	1.041
Importance of Time Factor	.222	.111	1	.044	1.249
Distance Factor	-.328	.120	1	.006	.721
Constant	-.814	.466	1	.081	.443

CHAPTER 6: CONCLUSIONS AND FURTHER RESEARCH

6.1 Contribution

The major contributions of this thesis consist of the following:

- A framework for route choice has been developed here. The attributes influenced the route choice were combined and studied. In this framework, driver's perceptions and the principle road attributes were identified which could be used as the factors of choosing the route. The set of the principle factors can be used in the trip assignment model.
- Impacts of socio-demographic factors on the driver's attitude and perceptions towards route choice and diversion were studied.
- The detailed survey revealed the differences in attitude for school (work) and shopping trip. Some of the factors significantly different in choosing the route for work and shop.
- Finally, the primary data from the conducted survey revealed the nature of the choice behavior in the city like Toledo. Surveys on the driver's route choice behavior have been conducted in greater city than Toledo. This behavioral analysis on commuters in Toledo can reflect the choice characteristics of U.S. mid-size city.

6.2 Major Findings

Comparing the work with other research worker, the following can be said:

- Importance of time is crucial factor for route choice. Congestion, risk of delay, traffic lights, commute time are measures of time factor for commuters. This supports Dudek *et. al.*, Polydoropoulu (1991), Khattak *et. al.* (1990), Heathington *et. al.* Shortest distance is an important criterion for both the shopping and the school trip, which was reflected in previous works. En-route information did not turned out as an important criterion for the choice. A. Polydoropoulu (1991), Khattak *et. al* .(1990), Mahmassani *et. al* .(1991), Dudek *et. al.* (1978) observed the importance of en-route traffic information on route choice. The conducted the survey bigger city than Toledo where commuters really get the en-route traffic info as compared to Toledo. So this study did not reflect any significant impact on en-route traffic information in choosing the route.
- The study analysis indicates that there are relationships between the attitude of respondents toward the choice of route and the social-demographic and trip characteristics.
- The attitude of the commuter significantly varies when the purpose of the tour changes.
- Two-third commuters of the survey change their route during work trip and this route switching depend on the commuter's socio-demographic

characteristics, trip characteristics, route distance and individual use of space and time.

- Shewey (1982) found significance variation in route switching with the commute time and distance. This survey did not reflect any preference of route switching depending on travel time.
- The time factor and the distance factor do not impact route choice for shopping trip as these do in work trip.

6.3 Directions for Further studies

This survey has been done for the city of Toledo. Previous experiments have been done mostly in bigger cities than Toledo. The commuter's behavior and travel characteristics change with cities. After the study it has been found that the choice set considered here in this study was not sufficient enough to represent all attributes for route choice. Because, except than the criteria mentioned in the survey an open ended question about additional factors for the choice of route was asked in the questionnaire. Most of the people mentioned 'road construction' as a factor for route choice. This factor has not been included in the surve y questionnaire so it was outside the scope of the analysis. It is recommended to include this factor for further research.

A pilot test of this questionnaire for any further survey is recommended. Due to scope of the study and time constrained, the administration of the questionnaire has not been proper. The R^2 value for the binary logistic regression was low. To increase the R^2 value re- administration, pilot testing and the sample size should be increased.

These relationships between attributes could have been explained in details. But due to limitation of the data, it was not possible. More information and emphasis are needed for alternative routes available to the commuters and how they use it.

In spite of the limited success of the research, this study demonstrated the feasibility of this type of study in the city like Toledo and thus it is possible to identify the elements of choice set and theirs values. It is hoped that this methodology and the findings of the research will contribute to the urban transportation planning and evaluation process.

The concept of this study can be applied in some fields of intelligent transportation system. For example, incident management includes diversion of traffic to safer and better routes in case of congestion, accidents and other unusual incidents. This rerouting is done depending on the prevailing road conditions on the affected roads and those on the proposed detours. Commuter route choice behavior can be used as an important tool in incident management. Diversion of traffic can be made not only according to road conditions, capacity of proposed detour etc but also on all the parameters considered in this study. This will further help the planning authorities to reroute traffic not only on limited features but also according to commuters' convenience and choice.

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APPENDIX- A: HSRRC, UNIVERSITY OF TOLEDO APPROVAL

THE UNIVERSITY OF TOLEDO
University Office of Research

Mail Stop 944
Toledo, Ohio 43606-3390
419.530.2844 Phone
419.530.2841 Fax
www.research.utoledo.edu

Human Subjects Research Committee

6/15/2004

TO: **Anirban Pal**

RE: Research Project# **204-131**
Commuters' Route Choice Behavior for work and shopping trip in the City of Toledo

The University of Toledo Human Subjects Research Review Committee has completed its review of your project utilizing human subjects.

Your project has been approved as submitted, and you are authorized to use human subjects in that project until 6-15-05 . At the end of that time, if your project is not complete, you must submit a request for an extension and a progress report in order to continue the project beyond that date. When your project has been completed, please fill out and send me the enclosed Certificate of Compliance.

This approval for the use of human subjects is contingent upon your following the research plan presented in your submitted proposal. You are not permitted to undertake any actions involving human subjects which are not a specific part of that proposal. If it becomes necessary to make changes, you may use those modifications only after you submit them for review and inclusion in your project file. Without such review, this authorization is void and you are not permitted to use human subjects in your research.

If any untoward incidents or unanticipated adverse reactions should develop in the course of your research on human subjects, you must suspend the project temporarily and notify me immediately.

Thank you very much for your cooperation. If you have any questions, please feel free to contact me at 419-530-1918.

Sincerely,

Gerald P. Sherman

Gerald P. Sherman, Chair

cc: Office of Research HSRC File
Dr. Jiwan Gupta, MS# 307

APPENDIX- B: COVER LETTER FOR QUESTIONNAIRE

A Survey of Your Route Choice Behavior

Department of Civil Engineering
University of Toledo

Attached is a questionnaire prepared by a Transportation Engineering Research Group in the Department of Civil Engineering at University of Toledo. This is a part of research in the area of Intelligent Transportation System (ITS), which aims at providing a highly efficient and productive service of transportation facilities, thereby reducing traffic congestion. This survey is designed for transportation planners for having a better understanding of travel behavior and route choice characteristics. Research is particularly focused on target sample of faculty, students and staff of The University of Toledo. Being familiar with this city, you can make a great contribution with your responses, ideas and views through the questionnaire.

Please feel free to participate in this survey and ready to share your views by filling up the online questionnaire. This survey is designed to take not more than ten (10) minutes of your time. Your response is extremely valuable to us. Please do not put your name on the questionnaire. We assure you that all the responses will be strictly kept confidential. Your participation in this study is voluntary, and your decision to participate will not affect your relationship with The University of Toledo.

If you have any further question(s) or comment(s) please feel free to mail apal@eng.utoledo.edu

APPENDIX- C: SURVEY QUESTIONNAIRE

Part I: About Yourself

All information requested in this section is related to your personal and household data. We need this information for better understanding of personal and family characteristics affecting commuting choices. All information collected will remain strictly confidential.

1. Sex:

☐ Male ☐ Female

2. Marital Status:

☐ Single ☐ Married

3. What is your age group?

☐ 20 or Less than 20 years ☐ 21-30 years ☐ 31-40 years

☐ 41-50 years ☐ 51-64 years ☐ 65 years or older

4. Do you have a car?

☐ Yes ☐ No

Part II: School Trip

5. Do you usually drive car for coming to school?

☐ Yes ☐ No

(The Questionnaire was designed in such a way that if the answer for Q.5 is "No", then it will directly go to the Part III)

6. How many days in a week do you usually commute to school? ☐ Days

7. During driving to school:

   (If you come to school more than once from home, then indicate the earliest leaving time from home and latest arrival time at home)

   What time do you leave home? ☐ Hours ☐ Minutes.

   What time do you come home? ☐ Hours ☐ Minutes.

8. What is your usual commuting time assuming "Regular" traffic condition, i.e. no extreme traffic delay, no major incidents and no weather related problems?

   Home to School? ☐ Minutes

   School to Home? ☐ Minutes

9. What is the shortest driving time that you have experienced during past 6 months:

   Home to School? ☐ Minutes

   School to Home? ☐ Minutes

10. What is the longest driving time that you have experienced during past 6 months.

   Home to School directly? ☐ Minutes

   School to Home directly? ☐ Minutes

11. Did you switch your route during past 3 month for:

   School to Home?

   ☐ Yes ☐ No

Home to School?

☐ Yes ☐ No

12. How many different routes did you use during the trip from home to school or school to home?

☐ (in numbers)

13. Indicate the importance of following factors in choosing the route for school trip on a scale of 1 to 5, where 1 indicates "Not important at all" and 5 indicates "Very important":

	Not important at all 1	2	3	4	Very important 5
Time of day when you travel					
Commute time					
Habituation of route					
Traffic Congestion					
Number of traffic lights					
Traffic forecasting report					
Risk of delay					
Weather					
Condition of Road					
Scenic beauty of road					
Number of turns					
Shortest distance					
Number of passengers traveling with you					
Purpose of trip					
Cost of the travel					
Safe route					
En-route real time traffic info (e.g. display signs on road)					

14. If you feel that there is any other factor(s) influenced your route choice, please feel free to write it here.

Part III: Your Shopping Trip

15. Do you drive car for shopping?

☐ Yes ☐ No

(The Questionnaire was designed in such a way that if the answer for Q.15 is "No", then it will directly go to the Part IV)

16. Do you go for shopping during

☐ Weekdays only ☐ Weekend only ☐ Both

17. How frequent do you go out for shopping?

☐ Once in a Month ☐ Once in a Week

☐ More than Once in a Week but not Daily ☐ Daily

18. Indicate the importance of following factors in choosing the route for shopping trip on a scale of 1 to 5, where 1 indicates "Not important at all" and 5 indicates "Very important":

	Not important at all 1	2	3	4	Very important 5
Time of day when you travel					
Commute time					
Habituation of route					
Traffic Congestion					
Number of traffic lights					
Traffic forecasting report					
Risk of delay					
Weather					
Condition of Road					
Scenic beauty of road					
Number of turns					
Shortest distance					
Purpose of trip					
Cost of the travel					
Safe route					
En-route real time traffic info(e.g. display signs on road)					

19. If you feel that there is any other factor(s) influenced your route choice for shopping, please write it here.

20. If your feel any question(s) unclear or any missing term please feel free to write here.

Part IV

Thanks for your willingness to participate.