A FRAMEWORK FOR MODELING RICKSHAW MOVEMENTS IN HETEROGENEOUS TRAFFIC CONDITIONS

By

MD. MOZAHIDUL ISLAM

A thesis submitted to the Department of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka, In partial fulfillment of the requirements for the degree of

BACHELOR OF SCIENCE IN CIVIL ENGINEERING
(Transportation)

Department Of Civil Engineering
BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

February, 2011
CERTIFICATION OF APPROVAL

A thesis paper on

A FRAMEWORK FOR MODELING RICKSHAW MOVEMENTS IN HETEROGENEOUS TRAFFIC CONDITIONS

Prepared by

MD. MOZAHIDUL ISLAM

Supervised by

Dr. Charisma Farheen Choudhury
Assistant Professor
Department of CE, BUET
DECLARATION

I hereby declare that the research work presented in this thesis submitted to the department of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka, Bangladesh has been performed by me and this report or any part of it has not been submitted elsewhere for any other purposes except for publication.

MD. MOZAHIDUL ISLAM
ACKNOWLEDGEMENT

The author would like to express his sincere appreciation and gratitude to his supervisor, Dr. Charisma Farheen Choudhury, Assistant Professor, Department of Civil Engineering, Bangladesh University of Engineering and Technology (BUET), for her continuous guidance, invaluable suggestions and affectionate encouragement at all stage of this study. Without her valuable direction and cordial assistance, this research work could never be materialized. The author’s debt to her is immense.

The author is indebted to Md. Asif Imran, MSc., Bangladesh University of Engineering and Technology for his draft copy of thesis paper which has helped to a great deal regarding thesis writing.

The author is thankful to Japan International Co-operation Agency (JICA) for their valuable information which has helped to devise and initiate the observation process.

The author is grateful to the authors of different articles mentioned in the reference which proved to be very helpful throughout the whole thesis work.

The author is indebted to Ferdous, Tonmoy, Sadri and his other friends and staffs who have helped by mental support and collecting papers and journals regarding the thesis.

Finally, the author is willing to show his solemn gratitude to his parents for their continuous support and motivation throughout the thesis work.
ABSTRACT

Heterogeneous traffic streams that contain motorized and non-motorized vehicles are becoming more common in urban areas. These streams contain standard vehicle types such as private cars, buses and trucks, as well as nonstandard vehicles such as rickshaws, bicycles, motorcycles and other vehicular forms. Models suitable for analyzing such traffic streams are not common. The existing models have their own limitations in terms of applicability and effectiveness. Most of the models which are developed for heterogeneous traffic condition deal with lane-based traffic only. In a metropolitan city of a developing country, for instance, Dhaka city of Bangladesh, where lane discipline is not common, can not give dependable predictions.

The vehicle selected for this study is rickshaw which is non-motorized and commonly found in developing countries. The nature of movement of rickshaw is complex in nature and it is difficult to replicate the deterministic rules in this type of movement. In this study, two types of data were used to analyze the movement pattern of rickshaws. The secondary data was obtained by global positioning system (GPS) to form a full trajectory for a given period of time. From this data, the direction of movement, acceleration and deceleration scenario has been obtained. The primary data was based on a number of hypothetical assumptions forming realistic scenarios. A number of questions were asked to gain information from the rickshaw-pullers regarding these scenarios. The analysis of this data has brought about the movement pattern and behavioral characteristics of the rickshaw drivers. The effect of various demographic factors has been determined as these factors have significant effect on movement pattern and behavioral characteristics of rickshaws as well. An attempt has been made to calibrate model parameters for movement in context of violation at a small scale.

The model has the potential to reflect the movement pattern of rickshaw in heterogeneous traffic conditions. The interactions of rickshaws with other vehicles may be helpful to conceive the nature of the heterogeneous traffic stream and can play an important role in simulation of such kind of traffic stream.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Declaration</td>
<td>iii</td>
</tr>
<tr>
<td>Acknowledgements</td>
<td>iv</td>
</tr>
<tr>
<td>Abstract</td>
<td>v</td>
</tr>
<tr>
<td>Table of Contents</td>
<td>vi</td>
</tr>
<tr>
<td>List of Tables</td>
<td>ix</td>
</tr>
<tr>
<td>List of Figures</td>
<td>x</td>
</tr>
<tr>
<td>List of Abbreviations</td>
<td>xiii</td>
</tr>
<tr>
<td><strong>Chapter 1: Introduction</strong></td>
<td></td>
</tr>
<tr>
<td>1.1 Background</td>
<td>1</td>
</tr>
<tr>
<td>1.2 Objective of this Thesis</td>
<td>2</td>
</tr>
<tr>
<td>1.3 Organization of this Thesis</td>
<td>3</td>
</tr>
<tr>
<td><strong>Chapter 2: Literature Review</strong></td>
<td></td>
</tr>
<tr>
<td>2.1 General</td>
<td>4</td>
</tr>
<tr>
<td>2.2 Review of the Models</td>
<td>5</td>
</tr>
<tr>
<td>2.2.1 Lane-changing models</td>
<td>5</td>
</tr>
<tr>
<td>2.2.1.1 Lane selection models</td>
<td>5</td>
</tr>
<tr>
<td>2.2.1.2 Gap acceptance models</td>
<td>6</td>
</tr>
<tr>
<td>2.2.2 Acceleration models</td>
<td>7</td>
</tr>
<tr>
<td>2.2.2.1 Car-following model</td>
<td>7</td>
</tr>
</tbody>
</table>
2.2.2.1.1 General motors non-linear model (GM model) 7
2.2.2.1.2 Collision avoidance model 8
2.2.2.1.3 Psychophysical model 9
2.2.2.2 General acceleration model 9
2.2.3 Other models 10
  2.2.3.1 The longitudinal headway model 10
  2.2.3.2 The oblique and lateral headway model 11
  2.2.3.3 The SITRAS model 12
2.3 Review of Models for Heterogeneous Traffic Conditions 12
2.4 Limitations of state-of-the-art Models 17

Chapter 3: Model Structure

3.1 General 18

3.2 Challenges of Modeling Rickshaw Movements in Heterogeneous Traffic Conditions 18

3.3 Proposed Model Structure 21

Chapter 4: Data Collection

4.1 General 29

4.2 Secondary Data 29

4.3 Primary Data 29
  4.3.1 General information about the rickshaw-pullers 29
  4.3.2 Data related to movement (travel pattern) 30

4.4 Summary 48
Chapter 5: Data Analysis and Model Development

5.1 General

5.2 Analysis of Secondary Data

5.3 Analysis of Primary Data

5.3.1 Effects of observed factors

5.3.2 Effects of demographic factors

5.4 Model Development

5.5 Summary

Chapter 6: Conclusions

6.1: Summary of Research

6.2: Scope for Further Research

References

Appendix (Part A)

Appendix (Part B)
LIST OF TABLES

Table 2.1: Summary of the studies conducted by different authors 15
Table 4.1: A brief explanation of the hypothetical situations 32
Table 5.1: Number of rickshaw-pullers according to age class 71
Table 5.2: Effect of age of rickshaw-puller in choosing options 72
Table 5.3: Violation of rules with the variation of age 75
Table 5.4: Value of different parameters used in the utility equation of violation 77
# LIST OF FIGURES

<p>| Figure 3.1: | A number of roads are not marked (no distinct lane) | 18 |
| Figure 3.2: | No lane-discipline is maintained in a major road | 29 |
| Figure 3.3: | Unplanned digging and poor surface condition of road | 20 |
| Figure 3.4: | All options for rickshaw are available to proceed | 23 |
| Figure 3.5: | Left direction travel is restricted for rickshaw | 23 |
| Figure 3.6: | Left and top right direction are restricted for rickshaw | 24 |
| Figure 3.7: | Only present direction is available for rickshaw | 24 |
| Figure 3.8: | Present direction is not available due to road block | 25 |
| Figure 3.9: | All options to move further in front direction | 26 |
| Figure 3.10: | Decision tree for lane or direction changing operation | 27 |
| Figure 4.1: | Destination at opposite side (undivided road, less congested) | 36 |
| Figure 4.2: | Destination at opposite road (undivided road, more congested) | 37 |
| Figure 4.3: | Destination at opposite side (divided road, less congested) | 38 |
| Figure 4.4: | Destination at opposite side (divided road, more congested) | 49 |
| Figure 4.5: | Effect of service road (undivided road, less congested) | 40 |
| Figure 4.6: | Effect of service road (undivided road, more congested) | 41 |
| Figure 4.7: | Queue jumping probability (undivided road, less congested) | 42 |
| Figure 4.8: | Queue jumping probability (undivided road, more congested) | 43 |
| Figure 4.9: | Queue jumping probability (divided road, less congested) | 44 |</p>
<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.10</td>
<td>Queue jumping probability (divided road, more congested)</td>
</tr>
<tr>
<td>4.11</td>
<td>Adverse road condition (undivided road, less congested)</td>
</tr>
<tr>
<td>4.12</td>
<td>Adverse road condition (undivided road, more congested)</td>
</tr>
<tr>
<td>5.1</td>
<td>Rickshaw trajectory obtained by GPS Visualizer_gobi maps</td>
</tr>
<tr>
<td>5.2</td>
<td>Speed-distance curve from GPS data</td>
</tr>
<tr>
<td>5.3</td>
<td>Speed-time-distance curve from GPS data</td>
</tr>
<tr>
<td>5.4</td>
<td>Effect of time when road is undivided (destination at opposite side, rickshaw side is less congested)</td>
</tr>
<tr>
<td>5.5</td>
<td>Effect of time when road is undivided (destination at opposite side, rickshaw side is more congested)</td>
</tr>
<tr>
<td>5.6</td>
<td>Effect of time when road is undivided (existence of service road, rickshaw side is less congested)</td>
</tr>
<tr>
<td>5.7</td>
<td>Effect of time when road is undivided (existence of service road, rickshaw side is more congested)</td>
</tr>
<tr>
<td>5.8</td>
<td>Effect of time when road is undivided (queue jumping probability, rickshaw side is less congested)</td>
</tr>
<tr>
<td>5.9</td>
<td>Effect of time when road is undivided (queue jumping probability, rickshaw side is more congested)</td>
</tr>
<tr>
<td>5.10</td>
<td>Effect of time when road is undivided (adverse roadway condition, rickshaw side is less congested)</td>
</tr>
<tr>
<td>5.11</td>
<td>Effect of time when road is undivided (adverse roadway condition, rickshaw side is more congested)</td>
</tr>
<tr>
<td>5.12</td>
<td>Effect of time when road is divided (destination at opposite side, rickshaw side is less congested)</td>
</tr>
<tr>
<td>5.13</td>
<td>Effect of time when road is divided (destination at opposite side, rickshaw side is more congested)</td>
</tr>
</tbody>
</table>
Figure 5.14: Effect of time when road is divided (queue jumping probability, rickshaw side is less congested) 68

Figure 5.15: Effect of time when road is divided (queue jumping probability, rickshaw side is more congested) 69

Figure 5.16: Violation of rules with the variation of age 75
LIST OF ABBREVIATIONS

ASC: Alternative Specific Constant
CCTV: Close Circuit Television
GPS: Global Positioning System
IBM: International Business Machines
ITS: Intelligent Transport System
JICA: Japan International Co-operation Agency
SITRAS: Simulation of Intelligent TRAnsport System
SP: Standard Preference
Chapter 1

Introduction

1.1 Background

In Dhaka city of Bangladesh, traffic congestion has been a serious problem for past few years. With the rapidly growing population and consequent vehicle increment, the problem is worsening day by day. This outrageous problem has affected the country’s overall socio-economic activities on a large scale.

A number of countermeasures have been undertaken in different times to alleviate the severity of traffic congestion especially in Dhaka city. The first franchise bus service ‘Suchona’ has been running since April, 2009. The close circuit television (CCTV) cameras have been introduced to enhance the surveillance system from May of the same year. Old vehicles have been banned on September (2009) for their conflict in speed and environmental hazards. In order to avoid the congestion new school and office timings has been adopted from October followed by a consensus of introducing school buses from November. In order to control and manage traffic flow automated traffic signals has been operated since late November (2009). In the next month enforcement of lane-usage rules has been implemented as well. A number of expressways and flyovers have been constructed and operated for a considerable period. But the strategies have not been proved effective as expected so far resulting in the persistence of congestion.

The conventional techniques of measuring traffic flow parameters to gain a clear conscious view of traffic pattern and trend are cumbersome, cost sensitive and time consuming. Traffic simulation software, which can be used to simulate the effect of alternative traffic improvement measures and evaluate their impact on the entire network, can be an effective way to alleviate the traffic congestion. It would help to prepare a roadmap for future planning and development as well.
Traffic simulation replicates the roadway existing travel pattern with least effort and greater accuracy and gives a way to perceive the situation clearly and devise our thoughts in a more realistic way. In assessing the effectiveness of an implemented traffic improvement measure of a road network this method is efficient as well. If continuous monitoring of traffic condition is possible and real time data are available, roadway traffic scenario can be mimicked readily with reasonable accuracy.

The conventional traffic simulation tools are mainly designed for the homogeneous traffic streams consisting of motorized vehicles only and strict lane discipline has to be maintained as well. In Dhaka city, traffic stream is heterogeneous and consists of both motorized and non-motorized traffic. Lane-discipline is not likely to be existed even in the major roads. Furthermore, calibration of parameters used in traffic simulation tools requires detailed data which is not available. As a result, the simulation tools can not be used directly for Dhaka city.

For non-motorized vehicles like rickshaw, the behavior modeling may be adopted to understand their pattern of moving in heterogeneous traffic condition and these models may be used later in simulation of the corresponding traffic stream. Although the rickshaw behavior is somewhat complex in nature, the rickshaw behavior modeling and subsequent simulation may serve as an important tool to get a clear view about their activity on roadway, to predict their movement under a definite countermeasure and select the best one to reduce congestion in Dhaka city and other urban areas.

1.2 Objective of This Thesis

The prime objective of this study is to develop rickshaw behavior model using rule based models in order to represent various aspects of rickshaw movement in heterogeneous traffic condition.

The specific objectives of this study are as follows,

- To analyze the pattern of spatial movement of rickshaw
- To develop a decision framework of rickshaw drivers in heterogeneous traffic situations
• To perform detailed data collection and analysis of special situations where rickshaw-pullers are most likely to violate the traffic rules
• To develop equations for discrete choice model to show the combined effect of different factors leading the rickshaw-pullers towards violation

1.3 Organization of This Thesis

• This thesis comprises of seven chapters illustrating the necessary steps taken to achieve the above mentioned objectives. The thesis is organized as follows
  • Chapter 1 gives the context of the study in a nutshell
  • Chapter 2 focuses on the review of the previous thesis papers and other sources related to this topic by comparison of different approaches, cross referencing, recommendation and necessary citations
  • Chapter 3 describes the model structure developed for thesis and also the challenges of modeling rickshaw behavior
  • Chapter 4 highlights on data collection prior to model development
  • Chapter 5 illustrates the analysis of data and subsequent model development using this data
  • Chapter 6 presents the conclusion of the entire study and provides suggestions and recommendations for further development of the work
Chapter 2

Literature Review

2.1 General

Different models have been used for representing behavior of various traffics in homogeneous and heterogeneous traffic conditions under different specific situations (e.g. roadway geometric and operating condition, driver characteristics, vehicle characteristics etc.). Some of them are narrated as follows:

Lane changing models

- The target lane (direction) model
- Gap acceptance model
- The lane (direction)-changing model
- The immediate lane (direction) change model

Acceleration models

- Car-following models
  - General motors non-linear models (GM model)
  - Collision avoidance models
  - Psychophysical (action point) models
- General acceleration models

Other models

- Lateral moving models
- Longitudinal following models
- Cellular automata models
- The longitudinal headway model
- The oblique and lateral headway model
- The path choice model
- Projective model
2.2 Review of the Driving Behavior Models

The movement of a vehicle may be classified into two classes; lateral movement and longitudinal movement. For describing longitudinal movement of vehicles various acceleration models have been developed. On the contrary, for lateral movement a number of lane changing models have been used.

2.2.1 Lane changing models

The lateral movement of vehicle is founded on some fundamental decisions of the driver including selection of target lane, finding necessary gaps and execution (lane changing). In order to delineate these basic maneuvers the lane-changing models have been developed.

2.2.1.1 Lane selection models

As lane or direction changing operation is the point of interest in delineating the lateral movement of vehicle on roads, it is of utmost importance to review the works on lane changing behavior. Lane changing models have been proposed by Choudhury (2005) setting the activities of target lane selection and attaining sufficient gap or scope to attain the target lane. It has been found that lane changing may be either mandatory (MLC) or discretionary (DLC). For capturing both MLC and DLC situations a general model framework was developed by Ahmed et al (1996) and Ahmed (1999). Yang and Koutsopoulos (1996) implemented in MITSIM a rule based lane changing model in which lane changing has been used as MLC and DLC that Toledo (2007) has mentioned later addressing CORSIM. A similar model was implemented by Hidas and Behbahanizadeh (1998) in the micro simulator SITRAS. In their model they have illustrated the concept of MLC and DLC. DLC has been suited in the situation where the adjacent lane has greater travel speed and queue advantage as well. On the other hand if a vehicle is in MLC situation he has to change lanes with the leading vehicle to remain cooperative. Depending on the aggressiveness of the driver an unlikely lane changing may occur. In practical situation when the subject vehicle follows the leading vehicle and the lagging vehicle follows the subject vehicle, a gap is created allowing the subject vehicle to change its lane.
Roberch (1976) developed a model of lane changing behavior in two lane motorways. A vehicle may be in either of the four steps depending on its position (left lane or right lane) and traffic operating condition (free flow or constrained). To model transitions between the states a stochastic Markov process has been used. It has also been found that lane changing behavior in the right lane and the left lane are different. In almost all the lane changing models MLC and DLC situations have been arisen in the downstream movement and lane blockage depending on the distance to the point where the lane changing must be completed.

Target lane or direction choice is immediate to see but not a simple phenomenon to delineate as there are a number of factors involved in making such a decision. Choudhury (2008) has marked the conspicuous factors such as lane attributes (queue lengths, average speeds, and queue discharge rates), inertia to stay in the current lane, proximity of a lane to the current lane of the driver, neighborhood variables (presence of other variables and their actions, relative position and speed of the subject vehicle with respect to neighboring vehicles), geometric elements of the roadway, driving style and capabilities etc. The utility of the lane has been the major concern here in selecting the target lane or direction.

2.2.1.2 Gap acceptance models

Gap acceptance model has been developed by a number of researchers in their own way as they have perceived the situation. These models are used to represent the execution of lane change. Choudhury (2008) has introduced lead gap and lag gap terms to explain the gap in the roadway operating condition and also compared the gaps with the critical gap which is the minimum available gap for a driver to reach the target lane (direction). The gap acceptance is only possible when the available gap exceeds the critical gap. Critical gaps have been modeled as random variables by Toledo (2003) and Choudhury (2008). Hernan and Weiss (1961) assumed an exponential distribution. Drew et al (1967) assumed a lognormal distribution. Later on a normal distribution was assumed by Miller (1972). In the gap acceptance models Mahmassani and Sheffi (1981) introduced impatience functions. In this case critical gaps have been shown as a function of explanatory variables. The number of rejected gaps or waiting time has been found significant impact on gap acceptance behavior (Toledo, 2003). Gap acceptance parameters were estimated jointly with other
components of model and were found that lead and lag gaps under MLC situations were lower than under DLC situations.

2.2.2 Acceleration models

Acceleration is a common operation of daily movement of traffic. The acceleration that a driver applies depends on a number of factors including the driver to stimulus, road signs, markings and signals, the roadway condition, vehicle characteristics, relative speed with the leading vehicle and relationship with the surrounding vehicles. Acceleration models may be classified into two major groups.

- Car following models: whether the driver will apply acceleration or not depends on the characteristics of the leading car driver
- General acceleration models: can describe car following behavior and even when car is not present as a leading vehicle, then this model is used to illustrate the following mechanism of the subject vehicle driver

2.2.2.1 Car following model

The concept of car following was first proposed by Reuschel (1950) and Pipes (1953). Car following models describe the interaction between adjacent vehicles in the same lane (Brackstone and McDonald, 1999). The subject vehicle follows the leader (vehicle in front) and responds to its action. These models are the major parts of the microscopic vehicular movements modeling which provide the foundation for traffic simulation systems. In order to get profound notions about car following models, three characteristic models, named as General Motors non-linear models, the collision avoidance models and the psychophysical models may be reviewed.

2.2.2.1.1 General motors non-linear model (GM Model)

The General Motors non-linear models known as GM Models (Brackstone and McDonald, 1999) developed from a series of studies conducted at the General Motors research laboratories in Detroit in the late 1950s (Chandler et al., 1958; Gazis et al., 1959; Gazis et al., 1961). Researchers at the GM Research Laboratory introduced the sensitivity-stimulus framework that is the basis for most car following models to date (Toledo, 2003). According to this framework a driver reacts to stimuli from the environment. The response of the driver is given by
response (t) = sensitivity (t) × stimulus (t-τ)

Where, t is the time of observation and τ is the reaction time for drivers. The time interval between seeing, hearing, or feeling and the starting to do something in response to the stimulus of a traffic or highway situation are called ‘reaction time’. The psychological process constitutes four operations; perception, identification or intellection, emotion or judgment and volition or reaction (means execution of decision).

2.2.2.1.2 Collision avoidance model

The collision avoidance models assume that the following vehicle will maintain a safety distance to the vehicle in front and will select its speed to ensure the vehicle can stop safely to avoid a rear-end collision (Lee, 2007). Such models (e.g. Kometani and Sasaki, 1959; Gipps, 1981) are developed based on the equations of motion. This type of model has been criticized as the following vehicle can not react in time when the leading vehicle performs a sudden break or deceleration. To facilitate a clear conscious view of vehicular flow characteristics Gipps (1981) developed a model in which extra safety reaction time and safety headway margin were introduced. No calibration of parameters was required in his model. This model was able to reflect the real traffic flow characteristics when realistic values were assigned to the parameters.

The advantage of collision avoidance model is that longitudinal and lateral movement of vehicle both can be described by this model after a few adaptations. Gunay (2007) tried to integrate the lateral offset of the following vehicle into the Gipps following model. This study was a pioneer to describe the two-dimensional movement of cars. This model can allow flexibility to alter kinematic properties as well.

The greatest challenge to the validity of collision avoidance model emerged when it was appeared that Newtonian mechanics could fail to illustrate a short headway. This suspicion arouse when Brackstone et al. (2002) found that the minimum desired following distance was far lower than believed when they investigated the parameters for the action point model. In fact, it is obvious that a driver should be vigilant while following a vehicle closely and the reaction time will be less than usual. An extremely short headway can be described by a collision avoidance model if the driver expects a low deceleration difference to the preceding vehicle (Lee, 2007).
2.2.2.1.3 Psychophysical model

The psychophysical model, developed by Weidmann (1974) and Leutzbach (1988), assume that the drivers of the following vehicles follow the leaders even when the space headway is large and they fabricate a perception threshold to avoid any kind of collision. The concept was first brought up by Michaels (1963). A vehicle driver wants to drive to his desired speed in free flow condition. The response of the driver is influenced by the perception threshold on a large scale. In fact, the term ‘perception threshold’ works in two mutually related and subsequent operations. First of all, a driver will increase the speed until he realizes that the further increment will be venturesome enough to cause a rear-head collision. Then he will try to maintain the speed with the leading vehicle. It is not always possible to maintain the equal space headway all the time. In the second case, when the preceding vehicle will be far beyond the perception threshold or space headway will increase, the same driver of the following vehicle will try to accelerate his vehicle. The mechanisms are periodic termed as ‘following spiral’. As following and leading vehicles are totally relative to each other, there is no way to stop the cycle. As a result, the psychophysical model is able to illustrate the oscillating phenomenon observed in car following experiments. The perceptual threshold was found from a number of acceleration and deceleration decisions made by the drivers. For probably being somewhat psychological, no rigorous framework for calibrating the model has been proposed yet.

2.2.2.2 General acceleration model

Gipps (1981) developed the first general acceleration model that applies to both car following and free flow conditions. The maximum applicable acceleration is based on two constraints: speed and headway. It is assumed that the speed may not exceed its desired value and the minimum safe headway must be kept. The safe headway is the minimum distance that is required for the following vehicle to avoid a collision when the leading vehicle reduces its speed abruptly by applying emergency braking. Calculations are based in the equations of laws of motion. The vehicles are characterized through the upper bounds of acceleration and deceleration values.

Benekohal and Treiterar (1988) developed a similar model for the CARSIM simulation tool. The acceleration is calculated separately for five different situations. Yang and Koutsopoulos (1996) developed a general acceleration model and
implemented it in MITSIM, a microscopic traffic simulator. The driver is assigned to one of three regimes based on time headway: emergency, car following and free-flow. Zhang et al. (1998) implemented a multi-regime acceleration model in MRS, a microscopic traffic simulator. They define several different driving regimes based on space headways. The regimes are emergency, normal car following, uncomfortable car following and free flow. When the space headway is smaller than a pre-specified threshold value, it is termed to be emergency regime. The normal car following model uses the non-linear GM model (Gazis et al. 1959). Uncomfortable car following is applied when the acceleration calculated by normal car following is positive and the headway is positive based on Pipes’ definition (1953). In this case the driver applies a normal deceleration instead of normal acceleration. Normal accelerations and decelerations are also applied in free-flow regime in an attempt to attain the desired speed. Ludmann et al. (1997) used similar driving regimes in the microscopic traffic simulator PELOPS.

All the models discussed above can be shown in brief by the following table. The factors considered by the authors are enlisted as well.

### 2.2.3 Other behavior models

The models mentioned above are somewhat universal in delineating the movement of vehicle in the traffic stream. For a closer look deep into some specific vehicles (e.g. motorcycle) supplementary approaches have been performed and developed by a number of transport modelers. The following models also try to describe the behavior of driver in heterogeneous traffic condition.

#### 2.2.3.1 The longitudinal headway model

The longitudinal headway may be defined as the following distance in the situation that the subject vehicle is following directly behind a preceding vehicle. This model was developed by Lee (2007) for delineating the longitudinal movement of motorcycles.

In motorcycle context, two scenarios; the minimum following distance without swerving maneuvers and with swerving maneuvers have been discussed as swerving is a common operation in longitudinal movement of motorcycles. For rickshaw, though swerving is not prevalent, it is noticed in some situations while moving
longitudinally. When swerving is not performed, the rickshaws are more likely to decelerate or reduce speed to avoid collision as the motorcycle does. This strategy is mainly applicable for lane based traffic and can be used to determine the minimum following distance for safety purpose.

When a motorcycle performs swerving, it tends to dodge away from the line to avoid rear end collision. For rickshaws, the same scenario is viewed occasionally basically when the vehicle is in a hurry to reach to the destination. The extent of this action is quite less than that of rickshaw as rickshaw requires more space and the pace of rickshaw is low as well. When the rickshaw swerves and follows another vehicle, it has to maintain a safety distance with the leading vehicle to avoid rear end collision.

It has been found that the minimum following distance is a function of the speeds, braking decelerations of the relevant vehicles and the reaction time of the motorcyclists (Lee, 2007). The findings may also be applicable for rickshaws as all the contributing factors are logical enough to describe the situation and perception of the safety margin.

2.2.3.2 The oblique and lateral headway model

The oblique headway may be defined as the safety distance that a motorcyclist maintains when following another vehicle obliquely; following at the rear left or rear right end of the preceding vehicle (Lee, 2007). The lateral headway, on the other hand is the safety distance that a driver maintains when overtaking the preceding vehicle, or following vehicle laterally. Oblique headway is common in the movement of the motorcycles. Lee (2007) has also found that for motorcycle the development of equations to delineate the oblique headway is complicated as merely avoiding a rear end collision is not the only concern of the motorcyclists. Some lateral movements and unobserved psychological factors are also involved in this phenomenon. Therefore, he suggested the warrants of regression model to describe the oblique headway. In case of lateral headway, the following angle 90°. So the headway can be represented in terms of the speed difference or the relative speed of the two vehicles. For motorcycle both oblique and lateral headway model has been accepted and developed by Lee (2007). For rickshaw, the lateral headway is common, but maintaining oblique headway is not noticed too often.
2.2.3.3 The SITRAS model

The Simulation of Intelligent TRAnsport System (SITRAS), a massive multi-agent simulation system in which driver-vehicle objects are modeled as autonomous agents, was introduced by Hidas (2002) in modeling lane changing and merging in microscopic traffic simulation. This is a microscopic time-interval update simulation model being developed at the University of New South Wales since 1995. The model is implemented in an object-oriented structure under the Microsoft Windows operating system on IBM-compatible personal computers. The model aims at providing a general evaluation tool for Intelligent Transport System (ITS) applications such as congestion and incident management, public transport priority and dynamic route guidance. Hidas (2002) used SITRAS model in for simulation of lane changing behavior of vehicles under some assumptions. First of all, the driver of a vehicle does not force another vehicle under uncongested condition to reach their destination lane. The second assumption is taken for congested traffic condition. It has been speculated that almost all the drivers force other vehicles while moving to the destination lane. The interactions between drivers involved in such a maneuver require complex behavioral decision-making process which can be modeled by Autonomous Agent techniques (Hidas, 2002). No information dealing with ‘forced’ or ‘co-operative’ lane changing situations was found in the literature. Thus, by expanding the capabilities of previous models, a model was developed and implemented in SITRAS which is able to handle lane changing under congested (and incident affected) traffic conditions.

2.3 Review of the Models for Heterogeneous Traffic Conditions

A number of studies have been conducted for heterogeneous traffic condition, particularly involving motorcycles. Most of these studies have highlighted on the interaction between motorcycles and other vehicles in heterogeneous traffic stream. An attempt has been made by Lawrence and Chiung-Wen (2003) to develop a particular-hoping model with fixed moving rules to describe motorcycle’s moving behavior in mid blocks of heterogeneous traffic flows. Chan and Yuh-Ting (2004) assumed that the movement of a motorcycle was a two-dimensional movement, in which the longitudinal one makes the motorcycles go forward while the lateral one makes it get appropriate positions in its way. In the same line, Nguyen (2004)
introduced a concept of personal space to explain the movement behavior of the motorcycles under the influence of surrounding motorcycles. This concept was proposed for both signalized and non-signalized intersections. Chu et al. (2005a, 2005b, 2006) analyzed several specific behaviors of the motorcycle traffic including overtaking and paired riding behaviors at mid-blocks, deceleration behavior at signalized intersections and the speed-flow-headway relationships of motorcycle traffics.

Lack of understanding while negotiating at intersections, non-cooperative behaviors of the drivers, both motorcycle and car or bus drivers are greatly responsible for significant reduction in speed and high risk of accidents. Deep understanding of the interactions will be useful for introducing effective policies or measures to enhance heterogeneous traffic performance (Hsu et al., 2003).

In the capital of Vietnam (Hanoi), at two-phased intersections, when the signal light turns amber (or green) motorcycles and cars from directions of the main road start to go through (or straight) and to turn left in groups, not in platoons. The conflict between the two groups can be explained using the two-player non-cooperative game, in which each player or group chooses one strategy to move from their set of strategies. The aftermath of the interaction is a combination of the strategies chosen by the two groups. The decision made one group may be dependent on the strategy selected by another group.

Oketch (2000, unpublished work) has proposed a new modeling approach for heterogeneous-traffic streams with non-motorized vehicles. This model covers different vehicle types, including non-motorized ones, and allows for some special behaviors such as seepage to front of queues by two-wheeled vehicles and simultaneous use of two-lanes. In addition to normal car-following rules, the model incorporates lateral movement with a gradual lane change maneuver, the decisions of which are governed by fuzzy logic rules. In this model, a microscopic traffic simulation approach was adopted in the study. The simulation model was comprised of several features such as, seepage of motorcycles and bicycles in front of queues, lateral movement model, identification of options and evaluation of options by using fuzzy logic.
Matasuhashi et al. (2005) has analyzed image processing of motorcycle oriented heterogeneous traffic flow in Vietnam. This analysis was performed prior to the implementation of transport policy and modifications in the public transport system. This study was aided by simulation technique which was used to evaluate the impacts of a possible future migration from motorcycle to private cars or to the public transport system. “VISSIM” 3.7 was used to perform the simulation in this study. Various parameters were used in the simulation such as network parameter (number of lanes, lane width), traffic parameter (traffic volume, composition of traffic), vehicle parameter (desired speed), and driving behavior parameter (lane change, minimum headway, look-ahead distance, additive part of desired safety, overtake on same lane).

Zhang et al. (2007) used cellular automata for modeling heterogeneous traffic flow at cross-walks in micro-simulations. This approach focused on the pedestrian characteristics such as proportion of pedestrians violating traffic rules and regulations, the grouped effect and expected waiting time of pedestrians.

Nagel and Schreckenberg (1992) proposed a one-dimensional cellular automata model to simulate traffic flow on freeway, providing the basic principles for more complex surroundings such as city traffic flow. Improvements have been made to this model to adapt it to more realistic circumstances, including the slow-to-start rule and the extension from single lane to multi-lane models.

Blue et al. (1997) proposed a pedestrian movement model for large scale open areas. Muramastu et al. (1999) developed a pedestrian movement model based on stochastic process. Blue and Adler (2000) then developed a four-directional pedestrian cross-walk model. A year later Blue and Adler (2001) proposed a bi-directional pedestrian cross-walk model.

Hossain and McDonald (1998) developed a model to demonstrate the effect of banning non-motorized traffic in heterogeneous traffic condition from urban corridors of some developing cities. The model revealed that in Dhaka city of Bangladesh, such banishment can increase the passenger carrying capacity of the roads up to 300% for the same travel time. It could also reduce corridor travel time by around 30%.
Table 2.1: Summary of the studies conducted by different authors

<table>
<thead>
<tr>
<th>Model</th>
<th>Methodology</th>
<th>Factors affecting decision making</th>
<th>Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lane changing model</td>
<td>Capturing mandatory (MLC) and discretionary (DLC) situations; introduction of CORSIM</td>
<td>Vehicle type (heavy vehicle or not), speed (potential speed), headway, traffic density, nearside or offside, presence of heavy vehicles regulations, distance (or time) to the intended turn, space/scope</td>
<td>Roberch (1976); Ahmed et al (1996); Yang and Koutsopoulos (1996); Hidas and Behbahanizadeh (1998); Ahmed (1999); Choudhury (2005); Choudhury (2008)</td>
</tr>
<tr>
<td>Gap acceptance model</td>
<td>Assumption of exponential distribution of critical gaps, introduction of impatience functions, comparing the gaps with critical gaps</td>
<td>Lead gap, lag gap, relative speed, presence of heavy vehicles</td>
<td>Hernan and Weiss (1961); Drew et al (1967) Miller (1972); Mahmassani and Sheffi (1981); Toledo (2003); Choudhury (2008)</td>
</tr>
<tr>
<td>Car following model (GM model, collision avoidance model and psychophysical model)</td>
<td>Introduction of sensitivity-stimulus framework, fabrication of perception threshold</td>
<td>Relative velocity, regulations, driver psychology (e.g. tailgating behavior), headway (time or speed), reaction time of the following vehicle</td>
<td>Reuschel (1950); Pipes (1953); Chandler et al. (1958); Gazis et al. (1959); Kometani and Sasaki (1959); Gazis et al. (1961); Michaels (1963); Weidmann (1974); Gipps (1981); Leutzbach (1988); Brackstone and McDonald (1999); Brackstone and McDonald (2002); Toledo (2003); Lee (2007); Gunay (2007)</td>
</tr>
</tbody>
</table>
In order to select from the above mentioned models a number of evaluation criteria has to be set and proper assessment of these criteria are required. Some of the models are based on the behavioral characteristics of the vehicle driver. In evaluating these models vehicular characteristics and driver psychology are important factors. The roadway condition, whether for homogeneous or heterogeneous traffics, should be

<table>
<thead>
<tr>
<th>Model</th>
<th>Methodology</th>
<th>Factors affecting decision making</th>
<th>Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitudinal headway model</td>
<td>Consideration of swerving and non-swerving situations</td>
<td>Longitudinal headway, vehicle maneuver technique (swerving or not)</td>
<td>Lee (2007)</td>
</tr>
<tr>
<td>Oblique and lateral headway model</td>
<td>Regression analysis for the delineation of oblique headway</td>
<td>Oblique headway (vehicle following at rear left or rear right end creating an angle), lateral headway (vehicle following or overtaking in parallel), longitudinal gap, lateral gap, speed difference, speed of the following vehicle</td>
<td>Lee (2007)</td>
</tr>
<tr>
<td>SITRAS model (for lane changing)</td>
<td>It depends on the purpose and certain aspect of vehicle movement (here lane changing behavior)</td>
<td>Factors affecting lane changing behavior</td>
<td>Hidas (2002)</td>
</tr>
<tr>
<td>General acceleration model</td>
<td>Considering speed and headway to be the prime determinant in case of applying maximum acceleration</td>
<td>Driving regimes based on time headway and space headway (e.g. emergency, car following, free flow)</td>
<td>Pipe (1953); Gazis et al. (1959); Gipps (1981); Benekohal and Treiterar (1988); Yang and Koutsopoulos (1996); Ludmann et al. (1997); Zhang et al. (1998)</td>
</tr>
</tbody>
</table>
considered as well. The model (or models) which will reflect the movement of rickshaw should fulfill the major criteria set prior to evaluation process.

In Bangladesh, rickshaw behavior is sometimes whimsical and movement is erratic. A sound judgment based on professional skill and experience may be helpful in anticipating and in diagnosis of rickshaw behavior. For more accuracy in assessing a complete survey of the rickshaw movement is recommended.

2.4 Limitations of State-of-the-art Models

There are a number of limitations in the assumptions of behavior models in terms of the decision making process and the decision itself.

1. There is a considerable number of research work conducted for driving behavior in homogeneous traffic conditions. The work done for heterogeneous traffic condition is quite less.
2. The research work regarding heterogeneous traffic condition has been done mainly on lane-based traffic.
3. Analysis of heterogeneous streams that use traditional approaches has achieved limited success and has involved much recalibration effort and significant model modifications.
4. There are a few works regarding the movement of non-motorized traffic in heterogeneous traffic condition (Hossain and McDonald, 1998).
Chapter 3

Model Structure

3.1 General

The previous chapter dealt with the previous research works related to this thesis. In this chapter, the challenges of modeling rickshaw behavior in heterogeneous traffic conditions and the development of model structure will be discussed.

3.2 Challenges of Modeling Rickshaw Movements in Heterogeneous Traffic Condition

The tentatively selected rule based model for rickshaw movement may be suitable under idealized condition. But in practical situation some very common and a few irregular obstacles are likely to clog the way of successful implementation of the model. The growing challenges of modeling rickshaw behavior lie under the following facts.

Lane marking: There is no distinct lane marking in most of the roads. So the lanes are not visible and it is difficult for a rickshaw-puller to maintain a particular direction in his way. This non-systematic movement makes modeling for rickshaw behavior a difficult and cumbersome task.

Figure 3.1: A number of roads are not marked (no distinct lane)
**Lane discipline:** In some roads lanes are marked. But even in the lane-based roads, the rickshaw movement is somewhat complex in the fact that they can not maintain their direction for the entire way due to mismatch of lane width and width of rickshaw. A lane width should be in the range of 2.5 to 4 meter. In Bangladesh 4 meter lane is not common. The lane width is greater than one rickshaw width but less than two of them. Moreover, during direction changing they use least scope to attain the target lane or direction. This affects the whole traffic maneuverability and has become a challenge for modeling.

![Figure 3.2: No lane-discipline is maintained in a major road](figure)

**Defiance of rickshaw-pullers:** The rickshaw-pullers are most often defiant of the traffic rules and regulations. So their movement in such cases is unconventional and unpredictable. Sometimes the rickshaw-pullers maintain very small or zero headway in longitudinal direction. In some cases they occupy the front positions of approach of intersections in red phase of the signal as well. This criterion has emerged to be a challenge for modeling rickshaw behavior.
**Heterogeneity in behavior:** For a particular motorized vehicle speed, acceleration and such properties are almost certain in nature. But in case of rickshaw, speed or acceleration varies due to a number of human factors e.g. potential of rickshaw-puller, experience, perception of the existing situation etc. This remarkable variation is also a challenge for modeling rickshaw behavior in heterogeneous traffic condition.

**Effects of roadway condition:** The movement of rickshaws varies greatly with the prevailing condition of road. The geometric properties of road, its physical condition has remarkable influence on rickshaw maneuverability as well. Under this condition rickshaw movement becomes inconsistent and becomes a challenge for modeling.

Figure 3.3: Unplanned digging and poor surface condition of road
Lack of necessary data: Due to the complexity of rickshaw behavior, data for modeling of rickshaw behavior has to be thorough and well-organized. As image processing software can not identify non-lane based vehicle movement, data acquisition has become a difficult job to do. This is a big challenge for modeling.

3.3 Proposed Model Structure

Movement of any vehicle may include several processes like turning, weaving, lane or direction changing, merging, diverging, overtaking etc. The direction-changing maneuver generally occurs in mid section of a road (within two subsequent intersections). In intersections, direction-changing is performed when necessary. The rickshaw-pullers perform their direction-changing operation in order to reach the target direction which is the direction in which they intend to move on considering a variety of reasons.

A rickshaw-puller will try to achieve the easiest path to reach the destination in least travel time. Since quicker way to the destination means more revenue, he will try to move forward using all scopes even when other vehicles are stagnant. If a rickshaw-puller thinks maneuverability will be difficult in a particular direction, he makes an immediate decision to avoid that direction. Safety is another concern of a rickshaw puller. He may try to avoid any kind of risks that may arise in his way.

This scenario is not uncommon that empty rickshaws are likely to select left most lanes to get passengers waiting for a ride. In order to do so they move near the edge of the road and closer to the footpath.

Target lane or direction can therefore be defined as the direction along which the rickshaw-puller finds more attraction in terms of

- Travel time
- Maneuvering effort
- Distance
- Safety
- Potential revenue (in case of empty rickshaws)
Actually there exists an implicit correlation among these terms. For instance, there is a divider in a road separating the direction of flow. A rickshaw is moving in a certain direction on one side of the divider. If he perceives there is queue in front of him and the right side of the divider is empty, he may switch to the other side of the divider if possible. But there will always be a risk of accident for vehicles moving in opposite direction. In this case there is a tradeoff between travel time and safety. In another case, let a rickshaw is running along a certain direction. In the existing direction the road condition is not favorable after a certain distance and the preceding vehicles are leaving that portion of road. But the rickshaw-puller may use that portion of road to minimize travel time with a greater maneuvering effort. Here he actually sacrifices his ease of maneuverability for less travel time.

If a rickshaw-puller finds him suited in the present direction, then he will remain in the present direction and no direction change will occur. If he needs to move for any reason mentioned above and sufficient scope is present, he will turn to left or right according to his requirement to reach the target direction. Direction-changing will be visible only if there is sufficient scope to mode to the target direction. No scope expresses that no direction-changing will occur.

As direction-changing operation contains the major portion of lateral movement maneuver of rickshaw in heterogeneous traffic condition, this phenomenon will be emphasized. A direction-changing maneuver has several aspects, e.g.

1. To select the target direction
2. To find necessary scope
3. To reach the target direction by using the available scope (execution)

For instance, in a four lane (if the lanes are marked) or equivalent width containing road (2.5m ~ 4m for a single lane) a rickshaw is in the second lane (or equivalent position) and moving in a certain direction. His movement (lateral or longitudinal) is dictated by direction changing. As rickshaw movement is continuous and erratic it can be simplified to understand clearly. The figures given below are for instantaneous direction change of a rickshaw-puller. The overall movement of rickshaw will be a combination of such maneuver with time.
**Assumptions:** Lanes (showing direction) are not exclusive; the first four cases will allow the movement of rickshaw along the present direction; present lane may be the target lane as well

*Case 1:* All directions are available. The rickshaw-puller may select any direction as target direction for that instance.

![Figure 3.4: All options for rickshaw are available to proceed](image)

*Case 2:* One direction (TD 1) is blocked somehow reducing the option for the rickshaw puller. He may now choose the present direction, TD 2 and/or TD 3.

![Figure 3.5: Left direction travel is restricted for rickshaw](image)
Case 3: TD 3 is blocked as well as TD 1. The rickshaw puller will have to choose his present direction or TD 2 as target direction in this case.

![Diagram](image1)

Figure 3.6: Left and top right direction are restricted for rickshaw

Case 4: TD 1 and TD 2 are blocked. Consequently TD 3 will be unavailable too. The puller is bound to move through the present lane inevitably. He has got no option here.

![Diagram](image2)

Figure 3.7: Only present direction is available for rickshaw
Case 5: In the previous four cases present lane was available. In this situation present lane has been blocked due to technical or other reason. The rickshaw puller may choose TD 1, TD 2 and/or TD 3.

It must be noted that if maneuverability would be the sole criterion to select the target direction and then the rickshaw puller would always choose the present direction as it warrants the least maneuvering effort. There may be other combination of cases applying combination formula. The decision making will be harmonious with the mentioned cases.
Overall we may get the following exposure

**Figure 3.9:** All options to move further in front direction

**Legends**
- Subject vehicle (here rickshaw)
- Other rickshaw
- Car
- Bus

Direction of movement of rickshaws is shown by arrows and the lines depicting the lane width are somewhat arbitrary. It should be noted that in non-lane based links (or road sections), equivalent width available for adjacent rickshaws or rickshaws with other vehicles will predominate.

The decision tree to select the target direction is shown as below which clarifies that the movement (here direction changing) of rickshaws is affected by a number of factors.
Figure 3.10: Decision tree for lane or direction changing operation

- Is direction change mandatory?
- Select target direction
- Is there available scope to move laterally to go to target direction?
- Is there any possibility of collision with vehicle right behind?
- Is it possible to accelerate the vehicle to go to target direction?
- Is it possible to decelerate the vehicle to go to target direction?
- Remain in present direction
- Change to target direction
The above flow-chart only shows the major criteria those have direct influence on decision making of a rickshaw-puller. In fact, it is a very simple and common conscience of a vehicle driver. In order to change the existing direction the driver will have to feel the necessity of changing direction at first. In the rudimentary base he seeks for the available scope in terms of space. If this requirement is fulfilled he thinks for his personal safety and tries to avoid any type of collision. For achieving this he should be vigilant for the succeeding vehicles right next to him and make an immediate decision to accelerate or decelerate vehicle to reach the target direction. There are some other criteria which may affect decision making e.g. roadway condition, maneuvering effort, condition of rickshaw itself etc. For simplicity, they have been omitted in consideration.
Chapter 4

Methodology and Data Collection

4.1 General

To understand the behavior of rickshaw in a systematic way the available data has been explored (secondary data). In addition, direct behavior data (primary data) has been collected to complement the available data. In this chapter, the methodology and data collection has been illustrated.

4.2 Secondary Data

Secondary data consists of the movement of rickshaw on the basis of Global Positioning System (GPS). The data collection was conducted by Japan International Co-operation Agency (JICA). In this data the location of a vehicle has been recorded for a particular period of time. The precision has been set by taking the data in a certain interval. This data is useful in depicting the trajectory of a rickshaw. But this type of data was inadequate to delineate the travel behavior of rickshaws.

4.3 Primary Data

Primary data is based on the concept of focus group study. In this study the focus group is comprised of rickshaw pullers only. This type of study is useful as a direct conversation is performed. The data may reflect the psychological or behavioral characteristics of the rickshaw pullers. Several types of data have been collected. The data collected with their needs are given below.

4.3.1 General information about the rickshaw-pullers

Name: In order to draw the attention of the rickshaw-pullers and making them interested.
Age: As age is directly related to the maturity both physically and mentally and judgment skill in turn is related to maturity level

Time pulling rickshaw: The experience in handling and hauling rickshaw certainly affects the decisions.

Time pulling rickshaw (in Dhaka city): The decisions taken at one place at any circumstances may not be applicable to other places for the same situation.

Other occupation before pulling rickshaw: The past activity may have effect on mind which may be reflected in decision making.

Rickshaw training (or self guided): Training is considered as a tool to make the rickshaw-pullers capable of taking the correct decision if situation arises.

Rickshaw owned (or hired): The handling of rickshaw and the effect of time on the movement depends on rickshaw tenure ship on a large scale.

4.3.2 Data related to movement (travel pattern)

Under the observation, the following standard conditions have been identified when the drivers violate the traffic rules.

1. The decisions of the rickshaw pullers in moving and maneuvering concerned only and the role of the passengers is restricted in apprising the drivers (rickshaw pullers) about their destinations.
2. The drivers with full authority and freedom in taking their decisions.
3. A close interrelation among traffic condition, geometric condition and time has been identified.

Various situations used for questioning the rickshaw pullers are illustrated in the succeeding sections.

The basic situation delineators are,

Road geometry: Undivided road/Divided road

My side (subject rickshaw puller): less congested/more congested

Time frame: Time at hand/running out of time
A combination of these basic delineators constitutes every situation described below. At first the symbols used in the figures are presented and numbers are used to indicate them.

Median/ divider breaker

Destination

Subject rickshaw

Rickshaws (others)

Car

Bus

Adverse road condition

The arrowhead is used to show the probable direction of travel and the numbers into the circle stand for the option number. The table in the following page shows the brief explanation of all scenarios and options available for rickshaw-pullers.
### Table 4.1: A brief explanation of the hypothetical situations

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Traffic condition</th>
<th>Options available</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Destination at opposite side (undivided road)</td>
<td>a) Less congested (time at hand/ running out of time)</td>
<td>(i) Remain at present side and leave the passenger at road side</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(ii) Go to the opposite side to reach the destination</td>
</tr>
<tr>
<td></td>
<td>b) More congested (time at hand/ running out of time)</td>
<td>(i) Remain at present side and leave the passenger at road side</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(ii) Go to the opposite side to reach the destination</td>
</tr>
<tr>
<td>2. Effect of service road (undivided road)</td>
<td>a) Less congested (time at hand/ running out of time)</td>
<td>(i) Not using the service road by leaving the passenger at the present road side</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(ii) Use the U-turn facility at some distance ahead of the present direction and return to use the service road</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(iii) Enter the service road from present side by using hand signal only</td>
</tr>
<tr>
<td></td>
<td>b) More congested (time at hand/ running out of time)</td>
<td>(i) Not using the service road by leaving the passenger at the present road side</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(ii) Use the U-turn facility at some distance ahead of the present direction and return to use the service road</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(iii) Enter the service road from present side by using hand signal only</td>
</tr>
<tr>
<td>Scenario</td>
<td>Traffic conditions</td>
<td>Options available</td>
</tr>
<tr>
<td>----------</td>
<td>-------------------</td>
<td>------------------</td>
</tr>
</tbody>
</table>
| 3. Queue jumping (undivided road) | a) Less congested (time at hand/ running out of time) | (i) Leave the passenger at the signal (not taking to the destination ay all)  
(ii) Wait for the signal for permission and then move forward in the same direction  
(iii) Not wait for permission and using the right side of the road beyond the crossing |
| | b) More congested (time at hand/ running out of time) | (i) Leave the passenger at the signal (not taking to the destination ay all)  
(ii) Wait for the signal for permission and then move forward in the same direction  
(iii) Not wait for permission and using the right side of the road beyond the crossing |
| 4. Adverse road condition (undivided road) | a) Less congested (time at hand/ running out of time) | (i) Move through the present side of the road with great effort  
(ii) Use the opposite side for the affected portion (present side) |
| | b) More congested (time at hand/ running out of time) | (i) Move through the present side of the road with great effort  
(ii) Use the opposite side of the road for the affected portion (present side) |
| Scenario                                                                 | Traffic condition                              | Options available                                                                                                                                 |
|-------------------------------------------------------------------------|-----------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------
| 5. Destination at opposite side (divided road)                         | a) Less congested (time at hand/ running out of time) | (i) Remain at present side and leave the passenger at road side  
(ii) Use the U-turn facility at some distance ahead of the present direction and return to reach the destination  
(iii) Take the vehicle at right most lane to use the median breaker to leave the passenger |
|                                                                        | b) More congested (time at hand/ running out of time) | (i) Remain at present side and leave the passenger at road side  
(ii) Use the U-turn facility at some distance ahead of the present direction and return to reach the destination  
(iii) Take the vehicle at right most lane to use the median breaker to leave the passenger |
<table>
<thead>
<tr>
<th>Scenario</th>
<th>Traffic condition</th>
<th>Options available</th>
</tr>
</thead>
</table>
| 6. Queue jumping (divided road) | a) Less congested (time at hand/ running out of time) | (i) Leave the passenger at the signal (not taking to the destination at all)  
(ii) Wait for the signal for permission and then move forward in the same direction  
(iii) Not wait for permission and using the right side of the road beyond the crossing |
|                          | b) More congested (time at hand/ running out of time) | (i) Leave the passenger at the signal (not taking to the destination at all)  
(ii) Wait for the signal for permission and then move forward in the same direction  
(iii) Not wait for permission and using the right side of the road beyond the crossing |

The situations were described to every rickshaw-puller in the survey. Total 30 rickshaw-pullers were selected of various age and experience. They were asked to choose their options in different scenarios and share their thought process underlying the making of every decision. They were only informed about the options, not mentioning or indicating whether their decisions withhold or violate traffic rules and regulations to get a reliable outcome.

The situations are illustrated by show-cards presented in the following page.
Situation 1

Destination at opposite side

- Road geometry: undivided road
- My side (left side): less congested
- Time frame: time at hand/ running out of time
- Options in hand (to move/other decision):

Option 1 (leave passenger at present side)

Option 2 (go to destination at opposite side)

Figure 4.1: Destination at opposite side (undivided road, less congested)
Situation 2

Destination at opposite side

- Road geometry: undivided road
- My side: more congested
- Time frame: time at hand/ running out of time
- Options in hand (to move/other decision):

Option 1 (leave passenger at left side)

Option 2 (go to destination at right side)

Figure 4.2: Destination at opposite road (undivided road, more congested)
Situation 3

Destination at opposite side

- Road geometry: divided road
- My side: less congested
- Time frame: time at hand/ running out of time
- Options in hand (to move/other decision):

Option 1 (leave passenger at left side)

Option 2 (go to destination at right side using U-turn)

Option 3 (leave passenger at median breaker)

Figure 4.3: Destination at opposite side (divided road, less congested)
Situation 4

Destination at opposite side

- Road geometry: divided road
- My side: more congested
- Time frame: time at hand/ running out of time
- Options in hand (to move/other decision):

Option 1 (leave passenger at left side)

Option 2 (go to destination at right side using U-turn)

Option 3 (leave passenger at median breaker)

Figure 4.4: Destination at opposite side (divided road, more congested)
**Situation 5**

**Existence of service road at opposite side**

- Road geometry: *undivided* road
- My side: less congested
- Time frame: time at hand/ running out of time
- Options in hand (to move/other decision):

    Option 1 (not taking service road by leaving passenger earlier)

    Option 2 (go to service road at opposite side using U-turn)

    Option 3 (go to service road at opposite side using hand signal)

---

**Figure 4.5:** Effect of service road (undivided road, less congested)

---

40
Situation 6

Existence of service road at opposite side

- Road geometry: undivided road
- My side: more congested
- Time frame: time at hand/ running out of time
- Option in hand (to move/other decision):

Option 1 (not taking service road by leaving passenger earlier)

Option 2 (go to service road at opposite side using U- turn)

Option 3 (go to service road at opposite side using hand signal)

Figure 4.6: Effect of service road (undivided road, more congested)
Situation 7

Queue jumping probability in signalized crossing

- Road geometry: undivided road
- My side: less congested
- Time frame: time at hand/ running out of time
- Options in hand (to move/ other decision):

Option 1 (leave passenger at left side at signalized crossing)

Option 2 (go through the present side using signal)

Option 3 (go and take opposite side of the road ahead defying signal)

Figure 4.7: Queue jumping probability (undivided road, less congested)
Situation 8

Queue jumping probability in signalized crossing

- Road geometry: undivided road
- My side: more congested
- Time frame: time at hand/ running out of time
- Options in hand (to move/other decision):

Option 1 (leave passenger at left side at signalized crossing)

Option 2 (go through the present side using signal)

Option 3 (go and take opposite of road ahead side defying signal)

Figure 4.8: Queue jumping probability (undivided road, more congested)
Situation 9

Queue jumping probability in signalized crossing

- Road geometry: **divided** road
- My side: **less** congested
- Time frame: time at hand/ running out of time
- Options in hand (to move/other decision):

Option 1 (leave passenger at left side at signalized crossing)

Option 2 (go through the present side using signal)

Option 3 (go and take opposite of road ahead side defying signal)

**Figure 4.9:** Queue jumping probability (divided road, less congested)
Situation 10

Queue jumping probability in signalized crossing

- Road geometry: divided road
- My side: more congested
- Time frame: time at hand/ running out of time
- Options in hand (to move/other decision):

Option 1 (leave passenger at left side at signalized crossing)

Option 2 (go through the present side using signal)

Option 3 (go and take right side defying signal)

Figure 4.10: Queue jumping probability (divided road, more congested)
Situation 11

Adverse road surface condition at present side of travel

- Road geometry: **undivided** road
- My side: **less** congested
- Time frame: time at hand/ running out of time
- Options in hand (to move/other decision):

Option 1 (go through present side of road with greater effort)

Option 2 (use opposite side of the road for the affected portion of present side)

**Figure 4.11:** Adverse road condition (undivided road, less congested)
Situation 12

Adverse road surface condition at present side of travel

- Road geometry: undivided road
- My side: more congested
- Time frame: time at hand/ running out of time
- Options in hand (to move/other decision):

Option 1 (go through present side of road with greater effort)

Option 2 (use opposite side of the road for the affected portion of present side)

Figure 4.12: Adverse road condition (undivided road, more congested)
4.4 Summary

It has been mentioned that the study for primary data collection is set to be conducted by focus group survey consisting of the rickshaw-pullers only. Such type of focus group study was denoted by Kondyli and Elefteriadou (2009) for illustrating the driving behavior of freeway and ramp vehicles in merging process. Video recording of the movements of the participants was done as well to understand the actual scenario and to see whether there exists anomaly in the decision making. This study is logical in the fact that the concerned participants are directly involved in the interview sharing their thought processes and to produce new ideas not introduced in the interview form. The interview aided by a video recording data may be more useful in the context of accuracy and reliability.
Chapter 5

Data Analysis and Model Development

5.1 General

As discussed in the previous chapter, two types of data have been collected. The primary data has been used to determine the variation of speed over time and space. This allows obtaining a full trajectory of a rickshaw including the turning and stopping, acceleration and deceleration. The data attained by roadside interview of rickshaw-pullers reveals their psychological status, their experience, knowledge, judgment skill and all over their intentions and desires in daily movement. This type of data may be converted to some numerical values for comparison under different criteria and to establish relationship between various factors affecting the decision-making of the rickshaw-pullers. A thorough analysis of these two types of data may help in making a framework for modeling of the movement of rickshaws in heterogeneous traffic conditions.

The analysis of the secondary data has been performed initially. The findings and the limitations has been identified which has led to the collection of primary data. The primary data has been collected and analyzed later. The analysis of both primary and secondary data is discussed in the subsequent sections and subsections.
5.2 Analysis of Secondary Data:

The data obtained by the global positioning system has been used to find the itinerary of a rickshaw in an area. The following trajectory has been found using this data as input in ‘GPS Visualizer_google maps’.

Figure 5.1: Rickshaw trajectory obtained by GPS Visualizer_google maps
Speed-distance curve and speed-time-distance curve

Figure 5.2: Speed-distance curve from GPS data

Figure 5.3: Speed-time-distance curve from GPS data
The former curve is speed-distance curve which shows the variation of speed of a rickshaw with time. The later shows the effect of time on the variation of speed.

The speed variation with distance gives an impression about the continuity of movement. It also enables us to scrutinize the deeper aspects of movement pattern. In co-ordination with the trajectory data and trajectory itself it can serve as a tool of checking the observed situation with the actual situation in terms of turning, acceleration, deceleration etc. In the presence of variation of speed over time it becomes easier to fit the data in actual behavioral circumstances.

For instance, in a trajectory data the position of the rickshaw for every time interval is recorded. As a result, the distance travelled by a rickshaw at a certain time difference can be worked out. From the trajectory the position of the rickshaw at the road network can be identified. In the case of abrupt change in speed at a certain period, if we can identify the location of the rickshaw, we may get an explanation of real time situation. A sudden decrease in speed may be associated with the stoppage of the rickshaw irrespective of the cause. A gradual decrease may be an indicator of the deceleration with time. In a similar way, it may be possible to get a sudden or gradual increase of speed.

If the location of the origin and destination are known for a number of rickshaws and the time frame is fixed, it may be possible to get at least some clues to compare the movement pattern of those rickshaws which may be helpful for further analysis like modeling or simulation. It must be noted that the roadway condition, socio-economic activities and the behavior of the rickshaw-puller will affect the movement of rickshaw on a large scale.

The secondary data provides necessary information for modeling longitudinal movement of rickshaw which may be used for simulation later. By using simulation software, an acceleration pattern of rickshaw may be developed.

5.3 Analysis of Primary Data

Analysis of primary data is a key to gain a fruitful result from the contents of primary data and secondary data served. The primary data are analyzed as per following ways.

By considering the effects of the observed factors affecting movement
By taking the psychological factors into account for affecting decision making pertaining to movement.
By analyzing the secondary data and finding any similarity or dissimilarity in the movement pattern with the trajectory of rickshaws in terms of time, space and distance

In order to idealize the whole concept of movement a thorough analysis of these two types of data is mandatory.

5.3.1 Effects of observed factors

The various data obtained by the roadside interview of the rickshaw-pullers may be analyzed in terms of comparison on the basis of a number of criteria. The following graphs have been obtained from the collected data which were formed on the hypothetical situations discussed in the previous chapter.

For convenience in understanding the choice of the rickshaw-pullers, the options mentioned earlier for each situation will be illustrated again. It is to be noted that total thirty rickshaw-pullers were questioned with related situations.

Scenario 1

This scenario has the following features

- Undivided road
- Destination at opposite side
- Rickshaw is moving in less congested condition existing in its side

The options were,

Option 1: leave passenger at present side (directly opposite to destination)

Option 2: go to destination at opposite side
The following result has been obtained for this situation

**Scenario 1: Destination at opposite side (less congested)**

<table>
<thead>
<tr>
<th></th>
<th>time at hand</th>
<th>running out of time</th>
</tr>
</thead>
<tbody>
<tr>
<td>option 1</td>
<td>100%</td>
<td>0%</td>
</tr>
<tr>
<td>option 2</td>
<td>0%</td>
<td>100%</td>
</tr>
</tbody>
</table>

- **Figure 5.4:** Effect of time when road is undivided (destination at opposite side, rickshaw side is less congested)

This figure illustrates that, the decision making in the above situation is dependent on the time available to the rickshaw puller. When the rickshaw puller had no rush out of thirty rickshaw-pullers twenty six of them agreed to take the passenger to the destination at opposite side of the present direction. But when they were running out of time, most of them (63%) liked to leave the passenger to the left side rather than taking them right at the destination.
Scenario 2

Rickshaw is moving in comparatively more congested condition. Other conditions remain same.

The result is shown by the following bar charts.

**Figure 5.5:** Effect of time when road is undivided (destination at opposite side, rickshaw side is more congested)

When time was available, the choice of going right or left was equal by number. In rush hour, the choice tilted to going left side and leaving the passenger without taking him to his destination precisely.
From the above two figures it is also evident that when congestion in the side of the subject rickshaw becomes more, the intention of the rickshaw-puller to go to the opposite side of the road becomes stifled even when time is available in both cases. A reason may be that the rickshaw-puller is not willing to take the risk of losing the position in traffic stream. Once he has left his direction and went to right for the passenger, it may seem to be difficult for him to be back to the previous stream at the left portion of the road. For the same reason the rate of change in choosing option 2 for time availability scenario in less congested situation is higher than in case of more congested situation.

**Scenario 3 and 4**

A service road is located at the opposite side of the road.

The present side of the rickshaw is not congested and movement is continuous. The condition is such that the rickshaw has to take the service road at opposite side its present side of road. The rickshaw-puller has to choose from any three of the following options.

Option 1: He doesn’t want to go the service road and leave the passenger to the left side of the road of present location. In fact this type of action is not expected to the passengers at all.

Option 2: He is willing to use the service road by using the U-turn facility up ahead the present road and will be back to take the service road at left (with respect to that position).

Option 3: He just wants to use his hands as signal to go right and reach the service road.
The result from the survey when the present side of the subject rickshaw becoming less congested is just as follows.

**Figure 5.6:** Effect of time when road is undivided (existence of service road, rickshaw side is less congested)

In the previous figure it can be seen that the use of hands as signal is prevalent in choosing and entering the service road when the driver is free from haste. The inclination towards the U-turn activity is not considerable. The selection of option dramatically changes when time becomes a constraint to the drivers. A wonder is that, the rickshaw-pullers even want to leave their passenger before reaching the service
road in rush period. The most interesting thing is the tradeoff between the time and the money as the passengers would not pay the full bill as they are not taken all the way to their destinations. But the rickshaw-pullers are not seemed to be much concerned about this matter. In the developing countries, most of the rickshaw-pullers pull the rickshaws which are not owned by them. These rickshaws are hired by them to pull in shift basis. Someone is settled for whole day while the others are stipulated for only half time (e.g. from morning to noon or noon to night). If the time for returning rickshaw is over and the rickshaw becomes inoperable to the next puller serving later, then the former rickshaw-puller is bound to pay all the bills to him as a fine or penalty. No doubt this payment is much greater than the loss he would incurred on him not by taking the passenger to his destination while running out of time.

When the congestion is more at the side of the rickshaw-puller concerned, the outcome of the survey becomes a little bit different.

The outcome is demonstrated by the bar charts shown in the following page.
Figure 5.7: Effect of time when road is undivided (existence of service road, rickshaw side is more congested)

It is found from the chart that, in congested situation, the driver may not wish to take the service road to take the passenger to his destination even when time is available to him although the case is minimum (3%). The rejection of using the service road increases as time becomes shorter. The number of choosing the U-turn facility has also reduced with the shortening of available time.

Scenario 5 and 6

The scenarios are described as follows,

The subject rickshaw is halted due to the stop signal at a signalized crossing.

The flow in the same side of the road ahead the crossing is sufficiently low.

The driver of this rickshaw has three options in hand to negotiate the situation.

Option 1: To leave the passengers at present side of the road before the signal turns amber. This action does not violate the traffic rule as rickshaw is not going to opposite side without using U-turn, but is bitterly distasteful to the passengers as they are not taken to their destination.

Option 2: To wait for the signal turning amber and using the present side (withhold the law).
Option 3: No wait for the permission to move forward and taking the opposite side of the same road ahead the crossing (complete defiance of traffic rule).

From the survey report the following scenario has been revealed.

**Figure 5.8:** Effect of time when road is undivided (queue jumping probability, rickshaw side is less congested)

When there is enough time in hand, the drivers of the rickshaws are likely to wait for the signal and then proceed further. There are a few exceptions about choosing the right side of the upcoming road beyond the crossing. A minimum number of
rickshaw-pullers have chosen to request the passenger not to take him any longer from this crossing when time is short. The number of traffic rule violators among them has also increased significantly (from 20% to 40%).

Figure 5.9: Effect of time when road is undivided (queue jumping probability, rickshaw side is more congested)
When the congestion in the present side of the rickshaw-puller is increased to a great deal and the he presages that even he waits for the signal he will be in the traffic congestion and more time will be spent as a whole, then the situation becomes more complicated. There is almost a complete reversal of choosing option 2 and option 3 taking place. It implicates the rickshaw-pullers of going to the right side of the road before they are permitted to enter that road from the left side (present side). Two activities are occurring at the same time; going right side (opposite side) and defying the signal. The removal of passenger from rickshaw at rush period is noticeable as well.

**Scenario 7 and 8**

Roadway condition is not favorable at some distance further at the present direction of the driver.

If the present side is less congested then there are two ways to go further in this road.

Option 1: Remain intact in the present direction (maneuverability may be difficult).

Option 2: For the affected portion of the road take the opposite side and cross that portion followed by returning to the present side (required effort is less).

The scenario is presented by the following show-card.
The attained information is composed to the following bar charts.

**Figure 5.10:** Effect of time when road is undivided (adverse roadway condition, rickshaw side is less congested)

When time is not a big issue, then major portion of the rickshaw-pullers are intended to remain in the present side and offer greater effort to pass the affected road surface. This tendency is reduced as the time comes into play as a major constraint.

With time being, the present direction becomes more congested and the loss of time becomes unbearable in some extent.
Figure 5.11: Effect of time when road is undivided (adverse roadway condition, rickshaw side is more congested)

The difference in more congested situation with less congested situation lies in the fact that the major portion of the drivers has chosen to go to opposite side of the road to overcome the adverse road surface of present side even when time is in hand. The intention to use opposite portion (right side) has also increased with shortening of time as expected.

So far, only the undivided roads have been discussed. If the roads are separated by median or divider, the nature and number of options may be changed according to the circumstances.

Scenario 9 and 10

Divided road

Destination at opposite side of road

The subject rickshaw is moving in less congested traffic condition on its side which becomes more congested at another period.

The number of available option is three. These are,

Option 1: Request the passenger to alight from rickshaw at present side of road and to go to opposite side on foot.
Option 2: To use U-turn facility up ahead and to take the passenger at the destination

Option 3: To request the passenger to use the median breaker by taking the rickshaw as close as possible to the median breaker.

From interview of the rickshaw-pullers the following information has been found when the traffic becomes more congested.

**Figure 5.12:** Effect of time when road is divided (destination at opposite side, rickshaw side is less congested)
The following show-card illustrates the situation with all the options available to the rickshaw-pullers regarding the scenario.

The result of this situation is given in next page by bar charts.

**Figure 5.13:** Effect of time when road is divided (destination at opposite side, rickshaw side is more congested)
In case of less congested condition, the drivers are willing to take the passengers to their destination at the opposite site if time is favorable although there are few exceptions. The tendency of the drivers to leave the passengers at present side has been increased when time has been shortened.

When traffic congestion in the operating side is heavy, a number of rickshaw-pullers are trying to get relieved by leaving their passengers to the present side even there is time in hand. In the survey phase, the drivers were trying to give priority to the value of time of the passengers in this phenomenon. The willingness to fulfill the passengers choice is still at large as a major portion of the drivers are still intended to take their passengers to their destination by using U-turn facility. In rush period, the intention to use the U-turn facility is greatly declined as a combined effect of time restriction and congestion.

**Scenario 11 and 12**

The following features are used to describe the scenarios.

The subject rickshaw is halted due to the stop signal at a signalized crossing.

The flow in the same side of the road ahead the crossing is sufficiently low.

The driver of this rickshaw has three options in hand to negotiate the situation.

Option 1: To leave the passenger at left side before the signal goes amber (not taking the passenger to destination).

Option 2: To wait for the signal turning amber and using the present side (withhold the law). Apparently, this is the most appreciable decision made by a wise and experienced rickshaw-puller.

Option 3: No wait for the permission to move forward and taking the opposite side of the same road ahead the crossing (complete defiance of traffic rule). As this option is risky and violate the traffic rules and regulations completely, the shrewd drivers are not supposed to take such action.
It is evident that this situation and the corresponding options are same in case of divided roads. The results obtained may or may not be different depending on the intentions of the driver regarding the situations and options available.

**Figure 5.14:** Effect of time when road is divided (queue jumping probability, rickshaw side is less congested)
The choosing of current side of road after the permission to cross the crossing is predominant in case of no rush. This scenario is very much alike to that for the same condition for undivided road. The time shortage has also the same type of effect as in case of undivided roads.

What happens if the present side beyond crossing becomes more congested has also been figured out.

**Figure 5.15:** Effect of time when road is divided (queue jumping probability, rickshaw side is more congested)
The number of rickshaw-pullers to wait for the signal to turn amber and moving to the same direction has been increased (from 60% in case of undivided road to 83% for divided road). The main cause may be the existence of the divider (or median) which prevents the movement to go to opposite side as there is no chance to return to present side until another crossing is found. The scenario at rush period is similar to that in case of undivided roads.

5.3.2 Effects of demographic factors

In the previous subsection, a number of perceptible data and their effect on choosing options in decision making have been analyzed. But the fact is not so simple at all. There are some other intangible psychological factors which may have direct impact on the movement pattern of rickshaw-pullers. The psychological factors that come into play are the age, experience, training, and rickshaw ownership status of the rickshaw-pullers. The effect of geological formation (birth place and socialization arena) may be important in some extent as well. The analysis of the effect of these factors may be helpful in demonstrating the behavior of rickshaw-pullers pertaining to driving and movement trends. There is also some scope of analyzing the combined effect of these factors on the psychology and emotional make-up of the rickshaw-pullers.

Effect of age on movement pattern

Some of the actions taken by the drivers are irrespective of their ages; solely dependent on the factors which are materialistic in nature (roadway condition, traffic flow characteristics etc.). Therefore, an attempt will be made here to find any discrepancy in the conventional movement pattern that can be related to age.

Procedure:

Total no. of rickshaw-pullers surveyed: 30

Their ages range from 18 to 20 years.

Age classes have been defined at first step. The number of rickshaw-pullers in each age class is calculated as well. From the study report,
Table 5.1: Number of rickshaw-pullers according to age class

<table>
<thead>
<tr>
<th>Age class (years)</th>
<th>No. of rickshaw pullers</th>
<th>% of rickshaw pullers</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;= 20</td>
<td>2</td>
<td>6.666</td>
</tr>
<tr>
<td>21-30</td>
<td>11</td>
<td>36.67</td>
</tr>
<tr>
<td>31-40</td>
<td>9</td>
<td>30</td>
</tr>
<tr>
<td>41-50</td>
<td>2</td>
<td>6.666</td>
</tr>
<tr>
<td>51-60</td>
<td>2</td>
<td>6.666</td>
</tr>
<tr>
<td>61-70</td>
<td>2</td>
<td>6.666</td>
</tr>
<tr>
<td>&gt;70</td>
<td>2</td>
<td>6.666</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>30</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

It has been seen that the major portion of rickshaw-pullers are in at the age ranges from 21 to 30 years and 31 to 40 years. As a result their decision making bears additional significance to analyze the movement pattern. If all the age classes are considered, then their decisions or movements can be split to 168 cells (24 situations*7 age classes) at aggregate. The introduction of all cells may be cumbersome and all of them may not be important at equal extent. Hence, only the critical conditions (in terms of traffic condition and time) will be reviewed. The focus will be also on to any anomalies in the decision making of the rickshaw-pullers of any age class.

The most critical condition from observation is the situation when there is huge traffic congestion at the side of subject rickshaw and he has a little or no time in hand (running out of time). This combination of traffic condition and time constitutes total 42 cells (6 situations* 7 age classes). For convenience in analysis, the five age classes which comprised of only 10 rickshaw-pullers may be discarded initially. Eventually, only 12 cells are left (6 situations* 2 age classes).

In general, maturity grows with age up to a certain level and then declines with further increment of age. As the age classes considered are 21-30 years and 31-40 years, the decisions may not be too different due to the proximity of maturity level.

The following results have been found from the two age classes which are predominating. The results are given in tabular form in the succeeding page.
Table 5.2: Effect of age of rickshaw-puller in choosing options

<table>
<thead>
<tr>
<th>Situation (with option)</th>
<th>Age class</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>21-30 years</td>
<td>31-40 years</td>
<td></td>
</tr>
<tr>
<td>Destination (undivided road)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Option 1</td>
<td>82%</td>
<td>56%</td>
<td></td>
</tr>
<tr>
<td>Option 2</td>
<td>18%</td>
<td>44%</td>
<td></td>
</tr>
<tr>
<td>Service road</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Option 1</td>
<td>0%</td>
<td>56%</td>
<td></td>
</tr>
<tr>
<td>Option 2</td>
<td>82%</td>
<td>11%</td>
<td></td>
</tr>
<tr>
<td>Option 3</td>
<td>18%</td>
<td>33%</td>
<td></td>
</tr>
<tr>
<td>Queue jumping (undivided road)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Option 1</td>
<td>9%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Option 2</td>
<td>27%</td>
<td>67%</td>
<td></td>
</tr>
<tr>
<td>Option 3</td>
<td>64%</td>
<td>33%</td>
<td></td>
</tr>
<tr>
<td>Roadway condition</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Option 1</td>
<td>18%</td>
<td>22%</td>
<td></td>
</tr>
<tr>
<td>Option 2</td>
<td>82%</td>
<td>78%</td>
<td></td>
</tr>
<tr>
<td>Destination (divided road)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Option 1</td>
<td>36%</td>
<td>45%</td>
<td></td>
</tr>
<tr>
<td>Option 2</td>
<td>0%</td>
<td>22%</td>
<td></td>
</tr>
<tr>
<td>Situation (with option)</td>
<td>Age class</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Option 3</td>
<td>64%</td>
<td>33%</td>
<td></td>
</tr>
<tr>
<td>Queue jumping (Divided road)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Option 1</td>
<td>9%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Option 2</td>
<td>36%</td>
<td>67%</td>
<td></td>
</tr>
<tr>
<td>Option 3</td>
<td>55%</td>
<td>33%</td>
<td></td>
</tr>
</tbody>
</table>

In case of taking passenger to the opposite side of the road the rickshaw-pullers within the age 21 to 30 are reserved taking decision in the most critical condition. A major portion of them (82%) are intended to leave the passengers at left side of the road. This decision may bear two implications; passenger safety and the other is the saving of their own time. It is not easy to comment whether the decision is right or wrong. In
the perspective of the passenger, it may have heterogeneous reactions. The rickshaw-pullers between 21 to 30 years of age are seemed to be more interested in reaching the passengers to their destinations. But in terms of going to opposite side of the road (violating the traffic rule) this decision may be criticized.

The existence of service road and moving to that road has not been favorable for the rickshaw-pullers of 31-40 years. As it is seen, more than half of them are inclined to leave their passengers before reaching the service road. This decision is a negation of their decision in case of taking decision when destination is at opposite side of road. On the other hand, the younger age classed rickshaw-pullers have shown the sign of shrewdness in taking their decision as they are not willing to leave no passenger left prior to the service road.

When queue jumping is considered in undivided road, the older drivers (31-40 years) are likely to be more passenger-friendly. Moreover, they are seemed to withhold the traffic rules more strictly than the younger drivers (21-30 years). Some of the drivers in the age ranges from 21 to 30 years are not interested to take the passengers ahead of the signalized crossing (9%) even when the most critical condition did not exist (only time was short, but the traffic flow was low). This is one of the most awe inspiring decisions taken by a rickshaw-puller.

The judgment of the rickshaw-pullers of 31-40 years of age also showed their maturity over the younger fellows. The percentage of the older drivers avoiding the wrong direction (22%) is greater than the younger drivers (18%).

When the road is divided, the movement pattern is quite different. For divided road the drivers between 31 to 40 years of age are more interested in leaving the passengers to the present side (present side) of the road rather than taking them to the destination at the opposite side of the road. Some of them used the U-turn facility as well (22%). On the contrary, the younger drivers (21-30 years of age) are reluctant to go to the opposite direction of the road. The number of rickshaw-pullers using U-turn facility of this age class is zero. The rest of them are dealing with the situation by leaving passengers at present side of the road at sidewalk or at the median breaker.
In case of queue jumping situation in divided road, the decision making characteristics of the rickshaw-pullers for the age of 31-40 years is identical to that of the undivided roads. For the younger drivers (21-30 years) movement trend is almost similar compared to the same condition for undivided roads as well.

The above qualitative analysis suggests that the relationship between the age of the drivers and their movement pattern may not be same type for every set of situations especially when the range of age is close. Probably the relationship would be more obvious in another type of situation rather than the most critical condition.

The rickshaw-pullers take continuous decisions in their daily movement. Sometimes, they obey the traffic rules and regulations strictly. The exception is not uncommon either. Especially when the roadway condition is not favorable or time becomes short or roadway traffic condition is congested, the drivers seek the bee-line (shortest) path to reach their destination regardless of its legitimacy. The violation in this thesis work will be limited only to the defiance of traffic rules in movement.

At first the actions which are considered as violation have to be listed. The main acts are,

1. To go to opposite side of road (not using U-turn facility)
2. To use the median or divider breaker by taking the rickshaw to the innermost lane adjacent to the breaker

To leave passengers at present road side whether congested or less congested situation, is not taken as violation although this type of act often worsen the roadway operating condition.

From the survey data, the following scenario has been counted.
Table 5.3: Violation of rules with the variation of age

<table>
<thead>
<tr>
<th>Age class (years)</th>
<th>Violation (%)</th>
<th>Non-violation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;= 20</td>
<td>54</td>
<td>46</td>
</tr>
<tr>
<td>21-30</td>
<td>47</td>
<td>53</td>
</tr>
<tr>
<td>31-40</td>
<td>41.5</td>
<td>58.5</td>
</tr>
<tr>
<td>41-60</td>
<td>42.7</td>
<td>57.3</td>
</tr>
<tr>
<td>61-70</td>
<td>35</td>
<td>65</td>
</tr>
<tr>
<td>&gt;70</td>
<td>21</td>
<td>79</td>
</tr>
</tbody>
</table>

Figure 5.16: Violation of rules with the variation of age

It can be deduced from the aftermath of the study that the violation tendency increases with increment of age quite fairly with a minor exception for 41 to 60 years.

In order to gain an overall characteristics of the thirty rickshaw-pullers interviewed, a weighted average of them have been taken. After taking weighted average it has been obtained that,

Overall violation= 42.71% and

Overall non-violation= 57.29%
It means that major portion of drivers (in this study) do not violate the traffic rules under these specified conditions.

5.4 Model Development

A transportation model is developed to show the interrelationship between a number of independent variables with one dependent variable. The number of independent variable is chosen in such a way that it is neither exaggerated nor inadequate. The factors which fulfill most of the criteria are selected.

The model formulated here is comprised of one independent variable and four dependent variables. The dependent variable is termed as ‘violation’. The independent variables are age (young), experience (low), congested situation and shortage of time which are likely to cause violation of traffic rules. The following equation has been assumed to develop the model.

\[ V_{\text{violation}} = \alpha_{\text{violation}} + \beta_1 \times (\text{Age})_{\text{young}} + \beta_2 \times (\text{Experience})_{\text{low}} + \beta_3 \times (\text{Congested}) + \beta_4 \times (\text{Running out of time}) \]  \hspace{1cm} \text{(5.1)}

\[ V_{\text{non-violation}} = 0 \]  \hspace{1cm} \text{(5.2)}

\[ P_{\text{violation}} = \frac{e^{V_{\text{violation}}}}{e^{V_{\text{violation}}} + e^{V_{\text{non-violation}}}} \]  \hspace{1cm} \text{(5.3)}

Where,

- \( V_{\text{violation}} \) = Utility for violation
- \( V_{\text{non-violation}} \) = Utility for non-violation
- \( P_{\text{violation}} \) = Probability of violation
- \( \alpha_{\text{violation}} \) = alternative specific constant which is responsible for the violation in the absence of any other variables
- \( \beta_1 \) = Model parameter representing the influence of young age for causing violation
- \( \beta_2 \) = Model parameter for showing the effect of experience on violation
\( \beta_3 \) = Model parameter for showing the effect of congestion on violation phenomenon

\( \beta_4 \) = Model parameter accounting for the shortage of time in maneuvering

There were some assumptions associated with age and experience. It was speculated that the rickshaw drivers below 30 years of age was positively related for causing violation. The effect of low experience (<5 years) was assumed to be positive or negative.

For calibration of the model parameters statistical software named ‘BIOGEME’ has been used. From 720 data sets, after calibration the following values of the parameters have been obtained.

**Table 5.4:** Value of different parameters used in the utility equation of violation

<table>
<thead>
<tr>
<th>Model parameter</th>
<th>Calibrated value</th>
<th>t- test</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \alpha_{\text{violation}} )</td>
<td>0.965</td>
<td>2.74</td>
</tr>
<tr>
<td>( \beta_1 )</td>
<td>-0.0471</td>
<td>-3.40</td>
</tr>
<tr>
<td>( \beta_2 )</td>
<td>0.0404</td>
<td>0.0159</td>
</tr>
<tr>
<td>( \beta_3 )</td>
<td>-0.0339</td>
<td>0.152</td>
</tr>
<tr>
<td>( \beta_4 )</td>
<td>-0.0108</td>
<td>0.152</td>
</tr>
<tr>
<td>Adjusted rho-square ( (\rho^2) )</td>
<td>0.018</td>
<td></td>
</tr>
</tbody>
</table>

It can be said that a number of rickshaw-pullers have compulsion for violating traffic rules (as the value of \( \alpha_{\text{violation}} \) is positive). The effect of age on violation which was determined previously in a different way is quite opposite to this result (as value of \( \beta_1 \) is negative). The reason may be the influence of other factors. Among five values of \( \alpha_{\text{violation}}, \beta_1, \beta_2, \beta_3 \) and \( \beta_4 \) from t-test result, three values (absolute value) are less than 1.96 (absolute value). It means that these three parameters are not in the 95% confidence interval with the critical value. The value of adjusted rho-square \( (\rho^2) \) is not quite satisfactory which implicates that the parameters are not fitted well with the variables.

The final form of equation (5.1) and (5.2) becomes,
\[ V_{\text{violation}} = 0.965 - 0.0471 \times (\text{Age\_young}) + 0.0404 \times (\text{Experience\_low}) - 0.0339 \times (\text{Congested}) - 0.0108 \times (\text{Running\_out\_of\_time}) \]

\[ V_{\text{non-violation}} = 0 \]

Theses equations are applicable only for the variables stated in the equation. If number of variables increases, then further calibration may be required.

5.5 Summary

At first, analysis of secondary data has been performed and the applicability of the findings has been worked out. Then, the analysis of the primary data has been accomplished and the effect of observed factors has been found out. Next, the effect of demographic factors on violation tendency of rickshaw drivers has been done. After that, an attempt has been made to see the combined effect of demographic factors on violation perspective. Finally, the discrete choice model equation has been developed by calibrating value of different model parameters used in the equation. The equation for the probability of violating traffic rules has been introduced as well.
Chapter 6

Conclusions

6.1 Summary of Research

This research work has focused on the rickshaw movement in heterogeneous traffic conditions. At the initial stage the available data were explored. This secondary data helped to find the trajectory of a rickshaw in a road network. The movement was detected by the trajectory figure and possible acceleration and deceleration could be at least speculated. But this type of data was inadequate and not so precise to model the complex lateral movement pattern of rickshaws which vary significantly with traffic conditions, driver characteristics and often on specific situation. Video data was not also found to be useful due to absence of image processing software that can handle heterogeneous traffic condition. As a result, the primary data was required. The primary data is based on a number of hypothetical assumptions. The assumptions incorporate the most seemingly factors that affect the movement of rickshaw. The data was collected by road-side interview survey of the rickshaw drivers which were developed based on the hypothetical situations and the decision making process of the rickshaw-pullers. Special emphasis was given on situations where rickshaw-pullers violate traffic rules and move along wrong side of the road. The demographic factors that shape the emotion and intention of drivers have also been introduced. Eventually a crude result has been obtained about the driving behavior of the rickshaw-pullers. This thesis has suggested the combination of the demographic factors with observed factors (traffic condition, roadway geometric condition, etc.) for a better understanding of the driving behavior which is reflected in the instantaneous decisions of the drivers pertaining to movement.

The outcome of analysis of data are given below

- The violation of traffic rules has been found to be greater in the absence of U-turn facility while the destination is situated at the opposite side of the road.
More precisely, when U-turn facility is operational, the complete violation has never occurred in this condition.

- The similarities and dissimilarities in taking decisions of the rickshaw pullers pertaining to movement may act as an important tool to conceive their behavior and their interactions and response to the roadway condition.
- This research may be associated with the state-of-the-art driver behavior models to fully acknowledge the driving behavior in heterogeneous traffic condition.
- In a closer view, the effects of various factors (e.g. age, experience, physical and mental ability of rickshaw-pullers, condition of road and traffic flow, condition of rickshaw, franchise of rickshaw etc.) which significantly affect the driving pattern of rickshaw-pullers can be understood in a broader way.

### 6.2 Scope for Further Research

The research conducted may usher the way of new thoughts to discover the driving characteristics, movements, and overall demographic aspects of a rickshaw-puller. There are some features related to the movement that the research has not dealt with. A number of inherent limitations are notable as well. The limitations of this thesis are given here. In the light of the limitations of this research some modification and improvements may be required. There may be a number of ways to overcome the drawbacks of this research done so far.

(1) In this thesis, for undivided road, when destination is at opposite side there was no provision for rickshaw-pullers to go to opposite side by not violating the traffic rules (no option suggesting U-turn facility). If the U-turn facility would be provided, the data would be complementary.

(2) This research is not able to give a systematic outline of the modeling framework. It is rather a building process of innovative ideas that constitute the framework. Further study needs to be carried out in this field.

(3) This research has been performed by limited data on a small scale. The output of the same research may be more reliable if sufficient data are available.

(4) The extent of information may be expanded by provision of more observed and demographic factors to make the interrelationship more clear and
intelligible. More advanced discrete choice models could be developed by this way.

(5) This thesis has been built up on some survey data which is an effort to collect data in micro-level. Moreover, data has been taken only for rickshaw. If data of the movement pattern of other vehicles is available (Sadri, 2011, unpublished work), the combination of these data may be used to perform complete simulation of traffic flows.

(6) Coding in simulation may be done to predict the scenario in future.
References

Ahmed K. I. (1999), Modeling drivers’ acceleration and lane changing behaviors, PhD thesis, Department of Civil and Environmental Engineering, MIT.


Choudhury C. and Ben-Akiva M., A Lane Section Model For Urban Intersections, Transportation Research Record, Journal of the Transportation Research Board.


Toledo T. (2003), Integrated driving behavior modeling, PhD dissertation, Massachusetts Institute of Technology, USA.


Appendix (Part A)
**Collection of Primary (Observed) Data**

Table: Collection of Primary (Observed) Data from SP Survey (Choosing Options)

<table>
<thead>
<tr>
<th>Rickshaw Serial No.</th>
<th>Situation</th>
<th>My Side</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Less Congested</td>
</tr>
<tr>
<td><strong>Undivided Road</strong></td>
<td></td>
<td>Time at Hand</td>
</tr>
<tr>
<td>Destination at Opposite Side</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Service Road</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Queue Jumping</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roadway Condition</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Divided Road</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Destination at Opposite Side</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Queue Jumping</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Collection of Primary (Demographic) Data**

Rickshaw Sample No.:

Name:

Age:

Time pulling rickshaw:

Time pulling rickshaw (in Dhaka):

Other occupation before rickshaw pulling:
Rickshaw training (or self):

Owner (or hired):

Appendix (Part B)
<table>
<thead>
<tr>
<th>Latitude</th>
<th>Longitude</th>
<th>Date</th>
<th>Time</th>
<th>ΔY</th>
<th>Distance(km)</th>
<th>ΔTime (hr)</th>
<th>Speed(km/hr)</th>
<th>Distance (Sum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>37.2389093</td>
<td>90.4249766</td>
<td>Sun Aug 2 2009</td>
<td>6:22:36</td>
<td>0.000229</td>
<td>0.068421</td>
<td>0.00502919</td>
<td>0.00833333</td>
<td>0.00833333</td>
</tr>
<tr>
<td>37.2389093</td>
<td>90.4249766</td>
<td>Sun Aug 2 2009</td>
<td>6:22:36</td>
<td>0.000229</td>
<td>0.068421</td>
<td>0.00502919</td>
<td>0.00833333</td>
<td>0.00833333</td>
</tr>
<tr>
<td>37.2389093</td>
<td>90.4249766</td>
<td>Sun Aug 2 2009</td>
<td>6:22:36</td>
<td>0.000229</td>
<td>0.068421</td>
<td>0.00502919</td>
<td>0.00833333</td>
<td>0.00833333</td>
</tr>
<tr>
<td>37.2389093</td>
<td>90.4249766</td>
<td>Sun Aug 2 2009</td>
<td>6:22:36</td>
<td>0.000229</td>
<td>0.068421</td>
<td>0.00502919</td>
<td>0.00833333</td>
<td>0.00833333</td>
</tr>
<tr>
<td>37.2389093</td>
<td>90.4249766</td>
<td>Sun Aug 2 2009</td>
<td>6:22:36</td>
<td>0.000229</td>
<td>0.068421</td>
<td>0.00502919</td>
<td>0.00833333</td>
<td>0.00833333</td>
</tr>
<tr>
<td>37.2389093</td>
<td>90.4249766</td>
<td>Sun Aug 2 2009</td>
<td>6:22:36</td>
<td>0.000229</td>
<td>0.068421</td>
<td>0.00502919</td>
<td>0.00833333</td>
<td>0.00833333</td>
</tr>
<tr>
<td>37.2389093</td>
<td>90.4249766</td>
<td>Sun Aug 2 2009</td>
<td>6:22:36</td>
<td>0.000229</td>
<td>0.068421</td>
<td>0.00502919</td>
<td>0.00833333</td>
<td>0.00833333</td>
</tr>
<tr>
<td>37.2389093</td>
<td>90.4249766</td>
<td>Sun Aug 2 2009</td>
<td>6:22:36</td>
<td>0.000229</td>
<td>0.068421</td>
<td>0.00502919</td>
<td>0.00833333</td>
<td>0.00833333</td>
</tr>
<tr>
<td>37.2389093</td>
<td>90.4249766</td>
<td>Sun Aug 2 2009</td>
<td>6:22:36</td>
<td>0.000229</td>
<td>0.068421</td>
<td>0.00502919</td>
<td>0.00833333</td>
<td>0.00833333</td>
</tr>
<tr>
<td>37.2389093</td>
<td>90.4249766</td>
<td>Sun Aug 2 2009</td>
<td>6:22:36</td>
<td>0.000229</td>
<td>0.068421</td>
<td>0.00502919</td>
<td>0.00833333</td>
<td>0.00833333</td>
</tr>
<tr>
<td>37.2389093</td>
<td>90.4249766</td>
<td>Sun Aug 2 2009</td>
<td>6:22:36</td>
<td>0.000229</td>
<td>0.068421</td>
<td>0.00502919</td>
<td>0.00833333</td>
<td>0.00833333</td>
</tr>
<tr>
<td>37.2389093</td>
<td>90.4249766</td>
<td>Sun Aug 2 2009</td>
<td>6:22:36</td>
<td>0.000229</td>
<td>0.068421</td>
<td>0.00502919</td>
<td>0.00833333</td>
<td>0.00833333</td>
</tr>
<tr>
<td>37.2389093</td>
<td>90.4249766</td>
<td>Sun Aug 2 2009</td>
<td>6:22:36</td>
<td>0.000229</td>
<td>0.068421</td>
<td>0.00502919</td>
<td>0.00833333</td>
<td>0.00833333</td>
</tr>
<tr>
<td>37.2389093</td>
<td>90.4249766</td>
<td>Sun Aug 2 2009</td>
<td>6:22:36</td>
<td>0.000229</td>
<td>0.068421</td>
<td>0.00502919</td>
<td>0.00833333</td>
<td>0.00833333</td>
</tr>
<tr>
<td>37.2389093</td>
<td>90.4249766</td>
<td>Sun Aug 2 2009</td>
<td>6:22:36</td>
<td>0.000229</td>
<td>0.068421</td>
<td>0.00502919</td>
<td>0.00833333</td>
<td>0.00833333</td>
</tr>
<tr>
<td>37.2389093</td>
<td>90.4249766</td>
<td>Sun Aug 2 2009</td>
<td>6:22:36</td>
<td>0.000229</td>
<td>0.068421</td>
<td>0.00502919</td>
<td>0.00833333</td>
<td>0.00833333</td>
</tr>
<tr>
<td>37.2389093</td>
<td>90.4249766</td>
<td>Sun Aug 2 2009</td>
<td>6:22:36</td>
<td>0.000229</td>
<td>0.068421</td>
<td>0.00502919</td>
<td>0.00833333</td>
<td>0.00833333</td>
</tr>
<tr>
<td>37.2389093</td>
<td>90.4249766</td>
<td>Sun Aug 2 2009</td>
<td>6:22:36</td>
<td>0.000229</td>
<td>0.068421</td>
<td>0.00502919</td>
<td>0.00833333</td>
<td>0.00833333</td>
</tr>
<tr>
<td>37.2389093</td>
<td>90.4249766</td>
<td>Sun Aug 2 2009</td>
<td>6:22:36</td>
<td>0.000229</td>
<td>0.068421</td>
<td>0.00502919</td>
<td>0.00833333</td>
<td>0.00833333</td>
</tr>
<tr>
<td>37.2389093</td>
<td>90.4249766</td>
<td>Sun Aug 2 2009</td>
<td>6:22:36</td>
<td>0.000229</td>
<td>0.068421</td>
<td>0.00502919</td>
<td>0.00833333</td>
<td>0.00833333</td>
</tr>
<tr>
<td>37.2389093</td>
<td>90.4249766</td>
<td>Sun Aug 2 2009</td>
<td>6:22:36</td>
<td>0.000229</td>
<td>0.068421</td>
<td>0.00502919</td>
<td>0.00833333</td>
<td>0.00833333</td>
</tr>
<tr>
<td>37.2389093</td>
<td>90.4249766</td>
<td>Sun Aug 2 2009</td>
<td>6:22:36</td>
<td>0.000229</td>
<td>0.068421</td>
<td>0.00502919</td>
<td>0.00833333</td>
<td>0.00833333</td>
</tr>
<tr>
<td>37.2389093</td>
<td>90.4249766</td>
<td>Sun Aug 2 2009</td>
<td>6:22:36</td>
<td>0.000229</td>
<td>0.068421</td>
<td>0.00502919</td>
<td>0.00833333</td>
<td>0.00833333</td>
</tr>
<tr>
<td>37.2389093</td>
<td>90.4249766</td>
<td>Sun Aug 2 2009</td>
<td>6:22:36</td>
<td>0.000229</td>
<td>0.068421</td>
<td>0.00502919</td>
<td>0.00833333</td>
<td>0.00833333</td>
</tr>
</tbody>
</table>