FLEXIBLE WORK HOURS FOR TRAFFIC MANAGEMENT IN PEAK HOURS: A CASE STUDY OF SRI JAYAWARDENAPURA KOTTE, SRI LANKA

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November 2020

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Dissertation submitted in partial fulfillment of the requirements for the degree Master of Spatial Planning and Design

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November 2020

DECLARATION

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CERTIFICATION

I certify herewith that P.M.A Kothalawala, Index number: 169179G of the 2016/2018 batch, has carried out research for the Masters dissertation under my supervision.

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Town and Country Planning

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ABSTRACTS

Traffic Congestion is one of the most intolerable problems in the most cities due to sudden increase in privacy. Transportation affects urban society, environment and the economy. Flexible Work Hour Implementation (FWH) is one of the important measures of traffic demand management (TDM) which can use to spread out the vehicle volume and traffic congestion during morning and evening peak periods. This study investigates taking different FWH measure can adjust transportation volume on road and alleviate transport stress in peak hour in Sri Jayewardenepura Kotte area. Nowadays it has seen rapid growth in transportation demand and serious road congestion in study area due to concentration of various functions and activities. Therefore, the trip features of employees in study area and transportation status are analyzed to implementing different working hour method as solution to reduce congestion. The traffic applicability of FWH in the selected case study area is analyzed through relevant statistics and social surveys. Finally evaluated the findings to find relationships among selected road segments obvious road demand and road demand after Implementing the FWH. To identified the effect of proposed TDM strategy on study area road segment at AM and PM peak periods through employment trip generations. The t-test analysis from SPSS software was used to derive the analysis outcome of prior and after implementing flexible work shifts of employees on the traffic flow . The result shows that the impact of trips generated due to the employment within the study area and proposed method shows considerable positive result in some time periods to reveal the selected links at peak hours. But synthetically the final output interpret it will as limited effect on FWH implement only in selected area to relieve total congestion on peak hour traffic in considerable level.

Keywords: Flexible working schedule, TDM, Trip generation, Trip attraction, Passenger Car Units, Level of service, Travel duration

ACKNOWLEDGEMENT

I would like to express my honest thankfulness to those who have contributed in your time, inputs encouragement and for the knowledge that you were there for me toward this research successful

My special thanks to my supervisor Dr. Chameera de Silva, Senior lecturer, Department of town and country planning, faculty of Architecture of the University of Moratuwa for his patience and guidance.

I am also expressing my thankfulness to Prof: Rangajeewa Ratnayake, Senior lecturer, Head of the Department of Town and Country Planning, Faculty of Architecture at the University of Moratuwa. I also appreciatively acknowledge the inspiration, guidance, and attention I have received from all my lecturers at the University of Moratuwa.

Then I appreciate acknowledging the help and provision that I received from all my 2016/2018 batch mates and non-academic staff members of the University of Moratuwa.

I'm also thankful to my parents and family for their support for me to complete the research. Finally, I wish to thankful for all who supports me directly or indirectly for successful completion of the study.

Contents

DECLARATION I

CERTIFICATION II

ABSTRACTS III

ACKNOWLEDGEMENT IV

TABLE OF CONTENTS V

LIST OF FIGURES VII

LIST OF MAPS VII

LIST OF TABLES VIII

LIST OF ANNEXURES VIII

LIST OF ABBREVIATIONS IX

CHAPTER ONE -INTRODUCTION 1

1.1. Research Background 1
1.2. Research need 3
1.3. Research objective 6
1.4. Method of Study 6
1.5. Significance of the Study 8
1.6. Scope and Limitations of the study 8

CHAPTER TWO - LITERATURE REVIEW 9

2.1. Introduction 9
2.2. Flexible working hours/ staggered shifts 9
2.3. Case studies 10
2.3.1. Applicability of flexible working/staggered hour system in other countries 10
2.3.2. Success Programs 10
2.3.3. Failure programs 12
2.4. Analysis the impacts of land use pattern to trip generations 13
2.5. Analysis of the Commuter Travel behavior and Flexible work shifts 14

CHAPTER THREE: RESEARCH DESIGN 15

3.1. Introduction 15
3.2. Case study Area selection 16
3.3.2. Study Area Zonation 19
3.3. Data collection 20
3.3.1. Questionnaire Survey 20
3.4. Data analysis methods 21
3.4.1. Impact of Flexible work shift arrangements on traffic 21
3.4.1.1. Traffic Analysis 22
3.4.2. Analysis of the study area Trip generation and Trip attraction 25

CHAPTER FOUR: ANALYSIS AND DISCUSSION 28

4.1. Introduction 28
4.2. Commuter Profile Analysis 28
4.2.1. Distribution of commute time 28
4.2.2. Commute travel distance distribution 30
4.2.3. Intermediate stop 30
4.2.5 Commute Mode distribution 31
4.2.5. Commuter's preference analysis 31
4.2.6. Gender Base preference 32

4.3. IMPACT OF FLEXI WORK HOURS ON TRAFFIC 32
4.3.1. Traffic Analysis *32*
4.3.2. Analysis of Number of PCU count due to the Employees *35*
4.3.3. Impact of Flexible work hours on traffic *40*
4.6. CONCLUSION 45
CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS _____ 46
REFERENCE _____ 48
ANNEXURES _____ 50

LIST OF FIGURES

Figure 1: Land use comparison in Year 1999 and 2018 _____ *4*
Figure 2: Distribution of the vehicle volume with Time _____ *5*
Figure 3: Research Design _____ *7*
Figure 4: Research Methodology _____ *15*
Figure 5: Road Links and Nodes Source: Compiled by Author _____ *18*
Figure 6: Methodology of Flexible work hour shift arrangement on traffic analysis *21*
Figure 7: Morning and Evening Vehicle flow in the study Area _____ *23*
Figure 8: Hourly Vehicle Distribution _____ *24*
Figure 9: Distribution of trip generation rate _____ *27*
Figure 10: (a) Distribution of the departure time from home and (b) Distribution of departure _____ *29*
Figure 11: Travel distance distribution _____ *30*
Figure 12: Commute mode distribution _____ *31*
Figure 13: Morning Trip Generation Rate _____ *36*
Figure 14: Evening Trip Generation _____ *36*

LIST OF MAPS

Map 1: Location Map _____ *16*
Map 2: Built up Area Map (2017) _____ *17*
Map 3: Study Area Zonation Map _____ *19*
Map 4: Morning PCU generation at each Zone due to employees Source: Compiled by Author _____ *38*
Map 5: Evening PCU generation at each Zone due to employees _____ *39*
Map 6 LOS variation of Before and after flexi working hour Implementation at 7 am to 8 am _____ *41*
Map 7 LOS variation of before and after flexi working hour Implementation at 8 am to 9 am _____ *43*
Map 8 LOS variation of before and after flexi working hour Implementation at 9 am to 10 am _____ ***Error! Bookmark not defined.***

LIST OF TABLES

Table 1: Road Description 4
Table 2: Success Case Studies 12
Node Description Table 3: 18
Table 4: Data Collection Summary 20
Table 5: PCU values per vehicle type 22
Table 6: Road Class Description 22
Table 7: Hourly Vehicle Flow 24
Table 8: Floor Area Allocation Per Employee 26
Table 9: Level of Service Calculation of links J-F, H-F & E-A 33
Table 10: Level of Service Calculation of Links G-B, D-I & J-G 33
Table 11: Level of Service Calculation of Links A-B, C-B & K-A 34
Table 12: Averaged Level of Service 35
Table 13: T-test Analysis Results 40
Table 14 T test analysis 8 am to 9 am 42
Table 15 T test analysis for 9 am to 10 am 44

LIST OF ANNEXURES

Annexures 1: Questionnaire Survey 50
Annexures 2: Departure time from Home 55
Annexures 3: Departure Time From Offices 55
Annexures 4: Hourly Vehicle flow within the links 56
Annexures 5: Number of Employees in the Morning 56
Annexures 6: Number of Employees in the Evening 57
Annexures 7:Common Trip Generation Rates 58
Annexures 8: Sample Size Selection 59
Annexures 9: Trip Generation and Employment simulation by Land utilization 60
Annexures 10: Trip Generation and Employment simulation by Land utilization 60
Annexures 10: MCC Count Total Trips by Trip Distribution with Peak time (15 Min Proximity) 61
Annexures 11: MCC Count Total Trips by Trip Distribution with Peak time (1 hour Proximity) 62
Annexures 12: Sample Data Forecasting for Normal Travel trips in Study area 63
Annexures 13: Sample Data Forecasting for Flexi Travel trips in Study area 64
Annexures 14: Employment distribution by Zone vise in Study area 65
Annexures 15: Flexi hour data of Zone vise in Study area 66

LIST OF ABBREVIATIONS

TDM -	Transport Demand Management
TSM-	Transport Supply Management
LOS –	Level of Service
PCU –	Passenger Car Unit
LRT -	Light Rail Transit
ITE –	Institute of Transport Engineers
TxDOT –	Texas Department of Transportation
MCC –	Manual classified Count
FTE –	Full-Time Equivalent
MNL –	Multinomial Logit Model
IIA -	Independence of Irrelevant Alternatives
AM -	Ante Meridiem
PM -	Post Meridiem
LOS –	Level of Service

CHAPTER ONE -INTRODUCTION

1.1. Research Background

Due to rapid urbanization, most cities are in a quandary. Traffic Congestion is one of the most intolerable problems of the city due to the sudden increase in privacy. Road traffic is serious a challenge for everyone in large and emerging cities. Wasting time , increased direct and indirect travel cost, physiological stress, noise and emission pollution including greenhouse gases, accidents, loss of foreign exchange, slowness of emergency vehicles, treats to non-renewal energy stocks are some of the problems created by traffic congestion (Silva et al, 2011).Transportation affects urban society, environment and the economy (Sougata, 2017). As other countries Sri Lankan context is currently experiencing this problem. A few years back it is limited to Colombo high developed commercial area, but now it has spread over the suburban of the country. Mostly the high traffic congestion occurs in peak periods as school opening time, especially between 7.30a.m- 8.30a.m, office start time within 8.00a.m -9.00a.m. Same traffic is seen in the afternoon and evening 1.30p.m-2.30p.m and 5.00p.m- 8.00p.m for the same reasons. (Edirisinghe, 2014)

Several methods have been introduced to relieve the traffic over the decades including; supply oriented approaches, social approaches, pricing, and regulatory mechanisms, restricting access, land use planning, and traffic engineering approaches. (Mannering, 1989; Rosenbloom, 1978). Although the number of initiatives has been carried out by the governments, long-term solutions are yet being achieved irradiating the adverse results of it. Many transport supply management techniques are implemented and discussed to reduce the existing and forecast traffic congestions but those are long term and vast projects to implement. In another way, some solutions can be done through the Transport Demand Management (TDM) tools and giving a better transportation system within a short period of time using affects the travel behavior. TDM policies help to reduce the travel demand or to distribute demand in space or in time.

A flexible working shift method is a one of the popular TDM principles that can reduce travel times during AM and PM peak periods and solve the traffic congestion problem. (Zong , Juan , & Jia , 2013) The concepts of flexible and staggered working hours are the techniques, which falls under the social approach category. (Mannering, 1989;

Rosenbloom, 1978). FWH are being proposed to mitigate the congestion through adjusting workers' starting and departure times to have different work schedules which can flatten peak congestion hence lowering individuals' commuting time at one time periods. Flexible working hours have the potential to mitigate congestion and to alleviate the excessive demands made on the transport infrastructure (Este, 1985).

Since Sri Jayewardenepura Kotte denoted as the administrative capital in Sri Lanka from 1982 to now from 02 decades from time period the considerable volume of administrative functions , supportive activities are established and area is becoming densified. According to above demand of the area has been increased typically as well as consequently creates a high percentage of commuter trips. Increases of Employee and employer attractions, as well as supportive services activities, commercial functions and other facilitative activities are grown parallel. Subsequently, Suddenly the surrounding area road network became more congested in peak hours due to these activities. However road infrastructure facility does not provide and implement to cater these requirements and it creates traffic congestion in the area.

In such a context important to know and implement the traffic problem to smoothen the travel way in home to work and work to home. Among the TDM strategies, a flexible working shift is a one of the most popular methods which applied in several cities in the world to reduce the peak hour congestion with different approaches. Sri Lanka not yet introduces and implemented such kind of strategies and there has less attention to research related to this aspect. Therefore, this study aims to identify whether employee attraction within the study area is caused to generate peak hour traffic congestion and relation of peak hour road congestion and employee attraction. This study will attempt to formulate appropriate plans and policies for urban transportation activities for approachable development.

1.2. Research need

Analyzing the development trend volume in study area from last two decades significant incensement of building density volume can be identified. Evaluation of the study area development conversion pattern is shown in figure 1. As far as conversion rates are considered, from the non-built to semi-urban conversion rate is 23.14% and from the semi urban into urban conversion rate is 41.42%. In past 10 years period , 13.54 Ha of lands have been converted from the non-built into semi-urban status and 5.82 Ha of lands have been converted from the semi-urban to urban status. Building density has being increased up to 11% than 1999 year. The government of Sri Lanka has chosen the Battaramulla and surrounding city area to locate most of main administrative functions for assist the general public activities , but a huge doubt exists whether the remaining transportation infrastructure has been adequate for proposed and existing developments. There for a more stressful traffic congestion could be observed specially in morning and evening peak hours around this section mostly along Kaduwela-Kandy main road, Parliament road and Borella- Kottawa road. As per the time series analysis from the Google Earth, within last 10years' time period significant number of mega developments has been implemented in the study area. Few of them Sethsiripaya Stage II building , Suhuruopaaya building with passport office and Department of Registration of Persons, Department of Census and Statistics, Auditor General's Department building , Arpico shopping complex, Bank of Ceylon, Sampath bank, Commercial Leasing & Finance, Asmara International Ltd etc. are generated more employee and commuter attractions. Moreover, many retail Outlets have been emerged within 10 years of period as supportive services of above. From all these projects, approximately 15,657 more trips have been generated.

According to the Evolution of the building volume in year 1999 and 2008 shows the figure 1 and potential for travel demand through built environment is increased proportionately. Distribution of vehicle demand over time was shown in figure 2.

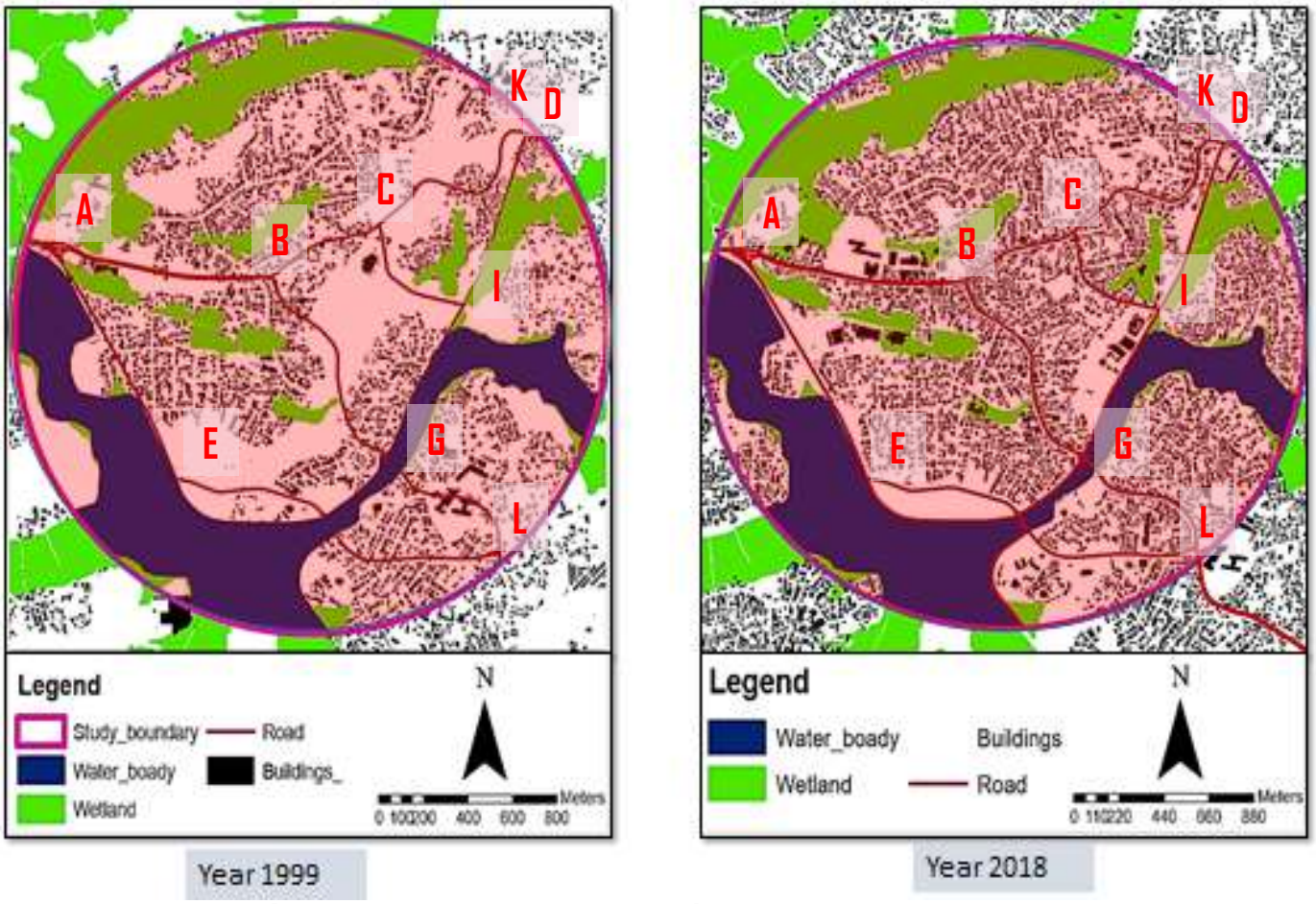


Figure 1: Land use comparison in Year 1999 and 2018

Source: Compiled by Author

Table 1:Study Area Road Description

Link	Description
J-F	Pelawatta junction to Apegama junction
H-F	Kibulawala junction to Apegama junction
E-A	Parliament junction to parliament ground
G-B	Palamthuna Junction to Battaramulla junction
D-I	Koswatta junction to Palamthuna junction
A-B	Parliament junction to Battaramulla junction
C-B	Ganahena junction to Battaramulla junction
K-A	Udahamulla Junction to Parliament junction

Source: Compiled by Author

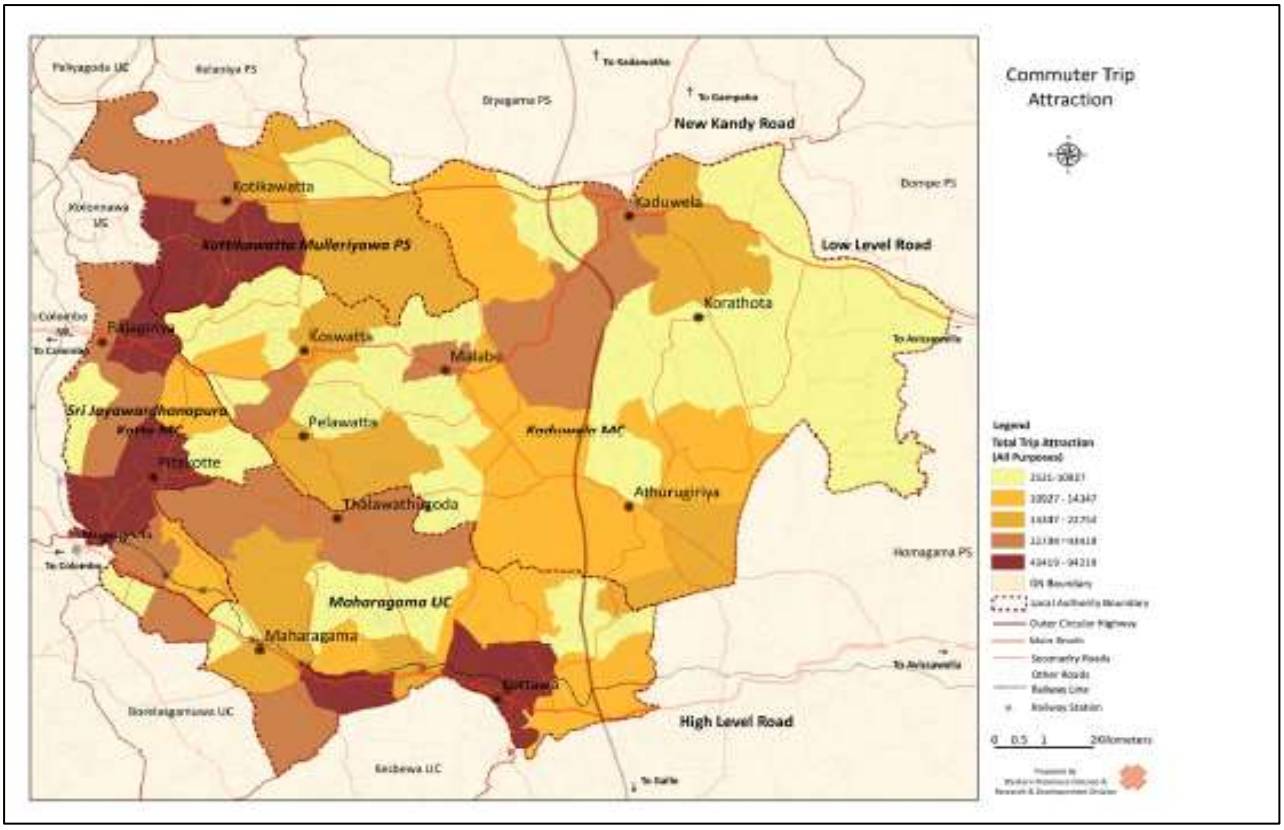


Figure 2: Distribution of the vehicle volume with Time
Source: Western Province Division and Research & Development Division, UDA. 2018

Capital city development plan in (2010-2030) made by Urban Development Authority, Sri Lanka above figure 02 map indicates comparatively high commute trip attractions generates in and around the study area. So above map implies and have been identified that, in morning peak hour and evening peak hour occur significant level of traffic.

From the huge body of literature, have the positive results of several studies about an applicability of flexible shift method to relieve the congestion. If there are a number of international researches related on implementation of flexible work schedules but, Sri Lanka has less attention about particular strategy and has limited research related to that area. In order to develop an effective flexible work shifts plan, it is necessary to examine the effect of the project on travel behavior, Therefore, this study focuses on identification of flexibility work schedules effects on departure time choice and travel duration (travel behavior) through a case study area.

1.3. Research objective

To investigate the impact of trip attraction and trip generation on the peak hour traffic due to study area employment.

- To identify the importance of Flexible work hours on traffic congestion at peak hours
- To identify the effects on road network by Flexible work shift implementation

1.4. Method of Study

Based on aforementioned objectives following methodology (figure 03) was followed during the research. Firstly, thorough literature review was done in order to identify the applications of Flexible work hour system, its implementation in other cities and its impacts on traffic. Then evaluate the selected study area and its functions, recent conditions etc. Further relationship among employee attraction and type of built environment was studied through the literatures. Based on the various building use total employment generation through the area and effect on road demand was examined. The social survey was carried out under 10 classified sub zones in order to find the required data to investigate the impact of FWH on travel duration and road demand. According to social survey findings number of trip attraction and trip generations based on each sub zones, type of employment, employee transportation mode, waiting times on junctions, etc. are reviewed. With available secondary data existing demand in each road segment was calculated. Finally impact on traffic in each road segment before and after implementing the FWH schedule was calculated and find whether this can be considered as good method to reduce peak hour traffic congestion in selected road segments.

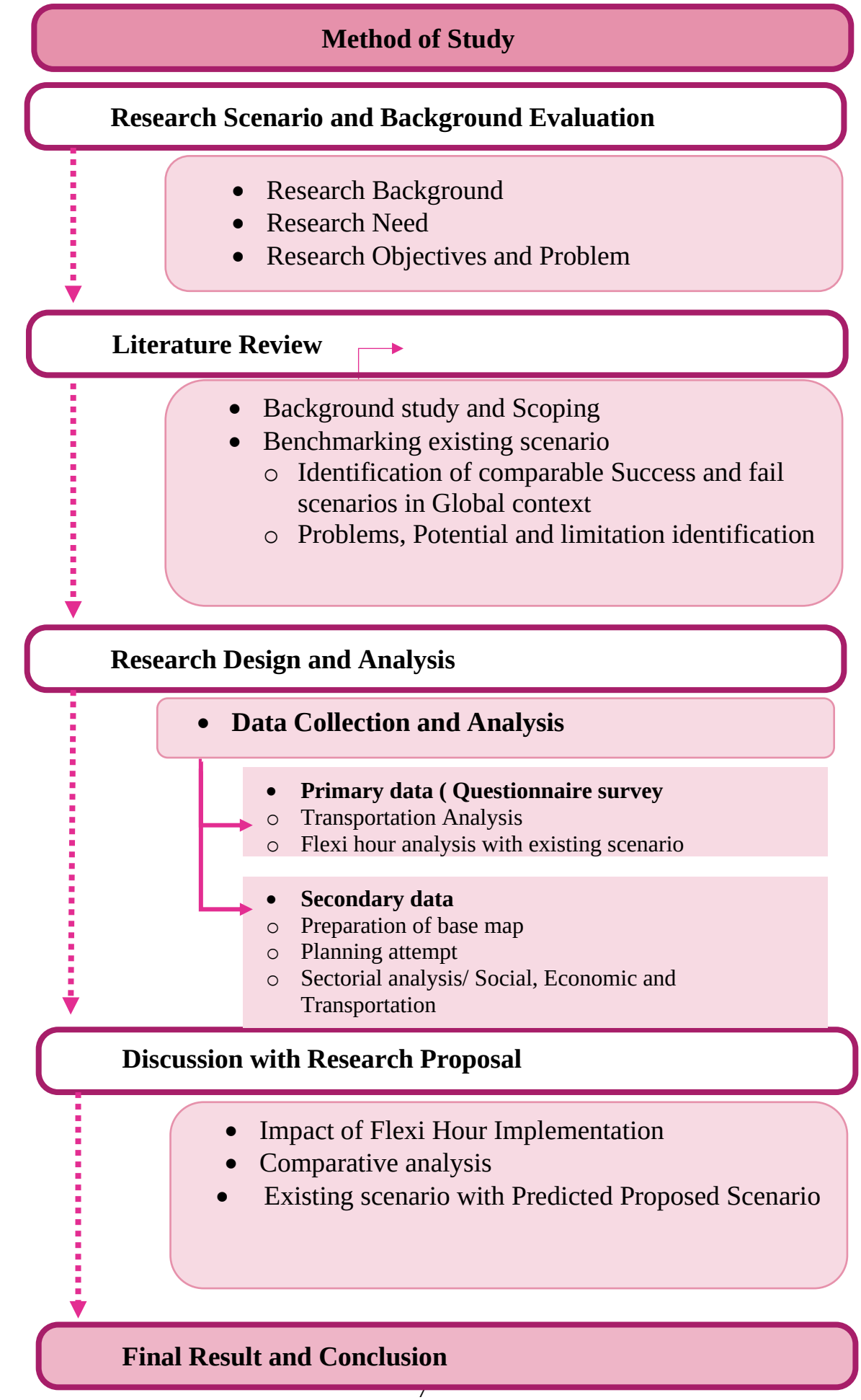


Figure 3: Research Design *Source: Compiled by Author*

1.5. Significance of the Study

Flexible work shift is not unfamiliar to the world. But in Sri Lankan context no any effort was taken in order to implement such a program to investigate the effect of FWH on road traffic and travel behaviors. Therefore, this study is an attempt to explore the situation of Sri Lankan context in this regard. The Selected study area is rapidly congested by peak periods due to converting the uses mainly in government and commercial base functions. Already the rapid physical developments have been occurred from 20 years of period while un-expectedly different congestion problems have been aroused with high trip attractions to and through the area. TSM techniques are proposed to overcome these traffic issue proposing new LRT lines, road improvement projects, extentions and electrifications of railway lines etc. But implementation of those TSM mechanisms are costly and protracted. Therefore one of the TDM technique is used to investigates the efficiency of traffic management in the study area.

1.6. Scope and Limitations of the study

This study area is only limited from the selected boundary in Sri Jayewardenepura Kotte area shown in below map no 01. This area becoming congested while high concentrated government related activitities as well as commuter supportive activities and services, some institutions and retail activities etc. High percentage of daily commuter attraction can be seen at this area due to above utilities. According to the existing traffic count data and sample social survey data carried out by author used to simplify the analysis. This study mainly focused the effect of the trip attraction and generation in morning and evening hours based on the land-use and building use data due to the unavailability of trip generation and attraction data and limited time period. Proposed LRT system and other proposed traffic mitigation methods are not considered in this study due to time limitations and available land use data in 2018and Manual classified Count data in year 2018 were also considered to the analysis.

CHAPTER TWO - LITERATURE REVIEW

2.1. Introduction

The literature review chapter mainly consists of concepts, statistical methods and theoretical backgrounds related to the research and it directs to path of strong theoretical background for the research. More than that about case studies in success and failures of FWH implementation and deterministic variable effect on travel behavior, trip generation and trip attractions, impact on road demand by FWH are the main theme discussed in this section.

2.2. Flexible working hours/ staggered shifts

Flexible work hours mean that adjusting the job start and end time with different work schedules which can flatten peak hour traffic congestion hence lowering individuals' commuting time and given some flexibility to the work schedules. Peak or rush time often lasts more than one-hour period and the rush refers to volume of traffic, not the speed or its flow. Normally it may occurs in morning 6am to 10am and evening 4pm to 8pm.But Peak traffic periods may vary from city, region or as well as the seasonally. (Wikipedia, 2020,) In applicability of flexible work schedules workers allows doing their normal office hours in each day but having flexibility to choose office arrival and departure time for their preference. But all employees need to work with some specific core time duration in the office. For example, some can change their work time from 8:00 to 4:30, others from 8:30 to 5:00, and others from 9:00 to 5:30. Working hours are a method of making better use of existing transportation facilities. Plan of restructuring, with minimal financial investment Working time can reduce commuter travel time and improve congestion Limited employment concentrations. As a result, energy consumption, air quality, and employee productivity can be improved. (Zong , Juan , & Jia , 2013)

2.3. Case studies

2.3.1. Applicability of flexible working/staggered hour system in other countries

Recently Flexible work schedule policy becomes the popular TDM strategy for managing traffic congestion in the world through reducing the number of commuter trips in peak periods. Among the practical situation in wide literature reviews most of the flexi hour programs were achieved successful results but some were failed due to many reasons. This chapter discusses the implementation cases of flexible work hour schedule programs to reduce peak hour traffic congestion and their outcomes.

2.3.2. Success Programs

Downtown Honolulu city in the United States

When discuss the successful programs related in, Downtown Honolulu which was 14th rank congested urban city in US, (EPA, 1998) conducted the flexi hour work program during 4 weeks period of time to reduce the early peak congestion in 1988 year. The study was focused to measure the effects on traffic flow, employee commuter experiences, employee attitudes, work performance, and productivity after enforcing the staggered working system. They incorporate the 18% from total workforce in Downtown and, results show the reduction of peak period travel time up to 9%-10% of total trip duration and average 4min commute time saving. Further study indicates employees more prefer to come work to earlier rather than later work schedules. But Giuliano et.al. (1988) concluded that nonparticipants for the pilot project are earned more benefits than participants in social aspects without inconvenience of having to change their work pattern. Finally, the above study concludes that flexible work hours can affect to alleviate traffic congestion but their impacts on employees are not uniform.

Denver, States of Colorado

A key takeaway of the successfully established Summary Work Week was held at a federal agency in Denver, where participants arrived an hour early and left an hour earlier than usual. The congestion was reduced in four working days, in addition to the vehicle miles excused for not working on the fifth day. The maximum percentage of total arrivals was reduced from 56 to 42 percent in one and a half hours, and the maximum half-hour of total departures was reduced from 47 to 34 percent. In terms of air quality, it is estimated that average carbon monoxide and hydrocarbon emissions for

employees have been reduced by 16.4 percent. The carefully controlled experiment involved 9,000 federal employees from 42 agencies.

San Francisco

Flexibility policy took place in San Francisco, where at least half of the participants were employed 30 minutes before the policy began. By traveling before the main peak period, car passengers reduced their commute by nine minutes on each route. For more than a week, these employees were left with one and a half hours of travel time (EPA, 1998)

China

According to the reported data in China, Beijing 6, 00,000 car populations was increased in every year since 2006. According to the predictions they rely total number of car population will exceed 10 million in end of year 2020.As a solution in vehicle congestion they attend about TDM strategies to control traffic. In 2008 they implemented flexible working hour system which is the one of TDM strategy during the Olympic Competitions and positive resulted. Further they used these techniques to resolve urban traffic in several other cities in china such as Changchun, Wenzhou, etc. and resulted to improve traffic conditions and environment quality.

The cases in Table 2 illustrate that most of the staggered shifts programs have achieved good effects. Some commuters opposed to the program because of occupational characteristics, living habits, or other reasons;

Implimentation time	City	Industry Type	Shifted job start time	Effects
2002-2003	Wenzhou	Goverment	7.30-9.00am	Increased travel speed by km/ on average
2002-2005	Hangzhou	Government,educational,institutional,Service industries	8.00,8.30,or 9.00am	Reduced peak period traffic volumes,did not solve the traffic jam problem completely
2003-2004	Suzhuou	Government,Service industries	9.00am	Reduced peak period traffic demand

2003-2009	Wuxi	Government,Service industries	9.00am	Reduce peak period volume by 12% from exsists level
2003-2012	Hebei	Goverment	8.30am	Relieaved traffic congestion by some degree
2003-2012	Shenzen	Goverment	9.00am	Transffered traffic volumes from AM peak to off peak period by 7-10%and volumes from PM peak to off peak by 3-7% from exsits level
2004-2011	Jinan	Goverment	9.00am	Reduce traffic volumes by more than 30% from exisits level

Table 2: Success Case Studies
Source: Compiled by Author

2.3.3. Failure programs

Hangzhou, China

The FWH shift changes cases have failed in many cities in different countries. Among them one of the Chinese cities is Hangzhou. It has been implemented to reduce traffic congestion. Their plan includes the government, education and service industries. Considering the maximum number of hours in the morning, they chanced started time. According to that they started work 8.00, 8.30 or 9.00. But the plan was not successful. The problem of traffic congestion has not been fully addressed.

They find complicated reasons why programs fail after program. According to the case studies, they have found complex reasons why programs fail. Some travelers may oppose the project because of professional qualities, customs or other reasons; Some projects are creating a new journey peak. Some researchers believe that there are winners and losers in the striking changes: those who leave early for work saves more travel time, while commuters who work late than usual lose time (Cao & Mokhtarian, 2005)

Considering 2013's aforementioned failed plans (Song, Juan, & Xia) to implement FWH changes, should a traveler adjust his travel time according to the new work schedule? For example, if a traveler sends children to kindergarten, he or she must start at 8:00 am while his / her working hours are changed to 9:00 am. Second, what is the policy industry? Finally, what is the best work schedule? Will the new travel time of

some businesses align with others? All of the above questions directly affect the outcome of FWH shift changes. (Zhang, Juan, & Jia, 2013)

2.4. Analysis the impacts of land use pattern to trip generations

The number of trips generated by an existing or proposed development is often of interest to transportation engineers and planners. Land use changes have great impacts on trip generation. There are number of studies have done to described the relationship between effect of land use and trip generation. Consequently, correlation between trip generations and land use variables were recognized. The major studies related this is done by The Institute of Transportation Engineers (ITE) produced its Trip generation handbook in part to aid analysts in estimating trip generation for several developments. (Bochner & Sperry, 2007) .This paper discuss the more accurate method to estimates of motor vehicular trip generations in smart growth areas. Two linear regression equations were developed one for AM peak hour and other for PM peak hours for 50 smart growth sites in Califonia. ITE's trip-generation rates typically relate vehicle trip counts to a measure of building size (e.g., gross square footage, number of units) for a particular land-use classification. Most of the rates are based on vehicle counts obtained at suburban locations that may or may not have transit or bicycle and pedestrian facilities, and ITE guidelines state that these rates should not be used for land-use projects located in urban areas near transit and within easy walking distance of other land uses (ITE 2004).

To identifying the Traffic impact of mixed development project in state of Texas was done by department of transportation (TxDOT) and they had developed the spread sheet estimator tool. Directional (vehicle in and out) trip generation for each land use, mode split, vehicle occupancy and internal distance between the land uses are considered as the inputs in above tool.

The study regarding understanding the vehicle trip generation rate for office building was carried out by Seoul, Korea and found the factors related.

The study done in Thessaloniki Metropolitan area found that the relationships between number of employees and building floor area. They found trips concerning Banks, two independent variables were examined: the floor space and the number of employees. Considering cultural activities, no relation was found for conference centers as it was expected. (Latino~ou, ,~ soh, & ~asb, 2001)

National Cooperative Highway Research Program (NCHRP) conducted the project to identify how many internal trips are generated within the mixed use developments. This study includes the six specific land use categories such as retail shops, residential units, offices, restaurants, cinema, and hotels. The ITE method covers trips between only the three most frequent components of MXDs—office, retail, and residential. Data are available for the weekday P.M. peak hour; midday; and what is called "daily," but which is drawn from data collected between noon and 6:30 P.M. The ITE method has nothing for the A.M. peak hour. The policy percentages mentioned above are applied to each analysis period used. (Bochner, Hooper, Sperry, & Dunphy, 2011)

2.5. Analysis of the Commuter Travel behavior and Flexible work shifts

A commuter is a person whose primary activity is outside the city in which he resides and travels regularly every day. (Handayeni & Ariyani , 2018) Commuter Travel behavior is the study of what people does over space, and how people use transport. There are different categories of Commuter travel behavior and some of the factors are travel route, mode use, intermediate stops, departure time, travel duration. (Zong , Juan , & Jia , 2013) Various methods have used to analyze staggered shifts and commuter travel behaviors. Mainly statistical analysis of survey data and well as use the mathematical models are Using travel behavior analysis.

For an instant, (Picado, 2000) and (Beers, 2000) were used the statistical analysis methods and develop the mathematical model and predict the strategies-for instant. (Cao & Mokhtarian, 2005) Used the binary logit model. Develop a simulation-based framework to model and evaluate the effects – for instant (Guo & Srinivasan, 2005) used this method. Some researchers examined the effect of staggered shifts by means of statistical analysis of survey data. For instance, (Picado, A question of timing, 2000) found that staggered shifts can reduce peak-period trips, particularly around large employment centers. (Freas & Anderson, 1991) Found that staggered shifts can make ridesharing and public transit use more feasible. (Beers, Flexible schedules and shift work: replacing the '9-to-5' workday?, , 2000) Noted that the proportion of workers on a staggered work schedule had grown more than double since 1985 when such data were first collected. (Galinsky, Bond, & Swanberg, 1998) Reported that there is an excess demand for more staggered hours and schedules, over and above what employers have been able to supply (Zong, Juan, & Liu, 2007)

CHAPTER THREE: RESEARCH DESIGN

3.1. Introduction

This chapter explains the process to be followed under the research problem and the way to achieve the objectives. The first part consisted of the study area selection, area zonation for study purpose, identification of the sampling techniques for data collection and database preparation and collection of secondary data. Existing road network pattern, available land use data and build up area data, number of trip generation and attractions in segregated nodes and links were considered. PCU and LOS in selected road network and the relationship between typical traffic and generated trip volume due to case study area employment was analyzed. The latter part of this chapter outlines the methods and the steps were followed in the data analysis.

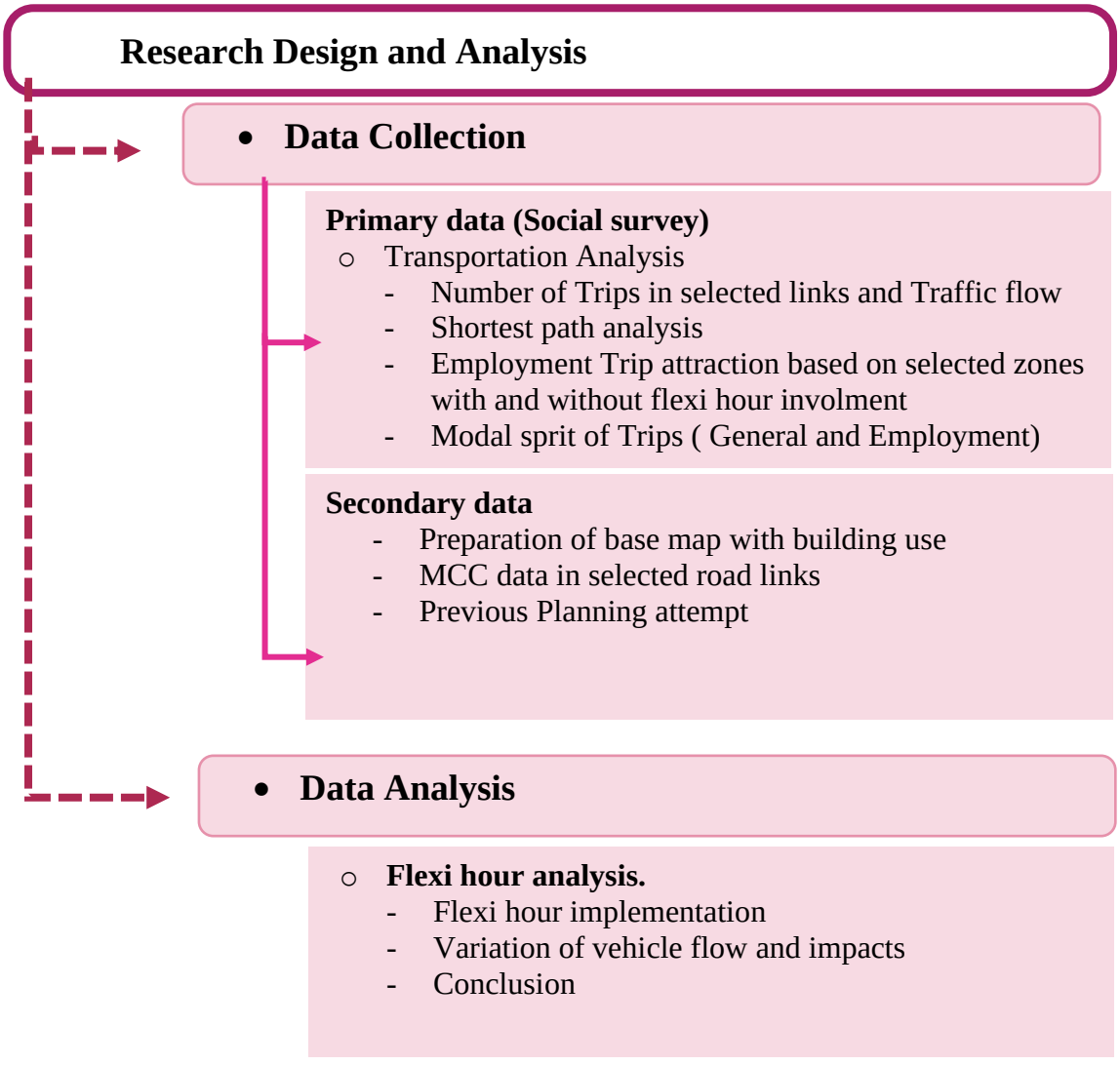
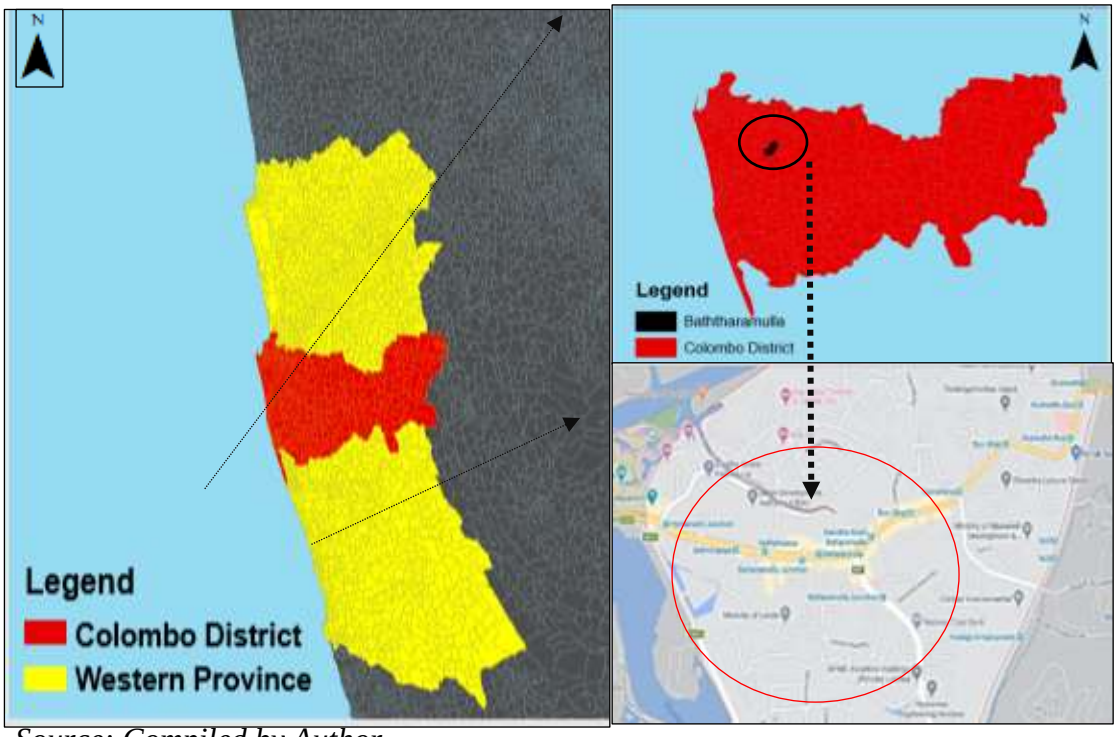


Figure 4: Research Methodology
Source: Compiled by Author

3.2. Case study Area selection

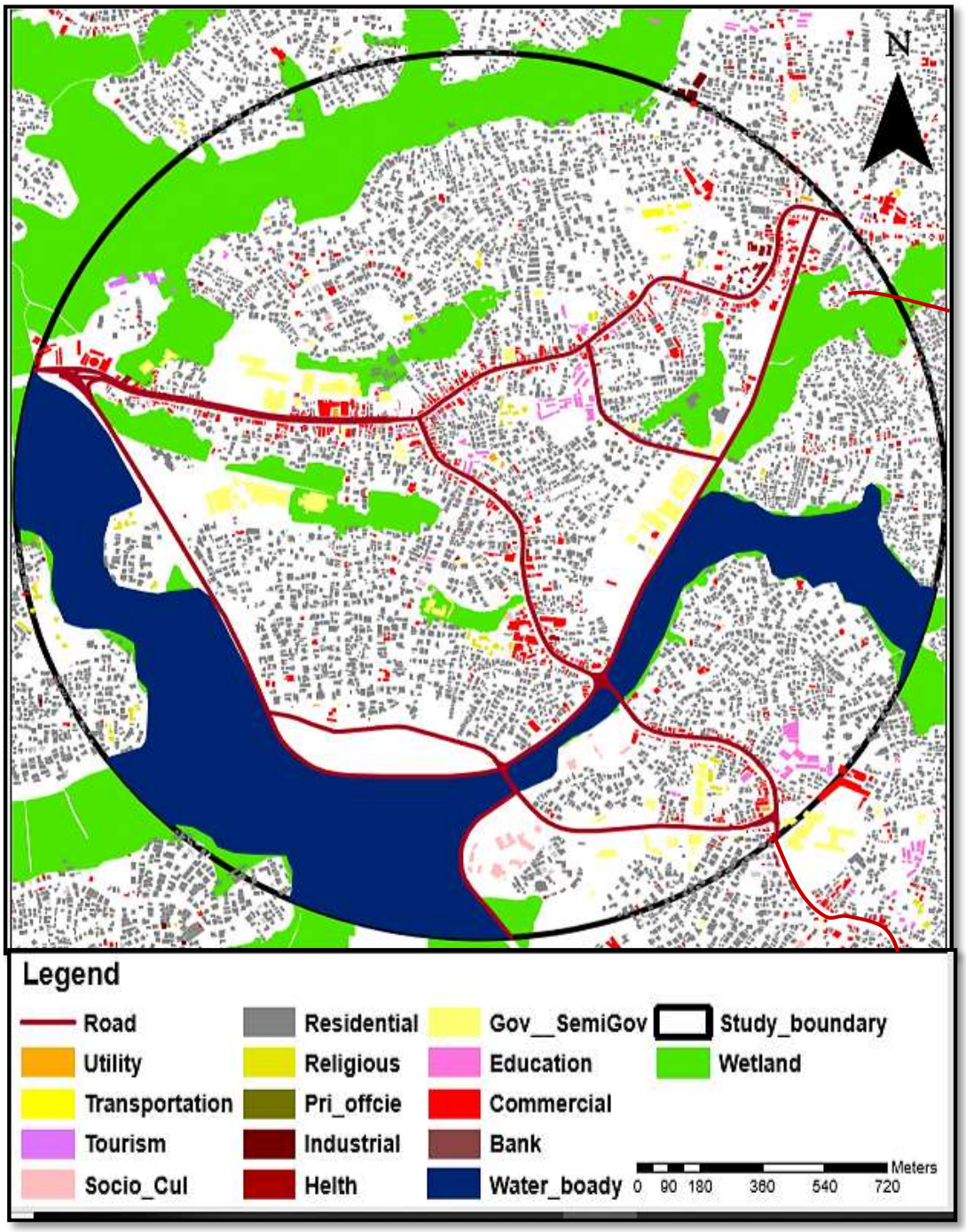
The urban area in Sri Jawardenapura Kotte the administrate capital of Sri Lanka has an extent of approx. 50,000 Acres bounded from Parliament junction, Koswatta junction, Pelawatta junction, Palamtuna junction and Parliament ground junction was selected as the case study area. The location of the study area is shown in Map 01. Analyzing the existing building distribution pattern of the study area more than 70 multi storied buildings relate with government functions, 80 Private office building, nearly 1200 commercial and retail activity places and more than 5000 residential units are identified using GIS land use survey data in 2018. Daily More than 50,000 employees concentrated and generated more than 15,000 Trips in this area due to occupational activities. Further consider the trip generations due to surrounding areas and through traffic via study area it shows more than 150,000 daily trips. Therefore, the high vehicle volume especially during peak hours has been seen through several routes which connect the employee origin places and particular study area. According to the surveys done by Transportation Engineering Division, University of Moratuwa (2018) the traffic flow towards Battaramulla surrounding area during 6.00 am and 1.00 pm is counted as approximately 72,000(unit) and the same amount of traffic flow outwards in the evening peak. The roads within the study area that exceed **1200** hourly flow of vehicles during peak hours.

Map 1: Location Map



Source: Compiled by Author

Below map no 02 shows the selected boundary of the study .



Map 2: Built up Area Map (2017)
Source: Compiled by Author

Main considerable Land use changes in this study is shown in map 02. Out of total study area it implies 40% from in residential uses 13.%, from commercial usage and in government and semi government institutional is 6% from total land use. Furthermore, selected nodes and links dispersal structure in the case study area shows in figure 05 and table 6.

Figure 5: Road Links and Nodes *Source: Compiled by Author*

Node	Name	Junction traffic control method
A	Parliament Junction	Uncontrolled (Police control during peak hours)
B	Battaramulla Junction	Traffic signal control
C	Ganahena Junction	Uncontrolled
D	Koswatta Junction	Uncontrolled
E	Near Parliament Junction	Uncontrolled
F	Near Ape Gama Junction	Uncontrolled
G	Palamthuna Junction	Traffic signal control
H	To Kimbulawala Junction	Uncontrolled
I	Denzil Kobbekaduwa Junction	Uncontrolled
J	Pelawatta Junction	Traffic signal control
K	Udumulla Junction	Uncontrolled
L	To Thalawathugoda Junction	Traffic signal control

Node Description Table 3:
Source: Compiled by Author

3.3.2. Study Area Zonation

The demarcated study area was separated into ten sub-zones to make analysis process convenience. The sub-zones were separated based on the Junctions (nodes) in the study area and Thiessen Polygon tool in ArcMap 10.3 software was used for the boundary demarcation of each zone.

Map 3: Study Area Zonation Map
Source: Compiled by Author

3.3. Data collection

In order to carry out the analysis primary and secondary data was collected. Primary data was collected based on a questionnaire survey. In the secondary data was collected from available land-use and building use data shape files and Traffic data count were collected by the published Traffic Impact Assessments reports and MCC from Department of transportation Engineering and Department of town and country planning in Moratuwa university.

Table 4: Data Collection Summary

	Data	**Source**
Primary	Data of Factors for the Departure time , Commute Time , origin and destinations, Travel Duration, Transport mode, and Traffic junctions ,etc	Questionnaire Survey (Social survey)
Secondary	Raw data of vehicle volume, and Traffic Data	Published Traffic impact Assessments and traffic surveys done by transport Engineering dept, University of Moratuwa
	Land-use and Building use Data	UDA
	Google time series data	Internet

Source: Compiled by Author

3.3.1. Questionnaire Survey

This study collects primary data from social survey covering all type of employments in the study area while interviewing the employees. The survey data includes information of Type of employment, work time duration, departure times from home and office, origin and destinations, travel distance, high traffic junction via daily trips, waiting time and places, transportation mode, number of intermediate stops within the trip, travel route, age category, etc (Annexture1). In the calculations it assumed every type of building uses except residential use and religious use in the area were employment or occupational generated places and Clustered sampling method used to conduct the sampling survey. Total study area divided in to 10 sub zones as A to K based on the classified nodes, and 500 employees were questioned. Sample was taken from representing every and each classified zones and sample size was determined

using below formula considering the total number of employments in the area according to literature surveys. (Annexure 2)

$$n = \frac{p(100-p)Z^2}{E^2}$$

n- Sample size
p- Percentage occurrence of a state or condition
E-Percentage maximum error required
Z-value corresponding to level of confidence required (Taherdoost, 2017)

3.4. Data analysis methods

3.4.1. Impact of Flexible work shift arrangements on traffic

The impact of trip generation by flexible work hours was examined using the vehicle volume per 15 min interval periods, road conditions and the PCU based on the number of trip attractions and using LOS calculations.

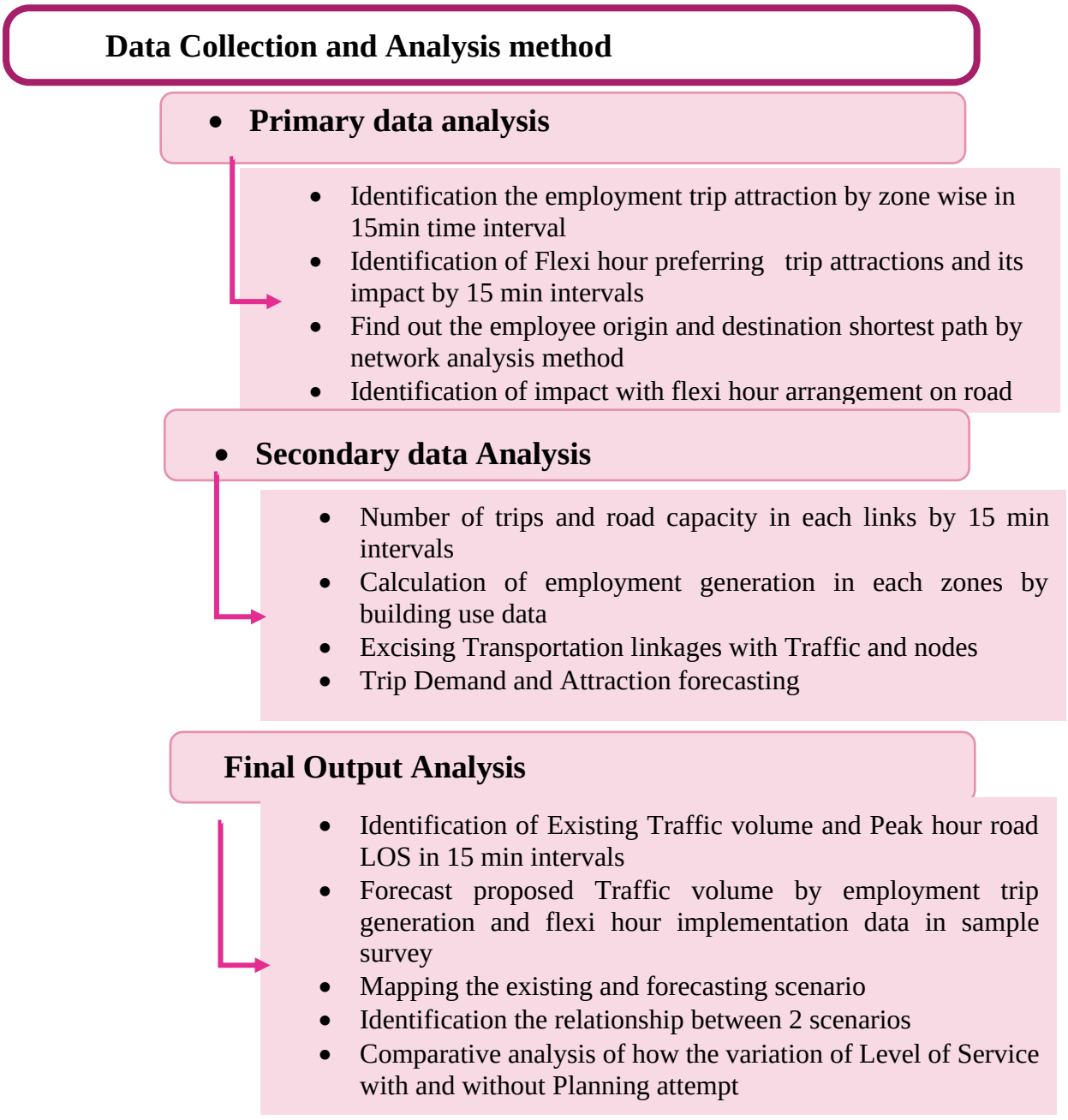


Figure 6: Methodology of Flexible work hour shift arrangement on traffic analysis
Source: Compiled by Author

3.4.1.1. Traffic Analysis

Following standards were used to calculate the LOS in each road links in Sri Lanka context. Available MCC surveys were carried out on road links, the number of PCUs on each road link is calculated by using following PCU values for different vehicle types.

Table 5: PCU values per vehicle type

Vehicle type	Motorcycle	3wheeler	car	Utility(van/jeep/pickup)	Freight vehicles	Buses
PCU	0.5	0.75	1	1.25	4	4

Source: High Way capacity manual,2000

In practical applications total count surveys were done on road links, the number of PCUs of a road link is calculated based on the following equation.

$$PCUs = 0.8 * No\ of\ vehicles$$

$$(Based\ on\ the\ past\ transport\ surveys\ carried\ out\ in\ srilanka)$$

The following equation is used to find the level of service in each hour for road links. (Road capacity: 1200PCUs (Passenger car units) per lane per hour)

$$\textbf{Level of service} = \frac{\textbf{Total PCUs of the road in particular hour}}{\textbf{Road capacity(PCUs)}} *_{\textbf{No of lanes}}$$

MCC: Manual classified count

Categories of Level of services at road links are as follows.

Table 6: Road Class Description

Road Class	Quality	Value
A	Free-Flow	<0.45
B	Reasonable Free flow	0.46<&<0.60
C	Near free flow	0.61<&<0.76
D	Medium flow	0.77<&<1.00
E	At Capacity flow	1.01<&<1.19
F	Congested flow	>1.2

Source: Highway Capacity Manual,2000

According to MCC survey data of Transportation Engineering Division, University of Moratuwa (2018) Hourly traffic flows to and from study area depicted in below flow charts. As per the 6.00 am to 1.00 pm number of total vehicles towards the study area considered to morning vehicle flow and 1.00pm to 7.00pm number of vehicles outward to study area considered as evening flow.

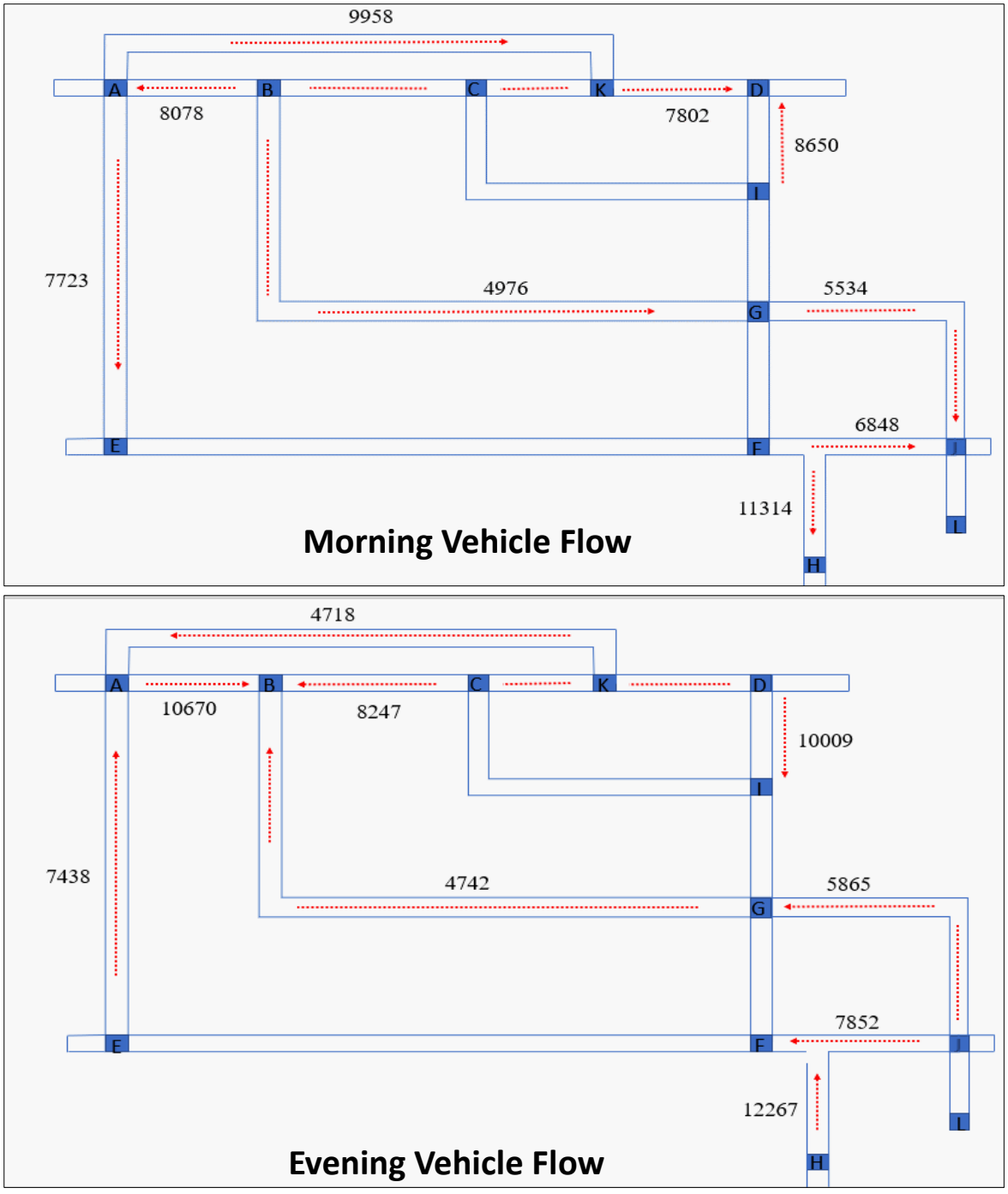


Figure 7: Morning and Evening Vehicle flow in the study Area
Source: Transportation Engineering Division, University of Moratuwa (2018)

Direction/ Hour	(6-7) am	(7-8) am	(8-9) am	(9-10) am	(10-11) am	(11-12) am	(12-1) pm	(1-2) pm	(2-3) pm	(3-4) pm	(4-5) pm	(5-6) pm	Total trips
A-B	611	1251	1906	1676	1570	1709	1741	1300	1254	1121	1274	1428	16841
B-A	884	1624	2260	1834	1542	1132	1186	1440	1395	1430	1684	1028	17439
B-C	464	1186	1113	1157	1023	1104	1009	1332	1154	1271	1426	1539	13778
C-B	598	1286	1379	1300	1117	1136	1168	974	864	1071	1408	1203	13504
C-K	586	578	1113	1270	1001	1022	1101	1332	1154	1183	1426	1539	13305
K-C	524	1284	1339	1300	1117	1136	1168	1103	986	1080	1204	1184	13425
A-K	23	329	384	244	76	47	63	321	243	561	569	338	3198
K-A	43	805	654	590	623	459	599	221	212	255	390	287	5138
K-D	423	775	1113	1060	1129	1020	1005	1123	1094	1183	1426	1566	12917
D-K	487	1284	1318	1300	1117	1136	1168	1002	1131	969	1257	1375	13544
D-I	243	1729	1953	1529	1247	1269	1164	967	994	866	832	977	13770
I-D	112	860	965	744	1029	955	970	986	1043	1184	1610	1783	12241
C-I	54	98	109	208	104	111	99	95	109	176	121	104	1388
I-C	36	137	189	229	97	102	105	123	101	119	282	175	1695
I-G	354	1979	2179	1877	483	387	365	205	221	267	240	269	8826
G-I	142	364	519	310	264	354	368	384	296	1441	1984	2142	8568
B-G	135	509	472	513	432	498	523	678	860	760	976	987	7343
G-B	421	611	757	877	827	784	656	764	691	590	716	720	8414
G-J	213	651	832	508	335	453	512	865	697	697	967	1187	7917
J-G	412	899	1272	867	687	756	861	752	943	456	622	746	9273
F-J	241	868	614	575	312	267	231	467	798	992	1184	1370	7919
J-F	434	1468	1314	978	1022	894	864	234	365	980	918	928	10399
G-F	301	1991	2262	1967	897	845	794	849	1096	147	262	195	11606
F-G	231	979	1261	882	464	413	406	880	987	1487	2383	2574	12947
F-E	552	2458	2524	2002	1543	1132	528	513	306	257	296	246	12357
E-F	213	876	1210	1456	994	1003	974	923	1264	2128	2502	2099	15642
A-E	212	621	532	1299	1003	1210	1158	1320	1521	698	1117	1023	11714
E-A	623	1083	1219	1162	1171	1048	1201	609	769	1430	576	541	11432
Total	9572	28583	32762	29714	23226	22382	21987	21762	22548	24799	29652	29553	296540

Table 7: Hourly Vehicle Flow
Source: Transportation Engineering Division, University of Moratuwa (2018)

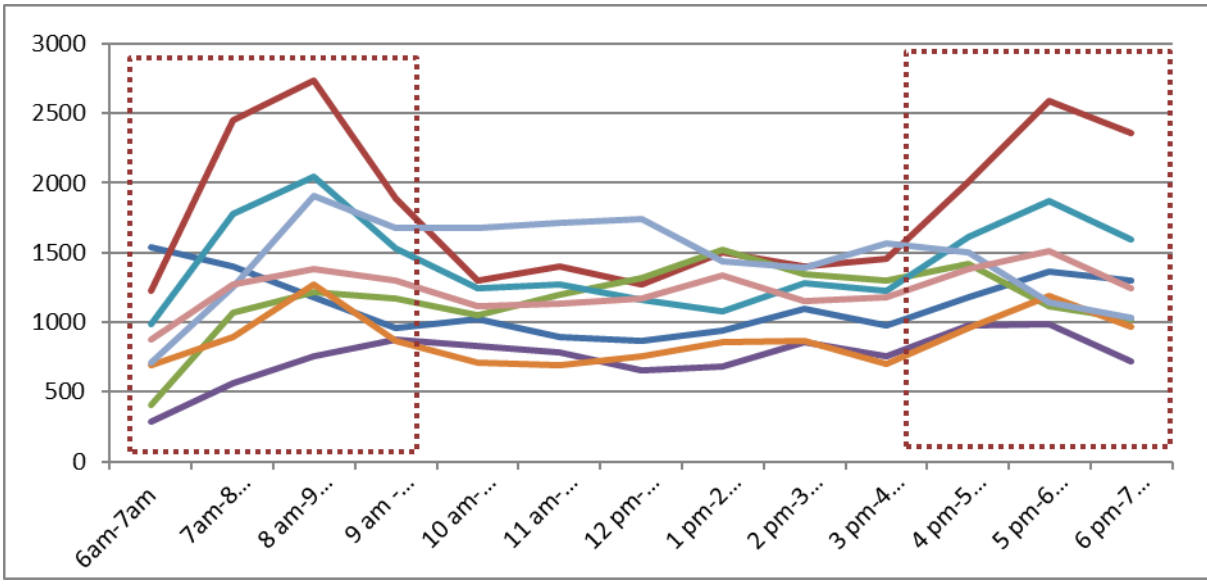


Figure 9: Hourly Vehicle Distribution
Source: Transportation Engineering Division, University of Moratuwa

Hourly traffic flow data (table 08) demonstrates the peak hour considerable traffic congestion is occurred in certain road links. (Figure 14) Level of service calculations were done through the above-mentioned equation. Employee and commuter attraction in study area as well as the through traffic to Colombo via study area also include the normal traffic volume. Effects of level of service by links for each node were calculated using the figures of level of services of links at each node. The averaged traffic impact (i.e. averaged level of service)

3.4.2. Analysis of the study area Trip generation and Trip attraction

Urban context affects number of vehicle trip generation rates across the land use and building use pattern. Trip generation rates have been the primary source for travel demand analysis. These trip generations rates may not be sufficient to guide the approval of proposed developments in urban infill areas. ((Caltrans), 2008) The trip generation can be estimate using each component land use from the Trip generation report or from similar sources. ITE's trip generation handbook for urban context examines, several studies have already been performed to compare the observed trip rates. Existing research has examined the differences between observed trip rates and the ITE predicted rates through comparison of the ITE predicted rates to observations at a particular type of urban context or development (Clifton, Currans, & Muhsc, 2015).

As per the prediction of trip generations in zones were calculated using the sample survey data. To forecast the trip generations percentage of employees' vehicle mode usage considered according to the below table 11.

To calculating the employment distribution base on the selected zone building floor area assistance to employee density guide below (table 8) with interrelation. Employment density refers to the average floor space (in m²) per Full-Time Equivalent (FTE) member of staff. It is used as a measure of intensity of building use and an indicator of how much space each person occupies within the workplace.

Then number of employees per each zone was calculated. The trip generation of each zone in peak hours were calculated based on the mode of travel used by the employees surveyed.

Table 8: Floor Area Allocation Per Employee

Use Class	Use Type	Area per FTE (m²)	Floor Area Basis	Comment on potential variation
Industrial				
B2	General	36	GIA	Range of 18 - 60 m²
B1(c)	Light Industry (Business Park)	47	NIA	
Warehouse & Distribution				
B8	General	70	GEA	Range of 25 - 115 m² The higher the capital intensity of the business, the lower the employment density
B8	Large Scale and High Bay Warehousing	80	GEA	Wide variations exist arising from scale and storage duration
Office				
B1(a)	General Office	12	NIA	Includes HQ, Admin and 'Client Facing' office types
B1(a)	Call Centres	8	NIA	
B1(a)	IT/ Data Centres	47	NIA	
B1(a)	Business Park	10	NIA	A blended rate of the above B1(a) uses where they are found in out of town business park locations
B1(a)	Serviced Office	10	NIA	Densities within separately let units are c.7 m² per workstation but 30% of a facility's total NIA for shared services reduces the overall density
Retail				
A1	High Street	19	NIA	Town/ City Centre
A1	Food Superstores	17	NIA	
A1	Other Superstores/ Retail Warehouses	90	NIA	
A2	Financial & Professional Services	16	NIA	Includes the back office function area as well as the customer facing areas
A3	Restaurants & Cafes	18	NIA	Range of 10 - 30 m²
Leisure & Visitor Attractions				
C1	Budget Hotels	1 employee per 3 bedrooms plus casual staff		
C1	General Hotels (3 star)	1 employee per 2 bedrooms		
C1	4/ 5 Star Hotels	1 employee per 1.25 bedrooms		
D1	Cultural Attractions	36	GIA	Very wide range exists, so use with caution. Excludes external areas
D2	Cinemas	90	GIA	Range of 90 - 120 m²
D2*	Amusement & Entertainment Centres	70	GIA	Range of 40 - 100 m² - excludes external areas
D2	Sports centres and Private Clubs	65	GIA	Range of 30 - 100 m²

Source: (Deloittee, 2010)

Vehicle mode / Zone	walk	Car/bicycle	Bus	Trip generated rate (%)
A	4	23	23	32.2
B	2	18	30	30
C	3	16	31	28.4
D	5	18	27	28.8
E	2	19	29	30.6
F	4	22	24	31.6
G	3	16	31	28.4
I	5	19	26	29.4
J	4	17	29	28.6
K	6	16	28	27.2

Table 9: Trip Generation Rates
Source: Compiled by Author

In study purpose assuming the private car and bicycle mode carrying the two employee in a trip and public Bus/Van carrying the 05 number of employees within the one trip. Then categorize the transportation mode by zone wise and average transportation mode is realized to study purpose as in table 09and figure 09.

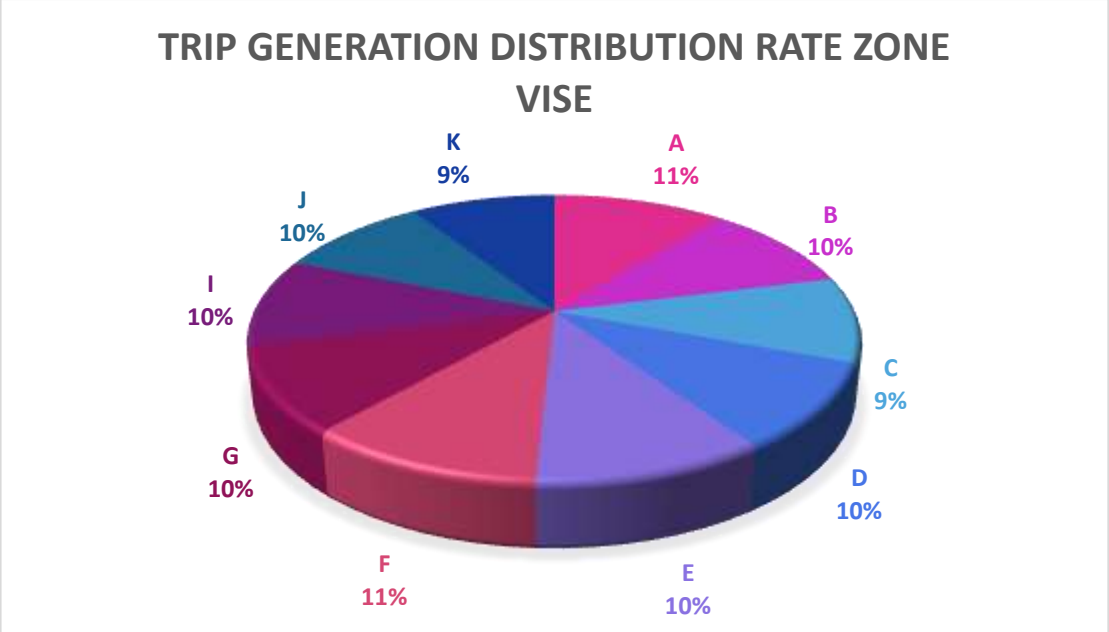


Figure 10: Distribution of trip generation rate
Source: Compiled by Author

CHAPTER FOUR: ANALYSIS AND DISCUSSION

4.1. Introduction

This chapter indicates the results of the analysis and interpretations. Firstly, the distribution of travel route, traffic waiting junctions and time, Distribution of commute departure time from home and from workstation, Commute mode distribution, employee origin and destinations places, Commute travel distance distribution, and Commuter's preference were analyzed based on the Survey Data collected. Secondly, the relationship between the LOS and the number of PCU generated by the employees work in each zone was analyzed and LOS was calculated in each links. Finally, the effect on flexible work shifts on selected links were examined and impact on roads were analyzed.

4.2. Commuter Profile Analysis

4.2.1. Distribution of commute time

Based on MCC count data in year 2018 current distributions of time away from home and work are calculated, and the results are presented in figure: 7 and figure 8. The results indicate that there are obvious morning and evening high commuter occurrence time and it is in AM peak 7:00 - 9:00. and PM peak 16:00 18:00. According to the questionnaire survey done by year 2019 below findings are observed. Further in detail, study area Government sector morning peak time is 7.00 am to 8.30 am and evening is 4.00 pm to 5.00 pm. The education sector morning peak time is 6.30 am-8.00 am and evening is from 6.00 pm to 7.00 pm. The medical institution sector morning peak time is 7.00 am to 8.00 am and evening from 4.00 pm to 5.00 pm and 7.00 pm to 8.00 pm. The commercial sector morning peak time is 6.00 am to 9.00 am and evening from 5.00 pm to 7.00 pm and also after 8.00 pm. The service sector morning peak time is 6.00 am to 7.00 am and evening is from 5.00 pm to 6.00 pm.

More than 2.75% of commuter's departure time from work place is before 16:00. More than 51.01% of travelers leaving from work place is 16:00-17.00 period. More than 10% employees are leaving from 17.00-18.00 pm and another 10% leaves 18.00-19.00 time period.Nearly 5% from from total employment are leaving 19.00-20.00pm period and d after 20.00 pm it could be identified near to 13%.

In other hand employee leaving home before 3:00 am- 4.00 am is 3.29%. The period of 4.00am -5.00 am 13.82% travelers leaving home. More than 50% of workers leaving home within 6.00-7.00 am time period and 7.00 to 8.00 am 22.37% workers are leaving home. Only 1.32% leaving home after 9.00 am. However, the period of 6.00-7.00 am can be identified as high percentage of employees leaving home to work and it is near to 55%. When analyze the departure time from workplace, the period of 16.00-17.00 pm can be identified as the highest number of workers leave their workplace and it is near to 51%.

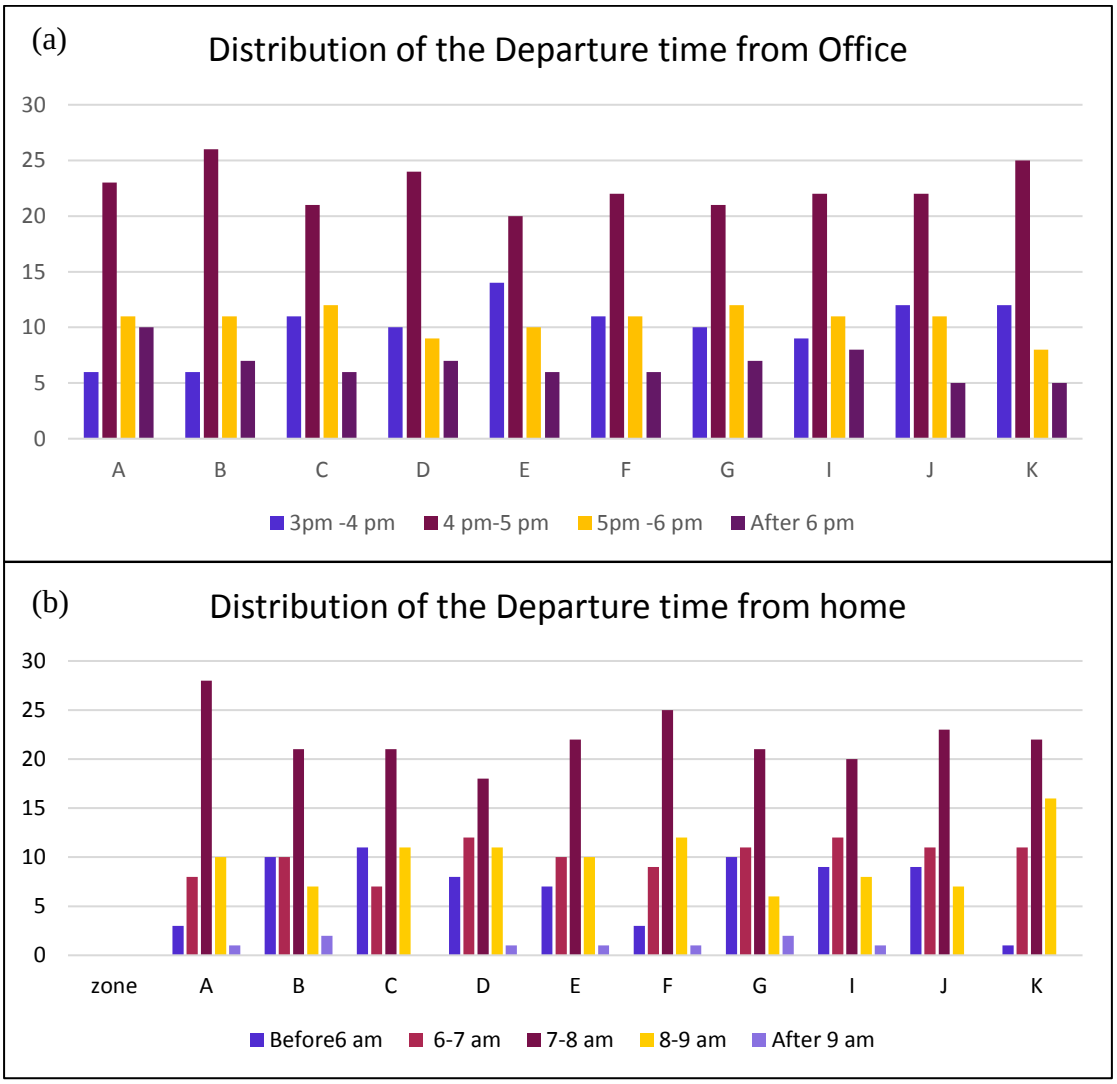


Figure 11: (a) Distribution of the departure time from home and (b) Distribution of departure time from work
Source: Compiled by Author

4.2.2. Commute travel distance distribution

The factor of travel distance can affect the effect of FWH implementations.. The reason is that most travelers with short-Distance (SD travel) can choose the mode of walking that is not affected by traffic. The traveler does not want to change his / her familiar travel time if his / her travel itinerary is an SD trip. (Zong , Juan , & Jia , 2013) On the other hand, for long motorized travel, traffic congestion affects whether passengers arrive at the workplace in a timely manner. The travel distance distribution in selected study area is shown in figure 9. It shows more than 50% employees stay less than 10km distance from their workplaces.

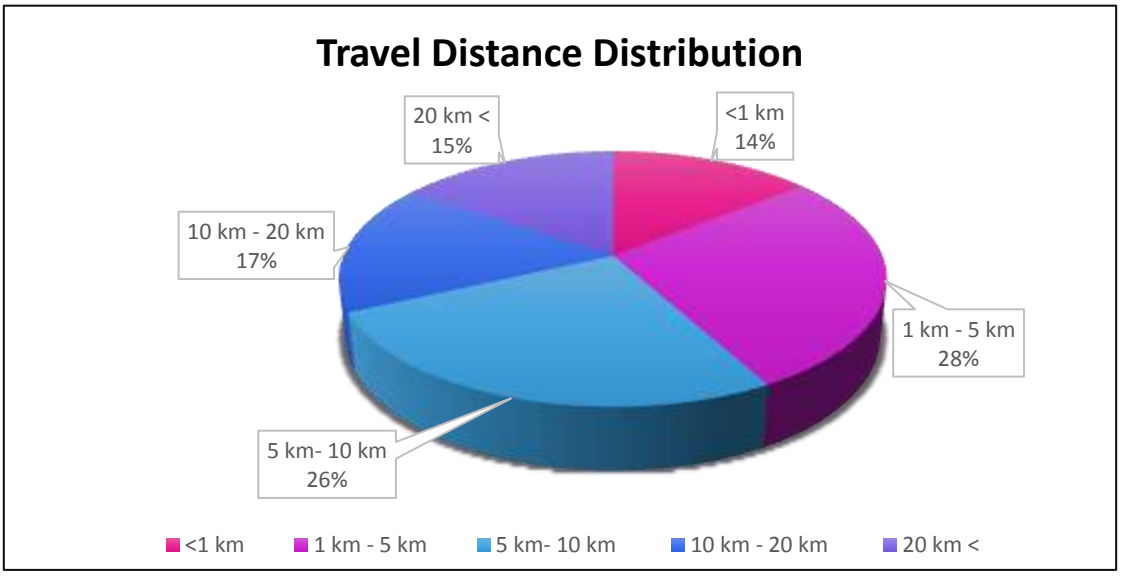


Figure 12: Travel distance distribution
Source: Compiled by Author

4.2.3. Intermediate stop

Approximately 1% of the respondents had an intermediate stop on the way to work and the way back to home. The other 99% of respondents no had intermediate stops. Generally, 1% of the respondents had intermediate stops based on different reasons. Such as, the need of send their children to school or to take family members to work and shopping. Their travel times are affected by no of intermediate transit stops.

4.2.5 Commute Mode distribution

The commute mode distribution is given in Figure: 10. About 1% commuters use train and 9% commuters use walking for transportation. Only 3% commuters used Motorbike as the travel mode and 32% used own vehicles. The highest number of commuters used public and common office buses/vans as their travel mode, and it is 55%.

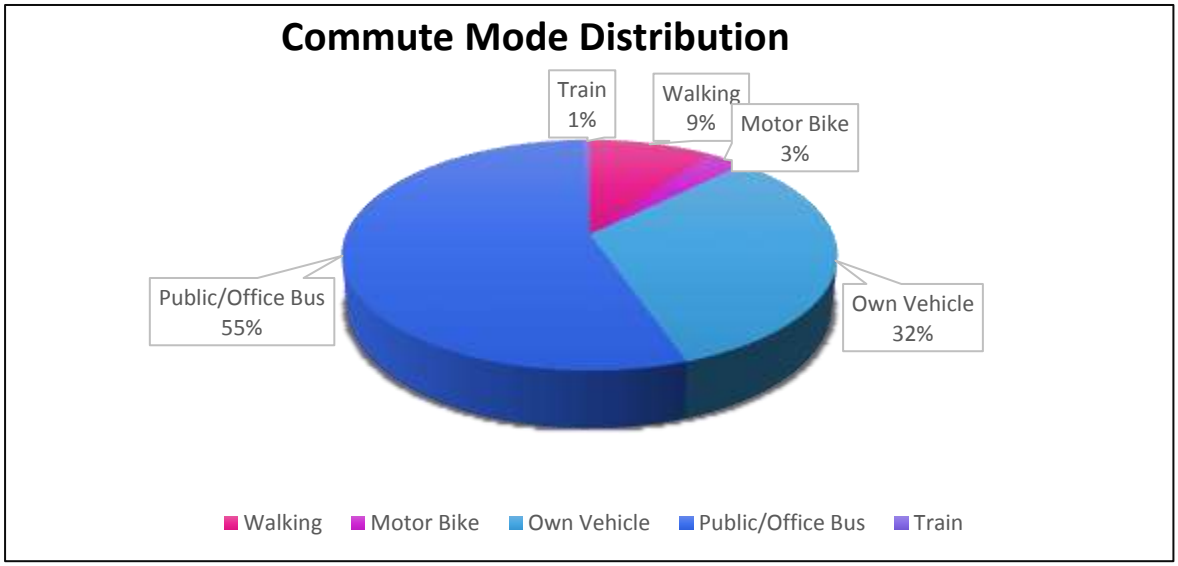


Figure 13: Commute mode distribution
Source: Compiled by Author

4.2.5. Commuter's preference analysis

About 22.63% of respondents think implementation of a Flexible work shifts strategy if Sri Lanka is one of the good transport demand management strategy and 77.37% of respondents think it is not a good transport demand management strategy and they mention they do not like the FWH According to the social survey data acceptability of FWH is not preferring. The reasons are probably as follows:

- The Flexible work shifts principle did not attract much attention;
- The Flexible work shifts policy has not yet implemented in Sri Lanka.
- Some travelers do not recognize the disadvantages of traffic congestion during peak periods.
- Some people have not idea about a Flexible work shifts program.

4.2.6. Gender Base preference

According to the field survey 6% from total employment willing to adhere the FWH implementation method and only 35% male employment proffering. It denotes below figure 12.1

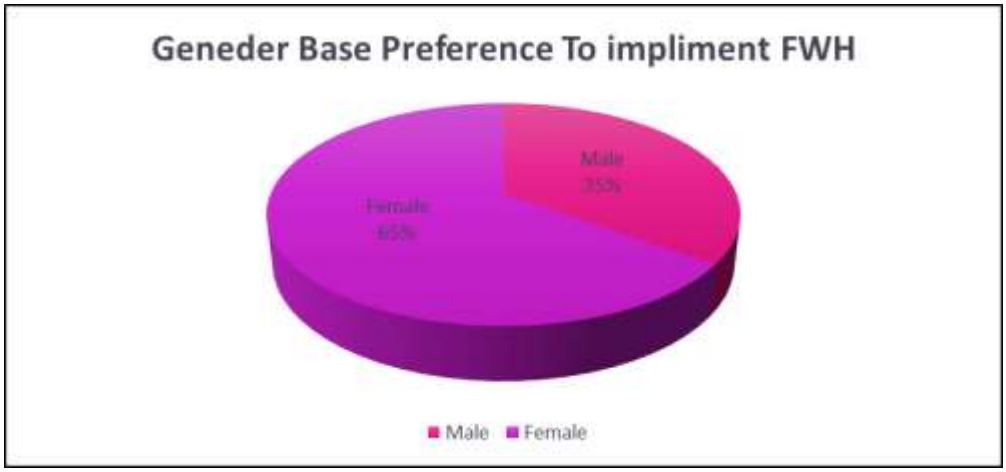


Figure 12.1: Gender base preferences Source: Compiled by Author

4.3. Impact of flexi work hours on traffic

4.3.1. Traffic Analysis

Shortest path (SD) from origin places to destinations was find out by network analysis method to identify the employee minimum travel distance and travel path in order to consider road segmentation (link) trip generations. Origin and destinations are denoted by sampling questionnaire survey results and input node has taken to entry point to study area. Below table also indicate the main nodes in each o origin and destination. Level of Service (LOS) in each links were calculated to existing scenario in 15min time intervals with MCC data as indicates the below tables.

Table 8: Network Analysis (S_D)

	A	B	C	D	E	F	G	I	J	K
A	0	0.93	1.47	2.48	1.18	1.87	1.97	2.08	2.77	1.75
B	_	0	0.54	1.55	2.11	1.46	1.04	1.15	1.74	0.82
C	B	_	0	1.01	2.47	1.88	1.36	0.61	2.06	0.28
D	B,C,K	C,K	K	0	2.66	1.97	1.55	0.8	2.25	0.73
E		A	I,G,F	I,G,F	0	0.69	1.11	1.86	1.59	2.93
F	E	G	I,G	I,G		0	1.12	1.03	0.9	2.06
G	B	_	I	I	F	_	0	0.75	0.7	0.82
I	B,C	C	_	_	F,G	G	_	0	1.45	0.89
J	E,F	G	I,G	I,G	F	_	_	G	0	2.34
K	B,C	C	_	_	A,B,C,	C,I,G	C,I	C	C,I,G	0

Table 9: Level of Service Calculation of links

Road Segment	(7-8)am	PCU	LOS	Road Class	(8-9)am	PCU	LOS	Road Class
A-B	1251	1001	1.33	F	1906	1525	2.03	F
B-A	1624	1299	1.73	F	2260	1808	2.41	F
B-C	1186	949	1.27	F	1113	890	1.19	E
C-B	1286	1029	1.37	F	1379	1103	1.47	F
C-K	578	462	0.62	C	1113	890	1.19	E
K-C	1284	1027	1.37	F	1339	1071	1.43	F
A-K	329	263	0.35	A	384	307	0.41	A
K-A	805	644	0.86	D	654	523	0.70	C
K-D	775	620	0.83	D	1113	890	1.19	F
D-K	1284	1027	1.37	F	1318	1054	1.41	F
D-I	1729	1383	1.84	F	1953	1562	2.08	F
I-D	860	688	0.92	D	965	772	1.03	E
C-I	98	78	0.10	A	109	87	0.12	A
I-C	137	110	0.15	A	189	151	0.20	A
I-G	1979	1583	2.11	F	2179	1743	2.32	F
G-I	364	291	0.39	A	519	415	0.55	B
B-G	509	407	0.54	B	472	378	0.50	B
G-B	611	489	0.65	C	757	606	0.81	D
G-J	651	521	0.69	C	832	666	0.89	D
J-G	899	719	0.96	D	1272	1018	1.36	F
F-J	868	694	0.93	D	614	491	0.65	C
J-F	1468	1174	1.57	F	1314	1051	1.40	E
G-F	1991	1593	2.12	F	2262	1810	2.41	F
F-G	979	783	1.04	E	1261	1009	1.35	F
F-E	2458	1966	2.62	F	2524	2019	2.69	F
E-F	876	701	0.93	D	1210	968	1.29	E
A-E	621	497	0.66	C	532	426	0.57	B
E-A	1083	866	1.16	F	1219	975	1.30	F

Source: Compiled by Author

Table 10: Level of Service Calculation of Links

Road Segment	(9-10)am	PCU	LOS	Road Class	(3-4)pm	PCU	LOS	Road Class
A-B	1676	1341	1.79	F	920	736	0.98	D
B-A	1834	1467	1.96	F	1430	1144	1.53	F
B-C	1157	926	1.23	F	1271	1017	1.36	F
C-B	1300	1040	1.39	F	1071	857	1.14	E
C-K	970	776	1.03	E	1183	946	1.26	E
K-C	1300	1040	1.39	F	1080	864	1.15	E
A-K	244	195	0.26	A	561	449	0.60	B
K-A	590	472	0.63	B	255	204	0.27	A
K-D	1060	848	1.13	E	1183	946	1.26	E
D-K	1300	1040	1.39	F	969	775	1.03	E
D-I	1529	1223	1.63	F	866	693	0.92	D
I-D	744	595	0.79	C	1184	947	1.26	F
C-I	102	82	0.11	A	86	69	0.09	A
I-C	229	183	0.24	A	119	95	0.13	A
I-G	1877	1502	2.00	F	267	214	0.28	A
G-I	310	248	0.33	A	1441	1153	1.54	F
B-G	513	410	0.55	C	760	608	0.81	D
G-B	877	702	0.94	D	590	472	0.63	C
G-J	508	406	0.54	B	697	558	0.74	C
J-G	867	694	0.92	D	456	365	0.49	B
F-J	575	460	0.61	B	992	794	1.06	E
J-F	978	782	1.04	E	708	566	0.76	C
G-F	1967	1574	2.10	F	147	118	0.16	A
F-G	882	706	0.94	D	1487	1190	1.59	F
F-E	2002	1602	2.14	F	257	206	0.27	A
E-F	1456	1165	1.55	F	2128	1702	2.27	F
A-E	1299	1039	1.39	F	698	558	0.74	C
E-A	1162	930	1.24	E	1430	1144	1.53	F

Source: Compiled by Author

Table 11: Level of Service Calculation of Links

Road Segment	(4-5)pm	PCU	LOS	Road Class	(5-6)pm	PCU	LOS	Road Class
A-B	1274	1019	1.36	F	1428	1142	1.52	F
B-A	1684	1347	1.80	F	1028	822	1.10	E
B-C	1426	1141	1.52	F	1539	1231	1.64	F
C-B	1408	1126	1.50	F	1203	962	1.28	F
C-K	1426	1141	1.52	F	1539	1231	1.64	F
K-C	1204	963	1.28	E	1184	947	1.26	F
A-K	569	455	0.61	B	338	270	0.36	A
K-A	390	312	0.42	A	287	230	0.31	A
K-D	1426	1141	1.52	F	1566	1253	1.67	F
D-K	1257	1006	1.34	F	1375	1100	1.47	F
D-I	832	666	0.89	D	977	782	1.04	E
I-D	1610	1288	1.72	F	1783	1426	1.90	F
C-I	94	75	0.10	A	104	83	0.11	A
I-C	282	226	0.30	A	175	140	0.19	A
I-G	240	192	0.26	A	269	215	0.29	A
G-I	1984	1587	2.12	F	2142	1714	2.28	F
B-G	976	781	1.04	E	987	790	1.05	D
G-B	716	573	0.76	C	720	576	0.77	C
G-J	967	774	1.03	E	1187	950	1.27	E
J-G	622	498	0.66	C	746	597	0.80	C
F-J	1184	947	1.26	F	1370	1096	1.46	F
J-F	918	734	0.98	D	928	742	0.99	D
G-F	262	210	0.28	A	195	156	0.21	A
F-G	2383	1906	2.54	F	2574	2059	2.75	F
F-E	296	237	0.32	A	246	197	0.26	A
E-F	2502	2002	2.67	F	2099	1679	2.24	F
A-E	1117	894	1.19	E	1023	818	1.09	D
E-A	576	461	0.61	B	541	433	0.58	B

Source: Compiled by Author

Table 12: Trips per hour base on directions

Road segments	No of trips/hour					
	(7-8)am	(8-9)am	(9-10)am	(3-4)pm	(4-5)pm	(5-6)pm
A-B	1251	1906	1676	920	1274	1428
B-A	1624	2260	1834	1430	1684	1028
B-C	1186	1113	1157	1271	1426	1539
C-B	1286	1379	1300	1071	1408	1203
C-K	578	1113	970	1183	1426	1539
K-C	1284	1339	1300	1080	1204	1184
A-K	329	384	244	561	569	338
K-A	805	654	590	255	390	287
K-D	775	1113	1060	1183	1426	1566
D-K	1284	1318	1300	969	1257	1375
D-I	1729	1953	1529	866	832	977
I-D	860	965	744	1184	1610	1783
C-I	98	109	102	86	94	104
I-C	137	189	229	119	282	175
I-G	1979	2179	1877	267	240	269
G-I	364	519	310	1441	1984	2142
B-G	509	472	513	760	976	987
G-B	611	757	877	590	716	720
G-J	651	832	508	697	967	1187
J-G	899	1272	867	456	622	746
F-J	868	614	575	992	1184	1370
J-F	1468	1314	978	708	918	928
G-F	1991	2262	1967	147	262	195
F-G	979	1261	882	1487	2383	2574
F-E	2458	2524	2002	257	296	246
E-F	876	1210	1456	2128	2502	2099
A-E	621	532	1299	698	1117	1023
E-A	1083	1219	1162	1430	576	541

Source: Compiled by Author

Next, calculate the proposed LOS in each links after implementing the flexible work shift adjustment according to the output from sample questionnaire survey data. In this calculation done based on categorized zone wise. According to the sample survey 24.8% of employees with positive intention for change their current working arrangement.

4.3.2. Analysis of Number of PCU count due to the Employees

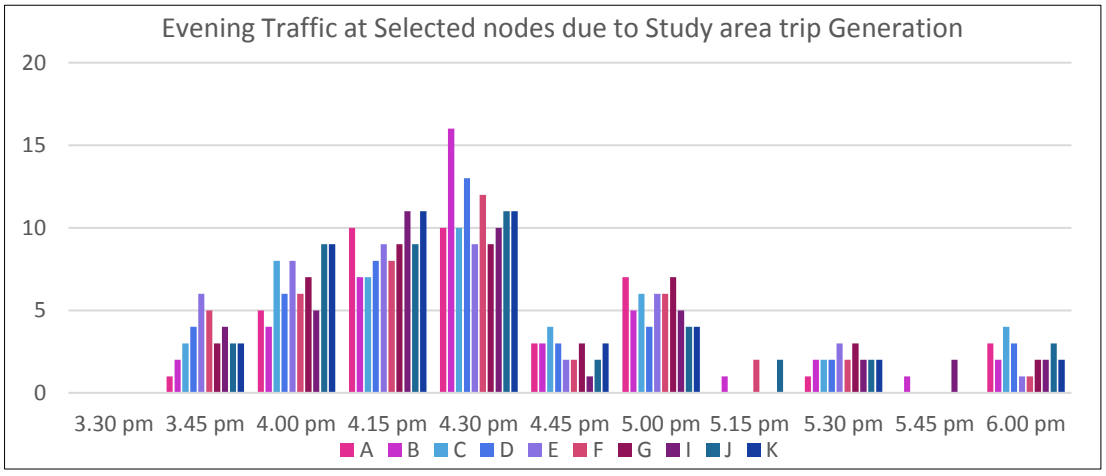
The traffic on peak hours are not an alien experience that we are experiencing in every morning and evening which we usually called as office hours in colloquially. In order

to investigate the impact of vehicular PCU – generation due to the employees many data are required for each node. For example, to calculate the traffic impact by a person who travels in an office by vehicle, it needs to consider his or her travel path, waiting time at each node, arrival or departure time from office and home etc.… But this study with the limited time available it is difficult to gather such a bulk of data as number of workers within the area is larger. Therefore, to calculate the impact or vehicular generation at each zone the number of workers within each node was calculated based on the building floor area and building use. Then the vehicular generation for each zone in morning and evening was categorized into 15 minutes time intervals based on MCC count data.

Finally, Calculated the number of trip generations in each zones using average use of vehicle mode derived based on the social survey data and occupying employment in each zones using below equation.

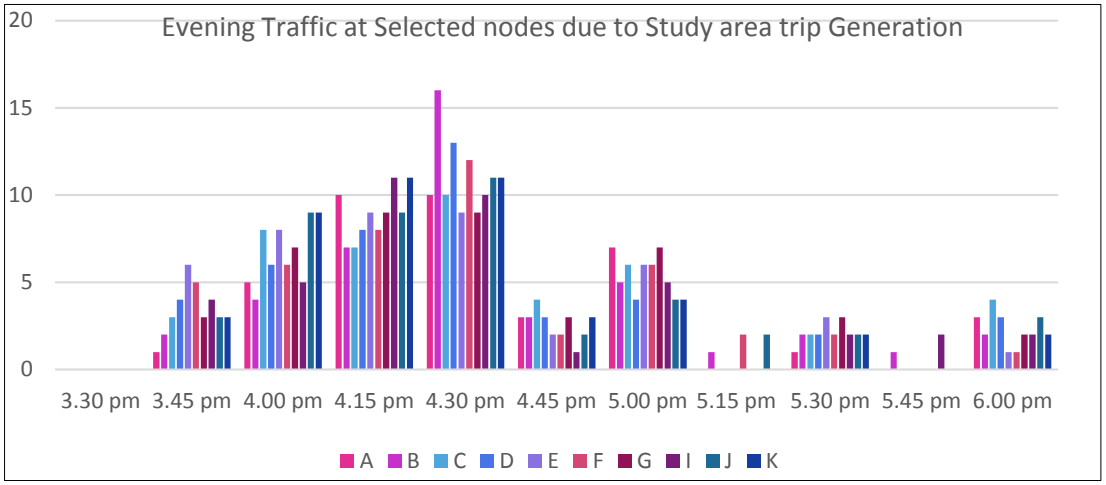
Total Vehicular Generation = Total No. of Employees * Rate derived based on the Vehicle mode

Figure 14: Morning Trip Generation

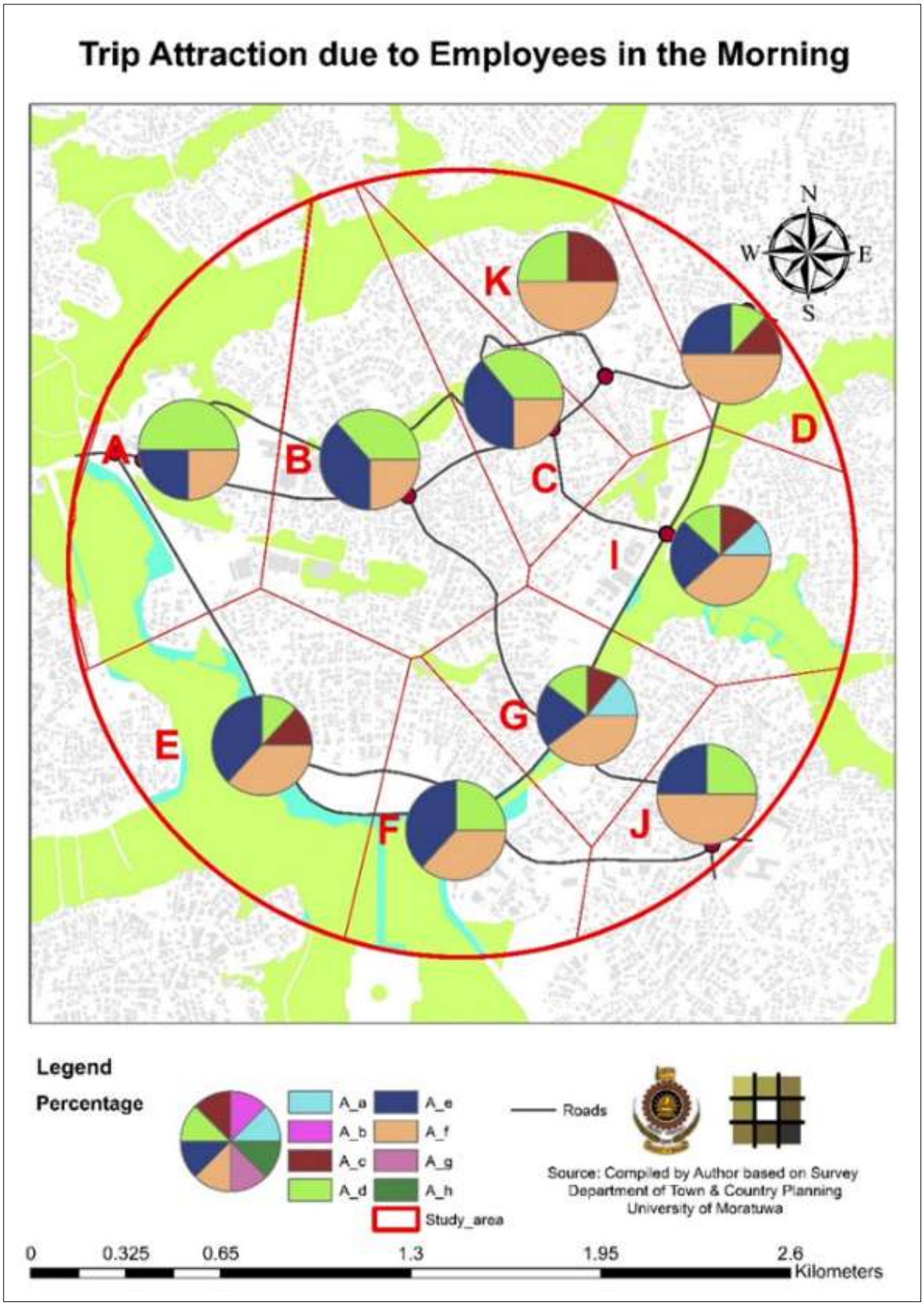


Source: Compiled by Author

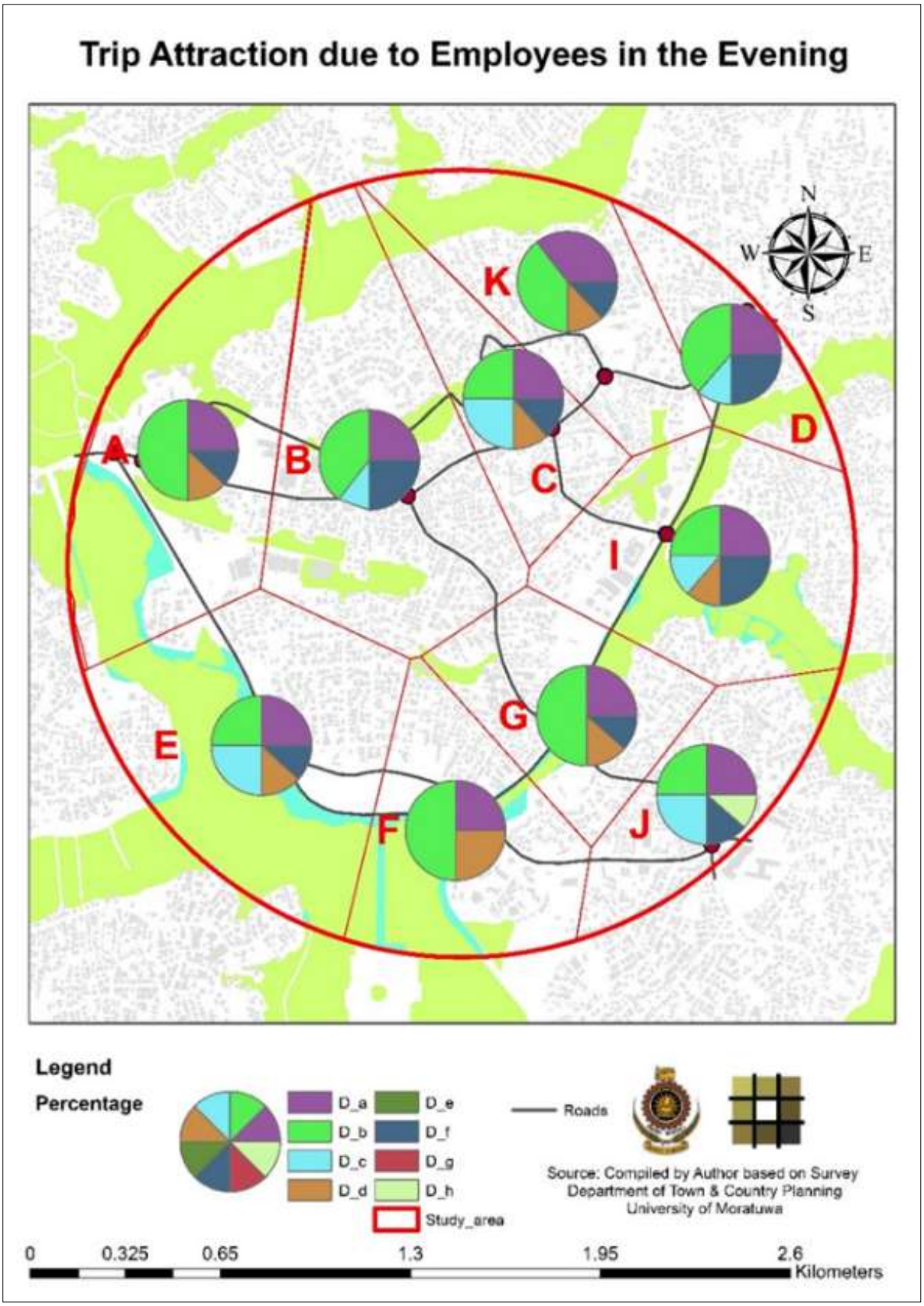
Figure 15: Evening Trip Generation



Source: Compiled by Author



Map 4: Morning PCU generation at each Zone due to employees *Source: Compiled by Author*



Map 5: Evening PCU generation at each Zone due to employees
Source: Compiled by Author

4.3.3. Impact of Flexible work hours on traffic

LOS value in each road segment with respect to normal daily vehicular movement and study area employment trip generations was calculated. Further according to the field survey data FWH prefer trips are categorized in to 15 min time intervals using current employee arrival and departure time. Then existing and proposed FWH prefer number of trip arrival and departure times are compared with each time slots and as well as considered SD path and relevant road segments. In the calculation process firstly number of trips in existing travel time periods in each road segment and those trips are added to proposed time periods in each links. Finally, 03 LOS calculated tables has been created comparing the normal vehicle flow in area, Veicle follow generated due to study area employee attraction and LOS level after implementing the proposed FWH traffic mitigating method with only prefer ones likes to adopt it.

Then, T-test analysis in SPSS software was used to measure whether any impact can be seen on road network in peak hours after implementing the aforesaid method.

As per the below table no 13 Change of the LOS is explaining by yes and no groups in the above data set. The "Yes" group indicates LOS changers based on the employees' movements between flexible hours as null hypothesis. The "NO" group indicated LOS changers not based on employee's movement between flexible hours.

T test for 7 am - 8 am time period

Table 13: T-test Analysis Results

Group Statistics

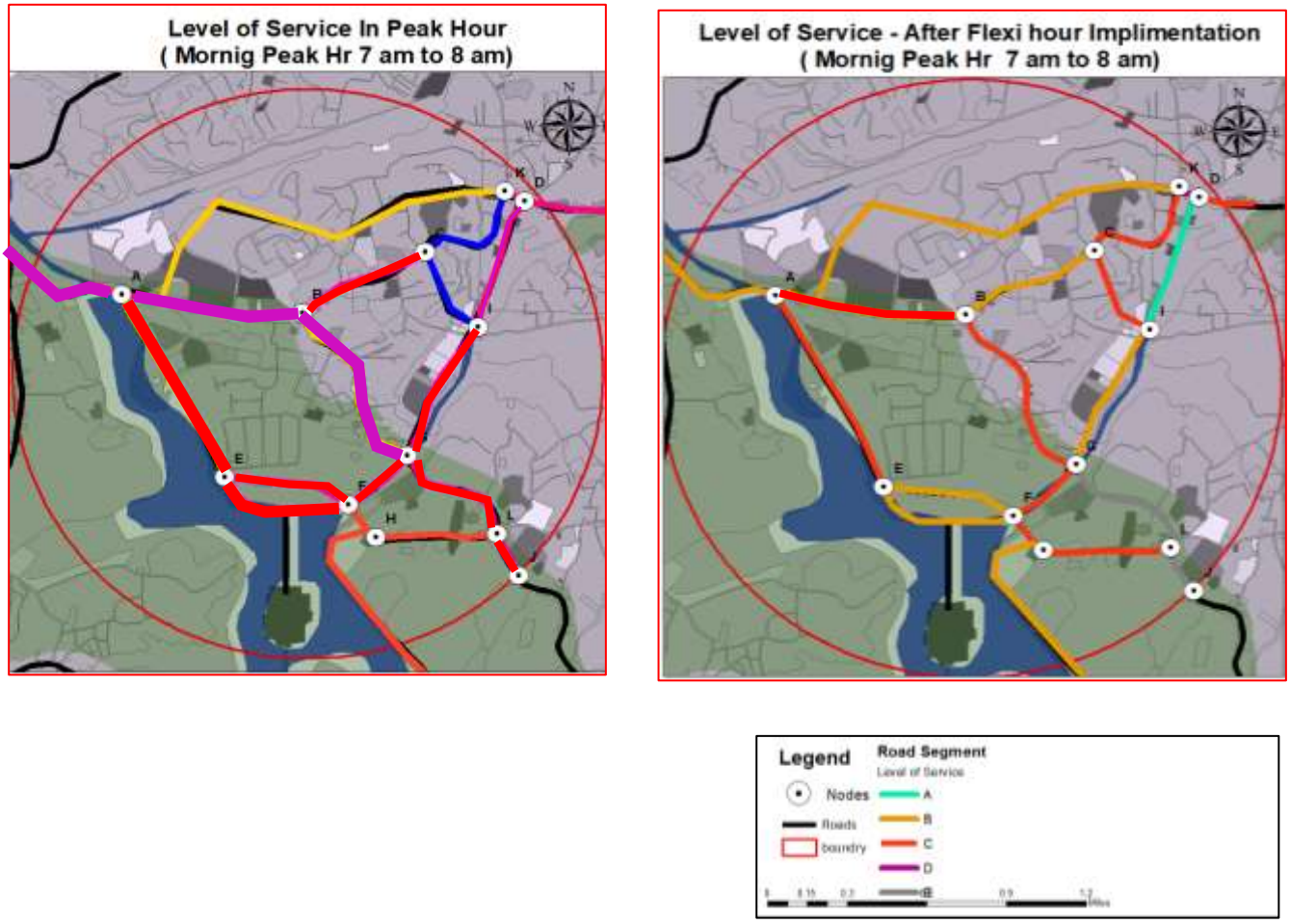
	Change_7_8	N	Mean	Std. Deviation	Std. Error Mean
After_7_8	Yes	3	1892.9753	777.03304	448.62024
	No	11	1429.8373	506.81126	152.80934

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
After_7_8	Equal variances assumed	1.243	.287	1.268	12	.229	463.13800	365.37624	-332.94845	1259.22445
	Equal variances not assumed			.977	2.484	.414	463.13800	473.93123	-1238.67543	2164.95143

Mean difference result of the t- test analysis indicates sense of the possibility to change LOS base on the flexible hour concept. Comparing the above 7am-8am peak hour time period it implies, Mean difference result by around 463 trip difference. That result expresses it has possibility to change LOS of the road segments between the 7am-8 am time period using this flexible work hour method.

The visually interpretation of changes of road capacity on study area road segments before and after implementation of flexi hour working times are as follows. The Simulated maps represent that, there can be identified significant variation on LOS in the Morning peak time 7 am to 8 am.



Map 6: LOS variation of before and after flexi working hour Implementation at 7 am to 8 am Peak hour
Source – Compiled by Author

T test for 8 am - 9 am time period

Table 14 T test analysis 8 am to 9 am

Group Statistics

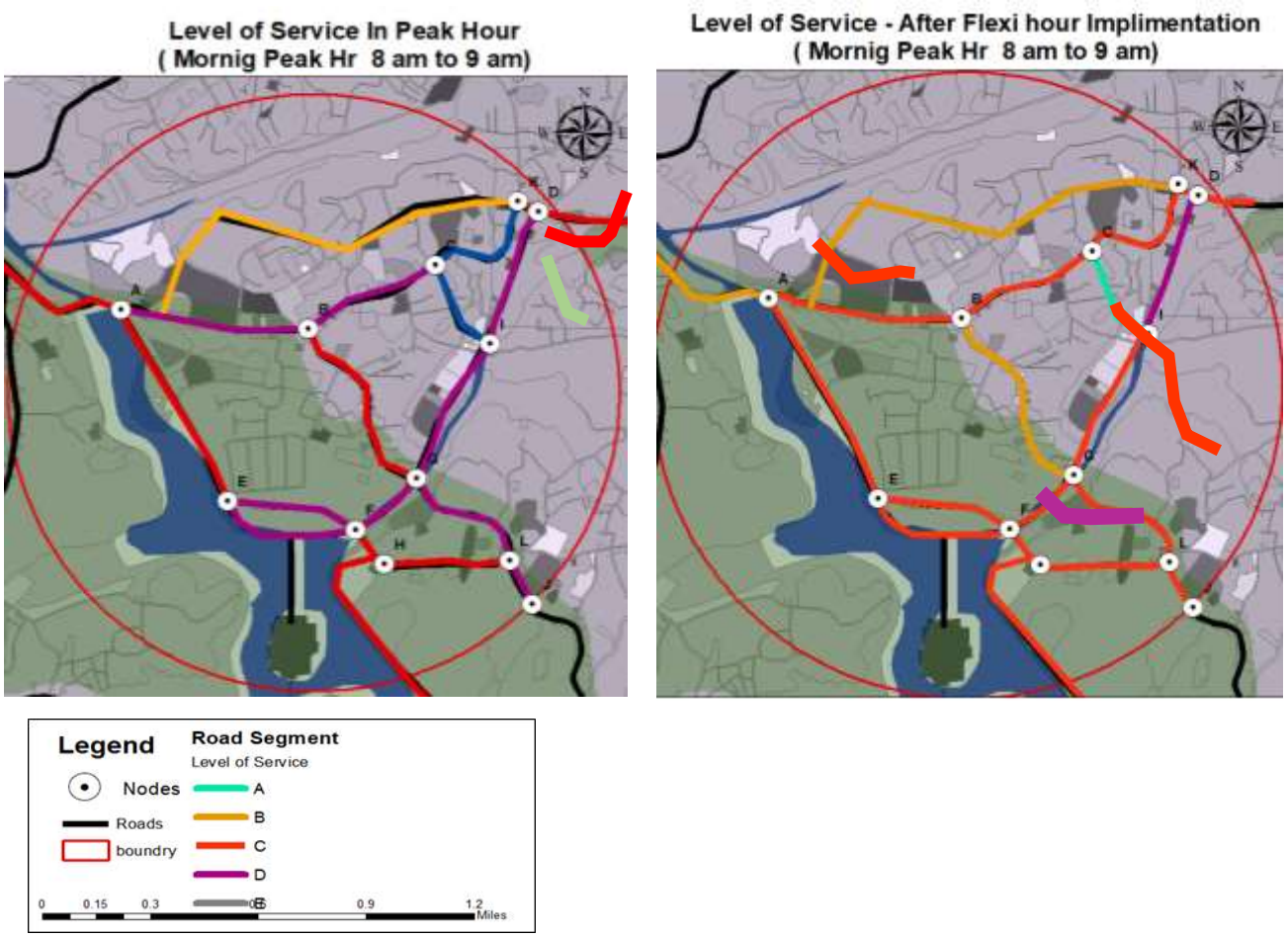
	Change_8_9	N	Mean	Std. Deviation	Std. Error Mean
After_8_9	Yes	1	1708.2000	.	.
	No	13	1593.1538	485.82186	134.74274

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
After_8_9	Equal variances assumed	.	.121	.228	12	.341	115.04615	504.16117	-983.42667	1213.51898
	Equal variances not assumed			.	.	.	115.04615	.	.	.

As per the above table 14 interpret the result between mornings 8am-9am time period LOS relationship in study area road segments. The result indicates around 115 trip difference. The result explains low mean difference among that. Therefore 8 am to 9 am time period is quite congested time slot . That means 115 trip difference cannot do considerable influence to reduce exsisting congestion and pattern of the vehicle movements in the selected road segments. Hence, it indicates flexible hour's movement cannot do considerable influence to change LOS of the study area on this 8am-9am peak time period.

The visually interpretation of changes of road capacity on study area road segments before and after implementation of flexi hour working times are as follows. The Simulated maps represent that, there cannot be identified significant variation on LOS in the Morning peak time 8 am to 9 am. Refer with the changing amount of trips are not highly considerable and cannot be considerable influence to change congestion and pattern of the vehicle movements in the study area.



Map 7: LOS variation of before and after flexi working hour Implementation at 8 am to 9 am Peak hour
Source Compiled by Author

T test for 9 am - 10 am time period

Table 15 T test analysis for 9 am to 10 am

Group Statistics

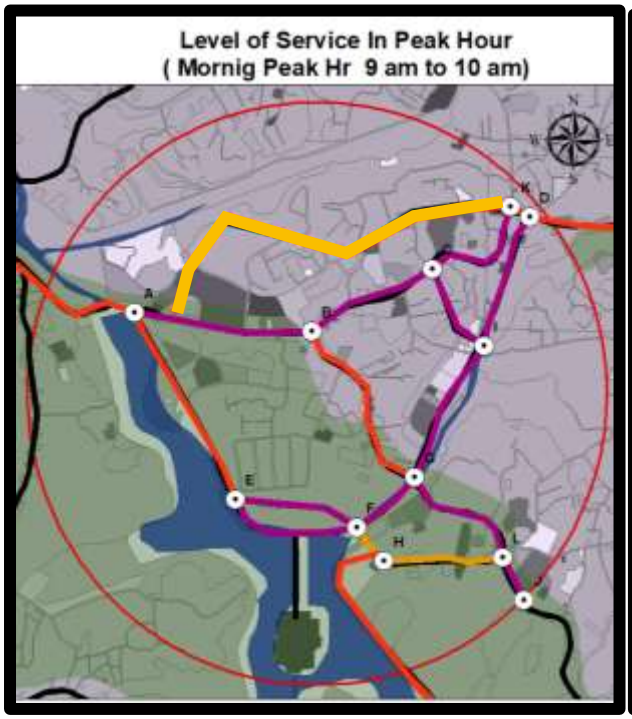
	Change_9_10	N	Mean	Std. Deviation	Std. Error Mean
After_9_10	Yes	1	2252.4000	.	.
	No	13	1383.5846	383.88742	106.47121

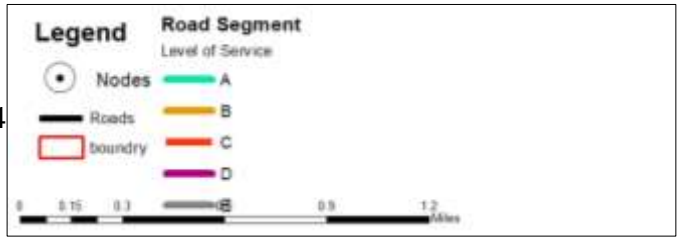
Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
After_9_10	Equal variances assumed	.	.012	2.181	12	.050	868.81538	398.37880	.82255	1736.80822
	Equal variances not assumed	.	.	.	.	.	868.81538	.	.	.

AS per the above table in 9am-10am peak period time Mean difference result indicates around 868 trip difference. That expresses higher possibility to change LOS of the road segments between the 9 am to 10 am time period.

The visually interpretation of changes of road capacity on study area road segments before and after implementation of flexi hour working times are as follows. The Simulated maps represent that, there cannot be identified significant variation on LOS in the Morning peak time 9 am to 10 am. Refer with the changing amount of trips are not highly considerable and cannot be considerable influence to change congestion and pattern of the vehicle movements in the study area.





Evaluating the above data finally can be interpret as the flexible work shift arrangement method make some positive influence on road network on morning peak hours. But Significant traffic generated time period on 8am-9am road congestion cannot reveal through tool as expected way.

4.6. Conclusion

Flexible work Shift is a TDM method adopt to relieving and distribution the congested road capacity in period of time mainly at peak hours. Therefore, two samples used to examine the effect of road capacity changes of certain study area. Firstly, find out the influence on road capacity by normal generated trips on 15 min time periods. Then estimation number of the trips creates from study area in same time slots are calculated and its effects on road capacity is examined. Finally estimates the road capacity while some percentage of study area employees prefer to change their working time on flexible basis according to the questionnaire sample survey data. In analysis Level of service in normal trip generations and Level of service after adopting the flexible arrangement was compared. Then compare the output before and after FWH implementation and its impact on road capacity. According to the study at morning 7am-8am time period and 9am-10 am time period shows the considerable positive changes that help to release the traffic congestion in different time slot. But in 8am to 9 am peak period traffic cannot decrease in considerable level while after implementing the FWH. That means the employee involvement of change their work time in different adjustment time period is less. However under this study propose modified employee work time period duration is only 1.5 hrs.That means only can change their work arrival time in between 7.30am to 9 am only. (that mean only 15 min to 1.5 hrs limit) But according to analysis output interpret that can not obtain the maximum out put after implement tis in short period of time because considerable vehicle volume distribute in other times too.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

This research discussed applicability of FWH in selected area of Sri Jayawardenapura Kotte by analyzing relevant statistics. The Study was initiated to investigate the impact of study area trip attraction and trip generation on the traffic and identify the best suitable traffic mitigation method to implement

Firstly occupancy in peak hour congestion at selected road segments and nodes are evaluated and hourly road demand is determined. Here discuss the daily trips in selected road segments are obvious in weekdays. According to the MCC data total network performance is under high load condition during the morning and evening peak times. The necessity of traffic mitigation method to use immediate effects is concern. Effects on traffic volume form study area trips are need to be detect and below objectives are chosen to build up the study further. Accordingly, identify the possibility of implementing the Flexible work hours on traffic congestion at peak hours and to identify the effects on road network by Flexible work shift implementation are the main two objectives of this study.

Mainly Primary data is collected through questionnaire survey from 500 participants representing the ten sub zones. And MCC data, building use data and road conditions etc. are collected from secondary data sources. As from social survey findings below statistics can be interpret.

According to the survey findings more than 56% are used to public transportation systems and more than 30% used their own vehicle as commute mode. In the study area 9% are used to walk to reach their office places. Furthermore, 54% majorities from total employments are living less than 10 Km distance from their work. only 1% from total are had intermediate stops in their way to workplace for many circumstances and it is not the considerable amount. Further according to the sample data only 22.63% from total are willing to adopt the FWH method and others are not. In gender base preferences to adhere the FWH it can be seen more than 65% of female employment wish to adhere FWH method and only 35% less male employee attention can be seen. and based on this willingness percentage the model was developed. According to the survey findings of the research it has been identified peak hour congestion is seen within the morning time 7am-9am 3.30pm to 6.30pm.

Finally conclude the relationships among road demand before and after execution the FWH at peak hours. At the study purpose with limited time availability all calculations

are only done based to morning peak period and it is assuming as evening peak period results are same as morning. Final research output found using t-test analysis in SPSS software. Once the FWH implement result conclude that morning 7am-8am and 9am-10am time periods interpret significant impact on road demand but in morning 8am-9am time period is not. That means the only study area selected 20% of total population FWH adoption may bring little improvement to the total network performance as well as different working hour has some roles to alleviate traffic congestion. but not much beneficial to improve the road traffic condition from considerable levels in this research area.

In the research output determined that study area employee generation affect the increment of morning and evening peak congestion in roads and junctions. But at 8am-9am period is highly congested and cannot be minimize the traffic while only changing the study area employment worktimes. Because highly vehicular demand is produced by the surrounding land uses mostly Colombo commercial capital and surroundings the vehicles to Colombo through this area creates considerable excess traffic volume. Therefore, shifting of job start time or job end time may have not much benefitted to mitigate the extensive traffic at zones.

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ANNEXURES

Annexures 1: Questionnaire Survey Sheet

THE IMPACT OF FLEXIBLE WORKING HOURS TO REDUCE THE TRAFFIC CONGESTION ON PEAK HOURS

(Survey sheet for participants in pilot project)

This questionnaire survey is carried out with the objective of assessing the impact of staggered working hours to reduce the traffic congestion on peak hours. The collected data will be used only for the academic purposes.

Survey Date:……

1. What is your working organization:
   ……?

2. Type of the industry:

Government/Semi government	
Educational Institutions	
Medical institutions	
Commercial sector (retail shops/wholesale shops/business)	
Service industries (filling stations, Banks, Garage, Insurance company, etc.)	
Other (write down the job category)	

3. Type of the Job position :

Labor	☐	Clerk	☐
Executive level	☐	Management level	☐
Shop owner	☐	Shop Assistant	☐
Other (write down the job) ……			

4. What is your normal office work time: ……

5. Which is your age group : :

18yrs-25yrs	☐	26-40 yrs	☐
40-55yrs	☐	above 55 yrs	☐

6. Sex : Female ☐ Male ☐

7. Where is your home located : …….

8. What is your departure time from home to workplace :
…….

9. What is your departure time from workplace to home :
……?

10. How long is your workplace to home distance:

Less than 1Km	☐	10Km-20Km	☐
1Km - 5Km	☐	More than 20Km	☐
5Km-10Km	☐		

11. What is your transport mode to travel the workplace :

Own vehicle	☐	Public Bus	☐
Train	☐	Walking	☐
Office Bus	☐	Other	☐

If Other which :…….
.

12. What locations you spend more time due to traffic on your way around administrative city area:

Junction name	Relevant location	Waiting time(seconds/Min)
Battaramulla junction		
Koswatta junction		
Pelawatta junction		
Diyatha junction		
Palam thuna junction		
Thalawathugoda junction		
Malabe junction		
Ganahena junction		
Kinulawela junction		
Ranaviru Monument		
Parliament Grounds_1		
Near CEA,RDA		
Other places		

13. How long do you currently spend on a one-way trip to your home to workplace?

Morning

Less than 30 min. ☐ Less than 1 hour ☐ 1 hour -2 hour ☐

more than 2 hrs ☐

Evening

Less than 30 min. ☐ Less than 1 hour ☐ 1 hour -2 hour ☐

more than 2 hrs ☐

14. Are you satisfy the current transportation system: Yes ☐ NO ☐

15. How many intermidiate stops do you have on your way to and from work place:

16. For why:……..

17. Do you engaged with pilot flexi hour program done by Ministry of Megapolis

a) Yes ☐ NO ☐
b) If Yes, are you gain any benefit or losses through it:…..……

18. If this implemented flexible working time schedule system again do you wish to co-operate with: Yes ☐ No ☐

19. If yes what working time schedule would you mostly like to use (mark 2 choices)

i.	7.30am -3.15pm	☐
ii.	8.00am -3.45pm	☐
iii.	8.30am -4.15pm	☐
iv.	9.00am -4.45pm	☐
v.	9.30am -5.15pm	☐

20. What do you think about outcomes of this proposed system?

Positive:……
……..…

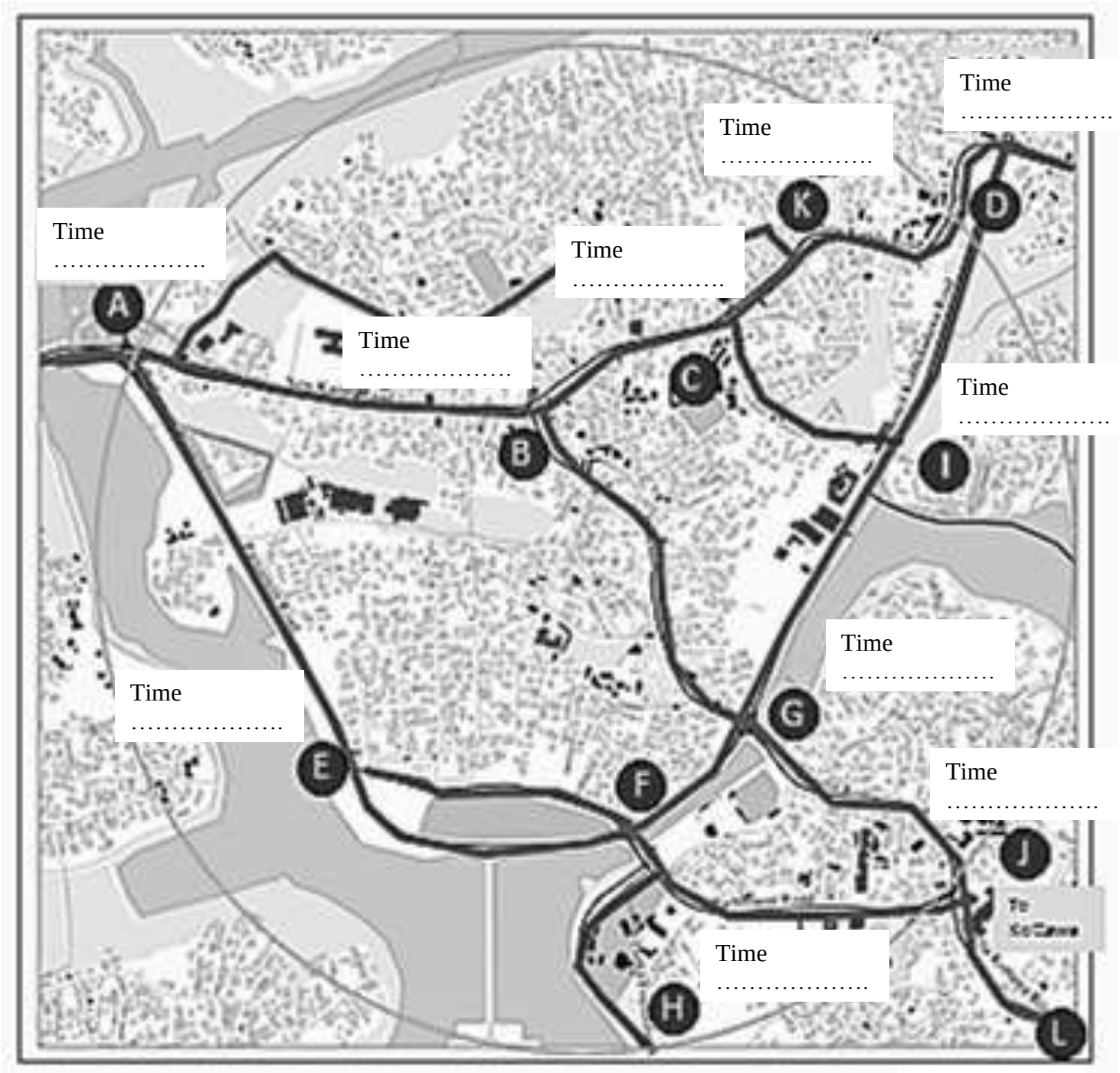
Negative:……
…….....

21. What modification should be imply to this method to get more benefits:…….

22. Please provide any suggestions you have about how your community's transportation services could be improved:

……
……
……
……
……
…….

23. Refer the bellow Map and mark at what time you pass thought the respective junction.



Time
…….

Time
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Time
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Time
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Time
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Time
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Time
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Time
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Time
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Time
…….

Annexures 2: Departure time from Home

Home Departure time / zone	Before6 am	6-7 am	7-8 am	8-9 am	After 9 am
A	3	8	28	10	1
B	10	10	21	7	2
C	11	7	21	11	0
D	8	12	18	11	1
E	7	10	22	10	1
F	3	9	25	12	1
G	10	11	21	6	2
I	9	12	20	8	1
J	9	11	23	7	0
K	1	11	22	16	0

Annexures 3: Departure Time From Offices

Office Departure Time / Zone	3pm -4 pm	4 pm-5 pm	5pm -6 pm	After 6 pm
A	6	23	11	10
B	6	26	11	7
C	11	21	12	6
D	10	24	9	7
E	14	20	10	6
F	11	22	11	6
G	10	21	12	7
I	9	22	11	8
J	12	22	11	5
K	12	25	8	5

Annexures 4: Hourly Vehicle flow within the links

Time duration	Hourly vehicle Flow within the links									Total per ho
	J-F	H-F	E-A	G_B	D-I	J-G	A-B	D-B	K-A	
6.00 am to 7.00 am	1536	1222	407	282	982	687	711	878	885	
7.00 am to 8.00 am	1402	2451	1072	562	1778	892	1251	1269	825	
8.00 am to 9.00 am	1176	2737	1219	754	2041	1267	1906	1379	654	
9.00 am to 10.00 am	958	1889	1171	877	1528	864	1676	1300	673	
10.00 am to 11.00 am	1022	1301	1048	827	1247	712	1676	1117	623	
11.00 am to 12.00 noon	894	1397	1201	784	1269	687	1709	1136	459	
12.00 noon to 1.00 pm	864	1270	1320	656	1164	756	1741	1168	599	
1.00 pm to 2.00 pm	936	1500	1521	678	1074	861	1440	1332	633	
2.00 pm to 3.00 pm	1096	1401	1345	860	1276	865	1395	1154	619	
3.00 pm to 4.00 pm	980	1456	1299	760	1222	697	1570	1183	561	
4.00 pm to 5.00 pm	1175	2011	1422	972	1610	957	1502	1378	469	
5.00 pm to 6.00 pm	1362	2587	1115	987	1873	1185	1143	1511	338	
6.00 pm to 7.00 pm	1299	2359	1021	719	1595	969	1028	1244	7338	
6.00 am-7.00 pm	**14700**	**23581**	**15161**	**9718**	**18659**	**11399**	**18748**	**16049**	**14676**	

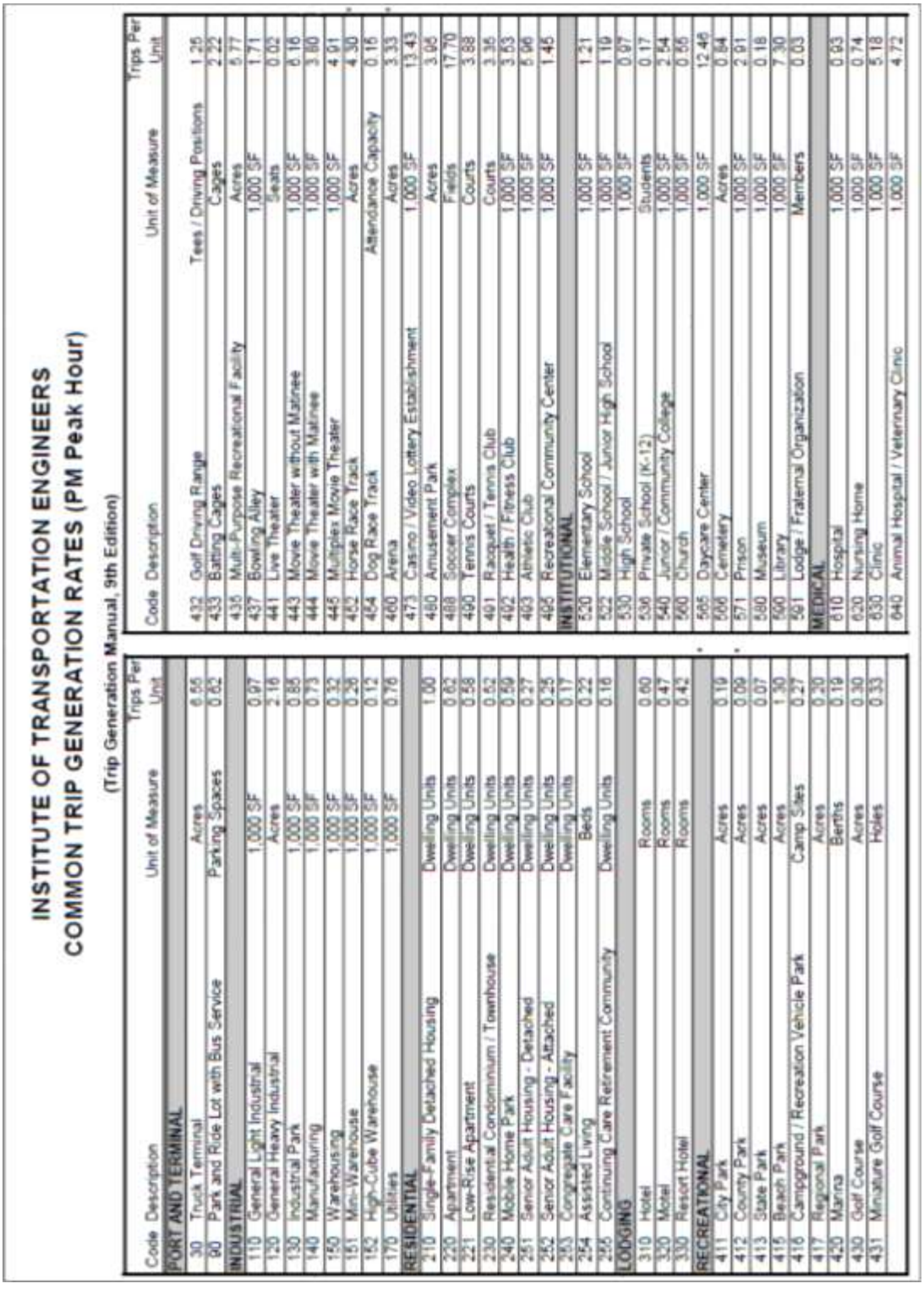
Annexures 5: Number of Employees in the Morning

Office start time (No of Employees)	7:00 AM	7.15 am	7.3o am	7.45 am	8:00 AM	8.15 am	8.30 am	8.45 am	9:00 AM	Total
A	3	0	2	8	11	14	2	10	0	50
B	6	1	1	10	8	16	1	7	0	50
C	1	0	2	8	9	17	2	10	1	50
D	2	1	3	8	9	14	3	10	0	50
E	2	1	1	7	11	13	2	11	2	50
F	2	0	1	8	11	14	0	12	2	50
G	5	0	2	9	9	15	1	8	1	50
I	7	0	1	8	7	15	1	10	1	50
J	2	0	0	13	11	13	2	9	0	50
K	2	0	1	9	10	11	3	12	2	50

Annexures 6: Number of Employees in the Evening

Office departure time (No of Employees)	3.30 pm	3.45 pm	4.00 pm	4.15 pm	4.30 pm	4.45 pm	5.00 pm	5.15 pm	5.30 pm	5.45 pm	6.00 pm	Total
A	0	1	5	10	10	3	7	0	1	0	3	40
B	0	2	4	7	16	3	5	1	2	1	2	43
C	0	3	8	7	10	4	6	0	2	0	4	44
D	0	4	6	8	13	3	4	0	2	0	3	43
E	0	6	8	9	9	2	6	0	3	0	1	44
F	0	5	6	8	12	2	6	2	2	0	1	44
G	0	3	7	9	9	3	7	0	3	0	2	43
I	0	4	5	11	10	1	5	0	2	2	2	42
J	0	3	9	9	11	2	4	2	2	0	3	45
K	0	3	9	11	11	3	4	0	2	0	2	45

Annexures 7: Common Trip Generation Rates



INSTITUTE OF TRANSPORTATION ENGINEERS
COMMON TRIP GENERATION RATES (PM Peak Hour)
(Trip Generation Manual, 9th Edition)

Code	Description	Unit of Measure	Trips Per Unit
PORT AND TERMINAL			
30	Truck Terminal	Acres	0.85
90	Park and Ride Lot with Bus Service	Parking Spaces	0.62
INDUSTRIAL			
110	General Light Industrial	1,000 SF	0.97
120	General Heavy Industrial	Acres	2.16
130	Industrial Park	1,000 SF	0.85
140	Manufacturing	1,000 SF	0.73
150	Warehousing	1,000 SF	0.32
151	Mini-Warehouse	1,000 SF	0.26
152	High-Cube Warehouse	1,000 SF	0.12
170	Utilities	1,000 SF	0.76
RESIDENTIAL			
210	Single-Family Detached Housing	Dwelling Units	1.00
220	Apartment	Dwelling Units	0.62
221	Low-Rise Apartment	Dwelling Units	0.58
230	Residential Condominium / Townhouse	Dwelling Units	0.52
240	Mobile Home Park	Dwelling Units	0.50
251	Senior Adult Housing - Detached	Dwelling Units	0.27
252	Senior Adult Housing - Attached	Dwelling Units	0.25
253	Congregate Care Facility	Dwelling Units	0.17
254	Assisted Living	Beds	0.22
255	Continuing Care Retirement Community	Dwelling Units	0.16
LODGING			
310	Hotel	Rooms	0.60
320	Motel	Rooms	0.47
330	Resort Hotel	Rooms	0.42
RECREATIONAL			
411	City Park	Acres	0.19
412	County Park	Acres	0.09
413	State Park	Acres	0.07
415	Beach Park	Acres	1.30
416	Campground / Recreation Vehicle Park	Camp Sites	0.27
417	Regional Park	Acres	0.20
420	Marina	Berths	0.19
430	Golf Course	Acres	0.30
431	Miniature Golf Course	Holes	0.33
432	Golf Driving Range	Tees / Driving Positions	1.26
433	Batting Cages	Cages	2.22
435	Multi-Purpose Recreational Facility	Acres	5.77
437	Bowling Alley	1,000 SF	1.71
441	Live Theater	Seats	0.02
443	Movie Theater without Matinee	1,000 SF	6.16
444	Movie Theater with Matinee	1,000 SF	3.80
445	Multiplex Movie Theater	1,000 SF	4.91
462	Horse Race Track	Acres	4.30
454	Dog Race Track	Attendance Capacity	0.16
460	Arena	Acres	3.33
473	Casino / Video Lottery Establishment	1,000 SF	13.43
480	Amusement Park	Acres	3.96
488	Soccer Complex	Fields	17.70
490	Tennis Courts	Courts	3.88
491	Racquet / Tennis Club	Courts	3.35
492	Health / Fitness Club	1,000 SF	3.53
493	Athletic Club	1,000 SF	5.96
495	Recreational Community Center	1,000 SF	1.45
INSTITUTIONAL			
520	Elementary School	1,000 SF	1.21
522	Middle School / Junior High School	1,000 SF	1.19
530	High School	1,000 SF	0.97
536	Private School (K-12)	Students	0.17
540	Junior / Community College	1,000 SF	2.54
560	Church	1,000 SF	0.55
565	Daycare Center	1,000 SF	12.46
566	Cemetery	Acres	0.84
571	Prison	1,000 SF	2.91
580	Museum	1,000 SF	0.18
590	Library	1,000 SF	7.30
591	Lodge / Fraternal Organization	Members	0.03
MEDICAL			
610	Hospital	1,000 SF	0.93
620	Nursing Home	1,000 SF	0.74
630	Clinic	1,000 SF	5.18
640	Animal Hospital / Veterinary Clinic	1,000 SF	4.72

Annexures 8: Sample Size Selection

Table 1. Sample size for ±3%, ±5%, ±7% and ±10% Precision Levels Where Confidence Level is 95% and P=.5.

Size of Population	Sample Size (n) for Precision (e) of:			
	±3%	±5%	±7%	±10%
500	a	222	145	83
600	a	240	152	86
700	a	255	158	88
800	a	267	163	89
900	a	277	166	90
1,000	a	286	169	91
2,000	714	333	185	95
3,000	811	353	191	97
4,000	870	364	194	98
5,000	909	370	196	98
6,000	938	375	197	98
7,000	959	378	198	99
8,000	976	381	199	99
9,000	989	383	200	99
10,000	1,000	385	200	99
15,000	1,034	390	201	99
20,000	1,053	392	204	100
25,000	1,064	394	204	100
50,000	1,087	397	204	100
100,000	1,099	398	204	100
>100,000	1,111	400	204	100

a = Assumption of normal population is poor (Yamane, 1967). The entire population should be sampled.

(Israel, 1992)

Annexures 9: Trip Generation and Employment simulation by Land utilization

Zone	Employment Generation	Generated Number of trips(due to floor area)
A	9188.891683	2958.823122
B	17004.39853	5101.319558
C	1591.437464	451.9682397
D	1305.990111	376.1251518
E	312.5878482	95.65188156
F	773.5102994	244.4292546
G	2716.285078	771.4249622
I	3603.897101	1059.545748
J	4615.698442	1320.089754
K	1496.033372	406.9210773
		12786.29875

Annexures 10: Trip Generation and Employment simulation by Land utilization

	A	B	C	D	E	F	G	I	J	K
A	0	0.93	1.47	2.48	1.18	1.87	1.97	2.08	2.77	1.75
B		0	0.54	1.55	2.11	1.46	1.04	1.15	1.74	0.82
C	B		0	1.01	2.47	1.88	1.36	0.61	2.06	0.28
D	B,C,K	C,K	K	0	2.66	1.97	1.55	0.8	2.25	0.73
E		A	I,G,F	I,G,F	0	0.69	1.11	1.86	1.59	2.93
F	E	G	I,G	I,G		0	1.12	1.03	0.9	2.06
G	B		I	I	F		0	0.75	0.7	0.82
I	B,C	C			F,G	G		0	1.45	0.89
J	E,F	G	I,G	I,G	F			G	0	2.34
K	B,C	C			A,B,C,	C,I,G	C,I	C	C,I,G	0

Annexures 10: MCC Count Total Trips by Trip Distribution with Peak time (15 Min Proximity)

		A-B	B-A	B-C	C-B	C-K	K-C	A-K	K-A	K-D	D-K	D-I	I-D	C-I	I-C	I-G	G-I	B-G	G-B	G-J	J-G	F-J	J-F	G-F	F-G	F-E
(7-8)	7-7.15	218	468	297	165.00	123.00	247.00	64	204	213	296.00	365	165	21	23	376	76	89	110	132	210	148	248	404	204	622
	7.15-7.30	192	435	270	332.00	134.00	295.00	89	175	143	281.00	432	132	24	35	513	98	121	131	147	247	224	324	532	232	613
	7.30-7.45	378	435	362	328.00	156.00	398.00	98	210	208	349.00	465	265	23	42	593	101	134	184	185	241	198	398	542	242	609
	7.45-8	463	286	257	461.00	165.00	344.00	78	216	211	358.00	467	298	30	37	497	89	165	186	187	201	298	498	513	301	614
		1251	1624	1186	1286.00	578.00	1284.00	329	805	775	1284.00	1729	860	98	137	1979	364	509	611	651	899.00	868	1468	1991	979	2458
(8-9)	8-8.15	546	652	297	452.00	159	496.00	86	141	197	384	487	210	29	39	576	134	86	144	214	305	146	346	574	314	652
	8.15-8.30	580	662	270	371.00	170	385.00	104	159	256	336	462	188	26	43	513	153	132	171	240	323	164	364	532	341	716
	8.30-8.45	466	597	262	298.00	201	254.00	116	158	264	312	515	269	23	51	593	120	112	194	180	271	120	320	542	310	542
	8.45-9	314	349	284	258.00	253	204.00	78	196	284	286	489	298	31	56	497	112	142	248	198	373	184	284	614	296	614
		1906	2260.00	1113	1379.00	1113	1339.00	384	654	1113	1318	1953	965	109.00	189	2179	519	472	757.00	832	1272.00	614	1314	2262	1261	2524
(9-10)	9-9.15	468	520.00	302	398.00	303	398.00	55	141	302	398.00	365	165	54	43	474	65	132	254	107	207	146	286	404	214	404
	9.15-9.30	438	473.00	284	374.00	335	374.00	48	138	246	374.00	432	232	43	57	313	71	113	181	123	217	142	214	518	261	487
	9.30-9.4	324	351.00	296	248.00	257	248.00	61	146	237	248.00	365	149	43	61	593	76	104	194	142	241	167	276	532	209	598
	9.45-10	446	490	275	280	375	280	80	165	275	280	367	198	68	68	497	98	164	248	136	202	120	202	513	198	513
		1676	1834	1157	1300.00	1270	1300	244	590	1060	1300	1529	744	208	229	1877	310	513	877	508	867	575	978	1967	882	2002
(3-4)	3-3.15	170	250	272	272	272	278.00	121	54	272	203	253	302	55	25	54	364	147	147	139	112	256	145	34	341	54
	3.1-3.30	132	270	280	280	280	274.00	156	62	280	276	219	289	29	32	68	336	171	141	192	108	264	167	38	374	63
	3.30-3.45	320	439	321	221	321	248.00	148	71	321	233	179	296	38	28	74	345	194	154	173	132	264	210	41	398	69
	3.45-4	498	471	398	298	398	280	136	68	398	257	215	297	54	34	71	396	248	148	193	104	208	186	34	374	71
		1120	1430	1271	1071	1183	1080.00	561	255	1183	969	866	1184	208	119	267	1441	760	590	697	456	992	708	147	1487	257
(4-5)	4-4.15	180	345	280	280	280	276.00	125	93	280	324	192	392	31	78.00	51	388	254	186	207	163	206	172	63.00	652	70.00
	4.15-4.30	289	387	348	348	348	291.00	147	104	348	357	189	389	26	67.00	62	465	242	168	237	147	246	263	67.00	617	69.00
	4.30-4.45	370	522	412	386	412	349.00	148	107	412	278	216	396	29	74.00	69	599	212	194	241	118	358	204	69.00	549	76.00
	4.4-5	435	430	386	394	386	288.00	149	86	386	298	235	433	35	63.00	58	532	268	168	282	194	374	279	63.00	565	81.00
		1274	1684	1426	1408	1426	1204.00	569	390	1426	1257	832	1610	121	282.00	240	1984	976	716	967	622	1184	918	262.00	2383	296.00
(5-6)	5-5.15	297	312	480	295	480	281.00	71	71	407	360	214	398	22	37.00	64	523	254	212	305	212	266	166	37.00	652	62.00
	5.15-5.30	373	269	337	248	337	324.00	76	76	337	342	282	433	27	53	67	528	242	168	297	178	296	254	53	716	59
	5.30-5.45	347	235	352	287	352	289.00	105	78	352	352	216	454	27	41	70	499	223	176	273	148	398	241	61	542	68
	5.45-6	411	212	370	373	370	290.00	86	62	470	321	265	498	27	44	68	592	268	164	312	208	410	267	44	614	57
	After 6	1428	1028	1539	1203	1539	1184.00	338	287	1566	1375	977	1783	103	175.00	269	2142	987	720	1187	746	1370	928	195.00	2574	246.00

Annexures 11: MCC Count Total Trips by Trip Distribution with Peak time (1 hour Proximity)

	A-B	B-A	B-C	C-B	C-K	K-C	A-K	K-A	K-D	D-K	D-I	I-D	C-I	I-C	I-G	G-I	B-G	G-B	G-J	J-G	F-J	J-F	G-F
(6-7)	611	884	464	598	586	524	23	43	423	487	243	112	54	36	354	142	135	421	213	412	241	434	301
(7-8)	1251	1624	1186	1286.00	578.00	1284.00	329	805	775	1284.00	1729	860	98	137	1979	364	509	611	651	899.00	868	1468	1991
(8-9)	1906	2260.00	1113	1379.00	1113	1339.00	384	654	1113	1318	1953	965	109.00	189	2179	519	472	757.00	832	1272.00	614	1314	2262
(9-10)	1676	1834	1157	1300.00	1270	1300	244	590	1060	1300	1529	744	208	229	1877	310	513	877	508	867	575	978	1967
(10-11)	1570	1542	1023	1117	1001	1117	76	623	1129	1117	1247	1029	104	97	483	264	432	827	335	687	312	1022	897
(11-12)	1709	1132	1104	1136	1022	1136	47	459	1020	1136	1269	955	111	102	387	354	498	784	453	756	267	894	845
(12-1)	1741	1186	1009	1168	1101	1168	63	599	1005	1168	1164	970	99	105	365	368	523	656	512	861	231	864	794
(1-2)	1300	1440	1332	974	1332	1103	321	221	1123	1002	967	986	95	123	205	384	678	764	865	752	467	234	849
(2-3)	1254	1395	1154	864	1154	986	243	212	1094	1131	994	1043	109	101	221	296	860	691	697	943	798	365	1096
(3-4)	1121	1430	1271	1071	1183	1080.00	561	255	1183	969	866	1184	176	119	267	1441	760	590	697	456	992	980	147
(4-5)	1274	1684	1426	1408	1426	1204.00	569	390	1426	1257	832	1610	121	282.00	240	1984	976	716	967	622	1184	918	262.00
(5-6)	1428	1028	1539	1203	1539	1184.00	338	287	1566	1375	977	1783	104	175	269	2142	987	720	1187	746	1370	928	195
	16841	17439	13778	13504	13305	13425	3198	5138	12917	13544	13770	12241	1388	1695	8826	8568	7343	8414	7917	9273	7919	10399	11606

Annexures 12: Sample Data Forecasting for Normal Travel trips in Study area

before 7		A-B	B-A	B-C	C-B	C-K	K-C	A-K	K-A	K-D	D-K	D-I	I-D	C-I	I-C	I-G	G-I	B-G	G-B	G-J	J-G	F-J	J-F	G-F	F-G
(7-8)	7-7.15	26				26	51				128	179	26			128		77			153			51	102
	7.15-7.30	51	102	51	51		128	26		77	153	128	51	51	77	205	77	102	77	51	77	51	102	179	128
	7.30-7.45	**179**	**179**	**179**	**153**	**205**	**128**	**51**	**26**	**26**	**153**	**179**	**51**	**77**	**77**	**205**	**102**	**153**	**77**	**26**	**128**	**77**	**128**	**205**	**256**
	7.45-8	230	205	230	205	384	128	26	26	179	77	179	77	77	102	256	256	128	153	77	281	77	128	153	230
(8-9)	8-8.15	205	307	153	102	256	102	26	51	77	128	153	179	51	281	332	205	77	153		281	230	153	256	128
	8.15-8.30	128	205	77	77	128	51	51	51		77	51	102	51	51	205	153	102	230	102	128	128	179	281	77
	8.30-8.45	77	77	26	51	51	26				51	26	77	26	26	153	153	51	51	51	102	77	51	102	26
	8.45-9	102	51		51	26					26		51		51	26	128	26		26	77			51	
(9-10)	9-9.15		51				26					26			26	26	51								
	9.15-9.30		26										26							26					26
	9.30-9.4																26				26				26
	9.45-10																26								
		997	1202	716	690	1074	639	179	153	358	793	921	639	332	690	1534	1176	716	742	358	1253	639	742	1279	997
	Total study area Emp			12786																					
	sample size			500																					

Annexures 13: Sample Data Forecasting for Flexi Travel trips in Study area

		A-B	B-A	B-C	C-B	C-K	K-C	A-K	K-A	K-D	D-K	D-I	I-D	C-I	I-C	I-G	G-I	B-G	G-B	G-J	J-G	F-J	J-F	G-F	F-G	F-E	E-F	A-E	E-A
(7-8)	7-7.15	-26				-26					26	26			26	-26	26	-26			-51			1	2			-26	
	7.15-7.30			26		26					-26				-26	26	-26		26		128								
	7.30-7.45	-26		-51	-26		-26				-26	0			51	128	0	-26	-26		77				-26			-26	
	7.45-8	-77	-26	-102	-26	-179	26			-26	26	-26	-26		-51	0	-128	-51	0		-102			0	-26	51	-26	-26	
(8-9)	8-8.15	-26	-77	-26	-26	-77				-26	-51	-77	-77		-205	-102	-51		51		-77	-51	-51	-51	26	-179	-26	-26	
	8.15-8.30	77	51	102	51	102					26	26	-77		102	-26	77	0	-51		77		-77	-128	26	-51	2	77	-51
	8.30-8.45	51	26	51		128				26		51	51		77	51	77	26	0		77	51		102	0	179			26
	8.45-9	51	26			51				26	26		102		51	26	26	26			102	51		179			-26		26
Total study area flex Emp			3171																										
sample size flavor to																													

Annexures 14: Employment distribution by Zone vise in Study area

	A	2959	B	5101	C	452	D	376	E	96	F	244	G	771	I	1060	J	1320	K	407
Before 7	2	118	6	612	1	9	1	8	2	4	1	5	0	0	0	0	1	26	1	8
7-7.15																				
7.15-7.30			6	612	6	54	3	23	3	6	4	20	3	46	2	42	2	53	3	24
7.30-7.45																				
7.45-8	8	473	8	816	7	63	10	75	8	15	9	44	10	154	12	254	8	211	7	57
8-8.15	13	769	10	1020	11	99	9	68	11	21	13	64	11	170	9	191	10	264	9	73
8.15-8.30	15	888	13	1326	17	154	15	113	17	33	16	78	18	278	20	424	19	502	21	171
8.30-8.45																				
8.45-9	12	710	7	714	8	72	12	90	9	17	7	34	8	123	7	148	10	264	9	73
Total	50	2959	50	5101	50	452	50	376	50	96	50	244	50	771	50	1060	50	1320	50	407

Annexures 15: Flexi hour data of Zone vise in Study area

Zone A	A-A/B-B/C-C/D/D-D/..	B-A	C-B	C-K	D-K	I-C	E-A	F-E	G-B
before 7									
7-7.15									
7.15-7.30									
7.30-7.45					(-1	(-1			
7.45-8		(-1	(-1	(-2	(+1				(-1
8-8.15	(-2	(-3	(-2	(+2					
8.15-8.30		(+2	(+2				(-2	(-2	
8.30-8.45	(+1	(+1				(+1	(+1	2	(+1
8.45-9	(+2	(+1					(+1		
after 9									

Zone B	A-A/B-B/C-C/D/D-D/..	A-B	c-B	K-C	D-K	G-B	J-G	I_G	F-G
before 7									
7-7.15		(+1			(+1				
7.15-7.30					(-1	(+1	(+1		
7.30-7.45			(-1	(-1		(-1	(+1		
7.45-8				(+1		(+1			(-2
8-8.15		(-1	(+1			(+2	(-1	(+1	(+1
8.15-8.30						(-2	(-1	(-1	(+1
8.30-8.45						-1			
8.45-9									
after 9									

Zone C	A-A/B-B/C-C/D/D-D/..	A-B	B-C	C-K	K-D	I-C	G-I	J-G	F-G
before 7						53			53
7-7.15		0					53		
7.15-7.30			53			0		53	
7.30-7.45		0		0		53	-106		
7.45-8		0	-106	-53		-53	0	53	-53
8-8.15			-53	0		0	0	106	
8.15-8.30		0				0	106	53	
8.30-8.45			106	53		106	53		
8.45-9						53			
after 9									

Zone D	A-A/B-B/C-C/D/D-D/..		C-K	K-D	I-D	G-I	J-G	F-G
before 7	Zone D	before 8						
7-7.15	1	7-7.16						
7.15-7.30							0	
7.30-7.45						0		-1
7.45-8			-2	-1	-1	-1	-3	
8-8.15	1			-1	-2	-3		
8.15-8.30	1				-4		3	
8.30-8.45	-3		2	1	2	3		1
8.45-9				1	4	1		
after 9								

Zone E	A-E	F-E	D-I	I-G	J-F	G-F
before 7	-1					
7-7.15						
7.15-7.30	1					
7.30-7.45	1		2	2		
7.45-8		2		0		2
8-8.15	-1	-7	-2	-2	-2	-2
8.15-8.30	1	0			-3	0
8.30-8.45		5				2
8.45-9						3

Zone F	A-A/B-B/C-C/D/D-D/..	A-E	E-F	D-I	I-G	G-F
Before 7						
7-7.15					1	
7.15-7.30						1
7.30-7.45		-1		-2		
7.45-8		-1	-1		-2	-2
8-8.15		2	-1	-1	-1	
8.15-8.30	-1		2		-1	-5
8.30-8.45		0		3		2
8.45-9	1		-1		3	4

Zone G	A-B	B-G	D-I	I-G	J-G	F-J	F-G
before 7				-1	-2		
7-7.15				-1	0		1
7.15-7.30				2	0		
7.30-7.45	1		-1				
7.45-8		1		-1			
8-8.15	-1						
8.15-8.30		-1	1				
8.30-8.45				1	1		
8.45-9				-1	2	2	(-1
after 9							

Zone I	A-A/B-B/C-C/D/D-D/..	D-I	G-I	J-G
before 7	-1		-1	
7-7.15			-1	
7.15-7.30				
7.30-7.45				
7.45-8			1	1
8-8.15	1	-1		
8.15-8.30	-1	1	1	
8.30-8.45	-1		0	-1
8.45-9	2			
after 9				

Zone J	A-A/B-B/C-C/D/D-D/..	A-B	B-G	D-I	I-F	I-G	J-G	F-J
before 7	-1							
7-7.15	-1	1	1	1		1		
7.15-7.30	2						3	
7.30-7.45	-2	-2	-1	1		1		
7.45-8	-1	-2	-3	-1		-1	0	
8-8.15	1	1				-1	-4	-2
8.15-8.30	1	1	1				0	
8.30-8.45		1	1	-1		1	1	
8.45-9			1			-1	1	2
after 9								

Zone K	A-B	B-C	C-K	I-C	J-G	G-I	J-G	F-G	D-K
before 7			-1	-1					
7-7.15			1	1		1		`	
7.15-7.30									
7.30-7.45	2					2	2		
7.45-8		-2	-2		-1	-2	-2		
8-8.15	2		-5	-6	1	1			-1
8.15-8.30		2	4	2					1
8.30-8.45			2	2		-1		-1	
8.45-9			2	2					
after 9									