

**DEVELOPMENT OF PREDICTIVE MODEL FOR INTRA-CITY BUS TRAVEL  
TIME IN MAKURDI METROPOLIS IN NIGERIA**

**BY**

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NIGERIA**

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TIME IN MAKURDI METROPOLIS IN NIGERIA**

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**Ewoh, James GODWIN B.ENG Civil (UAM) 2015  
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**DEPARTMENT OF CIVIL ENGINEERING  
FACULTY OF ENGINEERING  
AHMADU BELLO UNIVERSITY, ZARIA  
NIGERIA**

**FEBRUARY, 2020**

## DECLARATION

I declare that the work in this dissertation entitled **Development of Predictive Model for Intra-City Bus Travel Time in Makurdi Metropolis in Nigeria** has been performed by me in the Department of Civil Engineering, Ahmadu Bello University, Zaria.

The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this dissertation was previously presented for another degree or diploma at this or any other institution.

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NameSignature

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Date

## CERTIFICATION

This dissertation titled **Development of Predictive model for intra-city bus travel time in Makurdi Metropolisin Nigeri** by Ewoh James GODWIN meets the regulations governing the award of the degree of Master of Science in Civil Engineering of the Ahmadu Bello University, Zaria, and is approved for its contribution to knowledge and literary presentation.

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Dean, School of Postgraduate Studies                      Signature                      Date

## **DEDICATION**

With deep sense of humility, I dedicate this work to Almighty God, the one with whom all things are possible. The Alpha and Omega- the only one who determines the end from the beginning, the giver and protector of life, the Architect of the Universe and the Engineer of the Foundation of the world and to my beloved; Miss Henrietta Wueseter Usue and Miss Emmanuella Chivirter Usue.

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## **ABSTRACT**

The lack of information on bus travel time in Makurdi metropolis to enable trip makers plan for journeys is seen as a challenge in recent times. This study developed a multiple linear regression model for predicting bus travel time along bus routes within the metropolis and this was achieved through measurement of the physical characteristics of the roadway, identification of those factors that constitute impediment to intra-city bus travel time, measurement of intra-city bus travel time on the routes and development of prediction models for intra-city bus travel time using statistical package for social science and the development of curve fittings for the built models with data collected from field survey. The physical characteristic of the routes under study was determined and the lane width values obtained on the field were 3.6m, 3.7m, and 3.5m for Wadata, Modern Market, and Air force base routes respectively and these values conform with the Federal Ministry of works Highway Design Manual 2013 which states that 3.35-4.0m lane width be used for safety, efficiency and ease of operation and the manual also states that the minimum median width be 1.2m and usable shoulder width of 3m are desirable on all highways but narrow widths are acceptable on low volume highway. The factors that affect intra-city bus travel times were also determined with speed of travel, dwell times, 3-leg intersection and Cross intersections, volume of traffic which all ranged from 427-775 vehicles/hour which falls under the traffic category of heavy traffic as stated in the Federal Ministry of works Highway Design Manual, 2013 that traffic more than 1000 vehicles/day belongs to Heavy traffic, and number of roundabout and the route lengths been predominant.



The traffic data was collected from the metropolis using moving vehicle technique method of estimating travel time during survey, there was delay and congestion during the peak periods as compared to the off-peak period. From the regression analysis conducted, the built models captured route length which shows that the model is a good one for both peak and off-peak periods. A high value of coefficient of correlation for Peak and Off-Peak periods,  $R = 0.978$  and  $R = 0.997$  was obtained which indicates that there is a high and good correlation of about 97.8% and 99.7% between the dependent and independent variables and the models are very good reflection of the current traffic situation in the state capital. The coefficient of determination  $R^2$  which is a measure of goodness-of-fit, was found to be 0.956 and 0.994 respectively which indicates that 95.6% and 99.4% of the dependent variable (Travel time) at a confidence level of 95% and significant level of 0.05 is explained by both regression models. The findings also revealed that  $R^2$  value for the Off-peak period is relatively high which defines high accuracy of the model and the Peak period is associated with more complications but represent a more realistic travel situation.

The major findings, in the light of the peculiar set of present day conditions established that route length, T-junction and travel speed are important parameters used in the prediction of travel time because they contributed significantly to the built model at 95% confidence level and 0.05 interval levels. The proposed model is conceptually and operationally simple and should be used for cities in Nigeria having such challenges as noticed in Makurdi metropolis. On-street parking should be regulated so as to reduce traffic congestion on the highways within the metropolis

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## LIST OF ABBREVIATIONS/SYMBOLS

AFB: Air Force Base

ANN: Artificial Neural Network

APC: Automatic Passenger Counter

ARIMA: Autoregressive Integrated Moving Average

APNR: Automatic Plate Number Recognition

CBD: Central Business District

Df: Degrees of Freedom

HGV: Heavy Goods vehicles

LGV: Light Goods Vehicles

MM: Modern Market

MLR: Multiple Linear Regressions

NB: North Bank

$N_e$ : Average number of vehicles travelling western while test vehicle is travelling eastern

$N_w$ : Average number of vehicles travelling western while test vehicle is travelling western

$O_e$ : Average number of vehicles that overtake test vehicle while it was travelling eastward

$O_w$ : Average number of vehicles that overtake test vehicle while it was travelling western

$P_e$ : Average number of vehicles that test car passes while travelling eastern

$P_w$ : Average number of vehicles that test car passes while travelling western

R: Coefficient of Correlation

$R^2$ : Coefficient of Determination

RMSE: Root Mean Square Error

ROW: Right of way

SVM: Support Vector Machine

SEE: Standard Error of Estimation

SPSS: Statistical Package for Social Sciences

T: Travel time in Minutes

$T_w$  : Travel time in the westbound direction

$T_e$ : Travel time in the eastbound direction

UT: Urban Transport

UTC: Urban Traffic Control

$V_e$  : Volume in the eastbound direction

$V_w$ : Volume in the westbound direction

W: Wadata

WHO: World Health Organization

$X_1$ : Average dwell time in Seconds

$X_2$ : Route Length in Meters

$X_3$ : Time- headway in Minutes

$X_4$ : T- Junction

$X_5$ : Volume of traffic in Vehicle per Hour

$X_6$ : Travel speed in Meter per Minutes

$X_7$ : Number of stops

$B_0$ : Constant

$B_1 - B_7$ : Co-efficient which is the degree of contribution per unit change in the independent variable

# CHAPTER ONE

## INTRODUCTION

### 1.1 Background to the study

Transportation is a process that involves the movement of commuters, goods and services from a given point of origin to a specific destination (Okoko, 2006). Modes of transport include air, road, rail, water, cable, pipeline and space and travel time data can be gotten using automatic or manual method and elements are constantly being added to the world's highway, rail, airport, and mass transit systems, and new technologies are being applied for operating and maintaining the system safely and economically (Garber & Hoel, 2009).

Travel time may be defined as the total elapsed time of travel, including stop and delay, necessary for a vehicle to travel from one point to another over a specified route under existing traffic condition (Fosgerau and Fukuda, 2010).

“Man's ability to move himself and his materials from one point to another on the earth significantly influences his life and environment” (Ahmed, 2013). Tolley and Turton (1995) submitted both intra and intercity transportation system bridges the gap between people and resources in both space and time. Furthermore, Ogunsanya (2002) emphasized on the inevitability of transportation in the city and related basic necessities of life, and stressed that man's basic need of food, clothing and shelter could be hardly achieved without transportation. One can consider transportation to be the life of all social-economic and political life of a nation. This means that without transportation life as it is today would be inconceivable. The World Bank review (2012,a) echoed the same point by stressing that

economically, transport is the blood of cities; most countries, including developing countries, cities are the major source of the national economic growth.

The World Bank publication (2012,b) further asserted that socially, transport is the means of accessibility of jobs, health, education and social services that are essential to the welfare of the people. There is strong social demand for data that allows us to foresee the future and prepare for it as well as possible. This expectation is becoming stronger as environmental concerns become more alarming.

One of the essential parameter used for measuring the level of liveability of cities is the effectiveness of their public transport systems which mostly focuses on bus services (Cullinane, 2002; Ceder, 2007; Gurmu, 2010; Ibarra-Rojas et al., 2015; Gudmundsson et al., 2015). Public transport services in most urban areas of developing countries like Makurdi metropolis of Benue State employ the use of mini buses. These buses are usually owned and operated by non-governmental organizations or private individuals who gain profit from the business of providing public transport services. Bus services for public transport has been in use from time immemorial especially in developed countries (Cullinane, 2002; Zheng, 2011). The capacity of mini buses ranges between 10-14 persons, unlike standard bus services in modern cities in Europe, USA, Canada, and other cities that use coaches whose capacity range between 20-60 persons.

As the social economic characteristics of the people in the society changes with time and the development of transport corridors are leading to a drastic change in the way of living of the people in urban as well as in rural regions. Conceivably, separation between home and work, and similarity in most working hours through the whole spectrum of jobs have

resulted in movement of people between home and work each day at approximately the same times in the day and considerable volumes of traffic along relatively narrow corridors. In effect, heavy concentration of trips both in terms of time and space are the typical problems of commuting traffic; congestion, delays, frustration, and so forth (Olowosulu, 1998). Highly reliable transit service, therefore is of common interest and benefit to passengers and operators, and could always attract auto users to public transit. Hence the need to develop a model that will help commuters predict the time of travel from one point to another so as to ease transportation movement within the locality.

Travel time studies are used to carry out the following highway engineering tasks: determination of the efficiency of a route with respect to its ability to carry traffic, identification of locations with relatively high delays and causes for such delays; performance of before-and-after studies to evaluate the effectiveness of traffic operation improvements, determination of travel times on specific links for use in trip assignment models, determination of relative efficiency of a route by developing sufficiency ratings or congestion indices, compilation of travel time data that may be used in trend studies to evaluate the changes in efficiency and level of service with time and performance of economic studies in the evaluation of traffic operation alternative that reduce travel time (Garber & Hoel, 2009).

Like many other prediction models, researchers have stated that accurate prediction of bus travel time is very difficult, especially in a system where public transport system is not given priority (Liu, 2010), only average values could be easily estimated since most factors affecting the estimation of travel time are stochastic in nature (Ramezani and Geroliminis, 2012). These factors include weather condition, time of the day, driver behaviour, traffic

volume, vehicle characteristics and many more (Liu and Sinha, 2007; Izadpanah, 2010). Technically, major factors that can influence bus travel time include; intersection delays due to queues and traffic operations, delay caused by turning vehicles, on-street parking of vehicles, crossing pedestrians and cyclists, etc. (Liu, Clark, Montgomery, and Watling, 1999; Zheng, 2011;). Others include travel distance, number of stops, dwell times, number of boarding and alighting passengers and weather condition (Gurmu and Fan, 2014). Though a difficult task to achieve, technologies used for data collection in developed countries for travel time prediction have improved accuracy of estimations. And the modern devices used for data collection include; probe vehicles, loop detectors, digital cameras, Automatic Plate Number Recognition (APNR) camera, Bluetooth scanners, speed sensors (Coifman, 2000; Zheng, 2011; Bharti, Sekhar, and Chandra, 2017).

Urban transport (UT) matters for at least three reasons:

Urban transport systems facilitate the movement of people and goods and provide access to economic and social opportunities: The literature confirms that investments in transport lead to increased productivity and growth (Berg, Deichmann, Liu, and Selod, 2015).

Urban transport connects the urban poor to job opportunities and other services, and can facilitate safe accessibility for women and disabled and elderly persons: With planning and investment in public transit, integrated services and ticketing can improve affordability and convenience so that the poor can manage longer and often more complex journeys to their destinations (Suzuki, Cervero, and Luch, 2013).

Urban transport can help mitigate the negative consequences of congestion, Pollution, safety risks, and poor security associated with unplanned city growth: Rapid motorization puts city transportation systems and environment under pressure. Wasted time and fuel in traffic, and motor vehicle air pollution, cost billions of dollars (Litman, 2015). Weak

regulation and law enforcement increases urban safety risks. Africa, for example, has the highest proportion of pedestrian and cyclist deaths at 43 percent of all road traffic casualties (World Health Organisation, 2015).

The importance of public transport stemmed from the fact that it provides mobility for those who cannot afford to buy a car and helps in creating and maintaining livable communities by retrieving highway congestion and assuring long term sustainability in terms of resource consumption and environment (Paul, 2001). The increasing urbanization and the corresponding growing demand for urban transportation in addition to other factors such as low motoring have made urban transportation service a basic necessity (Olowosulu, 1996).

Trips are not just made but rather, people travel from one origin to a destination to satisfy their needs for various activities such as work, shopping, recreation etc. Thus, the importance of travel time cannot be overemphasized (Chiejina, 1982)

For Engineers, Regional and Town planners who conduct the traffic flow, travel time and delay studies are normal methods which are used to evaluate transportation facilities and plan improvement (Wolshon and Pande, 2016). Previous studies (Chapman, Gault, and Jekins, 1976; Bruzelius, 1979; Adebisi, 1986;) have investigated passengers' waiting time and several mathematical models have been proposed for its computation. A multiple linear regression model will be developed to help predict travel time within Makurdi metropolis.

## **1.2 Statement of the Research problem**

The problems facing Makurdi metropolis are not only many but are also very complex; one of the most apparent, being intra-town mobility. Intra-City transportation problems in Makurdi could include increase in delay and traffic congestion, poor road facilities, road

degradation, insufficient right of way. All these have existed for a long time and hence the need to develop a multiple linear regression model for predicting bus travel time along bus routes in the metropolis so as to minimize time waste by commuters and to better plan for a journey before embarking on any.

### **1.3 Justification of Study**

Proper information on bus travel time in Makurdi metropolis will help eliminate delay and traffic congestion on our major highways within the metropolis and this study has developed multiple linear regression models for predicting bus travel time along the routes in the metropolis by specifically assessing bus travel time on routes without designated bus stops, assessed bus dwell time, travel speed and volume of traffic in a heterogeneous traffic stream in Makurdi and developed the curve fittings for the built models to help check the sensitivity of its use in practice and this in turn will help reduce delay, traffic congestion and minimize travel time.

### **1.4 Aim and Objectives of study**

#### **1.4.1 Aim of study**

The aim of this research is to develop a predictive model for intra-city bus travel time of bus services in Makurdi metropolis.

#### **1.4.2 Objectives of study**

The objectives of the study include to:

1. Measure the physical characteristics of the roadway on the selected routes in the metropolis



2. Identify the factors affecting intra-city bus travel time of unconventional bus transit in Makurdi metropolis.
3. Measure intra-city bus travel times of unconventional bus transit of some selected routes in the metropolis
4. Develop a predictive model for intra-city bus travel time of unconventional bus transit in the metropolis
5. Develop the curve fittings for the built models.

### **1.5 Scope of Research**

This research work was limited to modelling intra-city bus travel times in Makurdi metropolis using the factors that influence bus travel time of unconventional bus transits. The routes covered during the research were Wadata route (11.8km), Modern market route (13.8km) and the Air Force Base route (10.2km).

## **CHAPTER TWO**

### **LITERATURE REVIEW**

#### **2.1 Conceptual Framework**

##### **2.1.1 Travel Time**

The importance of travel time in assessing road network performance by transport planners and engineers for efficient operation management and for developing travellers' information system for commuters cannot be overemphasized. This is because most travellers are keen about trip planning and wish to optimize or minimize waiting time due to their high value of travel time (Zaki Ashour, Morkary, and Hesham 2013; Gudmundson, Hall, Marsden and Zietsman 2015).

According to Bonsal, Liu, and Young (2005), the act of modelling behaviour of transport systems using realistic assumptions is very essential, "it is better to use values that are realistic-but-unsafe than values that are safe-but-unrealistic" and travel time can be carried out on all the modes of transportation i.e. road, air, rail, water, etc. (Rogers and Enright, 2016).

##### **2.1.1.1 Applications of Travel Time**

Travel time studies are used to carry out the following highway engineering tasks.

1. To determine the efficiency of a route with respect to its ability to carry traffic
2. To identify locations with relatively high delays and causes for such delays
3. Performance of before-and-after studies to evaluate the effectiveness of traffic operation improvements
4. To determine travel times on specific links for use in trip assignment models
5. Determination of relative efficiency of a route by developing sufficiency ratings or congestion indices

6. Compilation of travel time data that may be used in trend studies to evaluate the changes in efficiency and level of service with time
7. Performance of economic studies in the evaluation of traffic operation alternative that reduce travel time.

#### **2.1.1.2 Methods of Estimating Travel Time**

The methods that can provide travel time estimations can be divided into five categories

##### **2.1.1.2.1 The spot speed measurement methods**

These are based on the existence of inductance loop detectors (single or dual) for the provision of real time traffic information. Other techniques involve infrared and radar technologies. These systems only measure traffic stream speeds over a short road segment at fixed locations along a road. These spot speed measurements are used to compute spatial travel times over an entire trip using space mean speed estimates. New approaches that match vehicles based on their lengths have also been developed (Coifman and Cassidy 2002, Coifman and Ergueta, 2003).

##### **2.1.1.2.2 Spatial travel time methods**

This method use fixed location equipment to identify and track a subset of vehicles in the traffic stream. By matching the unique vehicle identifications at different reader locations, spatial estimates of travel times are computed. Typical technology includes automated vehicle identification (AVI) and licensed plate video detection systems.

##### **2.1.1.2.3 Probe vehicle technologies**

Track a sample of probe vehicles on a second-second basis as they travel through a link. These technologies include cellular geo-location, global positioning systems (GPS) and automated vehicle location (AVL) systems. The use of probe vehicles enables a sample of the travel times experienced by all vehicles travelling through the link to be obtained.

Previous research has examined how accurately probe vehicle travel times reflect the travel times of all the vehicles (Van, Hellinga, Yu, Rakha, 1993; Turner and Holdener, 1995).

#### **2.1.1.2.4 Regression models**

These are the most commonly used methods to estimate travel times and are based on regression analysis. Due to the large number of factors influencing the traffic delay, there are no accurate mathematical models describing the relationship between the travel time and its influencing factors. Therefore, the estimation of travel time becomes a complex problem due to the large number of factors that could affect traffic dynamics. The main characteristic of urban arterials and streets is the unexpected growth decay of queues. Such a travel time estimation algorithm should react quickly and accurately in the development of unexpected traffic problems when using dynamic data.

#### **2.1.1.2.5 Artificial Neural Network (ANN)**

This has been widely used in traffic engineering (Dougherty, 1995). They allow complex non-linear relationships between variables to be determined. Although the results of such techniques have been promising, they lack rigor and theoretical background.

### **2.1.2 Bus Transit**

In Nigeria, bus transit is the most important mode of intra- urban public transport, as people rely heavily on public transportation due to low level of household incomes.

The bus transit systems in operation in Nigeria are mostly privately run and they offer unscheduled services. They mostly operate the fixed route strategy where vehicles ply a designated route and stop at fixed stations or at any point along the route, on demand.

Overcrowding, long travel time, and ill- maintained vehicles, and delays are some travelers' impression on travel by passenger bus. Another very common feature is that drivers of

these buses are faced with the decision on whether to wait at a particular terminal for full load or gamble on finding passengers by the roadside.

Thus, planners of transit properties are faced with dilemma on which operating policies to enforce. A rational basis to guide the adoption of good operational practices that ensure improved quality of transit service is needed.

#### **2.1.2.1 Bus Passenger Trip Times**

Bus passenger trip times have been broadly classified into in-vehicle and out of vehicle time. The latter is the portion of the time a passenger commits to a trip even though the time is not spent in the vehicle; while the in-vehicle time is the time he spends in the vehicle.

The in-vehicle time is made up of three major elements: non-stop running time, delay at patron stop and what may be termed as “general delay” (Olowosulu, 1996).

Delay at stops comprises time spent in actual loading and unloading patron and a “penalty” time. The time for loading and unloading depends on several factors including fare collection mechanisms, the amount of baggage carried by patrons, number of passengers on the bus and the number to board or alight, physical design, number of doorways (Chapman, Gault, and Jekins 1976; Hendrickson 1981). It has been observed that bus passengers alight more quickly than board particularly when one man operation is used (Fouracre, Maunder, Pathak and Rao 1981).

Penalty time is subdivided dead time and penalty for stopping. Penalty for stopping is due to deceleration to and acceleration from the stop. Dead time is the period which the bus is stationary before any embarking or disembarking. It depends on whether passengers are to board or alight or both (Chapman, Gault, and Jekins 1977; Fouracre et al. 1981).

A number of researchers have assumed dead time to be constant (e.g Adebisi 1986). However, in situation where passengers lack knowledge of bus schedule and often inquire about bus destination, bus passengers tend to waste more time because of patron inadequacies, bus dead time times seems passenger/driver dependent (Chiejina 1982).

General delay comprises stop delays and traffic and roadway delays. The latter is due to traffic conditions, weather conditions, etc, that induces the bus drivers to maintain speed of travel less than the desired speed. Stop delay occurs during the period which the vehicle is stationary (e.g at traffic signals). The general delay depends on the speed of other traffic on the link, road design, probability of delay, amount of time spent in each delay (Chapman et al. 1976; Fouracre et al. 1981).

Passengers' out of vehicle time is made up of two components: the waiting time and walking time (access/egress time).

The waiting time experienced by a transit patron is one of the most important elements of the level of service provided by a public transport system. It consists of (i) the waiting time at the point of boarding and (ii) schedule delay. The latter represents the extra time a user commits to a trip because his actual arrival time at his destination differs from his preferred arrival time.

## **2.2 Travel Time Models**

Chien et al. (2002) categorized travel time prediction models into three main types: Univariate, Multivariate and Artificial Neural Network (ANN).

Univariate models are models with results that are based on historical traffic data. The multivariate model's travel time forecast is explained by a mathematical function with respect to a set of independent variables. Lastly, the ANN is a "black box" system that is built with a non-specified mathematical structure.

### **2.2.1 Univariate Models**

Univariate models can be categorized into historical average models and time series models. A link travel time prediction model for an urban traffic control (UTC) network was designed by Anderson, BellSayers, Busch, and Heymann (1994) using the Autoregressive Integrated Moving Average (ARIMA) approach. The outcome of the travel time model could assist transit service providers with bus management and provision of passenger information. Two different models were designed and evaluated by the authors. The first model was based on information of the previous 11 vehicles passing through the intersections while the second model was based on the predicted and actual link travel time of the preceding vehicle (Anderson et al. 1994). Overall, the second model included much simpler procedures without losing any predictive accuracy. Nevertheless, in the model calibration, all vehicles including cars, buses and heavy duty vehicles were assumed to decelerate to a complete stop and accelerated to a certain running speed at a constant rate, which does not reflect the real operations.

Van et al. (1997) utilized on-site loop detectors to collect traffic data and then applied a linear input-output ARIMA model to predict travel time on freeways in the Netherlands. In this research, the proposed algorithm was separated into two parts. The first part was intended to determine if there was traffic congestion. If the freeway was not congested, the travel time through the freeway link would be determined from the link distance and the free flow speed of 120 km/hr. If the roadway was congested, the ARIMA model would then be used to predict the new traffic volume leaving the link. Van et al. (1997) applied these new traffic volumes to a mathematical function and estimated the travel delay time. The final travel time was calculated as the sum of traffic delay and the free flow traffic travel

time. Univariate models usually have a short time lag in the predicted real-time bus journey time (Patnaik, Chien, and Bladikas 2004). Moreover, the accuracy of the prediction results changes according to the variation of the historical average results from previous trips (Smith and Demesky 1995)

### **2.2.2 Multivariate Models**

These are models having two or more independent variables such as regression models

#### **2.2.2.1 Regression Models**

Regression modelling is a simple and direct travel time estimation technique. This method has been applied to estimate traffic travel time along arterials and freeways, and transit travel time and delay.

Travel time prediction models on multilink streets in the Central Business District (CBD) of medium to large cities were developed by Frechette and Khan (1997), using a Bayesian regression approach. Several videocameras were used to collect traffic data on streets. Four different types of models were generated with respect to various street networks. Travel times were estimated based on counts of turning movements at intersections, average number of signalized intersections per kilometre, percentage of heavy vehicles on road, and average transit flows on links (Frechette and Khan 1997). When all four models were compared, the one-way street travel time model's prediction was found to have the smallest error value. Video camera installation for data collection was not, however, as dependable as loop detectors. The camera images could be affected by sunlight and fog, directly impacting the accuracy of the travel time prediction.

Abdelfattah and Khan (1998) developed a nonlinear regression model to estimate bus delays. The bus route was divided into different links in the model. The explanatory variables considered to affect bus delays included link length, number of bus stops per link,



total traffic density on each link and bus efficiency ratio estimates (Abdelfattah and Khan 1998). Dwell time and the number of passengers boarding buses, however, which were also relevant factors for bus delay prediction, were excluded from the model's calibration process. In addition, bus delay time was estimated in a link-based format. Therefore, the overall delay experienced by a bus in reaching its final destination would be the sum of delay estimates for individual links. Thus, the error of the delay estimation would be propagated downstream of the bus routing path (Chen and Chien 2001).

Final findings were dependent on the availability of probe vehicles or other similar high-quality data (Juri, Unnikrishnan, and Waller, 2007). This approach would be costly if many probe vehicles were required to collect data along freeways in order to develop a highly reliable model (Juri et al. 2007).

Bus travel time also depends on traffic congestion conditions and ridership along the route. Because there are more alighting and boarding passengers during rush hours, parameters used for each variable during such time periods should be different from those used during the non-rush hours. Even though regression models are easy and simple to apply, they suffer from several limitations, the biggest being that many variables in transportation are highly correlated (Jeong and, 2004). Moreover, regression models are not capable of estimating dynamic travel time, and hence the bus arrival time estimates may not be responsive to poor weather conditions or traffic incidents. Last but not least, regression models are site specific and have to be recalibrated for various environments (Liu and Ma, 2007). This increases the time and costs needed to implement them.

Multiple linear regression models is a mathematical function that defines the relationship between independent (input) and the dependent (output) variables that explain the behaviour of a system (Rohatgi and Saleh, 2001; Soong, 2004).

Development of multiple linear regression model usually employs statistical tools such as; Statistical Product for Service Solution (SPSS), Microsoft Excel, etc. which are capable of defining the relationship between the independent and dependent variables in form of a function. The strength of the function is usually examined using its coefficient of determination (also known as  $R^2$ ) value which ranges from 0-1, with 0 defining a weak relationship and 1 showing a stronger relationship between variables (Rohatgi and Saleh, 2001). Another relevant model performance indicator is the measure of the sensitivity of input variables using their respective P-values. The P-value tests the null hypothesis that coefficient of a variable is equal to zero, meaning the variable has no effect on the model; such that a low P-value ( $<0.05$ ) indicates that the null hypothesis should be rejected, that is, the variable is likely to be meaningful to the model.

### **2.2.3 Artificial Neural Network**

The ANN can model complicated input and output relationships, without specifying the form of an explicit function. Another advantage of ANN-based models is that they do not require independencies among input variables (Chen et al. 2007), like regression models. Currently, there are many methodologies to train ANNs. One of the common training methods is the backpropagation training approach. This algorithm is responsive to dynamic, non-lagging, and over-prediction conditions (Smith and Demetsky 1994).

Chien et al. (2002) developed two ANNs (one trained on link-based data and another on stop-based data) to study which model had the better travel time estimation performance. The stop-based model had a lower Root Mean Square Error (RMSE) than the link-based

model. It also had a higher capacity to accommodate stochastic conditions at stops further downstream than the link-based model. Moreover, the stop-based ANN was suitable for scenarios where there were multiple intersections between stops while the link-based algorithm was more suitable for many stops with few intersections. Based on the analysis, an enhanced ANN was developed with a combination of link-based and stop-based data (Chien et al. 2002).

Subsequently, Jeong and Rilett (2004) and Chen et al. (2007) used the backpropagation training method to generate ANNs. Both models were compared with other estimation models, including historical average and linear regression models, in terms of prediction accuracy. Although results obtained from the backpropagation training method were reliable, this training method had shortcomings including long computation time, very slow convergence rate, and arbitrary problems resulting from the selection of learning and momentum ratios (Hung and Adeli 1994). In addition, there are several alternative types of neural networks for estimating travel time. Yuet al. (2006) used a support vector machine (SVM) approach to predict bus arrival time.

### **2.3 Review of Empirical Works**

Chiejina (1982) modelled Intra-city bus travel time using primary data from Kaduna and he adopted strategies for modelling of travel time using distribution modelling technique and stepwise regression technique and statistical package for social sciences (SPSS) software was used in his analysis of data and his major findings were that in the light of peculiar set of present day conditions, buses total dead times at stops are random variables following a gamma distribution and boarding/ alighting times are linear functions of number of boarding/ alighting passengers.

Kwon et al. (2000) developed a linear regression model to estimate travel time on a freeway using flow and occupancy data collected from loop detectors and historical travel time information collected from probe vehicles. Owing to the limitations of loop detectors such as technical problems or impacts by weather conditions, some data were lost, and the interpolation of data from adjacent stations was required. All detectors for the proposed model development were required to be equally spaced. In real life, however, loop detectors on freeways are usually spaced irregularly. This caused the proposed model's results to be unrealistic. The authors emphasized that simple prediction models such as linear regression models were useful for short-term forecasts, but long-term travel time prediction required historical data.

Jimoh, (2003) worked on Journey time characteristics of an unconventional intra-urban bus transit service along Sabo- Samaru route, where he developed a model for predicting bus travel time using commercial buses in a typical Nigerian town. And he used the moving vehicle technique method of estimating travel time and he found out that his model could predict travel time with high value of 0.884 for the co-efficient of correlation ( $R$ ) and the co-efficient of determination ( $R^2$ ), was found to be 0.782 but some parameters he considered were not validated and the accuracy of the model is questionable since the model could not capture the length of the route under study.

A multivariate linear regression model to estimate bus arrival time between two points along a route was developed by Patnaik, Chien, and Bladikas, (2004). In order to include the dwell time in the bus delay estimation, the authors installed an Automatic Passenger Counter (APC) on buses to count the number of people getting on board and the time taken. The proposed regression model was explained by attributes of distances between points,

average dwell time, number of bus stops along the path and time periods (Patnaik et al. 2004). Owing to limited wireless telecommunication technology on buses, the APC data could only be downloaded after the bus had reached the garage or the bus terminal.

Adeke, (2019) modelled travel time of urban routes without designated bus stops in Makurdi town using artificial neural network and he considered journey speed, route of length, volume of motorcycles in the traffic stream, volume of trucks, average dwell time and he further analysed his data using SPSS software and he established an average bus travel time of 15 minutes approximately for all routes in Makurdi metropolis.

Olowosulu, (2002) worked on fixed stop and hail stop mode of service of fixed route intra-urban bus operation using dynamic system of operation and he developed a probability model for checking the behaviour of bus operations using two variables but the model failed to capture the length of travel as compared to other researchers

Bharti et al. (2017) considered traffic volume and car percentage composition in traffic stream as independent variables for travel time estimation modelling. The authors recommended the use of Artificial Intelligence method such as the Artificial Neural Networks (ANN) and the use of Stochastic Response Surface Methods (SRSM) since they yielded relatively accurate results.

Because there is no previous research work which attempted to predict bus travel time on routes without well established bus stops in a heterogeneous traffic stream associated with several uncertainties in estimating model input parameters, in this part of the world, this study is relevant and justified.

## CHAPTER THREE

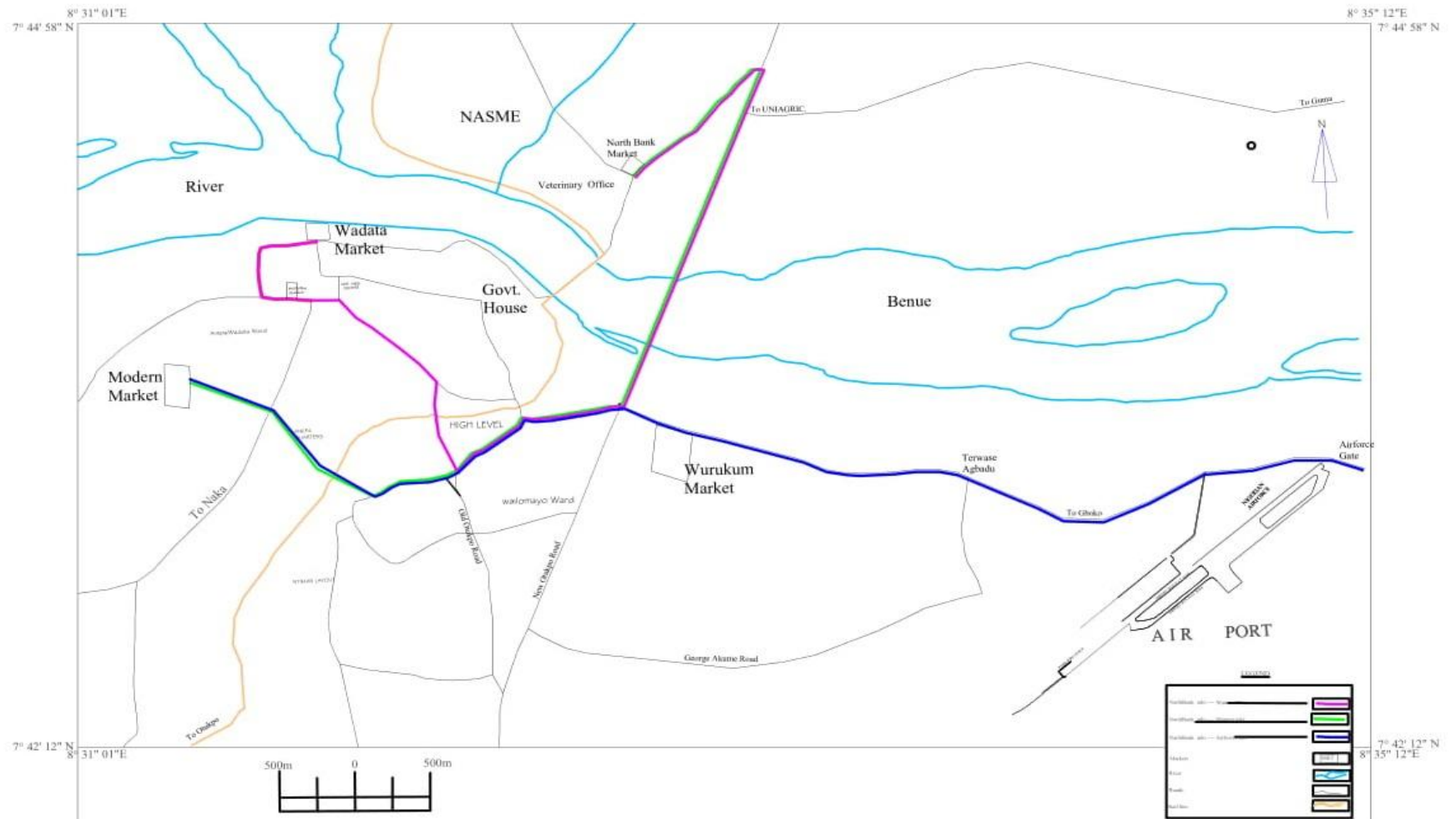
### METHODOLOGY

#### 3.1 Description of Study Area

This study considered Makurdi metropolis, the capital city of Benue state Nigeria. Makurdi is located on Latitude  $7^{\circ} 43' 56''$ N and Longitude  $8^{\circ} 32' 21''$ E (Nigeria Google Map, 2018). Nigeria population census (NPC) 2006 revealed that, human population in Makurdi metropolis was estimated at 500,797 people (NPC, 2006).

Residents of Makurdi are predominantly civil servants, business men and women, and students. Traffic stream in Makurdi metropolis is characterized by mixed traffic or heterogeneous comprising private cars, motorcycles, tricycles, minibuses, Heavy Goods vehicles (HGV), Light Goods Vehicles (LGV) and pedestrians and Mini-buses are the major mode of public transport for mass movement conveying people along routes within the traffic network.

The design and construction of roadways in the town does not provide special road facilities such as bus lane for the mini-buses therefore, the buses travel and share lanes with other traffic components. The routes in Makurdi metropolis considered for this research are presented in figure 3.1 which includes; North bank located on Lat.  $7^{\circ} 44' 46.8''$ N and Longitude  $8^{\circ} 32' 49.4''$ E – Wadata located on Lat.  $7^{\circ} 44' 13.1''$ N and Longitude  $8^{\circ} 31' 48.0''$ E (NB-W), North bank – Modern market located on Lat.  $7^{\circ} 43' 44.5''$  N and Long.  $8^{\circ} 31' 23.3''$  E (NB-MM) and Modern market – Air Force base located on Lat.  $7^{\circ} 43' 25.9''$ N and Longitude  $8^{\circ} 35' 10.8''$ E (MM-AFB)



**Figure 3.1: Makurdi metropolis showing study routes**  
**Source: Ministry of Lands and Survey (2019)**

### **3.2 Measurement of Physical characteristics of Roadway**

The data used for this study is the primary data from Makurdi metropolis and during the research study, a traffic study under the category of inventory was carried out and this provided a list of existing information of the roadway characteristics such as route length, street, route width, number of 4-legged intersections, number of 3-legged intersection, number of lanes and types of traffic controls were recorded via physical observation and measurement were carried out using measuring tapes and meter counter wheel. The routes covered during the research were Wadata route (11.8km), Modern market (13.8km) route and the Air Force Base route (10.2km), all in Makurdi metropolis since these were the routes that town service buses operate on.

### **3.3 Identification of the factors that affect intra-city Bus Travel Times**

Dynamic traffic study was carried out to determine those factors affecting travel, as it involves the collection of data under operational condition through physical survey and we were in the buses that were operating on them and this gave rise to our findings to these factors that influence bus travel time.

The time a bus spends at a stop while boarding or alighting passengers constitutes delay to patrons already on board and thereby increasing the travel time of buses while plying the routes within the metropolis and these parameters were gotten while the buses were in motion, as the vehicle stops to either alight or pick a passenger, the time spent were recorded and the averages taken and the number of times these buses stops before arriving its final destinations too were recorded using timing stop watch and record sheets and pen.



### **3.4 Measurement of intra-city Bus Travel Times on the Selected Routes**

The bus travel times on the routes were collected from a sample of sixty (60) buses for the two major route each and forty (40) for the Air Force Base route for both peak and off-peak periods with a total sample size of buses to one hundred and sixty (160) and in developing multiple linear regression model, the minimum number of sample of twenty (20) is allowed and this was achieved using the Moving Vehicle Technique; traffic data were collected and recorded in appendix A.

#### **3.4.1 Collection of travel time data using Moving – Vehicle Technique**

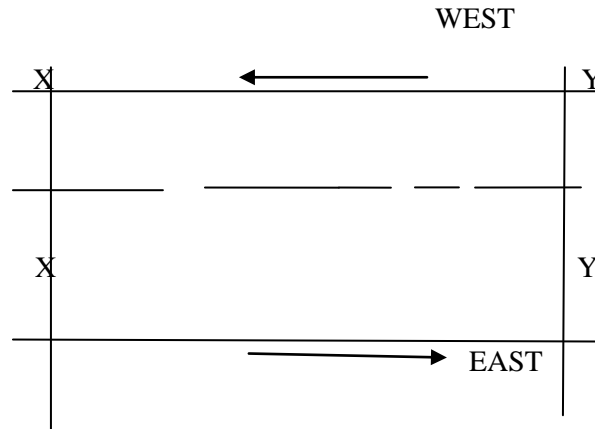
Data were collected from primary source via physical observation and field inventory of the routes under study, alongside dynamic study to help find lasting solutions to problems faced by commuters and the moving vehicle technique approach of estimating travel time was adopted to help reveal the real traffic situations within the metropolis.

Three trained enumerators were engaged in the collection of the data along the travel stream with each having a record sheet and pen for proper collection of data after a comprehensive training by the researcher.

First observer was responsible for counting the number of vehicles moving in opposite direction of the test vehicle ( $N_e$  and  $N_w$ ). Second observer was responsible for counting the number of vehicles that overtakes the test vehicle while travelling in both direction, ( $O_e$  and  $O_w$ ). Third observer was responsible for counting the number of vehicles that the test vehicle overtakes ( $P_e$  and  $P_w$ ).

In this technique, the observers make a round trip on both sections of the road as seen in the figure below, where it was assumed that the road runs west to east. The observers start

collecting the relevant data at section X-X and drive the car eastward to section Y-Y, then turns the vehicle around and drives westward to section X-X again. This procedure was repeated using different town service buses within the metropolis and a minimum 30 sample data was collected for each route of study except for Air force base route 20 samples of data was collected.



**Figure 3.2:** Travel direction on the routes.

The time it takes to travel east X-X to Y-Y is denoted as  $T_e$ , in minutes while the time it takes to travel west Y-Y to X-X was denoted as  $T_w$  in minutes. The number of vehicles that overtake the test car while travelling west from Y-Y to X-X, which is travelling in the westbound direction, was denoted as  $O_w$  and the average number of vehicle that overtake test vehicle while travelling eastward is  $O_e$

### 3.4.2 Traffic Volume Data and Travel Time Data

Traffic data collection and projections of traffic volumes are basic requirement for planning of road development and management schemes. According to (Garber & Hoel, 2009) the volume of the study section can be obtained from the expression:

The volume ( $V_e$ ) in the eastbound direction was obtained using data from Appendix B and calculated as seen in appendix C using Equation 3.1

$$V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} \quad (3.1)$$

The volume ( $V_w$ ) in the westbound direction can be obtained using equation 3.2:

$$V_e = \frac{(N_e + O_w - P_w)60}{T_w + T_e} \quad (3.2)$$

When taking data for travel time studies, the routes physical characteristics were measured and then vehicles were boarded and the times taken to cover the chosen section of the roads were recorded using the Moving Vehicle Technique method of obtaining travel time. This was conducted for both traffic streams; town service buses were used in carrying out the research work since it is the most common mode of transportation that plies the routes in Makurdi metropolis.

The traffic data collected was for the working days of the week and the travel time can be calculated using the formulae below; the average travel time  $T_w$  in the westbound direction is obtained from Equation 3.3:

$$\bar{T}_w = T_w - \frac{(O_w - P_w)60}{V_w} \quad (3.3)$$

The average in travel time  $T_e$  in the eastbound direction is obtained from equation 3.4:

$$\bar{T}_e = T_e - \frac{(O_e - P_e)60}{V_e} \quad (3.4)$$

where

$N_e$ : Average number of vehicles travelling western while test vehicle is travelling eastern

$N_w$ : Average number of vehicles travelling western while test vehicle is travelling western

$O_e$ : Average number of vehicles that overtake test vehicle while it was travelling eastward

$O_w$ : Average number of vehicles that overtake test vehicle while it was travelling western

$P_e$ : Average number of vehicles that test car passes while travelling eastern

$P_w$ : Average number of vehicles that test car passes while travelling western

T: Travel time in Minutes

$T_w$  : Travel time in the westbound direction

$T_e$ : Travel time in the eastbound direction

$V_e$  : Volume in the eastbound direction

$V_w$ : Volume in the westbound direction

### 3.4.3 Travel Speed

This is the bus speed over the length of the route for the period of the bus travel time (which excludes time at bus stops over the section of travel). This is mathematically expressed

$$\text{as: } \textit{Travel Speed} \left( \frac{M}{min} \right) = \frac{\textit{Route Length}}{\textit{Travel Time}} \quad (3.5)$$

The travel speeds were measured in Meter per Minute as this can be seen in appendix D and the various buses moved at different speeds due to lack of coordination within the transport sector in the state capital.

### 3.4.4 Time Headway

Headway is the time that elapses between the arrival of the leading vehicle and the following vehicle at the designated test point. This was measured by starting a stopwatch when the front bumper of the first vehicle crosses the selected point, and subsequently recording the time that the second vehicle's front bumper crosses over the designated point. Headway is usually reported in units of seconds or minutes and in this study, the minute unit was used.

The behavior of vehicle arrival is different at different flow conditions. As the vehicles arrive at a point at time  $t_1, t_2, \dots$ . Then the time difference between two consecutive arrivals is defined as the headway.

Mathematically headway:

$$h_1 = t_2 - t_1, \dots, h_2 = t_3 - t_2 \quad (3.6)$$

### 3.5 Model Formulation for Intra-City Bus Travel Time

The multiple linear regression models for estimating short term bus travel time along the major routes within the metropolis was developed using statistical package. The process involved creation of a spreadsheet in Microsoft Excel for the raw data which comprised the independent and dependent variables. The Excel file was then imported into SPSS for statistical analysis to build the regression models. Results of the analysis revealed the data characteristic which was used to check for accuracy of the built model. The built model was first validated using goodness of fit test based on the measured and predicted bus travel times.

The multiple linear regression (MLR) model for the Intra-City bus travel time is of the form

$$T = B_0 + B_1X_1 + B_2X_2 + B_3X_3 + B_4X_4 + B_5X_5 + B_6X_6 + B_7X_7 \quad (3.7)$$

Where T is the dependent variable,  $X_1, X_2, X_3$  and  $X_7$  are the independent variables,  $B_0, B_1, B_2, B_3$  and  $B_7$  are the unknown parameters. In effects,  $B_1, B_2, B_3, \dots, B_7$  are called the Partial Regression Coefficients and  $B_0$  is the regression constant which represent that portion of the value of dependent not explained by the independent variable “travel time”. However, one great advantage of multiple linear regression models is that they can reveal which inputs are less or more important for predicting travel times

Where,

T = Travel time in Minutes

$X_1$  = Average dwell time in Seconds

$X_2$  = Route Length in Meters

$X_3$  = Time- headway in Minutes

$X_4 = T$ - Junction

$X_5 =$  Volume of traffic in Vehicle per Hour

$X_6 =$  Travel speed in Meter per Minutes

$X_7 =$  Number of stops

$B_0 =$  Constant

$B_1 \dots B_7 =$  Co-efficient which is the degree of contribution per unit change in the independent variable.

Statistical Package for Social Sciences (SPSS) is leading statistical software used to solve a variety of research problems. It provides a range of techniques including ad-hoc analysis, hypothesis testing and reporting, making it easier to manage data, select and perform analyses, and share your results. It is a fast, powerful statistical package designed for researchers of all disciplines. Statistical package makes it easy to conduct data cleaning and management, distinctly styled graphs, descriptive analysis and advanced analysis.

The package is originally developed as a programming language for conducting statistical analysis, it has grown into a complex and powerful application which now uses both a graphical and a syntactical interface and provides dozens of functions for managing, analyzing, and presenting data. Its statistical capabilities alone range from simple percentages to complex analyses of variance, multiple regressions, and general linear models and these are some of the importance of the software: It is a fast, powerful and predictive statistical package designed for researchers of all disciplines, SPSS is a comprehensive set of statistical tools, integrated to run descriptive statistics, regression, advanced statistics and more, It enables users to create publication-ready charts, tables and decision trees in one tool, the statistical package makes it easy to analyze data as it uses a simple drag and drop interface to access a range of capabilities, and work across multiple

data sources, The versatility in analyzing different types of data across different fields from social research, Engineering research, health research to business research.

Output from statistical package subprogram regression includes the following:

1. Regression coefficients and their standard errors.
2. t-values or F-values for testing whether individual coefficients are significantly different from zero. The t-value is the ratio of a regression coefficient to its standard error. The F-values for testing the significance of individual regression coefficients are equal to the squares of the t-values (i.e.  $F = t^2$ )

The overall significance of the regression model can be determined from the F-values for the analysis of variance; the F-value can be tested against the F-distribution with degrees of freedom equal to those attributable to the regression and those of the residual term.

3. Multiple correlation coefficients,  $R$ , measure the correlation between the dependent variable and the set of independent variables and take a value between zero and unity.

4. Coefficient of determination,  $R^2$ , (square of multiple correlation coefficients) measures the proportion of variance in the dependent variable explained jointly by the independent variables included in the regression equation. It is also a measure of goodness-of-fit of the regression; it takes a value between zero and unity. Thus, a high value of  $R^2$  indicates a good fit, and a low value, a poor fit. Generally, the value of  $R^2$  increases with increasing number of independent variables.

5. Adjusted coefficient of determination,  $R^2$ , accounts for the number of coefficients estimated (independent variables and constants) in relation to the number of observations.

6. Standard Error of Estimation, SEE, measures the standard deviation of the residuals, that is, the standard deviation about the regression line established

### **3.6 Development of Curve Fittings for the Built Models**

The observed values of for the built model was plotted against the estimated values using confidence level of 95% to help check the level of correlation and this was done using Excel



## CHAPTER FOUR

### RESULTS AND DISCUSSION

#### 4.1 Physical characteristics of Roadway

The physical characteristics of the routes were identified and all the routes under study were faced with pavement failures both on the freeways and shoulders with lots of potholes which also constitute bus travel delays and congestions on the highways. Table 4.1 shows the dimensions of some sections of the roadway under study.

**Table 4.1: Physical characteristics of Road Geometry in Makurdi**

Major Locations	Lane width(m )	Shoulder (m)	Median (m)
North bank Market	10.8		
Lafia junction	7.4	2.25	
SRS junction	7.4	2.25	
Custom junction	7.4	2.25	
Wurukum roundabout	10.8		
Ageshi bus stop	7.5		1.2
Wadata route	7.65		1.2
High level route	7.65		1.2
Market route	10.8		
Terguma street	10.05		
Yogbo road	7.3	2.85	
Awe street	13.9		
Airport route	7.4	3.3	

**Source: Ewoh, 2019**

Table 4.2 shows the geometrical values of the roadway under study which is then compared with the Federal Ministry of works standards specification.

**Table 4.2: Geometric Characteristics of Minibus Routes in Makurdi metropolis**

Name of route	Number of lanes in one direction	Average lane width (m)	Route length (m)	Number of roundabout	Number of cross intersection	Number of T-intersection
Wadata	2	3.60	11.8	4	3	9
Modern market	2	3.70	13.8	3	3	8
Air force base	2	3.50	10.2	4	6	11

**Source: Ewoh, 2019**

The values shown in Table 4.1 and 4.2 are the physical roadway measurements in Makurdi metropolis and the values conform with the Federal Ministry of works Highway Design Manual 2013 which states that 3.35 – 4.0m lane width be used for safety, efficiency and ease of operation and the manual also states that the minimum median width should be 1.2m.

Some sections of the roadways have no road shoulders and proper drainage systems or have poor drainage system with poor road network and poor road pavements which accounts for the congestion of some sections of the roads within the metropolis leading to wide range of travel time and causing discomfort to the commuters who depend on public transport.

The drivers on these highways also exhibit poor driving and parking habits due to the absence of parking facilities and this has led to inadequate road capacity in the metropolis.

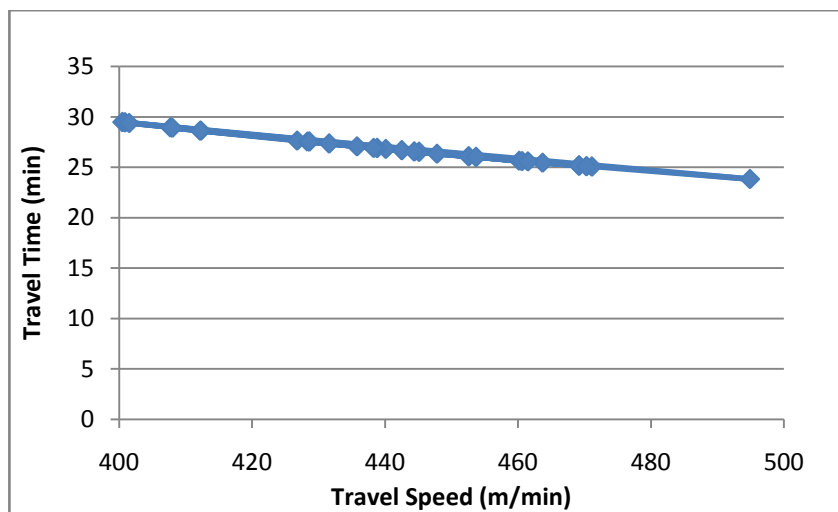
#### **4.2 Factors that Affect Intra-City Bus Travel Times**

In the process of carrying out the field work on the selected routes during the research, it was discovered that the following were the factors affecting bus travel time of unconventional bus transit within the metropolis: Travel speed, route length, dwell times, headways, number of

roundabouts, number of 3-leg intersections, 4-leg intersections, number of lanes, nature of traffic control, volume of traffic, number of stops, and number of potholes.

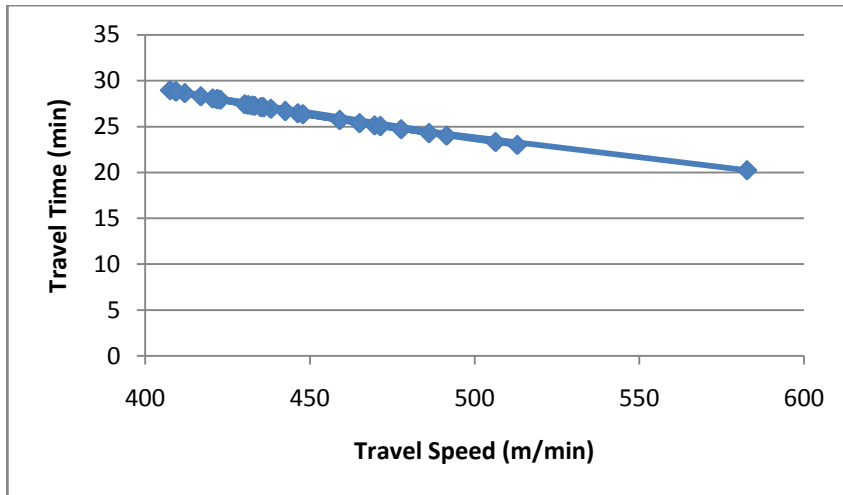
### 4.3 Travel Time Analysis

Data obtained from traffic survey as seen in Appendix B, indicates a rise in the number of travel time which was as a result of delays and congestions on the roads and the poor pavement conditions with lots of potholes and its corresponding factors such as volume of traffic, travel speed increasing with decrease in travel time for both peak and off-peak periods across the length of roads as this can be seen in Figure 4.1.



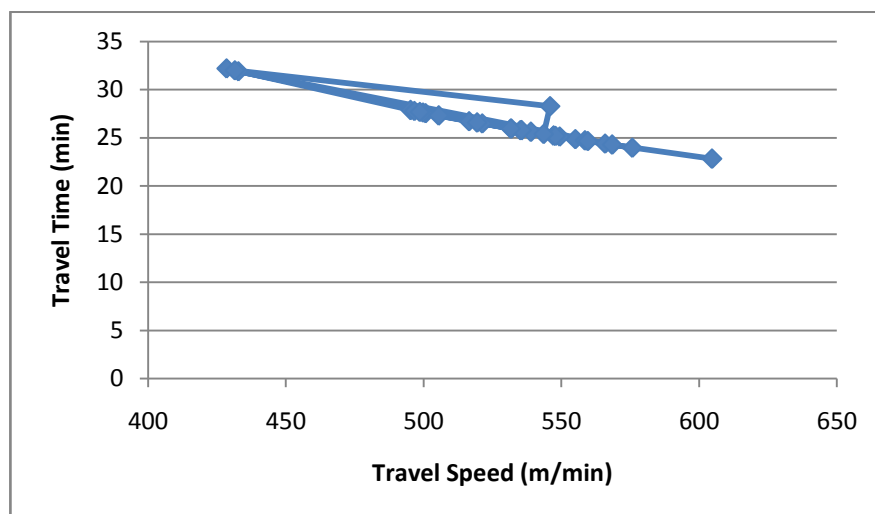
**Figure 4.1:** Relationship between Travel Time and travel speed for peak period on Wadata Route

Result presented in Figure 4.2 shows that travel time decreased with travel speed due to the reduction in the traffic on the highways as a result of low patronage during the off-peak periods along the Wadata route having a maximum travel time of 28.64min with a corresponding travel speed of 412m/min.



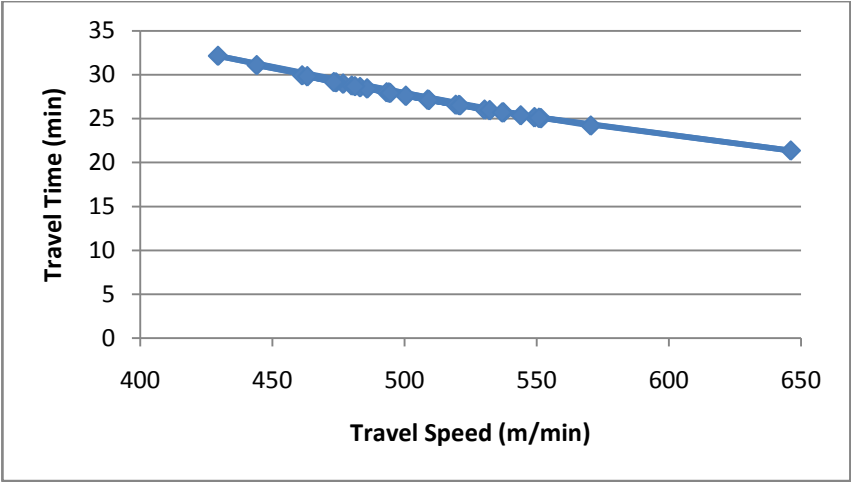
**Figure 4.2:** Relationship between Travel Time and travel speed for off- peak period on Wadata Route

Results in Figure 4.3, indicates the relationship that exist between travel time and travel speed and in the figure, travel time decreased with travel speed due to the reduction in the volume of traffic on the highways as a result of low patronage during the peak periods along the Modern market route having a maximum travel time of 32.21min with a corresponding travel speed of 428.4m/min. From the graph, it can be seen that there was high traffic on the route indicated by the cluster of the points



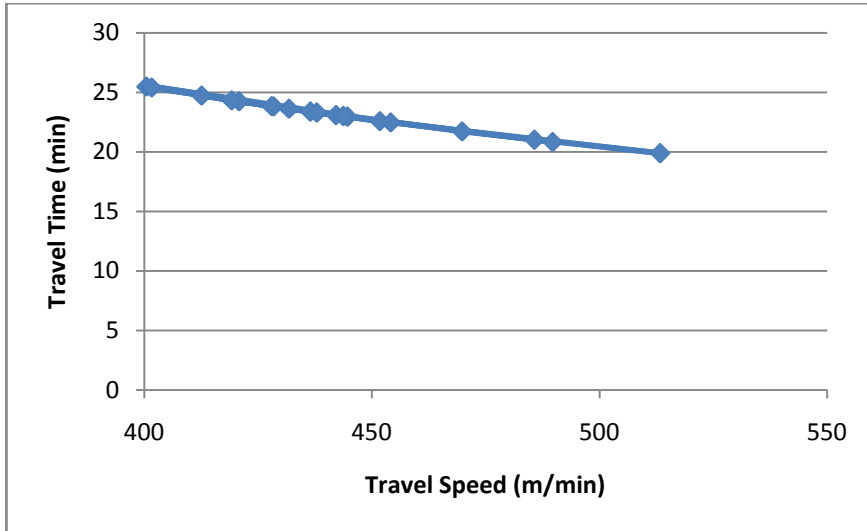
**Figure 4.3:** Relationship between Travel Time and travel speed for peak period on Modern market Route

Result presented in Figure 4.4, shows that travel time decreased with travel speed due to the reduction in the volume of traffic on the highways as a result of low patronage during the off-peak periods along the Modern market route having a maximum travel time of 32.14min with a corresponding travel speed of 429.4m/min and this shows an increased speed as compared to the peak period due to low patronage during the period of survey.



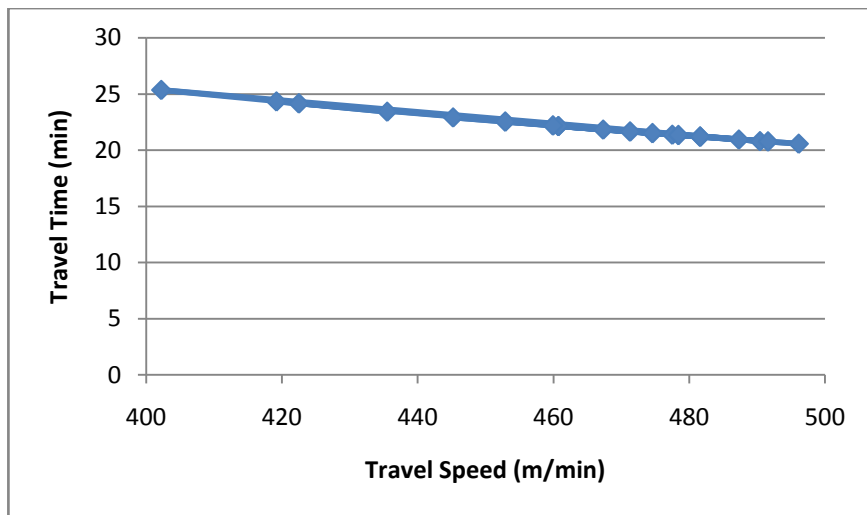
**Figure 4.4:** Relationship between Travel Time and travel speed for off- peak period on Modern market Route

Based on result in Figure 4.5, travel time decreased with travel speed due to the reduction in the volume traffic on the highways as a result of low patronage during the peak periods along the Air Force base route having a maximum travel time of 26.25min with a corresponding travel speed of 388.6m/min



**Figure 4.5:** Relationship between Travel Time and travel speed for peak period on Air force Base Route

Figure 4.6, is a plot that shows the relationship between travel time and travel speed and the figure shows that travel time decreased with travel speed due to the reduction in the traffic on the highways as a result of low patronage during the peak periods along the Air Force base route having a maximum travel time of 25.36min with a corresponding travel speed of 402.2m/min



**Figure 4.6:** Relationship between Travel Time and travel speed for off- peak period on Air force Base Route

#### 4.4 The Multiple Linear Regression Model

Multiple Linear Regression (MLR) model for estimating short term bus travel time on routes within Makurdi metropolis was developed using statistical package for social science computer program with reference to traffic data collected along the various routes. Hence the multiple regression models can be represented in the form indicated in Table 4.3

**Table 4.3: Summary of Statistical Results of the Multiple Linear Regression Model**

**Wadata Peak period**

Model	Unstandardized Coefficients		Standardized Coefficients Beta	T	Sig.	95% Confidence Interval for B	
	B	Std. Error				Lower Bound	Upper Bound
1 (Constant)	54.090	.402		134.653	.000	53.261	54.919
Ave. dwell time	.000	.002	.002	.192	.849	-.003	.004
Time Headway	-.039	.042	-.012	-.929	.362	-.125	.041
Vol. of Traffic	4.024E-5	.000	-.001	-.114	.910	-.001	.001
Travel speed	-.061	.001	-.997	-86.195	.000	-.063	-.060
No. of stops	-.016	.014	-.015	-1.218	.235	-.045	.012

**Source: Ewoh, 2019**

Table 4.3 shows that the time headway, volume of traffic, travel speed and number of stops affects bus travel time negatively, in other words, the variables are inversely proportional to bus travel time. This implies that the higher the magnitude of these aforementioned variables, the lesser the bus travel time. On the other hand, the higher the magnitudes of average dwell time, the higher the bus travel time. This model indicates that, the estimated average bus travel time along the routes in Makurdi metropolis without considering the effect of other variables is approximately 54 minutes. The P-values for travel speed showed a stronger relationship (having value of 0.00) between the inputs and outputs variables in the model. The P-values for Average dwell time, Time-headway, volume of traffic and number of stops along the route showed a slight ( $>0.05$ ) variation which indicates it significant strength in determining short term bus travel time using this model of peak

period. Therefore, the developed mathematical model for predicting short term bus travel time for peak period is as shown in equation 4.1;

$$T = 54.090 + 0.00X_1 - 0.039X_2 - 0.00004024X_3 - 0.061X_4 - 0.017X_5 \quad (4.1)$$

Where,

T = Travel time in Minutes

X<sub>1</sub> = Average dwell time in Seconds

X<sub>2</sub> = Time- headway in Minutes

X<sub>3</sub> = Volume of traffic in Vehicle per Hour

X<sub>4</sub> = Travel speed in Meter per Minutes

X<sub>5</sub> = Number of stops

B<sub>0</sub> = Constant

B<sub>1</sub> ... B<sub>5</sub> = Co-efficient which is the degree of contribution per unit change in the independent variable.

**Table 4.4: Model Summary Result for Peak Hour Values Wadata Route**

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.998 <sup>a</sup>	.997	.996	.09278

a. Predictors: (Constant), Number of stops, Time Headway, Average dwell time, Travel speed, Volume of traffic

From Table 4.4, the following analyses were made for Wadata peak period:

- I. The coefficient of correlation (R) is 0.998; this means that there is a high and good correlation (i.e. 99.8%) between the dependent and independent variables.
- II. The coefficient of determinations (R<sup>2</sup>) is 0.997. This means that 99.7% of the dependent variables is explained by the independent variable(s) and that only 0.3% is explained by other variables such as weather condition, average dwell time, time headway, volume of traffic, travel speed and number of stops and others not included in the model with four of



the variable significantly contributing to the model developed. With the adjusted R square factor of 0.996, indicating that 99.6% of the variance can be predicted from the independent variables.

**Table 4.5: Summary of Statistical Results of the Multiple Linear Regression Model off-Peak period**

Model	Unstandardized Coefficients		Standardized Coefficients Beta	T	Sig.	95% Confidence Interval for B	
	B	Std. Error				Lower Bound	Upper Bound
1 (Constant)	50.081	.862		58.072	.000	48.301	51.861
Ave. dwell time	.003	-.009	.009	.345	.733	-.016	.023
Time Headway	-.014	.013	-.026	-1.040	.309	-.041	.041
Vol. of Traffic	-.001	.002	-.009	-.348	.731	-.004	.003
Travel speed	-.052	.001	-.988	-39.249	.000	-.055	-.049
No. of stops	-.001	.021	-.001	-.030	.976	-.045	.043

**Source: Ewoh, 2019**

Table 4.5 shows that time headway, volume of traffic, travel speed and number of stops affects bus travel time negatively, in other words, the variables are inversely proportional to bus travel time. This implies that the higher the magnitude of these aforementioned variables, the lesser the bus travel time. On the other hand, the higher the magnitudes of average dwell time, the higher the bus travel time. This model indicates that, the estimated average bus travel time along the routes in Makurdi metropolis without considering the effect of other variables is approximately 50 minutes. The P-value for travel speed showed a stronger relationship (having value of 0.00) between the inputs and outputs variables in the model. The P-values for Average dwell time, Time-headway, volume of traffic and number of stops along the route showed a slight ( $>0.05$ ) variation which indicates it significant strength in determining short term bus travel time using this model of peak period.. Therefore, the developed mathematical model for predicting short term bus travel time for off-peak period is as shown in equation 4.2;

$$T = 50.081 + 0.03X_1 - 0.014X_2 - 0.001X_3 - 0.052X_4 - 0.01X_5 \quad (4.2)$$

Where,

T = Travel time in Minutes

X<sub>1</sub> = Average dwell time in Seconds

X<sub>2</sub> = Time- headway in Minutes

X<sub>3</sub> = Volume of traffic in Vehicle per Hour

X<sub>4</sub> = Travel speed in Meter per Minutes

X<sub>5</sub> = Number of stops

B<sub>0</sub> = Constant

B<sub>1</sub> ... B<sub>5</sub> = Co-efficient which is the degree of contribution per unit change in the independent variable.

**Table 4.6: Summary of Statistical Results of the Multiple Linear Regression Model off-Peak period**

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.994	.987	.985	.24979

From Table 4.6 above, the following analyses were made for Wadata off-peak period:

- I. The coefficient of correlation (R) is 0.994; this means that there is a high and good correlation (i.e. 99.4%) between the dependent and independent variables.
- II. The coefficient of determinations (R<sup>2</sup>) is 0.987. This means that 98.7% of the dependent variables is explained by the independent variable(s) and that only 1.3% is explained by other variables such as weather condition, average dwell time, time headway, volume of traffic, travel speed and number of stops and others not included in the model with four of the variable significantly contributing to the model developed. With the adjusted R

square factor of 0.985, indicating that 98.5% of the variance can be predicted from the independent variables.

**Table 4.7: Summary of Statistical Results of the Multiple Linear Regression Model Peak period Modern market**

Model	Unstandardized Coefficients		Standardized Coefficients Beta	T	Sig.	95% Confidence Interval for B	
	B	Std. Error				Lower Bound	Upper Bound
(Constant)	55.064	1.898		29.008	.000	51.146	58.982
Ave. dwell time	.008	.014	.028	.561	.580	-.022	.038
Time Headway	-.091	.262	-.018	-.349	.730	-.632	.449
Vol. of Traffic	-.004	.003	-.085	-1.563	.131	-.010	.001
Travel speed	-.052	.003	-.935	-17.793	.000	-.058	-.046
No. of stops	.071	.071	.050	1.004	.325	-.075	.218

**Source: Ewoh, 2019**

Table 4.7 shows that the time headway, volume of traffic, and travel speed affects bus travel time negatively, in other words, the variables are inversely proportional to bus travel time. This implies that the higher the magnitude of these aforementioned variables, the lesser the bus travel time. On the other hand, the higher the magnitudes of average dwell time and number of stops, the higher the bus travel time. This model indicates that, the estimated average bus travel time along the routes in Makurdi metropolis without considering the effect of other variables is approximately 54 minutes. The P-value for travel speed showed a stronger relationship (having value of 0.00) between the inputs and outputs variables in the model. The P-values for Average dwell time, Time-headway, volume of traffic and number of stops along the route showed a slight ( $>0.05$ ) variation which indicates it significant strength in determining short term bus travel time using this model of peak period. Therefore, the developed mathematical model for predicting short term bus travel time for peak period is as shown in equation 4.3;

$$T = 54.090 + 0.00X_1 - 0.039X_2 - 0.00004024X_3 - 0.061X_4 - 0.017X_5 \quad (4.3)$$

Where,

T = Travel time in Minutes

X<sub>1</sub> = Average dwell time in Seconds

X<sub>2</sub> = Time- headway in Minutes

X<sub>3</sub> = Volume of traffic in Vehicle per Hour

X<sub>4</sub> = Travel speed in Meter per Minutes

X<sub>5</sub> = Number of stops

B<sub>0</sub> = Constant

B<sub>1</sub> ... B<sub>5</sub> = Co-efficient which is the degree of contribution per unit change in the independent variable

**Table 4.8: Summary of Statistical Results of the Multiple Linear Regression Model Peak period**

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.972	.945	.933	.59338

From Table 4.8 above, the following analyses were made for Modern market peak period:

- I. The coefficient of correlation (R) is 0.972; this means that there is a high and good correlation (i.e. 97.2%) between the dependent and independent variables.
- II. The coefficient of determinations (R<sup>2</sup>) is 0.945. This means that 94.5% of the dependent variables is explained by the independent variable(s) and that only 5.5% is explained by other variables such as weather condition, average dwell time, time headway, volume of traffic, travel speed and number of stops and others not included in the model with four of the variable significantly contributing to the model developed. With the adjusted R square factor of 0.933, indicating that 93.3% of the variance can be predicted from the independent variables.

**Table 4.9: Summary of Statistical Results of the Multiple Linear Regression Model off-Peak period Modern market**

Model	Unstandardized Coefficients		Standardized Coefficients Beta	T	Sig.	95% Confidence Interval for B	
	B	Std. Error				Lower Bound	Upper Bound
(Constant)	51.978	.853		60.955	.000	50.218	53.738
Ave. dwell time	.023	.011	.049	2.031	.053	.000	.047
Time Headway	.016	.160	.002	.100	.921	-.314	.046
Vol. of Traffic	-.004	.002	-.074	-2.034	.053	-.007	.000
Travel speed	-.048	.002	-.930	-23.644	.000	-.052	-.044
No. of stops	.039	.023	.047	1.704	.101	-.008	.087

**Source: Ewoh, 2019**

Table 4.9 shows that the volume of traffic and travel speed affects bus travel time negatively, in other words, the variables are inversely proportional to bus travel time. This implies that the higher the magnitude of these aforementioned variables, the lesser the bus travel time. On the other hand, the higher the magnitudes of average dwell time, Time headway, and number of stops, the higher the bus travel time. This model indicates that, the estimated average bus travel time along the routes in Makurdi metropolis without considering the effect of other variables is approximately 51 minutes. The P-values for all the variables along the route showed a slight ( $>0.05$ ) variation which indicates it significant strength in determining short term bus travel time using this model of peak period. Therefore, the developed mathematical model for predicting short term bus travel time for off-peak period is as shown in equation 4.4;

$$T = 51.978 + 0.23X_1 + 0.016X_2 - 0.004X_3 - 0.048X_4 + 0.039X_5 \quad (4.4)$$

Where,

T = Travel time in Minutes

$X_1$  = Average dwell time in Seconds

$X_2$  = Time- headway in Minutes

$X_3$  = Volume of traffic in Vehicle per Hour

$X_4$  = Travel speed in Meter per Minutes

$X_5$  = Number of stops

$B_0$  = Constant

$B_1 \dots B_5$  = Co-efficient which is the degree of contribution per unit change in the independent variable

**Table 4.10: Summary of Statistical Results of the Multiple Linear Regression Model off-Peak period**

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.994	.987	.985	.27551

From Table 4.10, the following analyses were made for Modern market off-peak period:

- I. The coefficient of correlation (R) is 0.994; this means that there is a high and good correlation (i.e. 99.4%) between the dependent and independent variables.
- II. The coefficient of determinations ( $R^2$ ) is 0.987. This means that 98.7% of the dependent variables is explained by the independent variable(s) and that only 1.3% is explained by other variables such as weather condition, average dwell time, time headway, volume of traffic, travel speed and number of stops and others not included in the model with four of the variable significantly contributing to the model developed. With the adjusted R square factor of 0.985, indicating that 98.5% of the variance can be predicted from the independent variables.

**Table 4.11: Summary of Statistical Results of the Multiple Linear Regression Model Peak period Air force base**

Model	Unstandardized Coefficients		Standardized Coefficients Beta	T	Sig.	95% Confidence Interval for B	
	B	Std. Error				Lower Bound	Upper Bound
(Constant)	45.553	.502		90.780	.000	44.477	46.630
Ave. dwell time	.006	.007	.019	.816	.428	-.009	.021
Time Headway	.026	.074	.008	.348	.733	-.133	.185
Vol. of Traffic	.001	.001	.030	1.202	.249	-.001	.003
Travel speed	-.052	.001	-.007	-40.878	.000	-.054	-.049
No. of stops	-.037	.018	-.044	-2.030	.062	-.076	.002

**Source: Ewoh, 2019**

Table 4.11 shows that the travel speed and number of stops affects bus travel time negatively, in other words, the variables are inversely proportional to bus travel time. This implies that the higher the magnitude of these aforementioned variables, the lesser the bus travel time. On the other hand, the higher the magnitudes of average dwell time, Time headway, and volume of traffic, the higher the bus travel time. This model indicates that, the estimated average bus travel time along the routes in Makurdi metropolis without considering the effect of other variables is approximately 45 minutes (constant). The P-value for travel speed showed a great significant with value of 0.00 along the route and the other variables showed a slight ( $>0.05$ ) variation which indicates it significant strength in determining short term bus travel time using this model of peak period. Therefore, the developed mathematical model for predicting short term bus travel time for peak period is as shown in equation 4.5;

$$T = 45.553 + 0.006X_1 + 0.026X_2 + 0.001X_3 - 0.052X_4 - 0.037X_5 \quad (4.5)$$

Where,

T = Travel time in Minutes

X<sub>1</sub> = Average dwell time in Seconds

$X_2$  = Time- headway in Minutes

$X_3$  = Volume of traffic in Vehicle per Hour

$X_4$  = Travel speed in Meter per Minutes

$X_5$  = Number of stops

$B_0$  = Constant

$B_1 \dots B_5$  = Co-efficient which is the degree of contribution per unit change in the independent variable

**Table 4.12: Summary of Statistical Results of the Multiple Linear Regression Model Peak period**

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.997	.995	.993	.13520

From Table 4.12, the following analyses were made for Air Force Base peak period:

- I. The coefficient of correlation (R) is 0.997; this means that there is a high and good correlation (i.e. 99.7%) between the dependent and independent variables.
- II. The coefficient of determinations ( $R^2$ ) is 0.995. This means that 99.5% of the dependent variables is explained by the independent variable(s) and that only 0.5% is explained by other variables such as weather condition, average dwell time, time headway, volume of traffic, travel speed and number of stops and others not included in the model with four of the variable significantly contributing to the model developed. With the adjusted R square factor of 0.993, indicating that 99.3% of the variance can be predicted from the independent variables.



**Table 4.13: Summary of Statistical Results of the Multiple Linear Regression Model off- Peak period Air force base**

Model	Unstandardized Coefficients		Standardized Coefficients Beta	T	Sig.	95% Confidence Interval for B	
	B	Std. Error				Lower Bound	Upper Bound
(Constant)	45.118	.400		112.714	.000	44.260	45.977
Ave. dwell time	-.004	.004	-.016	-1.015	.327	-.013	.005
Time Headway	-.037	.030	-.018	-1.247	.233	-.102	.027
Vol. of Traffic	-.001	.001	-.026	-.784	.446	-.002	.001
Travel speed	-.049	.001	-.970	-33.605	.000	-.052	-.046
No. of stops	.015	.014	.016	1.047	.313	-.015	-.045

**Source: Ewoh, 2019**

Table 4.13 shows that the average dwell time, time headway, volume of traffic and travel speed affects bus travel time negatively, in other words, the variables are inversely proportional to bus travel time. This implies that the higher the magnitude of these aforementioned variables, the lesser the bus travel time. On the other hand, the higher the magnitudes of the number of stops, the higher the bus travel time. This model indicates that, the estimated average bus travel time along the routes in Makurdi metropolis without considering the effect of other variables is approximately 45 minutes. The P-value for travel speed showed a great significant with value of 0.00 along the route and the other variables showed a slight ( $>0.05$ ) variation which indicates it significant strength in determining short term bus travel time using this model of peak period. Therefore, the developed mathematical model for predicting short term bus travel time for peak period is as shown in equation 4.6;

$$T = 45.118 - 0.004X_1 - 0.037X_2 - 0.001X_3 - 0.049X_4 + 0.014X_5 \quad (4.6)$$

Where,

T = Travel time in Minutes

X<sub>1</sub> = Average dwell time in Seconds

$X_2$  = Time- headway in Minutes

$X_3$  = Volume of traffic in Vehicle per Hour

$X_4$  = Travel speed in Meter per Minutes

$X_5$  = Number of stops

$B_0$  = Constant

$B_1 \dots B_5$  = Co-efficient which is the degree of contribution per unit change in the independent variable

**Table 4.14: Summary of Statistical Results of the Multiple Linear Regression Model off-Peak period**

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.999	.998	.997	.07630

From Table 4.14, the following analyses were made for Air Force Base off-peak period:

- I. The coefficient of correlation (R) is 0.999; this means that there is a high and good correlation (i.e. 99.9%) between the dependent and independent variables.
- II. The coefficient of determinations ( $R^2$ ) is 0.998. This means that 99.8% of the dependent variables is explained by the independent variable(s) and that only 0.2% is explained by other variables such as weather condition, average dwell time, time headway, volume of traffic, travel speed and number of stops and others not included in the model with four of the variable significantly contributing to the model developed. With the adjusted R square factor of 0.997, indicating that 99.7% of the variance can be predicted from the independent variables.

**Table 4.15: Combined Summary of Statistical Results of the Multiple Linear Regression Model Peak period**

Model	Unstandardized Coefficients		Standardized Coefficients Beta	T	Sig.	95% Confidence Interval for B	
	B	Std. Error				Lower Bound	Upper Bound
(Constant)	30.969	1.277		24.252	.000	28.424	33.515
Ave. dwell time	.011	.007	.048	1.514	.134	-.003	.025
Route Length	.002	.000	1.118	22.077	.000	.002	.002
Time headway	-.283	.134	-.055	-2.106	.039	-.551	-.015
T-junction	-.139	.072	-.069	-1.930	.058	-.283	-.005
Vol. of traffic	-.002	.001	-.070	-1.914	.060	-.005	-.000
Travel speed	-.052	.002	-1.015	-26.532	.000	-.055	-.048
No. of stops	-.047	.038	-.032	-1.235	.221	-.124	.029

**Source: Ewoh, 2019**

Table 4.15 shows that the average time headway, T-junction, volume of traffic, travel speed and number of stops affects bus travel time negatively, in other words, the variables are inversely proportional to bus travel time. This implies that the higher the magnitude of these aforementioned variables, the lesser the bus travel time. On the other hand, the higher the magnitudes of average dwell time and route length, the higher the bus travel time. This model indicates that, the estimated average bus travel time along the routes in Makurdi metropolis without considering the effect of other variables is approximately 30 minutes as against 15 minutes stated by Adeke, 2019. The P-values for route length and travel speed variables showed a stronger relationship (having values of 0.00) between the inputs and outputs variables in the model. The P-values for T-junction and volume of traffic along the route showed a slight ( $>0.05$ ) variation which indicates it significant strength in determining short term bus travel time using this model of peak period. Other independent variables such as average dwell time and number of stops, shows less importance in estimating bus travel time using this model and time headway shows another strong significance in estimating the dependent variable; travel time using the model. Some

variables such as number of roundabout along the route and the cross intersection were ignored by the statistical tool used for the analysis which indicated their irrelevance to a great extent in predicting bus travel time using the built model. Therefore, the developed mathematical model for predicting short term bus travel time for peak period is as shown in equation 4.7;

$$T = 30.969 + 0.011X_1 + 0.002X_2 - 0.283X_3 - 0.139X_4 - 0.002X_5 - 0.052X_6 - 0.047X_7 \quad (4.7)$$

Where,

T = Travel time in Minutes

X<sub>1</sub> = Average dwell time in Seconds

X<sub>2</sub> = Route Length in Meters

X<sub>3</sub> = Time- headway in Minutes

X<sub>4</sub> = T- Junction

X<sub>5</sub> = Volume of traffic in Vehicle per Hour

X<sub>6</sub> = Travel speed in Meter per Minutes

X<sub>7</sub> = Number of stops

B<sub>0</sub> = Constant

B<sub>1</sub> ... B<sub>7</sub> = Co-efficient which is the degree of contribution per unit change in the independent variable

**Table 4.16: Model Summary Result for Peak Hour Values**

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.978 <sup>a</sup>	.956	.951	.52272

b. Predictors: (Constant), Number of stops, T- Junction, Time Headway, Average dwell time, Travel speed, Volume of traffic, Route length

From Table 4.16 above, the following analyses were made for peak period:

III. The coefficient of correlation (R) is 0.978; this means that there is a high and good correlation (i.e. 97.8%) between the dependent and independent variables.

IV. The coefficient of determinations ( $R^2$ ) is 0.956 as compared to Jimoh, 2003 who also gave a high value of coefficient of determination of 0.782 for sabo-samaru route in Zaria. This means that 95.6% of the dependent variables is explained by the independent variable(s) and that only 4.4% is explained by other variables such as weather condition, number of roundabouts, number of cross intersections and others not included in the model with four of the variable significantly contributing to the model developed. With the adjusted R square factor of 0.951, indicating that 95% of the variance can be predicted from the independent variables.

**Table 4.17: Combined Summary of Statistical Results of the Multiple Linear Regression Model Off-peak**

Model	Unstandardized Coefficients		Standardized Coefficients Beta	T	Sig.	95% Confidence Interval for B	
	B	Std. Error				Lower Bound	Upper Bound
(Constant)	27.022	.541		49.983	.000	25.945	28.100
Ave. dwell time	.010	.006	.019	1.819	.073	-.001	.021
Route Length	.002	.000	.986	49.584	.000	-.002	.002
Time headway	-.018	.012	-.015	-1.570	.121	-.042	.005
T-junction	-.130	.030	-.053	-4.318	.000	-.190	-.070
Vol. of traffic	-.001	.001	-.025	-1.421	.160	-.003	.000
Travel speed	-.051	.001	-.812	-54.996	.000	-.052	-.049
No. of stops	.013	.013	.011	1.045	.300	-.012	.038

**Source: Ewoh, 2019**

Table 4.17 shows that the average time headway, T-junction, volume of traffic and travel speed affects bus travel time negatively, in other words, the variables are inversely proportional to bus travel time. On the other hand, the higher the magnitudes of average dwell time, route length and number of stops along the route, the higher the bus travel time.

This model indicates that, the estimated average bus travel time along the routes in Makurdi metropolis without considering the effect of other variables is approximately 27 minutes against the established 15 minutes stated by Adeke, 2019. The P-values for route length, T-junction and travel speed variables showed a stronger relationship (having values of 0.00) between the inputs and outputs variables in the model. The P-values of average dwell time along the route showed a slight ( $>0.05$ ) variation which indicates it significant strength in determining short term bus travel time using this model of off peak period. Other independent variables such as time headway, volume of traffic and number of stops, shows less importance in estimating bus travel time using this model. Some variables such as number of roundabout along the route and the cross intersection were also ignored by the statistical tool used for the analysis which indicated their irrelevance to in predicting bus travel time using the built model. Therefore, the developed mathematical model for predicting short term bus travel time for Off-peak period is as shown in equation 4.8;

$$T = 27.022 + 0.010X_1 + 0.002X_2 - 0.018X_3 - 0.130X_4 - 0.001X_5 - 0.051X_6 + 0.013X_7 \quad (4.8)$$

Where,

T = Travel time in Minutes

$X_1$  = Average dwell time in Seconds

$X_2$  = Route Length in Meters

$X_3$  = Time- headway in Minutes

$X_4$  = T- Junction

$X_5$  = Volume of traffic in Vehicle per Hour

$X_6$  = Travel speed in Meter per Minutes

$X_7$  = Number of stops

$B_0$  = Constant

$B_1 \dots B_7$  = Co-efficient which is the degree of contribution per unit change in the independent variable

**Table 4.18: Model Summary Result for Off-peak Hour**

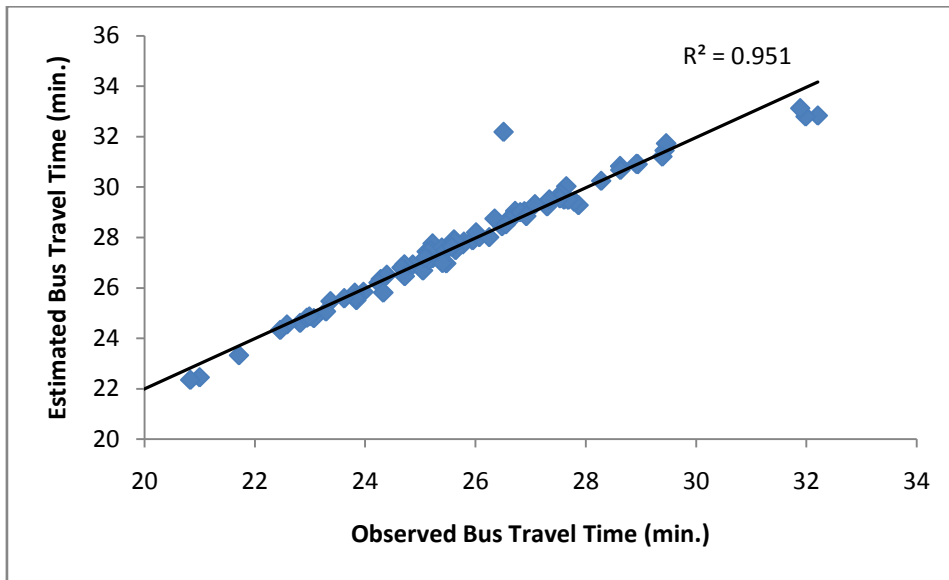
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
2	.997 <sup>a</sup>	.994	.993	.23335

a. Predictors: (Constant), Number of stops, T- Junction, Time Headway, Average dwell time, Travel speed, Volume of traffic, Route length

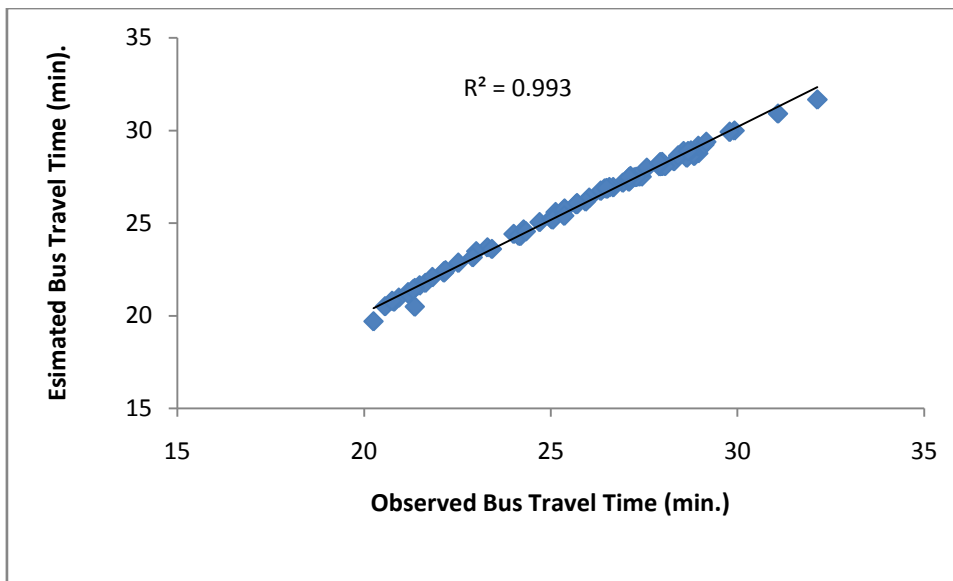
From Table 4.18, the following analyses were made for off-peak period:

- I. The coefficient of correlation (R) is 0.997; this means that there is a high and good correlation (i.e. 99.7%) between the dependent and independent variables.
- II. The coefficient of determinations ( $R^2$ ) is 0.994 as compared to the ANN approach of Adeke, 2019 which gave 0.9306. This means that 99.4% of the dependent variables is explained by the independent variable(s) and that only 0.6% is explained by other variables such as weather condition, number of roundabouts, number of cross intersections and others not included in the model with four of the variable significantly contributing to the model developed. With the adjusted R square factor of 0.993, indicating that 99% of the variance can be predicted from the independent variables.

#### 4.5 Curve Fittings for the Built Models



**Figure 4.7:** Relationship of estimated bus travel time to observe bus travel time for peak period



**Figure 4.8:** Relationship of estimated bus travel time to observe bus travel time for off-peak period



## CHAPTER FIVE

### CONCLUSIONS AND RECOMMENDATIONS

#### 5.1 Conclusion

Summarily, this study was carried out solely to identify those factors that constitute impediment to intra-city bus travel time and develop multiple regression models for bus travel time using statistical package and validating the developed bus travel time with data collected from field survey.

- I. The physical characteristic of the routes under study was determined and the lane width of the routes under study were Wadata is 3.6m, Modern market is 3.7m and Air Force Base; 3.5m and the values obtained conform with the Federal Ministry of works Highway Design Manuel 2013 which states that 3.35-4.0m lane width be used for safety, efficiency and ease of operation and the manual also states that the minimum median width be 1.2m and usable shoulder width of 3m are desirable on all highways but narrow widths are acceptable on low volume highway.
- II. The factors that affect intra-city bus travel times were determined to be speed of travel, dwell time, number of T-Junctions and Cross intersections, volume of traffic which all ranged from 427-775 vehicles/hour and this fall under the traffic category of heavy traffic as stated in the Federal Ministry of works Highway Design Manual, 2013 that traffic more than 1000vehicles/day belongs to Heavy traffic, and number of roundabout and the route lengths been predominant.
- III. There was delay and congestion during the peak periods as compared to the off-peak period along all the routes in the metropolis.
- IV. From the regression analysis conducted, the models developed for each route of study could not capture the route length which invariably shows that the model is not a good one since route length is a key function of travel time but the combined route models captured the route length which shows that the model is a good one for both peak and off-peak periods. A high value of coefficient of correlation for Peak

and Off-Peak periods,  $R = 0.978$  and  $R = 0.997$  was obtained which indicates that there is a high and good correlation of about 97.8% and 99.7% between the dependent and independent variables and the models are very good reflection of the current traffic situation in the state capital. The coefficient of determination  $R^2$  which is a measure of goodness-of-fit, was found to be 0.956 and 0.994, which indicates that 95.6% and 99.4% of the dependent variable (Travel time) at a confidence level of 95% and significant level of 0.05 is explained by both regression models. Though the  $R^2$  value for the Off-peak period is relatively high which defines high accuracy of the model and the Peak period is associated with more complications but represent a more realistic travel situation.

- V. The research also established that route length, T-junction and travel speed are important parameters used in the prediction of intra-city bus travel time since they gave good significant values.

## **5.2 Recommendation**

1. The proposed model is conceptually and operationally simple and should be used for cities in Nigeria having such challenges
2. On-street parking should be regulated so as to reduce traffic congestion on the highways within the metropolis

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## APPENDICES

### APPENDIX A: TRAVEL TIME DATA COLLECTED USING MOVING VEHICLE TECHNIQUE

**Table A1: Travel Time Data Collected during Peak Hour Modern Market Route**

No. of Trips	Travel time (Min)		No. of vehicles in opp. Direction		No. of vehicles that overtook test car		No. of vehicles overtaken by test car	
S/N	T <sub>e</sub>	T <sub>w</sub>	N <sub>e</sub>	N <sub>w</sub>	O <sub>e</sub>	O <sub>w</sub>	P <sub>e</sub>	P <sub>w</sub>
1	28	27	461	472	46	68	13	14
2	30	28	450	480	52	77	20	29
3	27	29	502	490	55	49	18	27
4	33	29	491	507	60	78	29	35
5	30	32	530	504	47	59	20	25

**Source:** (Ewoh,2019)

**Table A2: Travel Time Data Collected during Peak Hour**

No. of Trips	Travel time (Min)		No. of vehicles in opp. Direction		No. of vehicles that overtook test car		No. of vehicles overtaken by test car	
S/N	T <sub>e</sub>	T <sub>w</sub>	N <sub>e</sub>	N <sub>w</sub>	O <sub>e</sub>	O <sub>w</sub>	P <sub>e</sub>	P <sub>w</sub>
6	31	29	509	574	21	16	47	29
7	29	27	515	523	70	55	33	18
8	30	29	560	496	47	50	18	20
9	30	31	548	599	37	52	15	21
10	29	33	521	572	46	50	15	18

**Source:** (Ewoh,2019)

Table A3: Travel Time Data Collected during Peak Hour

No. of Trips	Travel time (Min)		No. of vehicles in opp. Direction		No. of vehicles that overtook test car		No. of vehicles overtaken by test car	
S/N	T <sub>e</sub>	T <sub>w</sub>	N <sub>e</sub>	N <sub>w</sub>	O <sub>e</sub>	O <sub>w</sub>	P <sub>e</sub>	P <sub>w</sub>
11	30	29	516	447	50	61	18	15
12	28	30	496	417	51	33	9	13
13	31	30	489	512	49	38	18	20
14	29	27	506	449	48	56	12	18
15	27	30	502	510	38	41	15	10

**Source:** (Ewoh,2019)

Table A4: Travel Time Data Collected during Peak Hour

No. of Trips	Travel time (Min)		No. of vehicles in opp. Direction		No. of vehicles that overtook test car		No. of vehicles overtaken by test car	
S/N	T <sub>e</sub>	T <sub>w</sub>	N <sub>e</sub>	N <sub>w</sub>	O <sub>e</sub>	O <sub>w</sub>	P <sub>e</sub>	P <sub>w</sub>
16	29	28	504	493	47	49	12	13
17	28	30	449	512	53	62	18	30
18	30	29	550	529	62	70	20	15
19	30	28	612	549	49	45	12	18
20	29	33	590	602	48	70	18	12

**Source:** (Ewoh,2019)

Table A5: Travel Time Data Collected during Peak Hour

No. of Trips	Travel time (Min)		No. of vehicles in opp. Direction		No. of vehicles that overtook test car		No. of vehicles overtaken by test car	
S/N	T <sub>e</sub>	T <sub>w</sub>	N <sub>e</sub>	N <sub>w</sub>	O <sub>e</sub>	O <sub>w</sub>	P <sub>e</sub>	P <sub>w</sub>
21	30	27	501	473	50	41	26	31
22	30	28	463	411	46	47	16	14
23	36	30	403	523	29	37	29	23
24	27	29	560	471	39	40	13	16
25	31	30	519	487	48	31	28	13

**Source:** (Ewoh,2019)

Table A6: Travel Time Data Collected during Peak Hour

No. of Trips	Travel time (Min)		No. of vehicles in opp. Direction		No. of vehicles that overtook test car		No. of vehicles overtaken by test car	
S/N	T <sub>e</sub>	T <sub>w</sub>	N <sub>e</sub>	N <sub>w</sub>	O <sub>e</sub>	O <sub>w</sub>	P <sub>e</sub>	P <sub>w</sub>
26	36	34	573	596	41	50	19	18
27	28	30	479	516	39	58	22	17
28	30	32	523	587	60	43	18	14
29	28	29	541	600	50	47	15	24
30	31	27	556	503	56	40	18	20

**Source:** (Ewoh,2019)

Table A7: Travel Time Data Collected during Peak Hour Wadata Route

S/N	Travel time (Min)		No. of vehicles in opp. Direction		No. of vehicles that overtook test car		No. of vehicles overtaken by test car	
	T <sub>e</sub>	T <sub>w</sub>	N <sub>e</sub>	N <sub>w</sub>	O <sub>e</sub>	O <sub>w</sub>	P <sub>e</sub>	P <sub>w</sub>
1	26	36	449	509	32	49	23	18
2	30	28	501	419	36	38	15	21
3	27	30	444	507	50	43	25	18
4	28	27	459	511	41	34	17	20
5	28	30	555	490	25	30	30	23

**Source:** (Ewoh,2019)

Table A8: Travel Time Data Collected during Peak Hour

S/N	Travel time (Min)		No. of vehicles in opp. Direction		No. of vehicles that overtook test car		No. of vehicles overtaken by test car	
	T <sub>e</sub>	T <sub>w</sub>	N <sub>e</sub>	N <sub>w</sub>	O <sub>e</sub>	O <sub>w</sub>	P <sub>e</sub>	P <sub>w</sub>
6	28	32	591	520	50	39	35	28
7	30	29	601	509	59	47	22	26
8	36	29	553	580	53	47	28	16
9	27	30	698	567	60	53	15	18
10	31	30	564	600	58	41	29	13

**Source:** (Ewoh,2019)

Table A9: Travel Time Data Collected during Peak Hour

No. of Trips	Travel time (Min)		No. of vehicles in opp. Direction		No. of vehicles that overtook test car		No. of vehicles overtaken by test car	
	$T_e$	$T_w$	$N_e$	$N_w$	$O_e$	$O_w$	$P_e$	$P_w$
11	27	30	417	510	38	47	12	16
12	29	28	427	418	41	50	20	18
13	30	28	420	503	33	43	15	13
14	28	30	450	511	37	41	25	16
15	28	30	512	417	47	39	22	14

**Source:** (Ewoh,2019)

Table A10: Travel Time Data Collected during Peak Hour

No. of Trips	Travel time (Min)		No. of vehicles in opp. Direction		No. of vehicles that overtook test car		No. of vehicles overtaken by test car	
	$T_e$	$T_w$	$N_e$	$N_w$	$O_e$	$O_w$	$P_e$	$P_w$
16	30	32	521	590	53	48	31	26
17	32	28	581	450	50	37	18	28
18	29	29	561	456	41	52	30	23
19	28	30	462	521	60	47	27	19
20	30	32	566	597	58	39	30	26

**Source:** (Ewoh,2019)

Table A11: Travel Time Data Collected during Peak Hour

S/N	Travel time (Min)		No. of vehicles in opp. Direction		No. of vehicles that overtook test car		No. of vehicles overtaken by test car	
	T <sub>e</sub>	T <sub>w</sub>	N <sub>e</sub>	N <sub>w</sub>	O <sub>e</sub>	O <sub>w</sub>	P <sub>e</sub>	P <sub>w</sub>
21	26	28	437	501	43	50	15	20
22	30	28	453	417	38	40	20	18
23	27	30	503	433	35	48	10	13
24	30	29	456	521	47	39	16	18
25	28	31	405	513	37	39	22	16

**Source:** (Ewoh,2019)

Table A12: Travel Time Data Collected during Peak Hour

S/N	Travel time (Min)		No. of vehicles in opp. Direction		No. of vehicles that overtook test car		No. of vehicles overtaken by test car	
	T <sub>e</sub>	T <sub>w</sub>	N <sub>e</sub>	N <sub>w</sub>	O <sub>e</sub>	O <sub>w</sub>	P <sub>e</sub>	P <sub>w</sub>
26	32	29	536	497	50	47	26	18
27	30	30	631	511	39	63	16	23
28	31	28	577	609	46	41	30	12
29	28	30	516	600	57	48	20	15
30	30	33	563	571	50	34	18	26

**Source:** (Ewoh,2019)

Table A13: Travel Time Data Collected during Peak Hour Air force Base Route

No. of Trips	Travel time (Min)		No. of vehicles in opp. Direction		No. of vehicles that overtook test car		No. of vehicles overtaken by test car	
S/N	T <sub>e</sub>	T <sub>w</sub>	N <sub>e</sub>	N <sub>w</sub>	O <sub>e</sub>	O <sub>w</sub>	P <sub>e</sub>	P <sub>w</sub>
1	26	24	523	499	29	32	16	20
2	25	27	518	600	32	36	30	27
3	20	28	512	594	21	39	17	19
4	25	29	541	604	32	40	22	16
5	27	23	450	506	44	46	30	28

**Source:** (Ewoh,2019)

Table A14: Travel Time Data Collected during Peak Hour

No. of Trips	Travel time (Min)		No. of vehicles in opp. Direction		No. of vehicles that overtook test car		No. of vehicles overtaken by test car	
S/N	T <sub>e</sub>	T <sub>w</sub>	N <sub>e</sub>	N <sub>w</sub>	O <sub>e</sub>	O <sub>w</sub>	P <sub>e</sub>	P <sub>w</sub>
6	25	28	567	498	53	42	25	23
7	27	24	506	497	34	44	16	28
8	22	28	550	490	28	35	27	30
9	24	26	583	603	39	36	33	26
10	27	20	499	561	35	40	15	18

**Source:** (Ewoh,2019)



Table A15: Travel Time Data Collected during Peak Hour

No. of Trips	Travel time (Min)		No. of vehicles in opp. Direction		No. of vehicles that overtook test car		No. of vehicles overtaken by test car	
	T <sub>e</sub>	T <sub>w</sub>	N <sub>e</sub>	N <sub>w</sub>	O <sub>e</sub>	O <sub>w</sub>	P <sub>e</sub>	P <sub>w</sub>
11	20	23	571	499	40	34	20	12
12	25	22	511	480	32	43	24	31
13	26	24	497	521	42	36	26	23
14	26	23	501	462	38	29	18	25
15	27	21	544	510	41	38	26	18

**Source:** (Ewoh,2019)

Table A16: Travel Time Data Collected during Peak Hour

No. of Trips	Travel time (Min)		No. of vehicles in opp. Direction		No. of vehicles that overtook test car		No. of vehicles overtaken by test car	
	T <sub>e</sub>	T <sub>w</sub>	N <sub>e</sub>	N <sub>w</sub>	O <sub>e</sub>	O <sub>w</sub>	P <sub>e</sub>	P <sub>w</sub>
16	26	28	467	570	33	35	23	30
17	26	24	564	486	49	32	18	22
18	20	25	436	501	50	41	28	30
19	24	22	516	480	46	42	18	21
20	23	25	498	520	39	30	28	19

**Source:** (Ewoh,2019)

Table A17: Travel Time Data Collected during off- Peak Hour Modern Market Route

No. of Trips	Travel time (Min)		No. of vehicles in opp. Direction		No. of vehicles that overtook test car		No. of vehicles overtaken by test car	
S/N	T <sub>e</sub>	T <sub>w</sub>	N <sub>e</sub>	N <sub>w</sub>	O <sub>e</sub>	O <sub>w</sub>	P <sub>e</sub>	P <sub>w</sub>
1	25	28	402	359	31	27	20	18
2	31	35	421	389	33	29	16	22
3	25	30	391	411	35	30	25	18
4	30	27	403	393	26	29	20	27
5	24	32	350	396	31	35	25	21

**Source:** (Ewoh,2019)

Table A18: Travel Time Data Collected during off-Peak Hour

No. of Trips	Travel time (Min)		No. of vehicles in opp. Direction		No. of vehicles that overtook test car		No. of vehicles overtaken by test car	
S/N	T <sub>e</sub>	T <sub>w</sub>	N <sub>e</sub>	N <sub>w</sub>	O <sub>e</sub>	O <sub>w</sub>	P <sub>e</sub>	P <sub>w</sub>
6	30	26	408	412	19	30	16	20
7	29	25	399	356	27	15	24	18
8	31	29	401	299	25	30	18	25
9	25	33	358	315	22	18	22	29
10	23	30	416	398	30	15	16	20

**Source:** (Ewoh,2019)

Table A19: Travel Time Data Collected during off-Peak Hour

No. of Trips	Travel time (Min)		No. of vehicles in opp. Direction		No. of vehicles that overtook test car		No. of vehicles overtaken by test car	
S/N	T <sub>e</sub>	T <sub>w</sub>	N <sub>e</sub>	N <sub>w</sub>	O <sub>e</sub>	O <sub>w</sub>	P <sub>e</sub>	P <sub>w</sub>
11	26	28	380	378	33	29	25	18
12	30	35	406	398	31	19	16	29
13	29	25	345	390	25	28	22	24
14	29	31	399	443	27	34	18	25
15	24	29	409	345	38	29	30	26

**Source:** (Ewoh,2019)

Table A20: Travel Time Data Collected during off-Peak Hour

No. of Trips	Travel time (Min)		No. of vehicles in opp. Direction		No. of vehicles that overtook test car		No. of vehicles overtaken by test car	
S/N	T <sub>e</sub>	T <sub>w</sub>	N <sub>e</sub>	N <sub>w</sub>	O <sub>e</sub>	O <sub>w</sub>	P <sub>e</sub>	P <sub>w</sub>
16	18	25	350	301	15	31	22	20
17	24	27	359	391	26	30	25	29
18	29	23	395	450	33	28	19	25
19	30	28	291	305	17	25	16	27
20	26	32	326	335	29	31	30	25

**Source:** (Ewoh,2019)

Table A21: Travel Time Data Collected during off-Peak Hour

No. of Trips	Travel time (Min)		No. of vehicles in opp. Direction		No. of vehicles that overtook test car		No. of vehicles overtaken by test car	
S/N	T <sub>e</sub>	T <sub>w</sub>	N <sub>e</sub>	N <sub>w</sub>	O <sub>e</sub>	O <sub>w</sub>	P <sub>e</sub>	P <sub>w</sub>
21	30	29	284	412	27	33	22	17
22	34	28	397	368	38	30	22	31
23	30	27	414	397	29	26	35	28
24	28	30	356	401	25	18	20	15
25	25	27	403	399	28	30	25	18

**Source:** (Ewoh,2019)

Table A22: Travel Time Data Collected during off-Peak Hour

No. of Trips	Travel time (Min)		No. of vehicles in opp. Direction		No. of vehicles that overtook test car		No. of vehicles overtaken by test car	
S/N	T <sub>e</sub>	T <sub>w</sub>	N <sub>e</sub>	N <sub>w</sub>	O <sub>e</sub>	O <sub>w</sub>	P <sub>e</sub>	P <sub>w</sub>
26	30	29	422	412	27	25	25	15
27	27	31	425	386	30	29	26	18
28	29	24	368	394	25	19	24	28
29	30	26	408	377	27	22	18	30
30	28	22	425	390	30	27	28	15

**Source:** (Ewoh,2019)

Table A23: Travel Time Data Collected during off-Peak Hour Wadata Route

S/N	Travel time (Min)		No. of vehicles in opp. Direction		No. of vehicles that overtook test car		No. of vehicles overtaken by test car	
	T <sub>e</sub>	T <sub>w</sub>	N <sub>e</sub>	N <sub>w</sub>	O <sub>e</sub>	O <sub>w</sub>	P <sub>e</sub>	P <sub>w</sub>
1	24	20	311	296	25	21	9	12
2	29	25	309	315	33	20	15	18
3	30	27	401	389	27	23	12	18
4	25	29	299	316	31	26	20	15
5	22	26	350	325	25	18	19	14

**Source:** (Ewoh,2019)

Table A24: Travel Time Data Collected during off-Peak Hour

S/N	Travel time (Min)		No. of vehicles in opp. Direction		No. of vehicles that overtook test car		No. of vehicles overtaken by test car	
	T <sub>e</sub>	T <sub>w</sub>	N <sub>e</sub>	N <sub>w</sub>	O <sub>e</sub>	O <sub>w</sub>	P <sub>e</sub>	P <sub>w</sub>
6	31	28	419	389	32	26	17	20
7	27	24	361	334	29	21	15	18
8	29	32	420	343	30	27	16	22
9	25	27	359	403	22	25	25	18
10	30	27	456	380	27	19	13	10

**Source:** (Ewoh,2019)

Table A25: Travel Time Data Collected during off-Peak Hour

No. of Trips	Travel time (Min)		No. of vehicles in opp. Direction		No. of vehicles that overtook test car		No. of vehicles overtaken by test car	
S/N	T <sub>e</sub>	T <sub>w</sub>	N <sub>e</sub>	N <sub>w</sub>	O <sub>e</sub>	O <sub>w</sub>	P <sub>e</sub>	P <sub>w</sub>
11	28	30	398	408	30	17	18	26
12	31	25	333	381	29	20	30	18
13	26	30	429	396	25	28	13	16
14	23	27	451	420	30	28	18	20
15	25	29	381	405	22	25	16	13

**Source:** (Ewoh,2019)

Table A26: Travel Time Data Collected during off-Peak Hour

No. of Trips	Travel time (Min)		No. of vehicles in opp. Direction		No. of vehicles that overtook test car		No. of vehicles overtaken by test car	
S/N	T <sub>e</sub>	T <sub>w</sub>	N <sub>e</sub>	N <sub>w</sub>	O <sub>e</sub>	O <sub>w</sub>	P <sub>e</sub>	P <sub>w</sub>
16	30	26	412	380	26	21	18	20
17	33	28	431	416	31	33	15	25
18	28	30	344	378	28	25	22	18
19	27	30	384	410	18	31	14	20
20	25	28	321	364	27	33	23	18

**Source:** (Ewoh,2019)

Table A27: Travel Time Data Collected during off-Peak Hour

No. of Trips	Travel time (Min)		No. of vehicles in opp. Direction		No. of vehicles that overtook test car		No. of vehicles overtaken by test car	
	$T_e$	$T_w$	$N_e$	$N_w$	$O_e$	$O_w$	$P_e$	$P_w$
21	31	26	388	403	36	28	25	21
22	25	29	411	375	19	25	19	26
23	28	24	380	334	27	29	19	22
24	26	28	347	408	29	15	20	14
25	22	30	422	390	33	29	12	14

**Source:** (Ewoh,2019)

Table A28: Travel Time Data Collected during off-Peak Hour

No. of Trips	Travel time (Min)		No. of vehicles in opp. Direction		No. of vehicles that overtook test car		No. of vehicles overtaken by test car	
	$T_e$	$T_w$	$N_e$	$N_w$	$O_e$	$O_w$	$P_e$	$P_w$
26	29	27	450	399	21	32	23	15
27	27	33	386	471	26	29	19	12
28	30	29	388	406	33	26	21	18
29	27	31	405	433	35	31	16	23
30	30	28	391	425	33	38	17	20

**Source:** (Ewoh,2019)

Table A29: Travel Time Data Collected during off-Peak Hour Air force Base Route

No. of Trips	Travel time (Min)		No. of vehicles in opp. Direction		No. of vehicles that overtook test car		No. of vehicles overtaken by test car	
S/N	T <sub>e</sub>	T <sub>w</sub>	N <sub>e</sub>	N <sub>w</sub>	O <sub>e</sub>	O <sub>w</sub>	P <sub>e</sub>	P <sub>w</sub>
1	20.4	29.6	334	356	23	30	22	19
2	22.3	25.3	341	316	29	20	21	23
3	22.9	27.6	309	356	22	19	20	22
4	20.3	23.0	414	383	20	24	19	21
5	22.1	25.8	399	372	20	22	23	25

**Source:** (Ewoh,2019)

Table A30: Travel Time Data Collected during off-Peak Hour

No. of Trips	Travel time (Min)		No. of vehicles in opp. Direction		No. of vehicles that overtook test car		No. of vehicles overtaken by test car	
S/N	T <sub>e</sub>	T <sub>w</sub>	N <sub>e</sub>	N <sub>w</sub>	O <sub>e</sub>	O <sub>w</sub>	P <sub>e</sub>	P <sub>w</sub>
1	23.5	19.8	382	391	23	20	21	19
2	21.0	23.6	401	386	23	19	22	17
3	19.2	24.3	395	406	19	24	21	20
4	22.7	20.6	359	384	18	20	15	18
5	19.8	21.4	394	367	18	23	20	20

**Source:** (Ewoh,2019)



Table A31: Travel Time Data Collected during off-Peak Hour

No. of Trips	Travel time (Min)		No. of vehicles in opp. Direction		No. of vehicles that overtook test car		No. of vehicles overtaken by test car	
S/N	T <sub>e</sub>	T <sub>w</sub>	N <sub>e</sub>	N <sub>w</sub>	O <sub>e</sub>	O <sub>w</sub>	P <sub>e</sub>	P <sub>w</sub>
1	20.1	23.6	403	381	20	20	23	22
2	22.7	19.7	394	369	22	25	21	21
3	21.6	20.9	410	376	23	20	20	22
4	23.6	21.3	311	353	23	19	19	23
5	22.4	20.7	419	378	25	28	22	24

**Source:** (Ewoh,2019)

Table A32: Travel Time Data Collected during off-Peak Hour

No. of Trips	Travel time (Min)		No. of vehicles in opp. Direction		No. of vehicles that overtook test car		No. of vehicles overtaken by test car	
S/N	T <sub>e</sub>	T <sub>w</sub>	N <sub>e</sub>	N <sub>w</sub>	O <sub>e</sub>	O <sub>w</sub>	P <sub>e</sub>	P <sub>w</sub>
1	21.9	23.1	398	403	22	23	19	20
2	19.7	21.3	376	384	20	19	23	20
3	22.6	23.0	389	390	22	22	23	23
4	22.7	21.8	403	379	23	23	17	19
5	20.3	22.9	358	401	19	19	21	21

**Source:** (Ewoh,2019)

## Appendix B

**Table BI: Traffic data collected along Wadata Market route Peak Hour:**

Trips	Travel Time (Min.)	Ave. Dwell Time (Sec.)	Route Length (m)	Time Headway (Min.)	No. of Roundabouts	No. of Intersections T-Junction	No. of Intersections Cross-Intersection	Volume of Traffic	Travel Speed (m/min.)	No. of Stops
1	29.46	20.0	11800	1.5	3	8	3	482.9	400.5	8
2	26.67	18.0	11800	1.6	3	8	3	495.6	442.5	10
3	25.64	22.5	11800	2.8	3	8	3	526.9	460.2	12
4	25.45	19.0	11800	2.1	3	8	3	549.8	463.7	10
5	28.94	30.2	11800	2.1	3	8	3	541.6	407.7	9
6	28.62	30.0	11800	2.5	3	8	3	568.5	412.3	12
7	26.51	27.2	11800	2.3	3	8	3	593.9	445.1	10
8	29.43	32.0	11800	2.3	3	8	3	548.8	400.9	11
9	25.05	29.4	11800	1.3	3	8	3	707.9	471.1	9
10	27.65	30.0	11800	1.6	3	8	3	600.5	426.8	10
11	25.15	42.0	11800	2.1	3	8	3	517.9	469.2	11
12	25.15	36.0	11800	1.4	3	8	3	472.7	469.2	8
13	26.07	22.2	11800	1.5	3	8	3	502.2	452.6	10
14	26.81	26.0	11800	1.8	3	8	3	516.2	440.1	11
15	26.01	47.3	11800	2.4	3	8	3	506.4	453.7	11
16	28.63	28.4	11800	1.6	3	8	3	558.9	412.2	10
17	27.55	18.6	11800	2.4	3	8	3	536.0	428.3	12
18	26.89	31.0	11800	2.5	3	8	3	546.8	438.8	10
19	25.62	19.8	11800	2.2	3	8	3	540.0	460.6	13
20	28.92	28.0	11800	1.0	3	8	3	582.6	408.0	12
21	23.84	33.8	11800	1.7	3	8	3	553.4	494.9	10
22	26.35	38.4	11800	2.3	3	8	3	470.7	447.8	13
23	25.09	51.0	11800	2.6	3	8	3	524.2	470.3	11
24	26.55	29.0	11800	1.8	3	8	3	523.3	444.4	12
25	27.08	44.5	11800	2.7	3	8	3	486.1	435.8	12
26	27.53	46.2	11800	2.3	3	8	3	534.1	428.6	13
27	26.92	37.0	11800	2.4	3	8	3	602.5	438.3	9
28	27.34	59.6	11800	1.6	3	8	3	626.9	431.6	11
29	25.57	53.2	11800	2.6	3	8	3	613.4	461.5	10
30	29.39	38.0	11800	1.8	3	8	3	559.1	401.5	10

**Source:** (Ewoh,2019)

**Table B2: Traffic data collected along Wadata Market route Off-Peak Hour:**

Trips	Travel Time (Min.)	Ave. Dwell Time (Sec.)	Route Length (m)	Time Headway (Min.)	No. of Roundabouts	No. of Intersections T-Junction	Cross-Intersection	Volume of Traffic	Travel Speed (m/min.)	No. of Stops
1	20.25	19.0	11800	1.0	3	8	3	430.9	582.7	7
2	25.37	22.2	11800	1.3	3	8	3	357.8	465.1	5
3	27.09	18.6	11800	1.0	3	8	3	426.4	435.6	9
4	25.13	23.6	11800	1.6	3	8	3	353.9	469.6	7
5	23.30	33.3	11800	1.2	3	8	3	428.2	506.4	4
6	27.98	29.6	11800	1.0	3	8	3	420.0	421.7	11
7	24.27	20.7	11800	1.4	3	8	3	418.8	486.2	8
8	28.95	32.0	11800	1.8	3	8	3	384.6	407.6	5
9	25.70	18.5	11800	1.2	3	8	3	441.9	459.1	9
10	26.93	27.3	11800	1.5	3	8	3	452.1	438.2	11
11	28.84	30.5	11800	2.0	3	8	3	418.5	409.2	4
12	27.91	34.1	11800	1.8	3	8	3	383.0	422.8	8
13	26.44	38.1	11800	1.0	3	8	3	454.8	446.3	10
14	28.64	29.7	11800	1.3	3	8	3	445.5	412.0	9
15	23.00	35.4	11800	1.1	3	8	3	446.7	513.0	13
16	27.36	29.7	11800	2.1	3	8	3	429.1	431.3	7
17	28.82	36.0	11800	1.3	3	8	3	428.4	409.4	9
18	27.97	26.8	11800	1.7	3	8	3	378.6	421.9	11
19	27.43	23.6	11800	1.4	3	8	3	425.8	430.2	6
20	25.03	32.6	11800	2.2	3	8	3	398.5	471.4	10
21	27.24	34.2	11800	1.5	3	8	3	425.8	433.2	7
22	27.07	34.9	11800	1.8	3	8	3	436.2	435.9	9
23	24.70	23.9	11800	2.1	3	8	3	422.3	477.7	4
24	26.34	34.0	11800	1.5	3	8	3	425.0	447.9	8
25	24.01	32.4	11800	1.3	3	8	3	486.9	491.5	6
26	27.12	28.6	11800	1.2	3	8	3	462.9	435.1	9
27	28.30	36.3	11800	1.4	3	8	3	440.5	416.9	9
28	28.06	29.8	11800	1.7	3	8	3	413.9	420.5	6
29	27.29	32.4	11800	1.3	3	8	3	460.4	432.4	8
30	26.67	28.6	11800	1.0	3	8	3	439.7	442.5	6

**Source:** (Ewoh,2019)

**Table B3: Traffic data collected along Modern Market route Peak Hour:**

Trips	Travel Time (Min.)	Ave. Dwell Time (Sec.)	Route Length (m)	Time Headway (Min.)	No. of Roundabouts	No. of Intersections T-Junction	Cross-Intersection	Volume of Traffic	Travel Speed (m/min.)	No. of Stops
1	22.82	43.3	13800	1.3	4	9	3	556.4	604.7	10
2	24.39	38.0	13800	2.6	4	9	3	522.5	565.8	12
3	24.86	32.1	13800	1.2	4	9	3	563.0	555.1	10
4	26.72	41.8	13800	2.4	4	9	3	518.7	516.5	9
5	27.56	54.0	13800	1.6	4	9	3	529.8	500.7	7
6	32.21	50.3	13800	1.5	4	9	3	522.0	428.4	10
7	24.28	54.0	13800	2.5	4	9	3	595.7	568.4	13
8	27.87	44.7	13800	2.8	4	9	3	567.9	495.2	12
9	27.79	49.0	13800	2.2	4	9	3	590.2	496.6	12
10	27.61	38.3	13800	2.0	4	9	3	559.4	499.8	10
11	25.12	47.6	13800	2.2	4	9	3	529.3	549.4	9
12	25.22	39.0	13800	1.6	4	9	3	504.3	547.2	11
13	27.68	37.5	13800	1.8	4	9	3	516.4	498.6	10
14	23.97	64.7	13800	2.1	4	9	3	551.3	575.7	12
15	25.61	45.9	13800	1.3	4	9	3	561.1	538.9	14
16	24.71	46.7	13800	1.6	4	9	3	562.1	558.5	10
17	25.22	43.2	13800	2.6	4	9	3	531.8	547.2	12
18	24.66	38.0	13800	2.4	4	9	3	598.0	559.6	13
19	25.95	48.0	13800	2.3	4	9	3	633.6	531.8	10
20	26.48	53.7	13800	2.1	4	9	3	622.3	521.2	13
21	26.57	39.6	13800	2.1	4	9	3	530.6	519.4	12
22	25.19	43.9	13800	1.9	4	9	3	484.7	547.8	14
23	31.89	49.0	13800	1.3	4	9	3	427.4	432.7	12
24	25.39	30.0	13800	1.2	4	9	3	579.1	543.5	10
25	28.28	48.2	13800	2.1	4	9	3	513.5	545.9	13
26	31.99	42.5	13800	2.1	4	9	3	487.7	431.4	12
27	25.79	59.3	13800	2.3	4	9	3	544.7	535.1	11
28	27.30	48.0	13800	1.9	4	9	3	571.5	505.5	12
29	25.77	32.0	13800	2.4	4	9	3	631.1	535.5	10
30	25.96	44.7	13800	1.9	4	9	3	577.8	531.6	12

**Source:** (Ewoh,2019)

**Table B4: Traffic data collected along Modern Market route Off-Peak Hour:**

Trips	Travel Time (Min.)	Ave. Dwell Time (Sec.)	Route Length (m)	Time Headway (Min.)	No. of Roundabouts	No. of Intersections T-Junction	Cross-Intersection	Volume of Traffic	Travel Speed (m/min.)	No. of Stops
1	25.13	37.6	13800	1.6	4	9	3	442.1	549.2	5
2	31.08	32.8	13800	1.2	4	9	3	379.1	444.0	13
3	26.03	28.9	13800	1.5	4	9	3	449.5	530.2	10
4	27.93	38.0	13800	1.1	4	9	3	423.2	494.1	6
5	26.51	29.6	13800	1.3	4	9	3	410.4	520.6	6
6	27.13	38.5	13800	1.6	4	9	3	446.3	508.7	9
7	26.57	28.7	13800	1.9	4	9	3	419.5	519.4	10
8	28.95	33.6	13800	2.0	4	9	3	356.0	476.7	5
9	29.92	32.3	13800	1.4	4	9	3	342.4	461.2	8
10	25.93	29.4	13800	1.8	4	9	3	465.9	532.2	4
11	25.68	33.2	13800	1.5	4	9	3	431.7	537.4	7
12	32.14	39.6	13800	2.1	4	9	3	373.4	429.4	10
13	26.49	33.6	13800	1.8	4	9	3	412.2	520.9	7
14	28.75	28.5	13800	1.2	4	9	3	430.0	480.0	9
15	25.70	34.9	13800	2.3	4	9	3	433.0	536.9	9
16	21.36	41.3	13800	1.6	4	9	3	456.9	646.1	4
17	25.37	38.4	13800	1.4	4	9	3	442.4	543.9	8
18	25.02	33.4	13800	2.1	4	9	3	497.3	551.6	10
19	29.11	23.1	13800	1.9	4	9	3	307.5	474.1	5
20	28.56	35.9	13800	1.6	4	9	3	344.5	483.2	7
21	27.57	39.5	13800	1.4	4	9	3	364.6	500.5	4
22	29.79	32.2	13800	1.1	4	9	3	377.4	463.2	12
23	29.16	29.0	13800	2.1	4	9	3	370.6	473.2	14
24	28.41	26.9	13800	1.9	4	9	3	395.7	485.8	9
25	25.05	24.4	13800	1.6	4	9	3	471.4	550.9	6
26	28.68	30.9	13800	2.0	4	9	3	430.0	481.2	10
27	27.98	34.7	13800	1.5	4	9	3	427.3	493.2	8
28	27.10	32.0	13800	1.3	4	9	3	426.8	509.2	8
29	27.91	39.4	13800	1.6	4	9	3	421.1	494.5	4
30	24.19	35.0	13800	1.4	4	9	3	497.4	570.5	9

**Source:** (Ewoh,2019)

**Table B5: Traffic data collected along Air force Base route Peak Hour**

Trips	Travel Time (Min.)	Ave. Dwell Time (Sec.)	Route Length (m)	Time Headway (Min.)	No. of Roundabouts	No. of Intersections		Volume of Traffic	Travel Speed (m/min.)	No. of Stops
						T-Junction	Cross-Intersection			
1	23.81	23.3	10200	1.3	4	11	6	628.2	428.4	10
2	25.47	28.0	10200	2.6	4	11	6	650.2	400.5	8
3	22.94	22.1	10200	1.2	4	11	6	706.3	444.6	10
4	25.40	31.8	10200	2.4	4	11	6	645.0	401.6	9
5	23.37	33.0	10200	1.6	4	11	6	592.8	436.5	10
6	24.24	30.3	10200	1.5	4	11	6	631.7	420.8	10
7	23.83	34.0	10200	2.5	4	11	6	610.0	428.0	11
8	24.72	34.7	10200	2.8	4	11	6	615.6	412.6	7
9	24.33	39.0	10200	2.2	4	11	6	721.2	419.2	15
10	21.71	33.3	10200	2.0	4	11	6	703.4	469.8	12
11	19.87	37.4	10200	2.2	4	11	6	775.8	513.3	9
12	22.58	34.3	10200	1.6	4	11	6	645.3	451.7	11
13	23.62	32.3	10200	1.8	4	11	6	628.2	431.8	10
14	23.29	24.7	10200	2.1	4	11	6	604.3	437.9	12
15	22.46	35.4	10200	1.3	4	11	6	680.6	454.1	14
16	26.25	36.2	10200	1.6	4	11	6	584.4	388.6	10
17	23.07	43.2	10200	2.6	4	11	6	654.6	442.1	12
18	21.00	32.2	10200	2.4	4	11	6	646.7	485.7	13
19	20.83	35.0	10200	2.3	4	11	6	681.5	489.7	10
20	22.99	38.9	10200	2.1	4	11	6	650.0	443.7	11

**Source:** (Ewoh,2019)

**Table B6: Traffic data collected along Air force Base route Off-Peak Hour**

Trips	Travel Time (Min.)	Ave. Dwell Time (Sec.)	Route Length (m)	Time Headway (Min.)	No. of Roundabouts	No. of Intersections		Volume of Traffic	Travel Speed (m/min.)	No. of Stops
						T-Junction	Cross-Intersection			
1	24.14	20.0	10200	1.0	4	11	6	424.0	422.50	8
2	23.42	22.0	10200	3.2	4	11	6	417.1	435.50	6
3	25.36	22.5	10200	1.4	4	11	6	394.5	402.20	8
4	20.80	21.9	10200	1.4	4	11	6	555.0	490.40	10
5	24.33	30.8	10200	1.8	4	11	6	479.1	419.20	10
6	21.49	32.3	10200	1.5	4	11	6	537.7	474.60	6
7	22.14	28.0	10200	2.8	4	11	6	531.4	460.70	10
8	21.64	30.7	10200	2.2	4	11	6	553.8	471.30	8
9	21.36	28.0	10200	2.7	4	11	6	518.3	477.50	11
10	20.56	29.3	10200	2.8	4	11	6	554.9	496.10	10
11	22.14	33.2	10200	2.3	4	11	6	534.8	460.70	10
12	20.93	31.3	10200	2.6	4	11	6	543.4	487.30	9
13	21.18	30.9	10200	2.8	4	11	6	555.7	481.60	10
14	22.52	34.9	10200	2.3	4	11	6	443.3	452.90	7
15	21.18	25.4	10200	2.3	4	11	6	559.7	481.60	9
16	22.18	39.2	10200	2.6	4	11	6	537.6	459.90	7
17	20.75	34.2	10200	2.3	4	11	6	552.3	491.60	10
18	22.91	29.7	10200	2.9	4	11	6	511.6	445.20	10
19	21.83	33.8	10200	1.3	4	11	6	532.8	467.30	10
20	21.32	32.2	10200	2.6	4	11	6	561.1	478.40	9

**Source:** (Ewoh,2019)

## Appendix C

### The Average Travel Time $T_w$ In The Westbound And $T_e$ In The Eastbound Direction Is Estimated From:

The volume ( $V_e$ ) in the eastbound and westbound ( $V_w$ ) direction can then be obtained from the expression for Modern Market Route (peak hour)

$$1 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(472 + 46 - 13)60}{28 + 27} = 550.9$$

Average  $V = 556.4$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(461 + 68 - 14)60}{28 + 27} = 561.8$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 27 - \frac{(68 - 14)60}{561.8} = 21.23$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 28 - \frac{(46 - 13)60}{550.9} = 24.41$$

$$2 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(480 + 52 - 20)60}{30 + 28} = 529.7$$

Average  $V = 522.5$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(450 + 77 - 29)60}{30 + 28} = 515.2$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 28 - \frac{(77 - 29)60}{515.2} = 22.41$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 30 - \frac{(52 - 20)60}{529.9} = 26.37$$



$$3V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(490 + 55 - 18)60}{27 + 29} = 564.6$$

Average V=563

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(502 + 49 - 27)60}{27 + 29} = 561.4$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 29 - \frac{(49 - 27)60}{561.4} = 26.65$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 27 - \frac{(55 - 18)60}{564.6} = 23.07$$

$$4V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(507 + 60 - 29)60}{33 + 29} = 520.6$$

V= 518.7

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(491 + 78 - 35)60}{33 + 29} = 516.8$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 29 - \frac{(78 - 35)60}{516.8} = 24.01$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 33 - \frac{(60 - 29)60}{520.6} = 29.43$$

$$5V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(504 + 47 - 20)60}{30 + 32} = 513.9$$

Average V=529.9

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(530 + 59 - 25)60}{30 + 32} = 545.8$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 32 - \frac{(59 - 25)60}{545.8} = 28.26$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 30 - \frac{(47 - 20)60}{513.9} = 26.85$$

$$6 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(574+21-47)60}{31+29} = 548$$

Average V=522

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(509+16-29)60}{31+29} = 496$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 29 - \frac{(16-29)60}{496} = 30.57$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 31 - \frac{(21-47)60}{548} = 33.85$$

$$7 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(523+70-33)60}{29+27} = 600$$

Average V=595.7

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(515+55-18)60}{29+27} = 591.4$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 29 - \frac{(70-33)60}{591.4} = 25.3$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 27 - \frac{(55-18)60}{600} = 23.3$$

$$8 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(496+47-18)60}{30+29} = 533.9$$

Average V=567.9

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(518+50-20)60}{30+29} = 557.3$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 29 - \frac{(50-20)60}{557.3} = 25.77$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 30 - \frac{(47-18)60}{533.9} = 26.74$$

$$9 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(499+37-15)60}{30+31} = 512.5$$

Average V=590.2

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(477+52-21)60}{30+31} = 499.7$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 30 - \frac{(37-15)60}{512.5} = 27.424$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 31 - \frac{(52-21)60}{499.7} = 27.278$$

$$10 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(572+46-15)60}{29+33} = 583.6$$

Average V=559.4

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(521+50-18)60}{29+33} = 535.2$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 33 - \frac{(50-18)60}{535.2} = 229.413$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 29 - \frac{(46-15)60}{583.6} = 25.813$$

$$11 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(600+50-18)60}{30+29} = 642.7$$

Average V=529.3

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(566+61-15)60}{30+29} = 622.4$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 29 - \frac{(61-15)60}{622.4} = 24.565$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 30 - \frac{(50-18)60}{642.7} = 27.013$$

$$12 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(517+51-9)60}{28+30} = 578.3$$

Average V=504.3

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(496+33-13)60}{28+30} = 533.8$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 30 - \frac{(33-13)60}{533.8} = 27.752$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 28 - \frac{(51-9)60}{578.3} = 23.642$$

$$13. \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(512+49-18)60}{31+30} = 534.1$$

Average V=516.4

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(489+38-20)60}{31+30} = 498.7$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 30 - \frac{(38-20)60}{498.7} = 27.834$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 31 - \frac{(49-18)60}{534.1} = 27.517$$

$$14 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(594+48-12)60}{29+27} = 675$$

Average V=551.3

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(586+56-18)60}{29+27} = 668.6$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 27 - \frac{(56-18)60}{668.6} = 23.59$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 29 - \frac{(48-12)60}{675} = 25.8$$

$$15 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(540+38-15)60}{27+30} = 592.6$$

Average V=561.1

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(600+41-10)60}{27+30} = 666.3$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 30 - \frac{(41-10)60}{666.3} = 27.208$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 27 - \frac{(38-15)60}{592.6} = 24.671$$

$$16 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(493+47-12)60}{29+28} = 555.8$$

Average V=562.1

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(504+49-13)60}{29+28} = 568.4$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 28 - \frac{(49-13)60}{568.4} = 24.2$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 29 - \frac{(47-12)60}{555.8} = 25.222$$

$$17. \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(512+53-18)60}{28+30} = 565.9$$

Average V=531.8

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(449+62-30)60}{28+30} = 497.6$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 30 - \frac{(62-30)60}{497.6} = 26.141$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 28 - \frac{(53-18)60}{565.9} = 24.289$$

$$18. \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(500+62-20)60}{30+29} = 551.2$$

Average V=598.0

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(550+70-15)60}{30+29} = 615.3$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 29 - \frac{(70-15)60}{615.3} = 23.64$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 30 - \frac{(62-20)60}{551.2} = 25.428$$

$$19. \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(549+49-12)60}{30+28} = 606.2$$

Average V=633.6

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(612+45-18)60}{30+28} = 661.0$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 28 - \frac{(45-18)60}{661} = 25.55$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 30 - \frac{(49-12)60}{606.2} = 26.338$$

$$20. V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(602+48-18)60}{29+33} = 611.6$$

Average V=622.3

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(590+70-12)60}{29+33} = 627.1$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 33 - \frac{(70-12)60}{627.1} = 27.451$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 29 - \frac{(48-18)60}{611.6} = 26.057$$

$$21. V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(473+50-26)60}{30+27} = 523.2$$

Average V=530.6

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(501+41-31)60}{30+27} = 537.9$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 27 - \frac{(41-31)60}{537.9} = 25.88$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 30 - \frac{(50-26)60}{523.2} = 27.25$$

$$22. V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(411+46-16)60}{30+28} = 456.2$$

Average V=484.7

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(463+47-14)60}{30+28} = 513.1$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 28 - \frac{(47-14)60}{513.1} = 24.14$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 30 - \frac{(46-16)60}{456.2} = 26.05$$

$$23. V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(523+29-29)60}{36+30} = 475.6$$

Average V=427.4

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(403+37-23)60}{36+30} = 379.1$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 30 - \frac{(37-23)60}{379.1} = 27.78$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 36 - \frac{(29-29)60}{475.6} = 36.0$$

$$24 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(471+39-16)60}{27+29} = 532.5$$

Average V=579.1

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(560+40-16)60}{27+29} = 625.7$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 29 - \frac{(40-16)60}{625.7} = 25.39$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 27 - \frac{(39-13)60}{532.5} = 24.07$$

$$25 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(487+48-28)60}{31+30} = 498.7$$

Average V=513.5

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(519+31-13)60}{61} = 528.2$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 30 - 2.04 = 27.96$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 31 - 2.41 = 28.28$$

$$26. \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(596+41-19)60}{36+34} = 529.7$$

Average V=487.7

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(479+58-17)60}{70} = 445.7$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 34 - 5.52 = 28.48$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 362 - 2.49 = 33.51$$

$$27 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(516+39-22)60}{28+30} = 551.4$$

$$\text{Average } V = 544.7$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(479+58-17)60}{58} = 537.9$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 30 - 4.57 = 25.43$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 28 - 1.85 = 26.15$$

$$28 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(587+60-18)60}{30+32} = 498.7608.7$$

$$\text{Average } V = 571.5$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(523+43-14)60}{62} = 534.2$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 32 - 3.26 = 28.74$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 30 - 4.14 = 25.86$$

$$29 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(600+50-15)60}{28+29} = 668.4$$

$$\text{Average } V = 631.1$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(541+47-24)60}{57} = 593.7$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 29 - 2.32 = 26.68$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 28 - 3.14 = 24.86$$

$$30 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(503+56-18)60}{31+27} = 559.7$$

$$\text{Average } V = 577.8$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(556+40-20)60}{58} = 595.9$$



$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 27 - 2.01 = 24.99$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 31 - 4.07 = 26.93$$

The Average Travel Time  $T_w$  In The Westbound And  $T_e$  In The Eastbound Direction Is Estimated From:

The volume ( $V_e$ ) in the eastbound and westbound ( $V_w$ ) direction can then be obtained from the expression for Wadata Market Route (peak hour)

$$1 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(509 + 32 - 23)60}{26 + 36} = 501.3$$

$$\text{Average } V = 482.9$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(449 + 49 - 18)60}{62} = 464.5$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 36 - 4.00 = 32.0$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 26 - 1.08 = 26.92$$

$$T = 29.46$$

$$2 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(419 + 36 - 15)60}{30 + 28} = 455.2$$

$$\text{Average } V = 495.6$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(501 + 38 - 21)60}{58} = 535.9$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 28 - 1.90 = 26.1$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 30 - 2.77 = 27.23$$

$$T = 26.67$$

$$3 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(507 + 50 - 25)60}{27 + 30} = 560$$

$$\text{Average } V = 526.9$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(444 + 43 - 18)60}{57} = 493.7$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 30 - 3.04 = 26.96$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 27 - 2.68 = 24.32$$

$$T = 25.64$$

$$4 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(511 + 41 - 17)60}{28 + 27} = 583.6$$

$$\text{Average } V = 549.8$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(459 + 34 - 20)60}{55} = 516$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 27 - 1.63 = 25.37$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 28 - 2.47 = 25.53$$

$$T = 25.45$$

$$5 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(490 + 25 - 30)60}{28 + 30} = 501.7$$

$$\text{Average } V = 541.6$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(555 + 30 - 23)60}{58} = 581.4$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 30 - 0.72 = 29.28$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 28 + 0.59 = 28.59$$

$$T = 28.94$$

$$6 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(520 + 50 - 35)60}{28 + 32} = 535$$

$$\text{Average } V = 568.5$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(591 + 39 - 28)60}{60} = 602$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 32 - 1.09 = 30.91$$

$$T_e = T_c - \frac{(O_e - P_e)60}{V_e} = 28 - 1.68 = 26.32$$

$$T = 28.62$$

$$7 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(509 + 59 - 22)60}{30 + 29} = 555.3$$

$$\text{Average } V = 593.9$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(601 + 47 - 26)60}{59} = 632.5$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 29 - 1.99 = 27.01$$

$$T_e = T_c - \frac{(O_e - P_e)60}{V_e} = 30 - 3.99 = 26.01$$

$$T = 26.51$$

$$8 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(580 + 53 - 28)60}{36 + 29} = 558.5$$

$$\text{Average } V = 548.8$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(553 + 47 - 16)60}{65} = 539.1$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 29 - 3.45 = 25.55$$

$$T_e = T_c - \frac{(O_e - P_e)60}{V_e} = 36 - 2.69 = 33.31$$

$$T = 29.43$$

$$9 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(567 + 60 - 15)60}{27 + 30} = 644.2$$

$$\text{Average } V = 707.9$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(698 + 53 - 18)60}{57} = 771.7$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 30 - 2.72 = 27.28$$

$$T_e = T_c - \frac{(O_e - P_e)60}{V_e} = 27 - 4.19 = 22.81$$

$$T = 25.05$$

$$10 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(600+58-29)60}{30+31} = 618.7$$

Average V=600.5

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(564+41-13)60}{61} = 582.3$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 31 - 2.89 = 27.11$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 30 - 2.81 = 28.19$$

$$T = 27.65$$

$$11 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(510+38-12)60}{27+30} = 564.2$$

Average V=517.9

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(417+47-16)60}{57} = 471.6$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 30 - 3.94 = 26.06$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 27 - 2.76 = 24.24$$

$$T = 25.15$$

$$12 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(418+41-20)60}{29+28} = 462.1$$

Average V=472.7

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(427+50-18)60}{57} = 483.2$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 28 - 3.97 = 24.04$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 29 - 2.73 = 26.27$$

$$T = 25.15$$

$$13 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(503+33-15)60}{30+28} = 538.9$$

Average V=502.2

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(420+43-13)60}{58} = 465.5$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 28 - 3.87 = 24.13$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 30 - 2.00 = 28.0$$

$$T = 26.07$$

$$14 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(511+37-25)60}{28+30} = 541.0$$

$$\text{Average } V = 516.2$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(450+41-16)60}{58} = 491.4$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 30 - 3.05 = 26.67$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 28 - 1.33 = 26.67$$

$$T = 26.81$$

$$15 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(417+47-22)60}{28+30} = 457.2$$

$$\text{Average } V = 506.4$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(512+39-14)60}{58} = 555.5$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 30 - 2.70 = 27.3$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 28 - 3.28 = 24.72$$

$$T = 26.01$$

$$16 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(590+53-31)60}{30+32} = 592.3$$

$$\text{Average } V = 558.9$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(521+48-26)60}{62} = 525.5$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 32 - 2.51 = 29.49$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 30 - 2.23 = 27.77$$

$$T = 28.63$$

$$17 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(450 + 50 - 18)60}{32 + 28} = 482$$

$$\text{Average } V = 536.0$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(581 + 37 - 28)60}{60} = 590$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 28 - 0.92 = 27.08$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 32 - 3.98 = 28.02$$

$$T = 27.55$$

$$18 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(456 + 41 - 30)60}{29 + 29} = 483.1$$

$$\text{Average } V = 546.8$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(561 + 52 - 23)60}{58} = 610.4$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 29 - 2.85 = 26.15$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 29 - 1.37 = 27.63$$

$$T = 26.89$$

$$19 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(521 + 60 - 27)60}{28 + 30} = 573.1$$

$$\text{Average } V = 540$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(462 + 47 - 19)60}{58} = 506.9$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 30 - 3.31 = 26.69$$

$$T_e = T_c - \frac{(O_e - P_e)60}{V_e} = 28 - 3.46 = 24.54$$

$$T = 25.62$$

$$20 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(597 + 58 - 30)60}{30 + 32} = 604.8$$

$$\text{Average } V = 582.6$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(566 + 39 - 26)60}{62} = 560.3$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 32 - 1.39 = 30.61$$

$$T_e = T_c - \frac{(O_e - P_e)60}{V_e} = 30 - 2.78 = 27.22$$

$$T = 28.92$$

$$21 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(501 + 43 - 15)60}{26 + 28} = 587.8$$

$$\text{Average } V = 553.4$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(437 + 50 - 20)60}{54} = 518.9$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 28 - 3.47 = 24.53$$

$$T_e = T_c - \frac{(O_e - P_e)60}{V_e} = 26 - 2.86 = 23.14$$

$$T = 23.84$$

$$22 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(417 + 38 - 20)60}{30 + 28} = 450$$

$$\text{Average } V = 470.7$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(453 + 40 - 18)60}{58} = 491.4$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 28 - 2.9 = 25.1$$

$$T_e = T_c - \frac{(O_e - P_e)60}{V_e} = 30 - 2.40 = 27.6$$

$$T = 26.35$$

$$23 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(433+35-10)60}{27+30} = 482.1$$

Average V=524.2

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(503+48-13)60}{57} = 566.3$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 30 - 3.71 = 26.29$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 27 - 3.11 = 23.89$$

$$T = 25.09$$

$$24 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(521+47-16)60}{30+29} = 561.4$$

Average V=523.3

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(456+39-18)60}{59} = 485.1$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 29 - 2.59 = 26.41$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 30 - 3.31 = 26.69$$

$$T = 26.55$$

$$25 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(513+37-22)60}{28+31} = 536.9$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(405+39-16)60}{59} = 435.3$$

Average V=486.1

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 31 - 3.17 = 27.83$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 28 - 1.68 = 26.32$$

$$T = 27.08$$

$$26 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(497+50-26)60}{32+29} = 512.5$$

Average V=534.1



$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(536+47-18)60}{61} = 555.7$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 29 - 3.13 = 29.19$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 32 - 2.81 = 25.87$$

$$T = 27.53$$

$$27 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(511+39-16)60}{30+30} = 534$$

$$\text{Average } V = 602.5$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(631+63-23)60}{60} = 671$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 30 - 3.58 = 26.42$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 30 - 2.58 = 27.42$$

$$T = 26.92$$

$$28 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(609+46-30)60}{31+28} = 635.6$$

$$\text{Average } V = 626.9$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(577+41-12)60}{59} = 616.3$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 28 - 2.82 = 25.18$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 31 - 1.51 = 29.49$$

$$T = 27.34$$

$$29 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(600+57-20)60}{28+30} = 658.9$$

$$\text{Average } V = 613.4$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(516+48-15)60}{58} = 567.9$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 30 - 3.49 = 26.51$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 28 - 3.37 = 24.63$$

$$T = 25.57$$

$$30 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(571 + 50 - 18)60}{30 + 33} = 574.3$$

$$\text{Average } V = 559.1$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(563 + 34 - 26)60}{63} = 543.8$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 33 - 0.88 = 32.12$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 30 - 3.34 = 26.66$$

$$T = 29.39$$

The Average Travel Time  $T_w$  In The Westbound And  $T_e$  In The Eastbound Direction Is Estimated From:

The volume ( $V_e$ ) in the eastbound and westbound ( $V_w$ ) direction can then be obtained from the expression for Air force base Route (peak hour)

$$1 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(499 + 29 - 16)60}{26 + 24} = 614.4$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(523 + 32 - 20)60}{50} = 642$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 24 - 1.22 = 22.878$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 26 - 1.269 = 24.731$$

$$T = 24.73$$

$$2 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(600 + 30 - 30)60}{25 + 27} = 692.3$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(518+36-27)60}{52} = 608.1$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 27 - 0.888 = 26.112$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 25 - 0.1733 = 24.83$$

$$3 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(594+21-17)60}{20+28} = 747.5$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(512+39-19)60}{48} = 665$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 28 - 1.805 = 26.195$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 20 - 0.321 = 19.679$$

$$4 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(604+32-40)60}{25+29} = 662.2$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(541+40-16)60}{54} = 627.8$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 29 - 2.294 = 26.78$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 25 - 0.906 = 24.094$$

$$5 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(506+44-30)60}{27+23} = 625$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(450+46-28)60}{50} = 561.6$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 23 - 1.923 = 21.077$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 27 - 1.346 = 25.654$$

$$6 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(498 + 53 - 25)60}{25 + 28} = 595.5$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(567 + 46 - 23)60}{53} = 667.9$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 28 - 1.707 = 26.293$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 25 - 2.821 = 22.179$$

$$7 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(497 + 34 - 16)60}{27 + 24} = 605.9$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(506 + 44 - 16)60}{51} = 614.1$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 24 - 1.563 = 22.437$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 27 - 1.782 = 25.218$$

$$8 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(490 + 28 - 27)60}{22 + 28} = 589.2$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(530 + 35 - 30)60}{50} = 642$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 28 - 0.467 = 27.533$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 22 - 0.102 = 21.898$$

$$9 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(603+39-33)60}{24+26} = 730.8$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(583+36-26)60}{50} = 711.6$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 26 - 0.843 = 25.157$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 24 - 0.493 = 23.507$$

$$10 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(561+35-15)60}{27+20} = 741.7$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(499+40-18)60}{47} = 665.1$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 20 - 1.985 = 18.015$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 27 - 1.618 = 25.382$$

$$11 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(499+40-20)60}{20+23} = 724.2$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(571+34-12)60}{43} = 827.4$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 23 - 1.595 = 21.405$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 20 - 1.657 = 18.343$$

$$12 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(480+32-24)60}{25+22} = 622.9$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(511+43-31)60}{47} = 667.7$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 22 - 1.078 = 20.922$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 25 - 0.771 = 24.229$$

$$13 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(521 + 42 - 26)60}{26 + 24} = 644.4$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(497 + 36 - 23)60}{50} = 612$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 24 - 1.275 = 22.725$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 26 - 1.489 = 24.511$$

$$14 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(462 + 38 - 18)60}{26 + 23} = 590.2$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(501 + 29 - 25)60}{49} = 618.4$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 23 - 0.388 = 22.612$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 26 - 2.033 = 23.967$$

$$15 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(510 + 41 - 26)60}{27 + 21} = 656.25$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(544 + 33 - 23)60}{48} = 705$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 21 - 1.702 = 19.298$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 27 - 1.371 = 25.629$$

$$16 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(570+33-23)60}{26+28} = 644.4$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(467+35-30)60}{54} = 524.4$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 28 - 0.572 = 27.428$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 26 - 0.931 = 25.069$$

$$17 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(486+49-18)60}{26+24} = 620.4$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(564+32-22)60}{50} = 688.8$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 24 - 0.871 = 23.129$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 26 - 2.998 = 23.002$$

$$18 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(501+50-28)60}{20+25} = 697.3$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(436+41-28)60}{45} = 596$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 25 - 1.107 = 23.893$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 20 - 1.893 = 18.107$$

$$19 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(480+46-18)60}{24+22} = 662.6$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(516+42-21)60}{46} = 700.4$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 22 - 1.799 = 20.201$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 24 - 2.538 = 21.465$$

$$20 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(520+39-28)60}{23+25} = 663.75$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(498+30-19)60}{48} = 636.25$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 25 - 1.037 = 23.963$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 23 - 0.994 = 22.006$$

Off-Peak Average Travel Time  $T_w$  In The Westbound And  $T_e$  In The Eastbound Direction Is Estimated From:

The volume ( $V_e$ ) in the eastbound and westbound ( $V_w$ ) direction can then be obtained from the expression for modern market Route (off-peak)

$$1 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(359+31-20)60}{25+28} = 418.9$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(402+27-18)60}{53} = 465.3$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 28 - 1.161 = 26.84$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 25 - 1.576 = 23.42$$

$$2 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(389+33-16)60}{31+35} = 369.1$$



$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(421+29-22)60}{66} = 389.1$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 35 - 1.079 = 33.92$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 31 - 2.764 = 28.24$$

$$3 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(411+35-25)60}{25+30} = 459.3$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(391+30-18)60}{55} = 439.6$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 30 - 1.638 = 28.36$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 25 - 1.306 = 23.69$$

$$4 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(393+26-20)60}{30+27} = 420$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(403+29-27)60}{57} = 426.3$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 27 - 0.2815 = 26.72$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 30 - 0.8571 = 29.14$$

$$5 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(396+31-25)60}{24+32} = 430.7$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(350+35-21)60}{56} = 390$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 32 - 2.154 = 29.85$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 24 - 0.8359 = 23.16$$

$$6 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(412+19-16)60}{30+26} = 444.6$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(408+30-20)60}{56} = 447.9$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 26 - 1.339 = 24.66$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 30 - 0.4049 = 29.59$$

$$7 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(356+27-24)60}{29+25} = 398.9$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(399+15-18)60}{54} = 440$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 25 + 0.4091 = 24.59$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 29 - 0.4512 = 28.55$$

$$8 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(299+25-18)60}{31+29} = 306$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(401+30-25)60}{60} = 406$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 29 - 0.7389 = 28.26$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 31 - 1.373 = 29.63$$

$$9 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(315+22-22)60}{25+33} = 325.9$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(358+18-29)60}{58} = 358.9$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 33 + 1.839 = 34.84$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 25 - 0 = 25.0$$

$$10 \ V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(398 + 30 - 16)60}{23 + 30} = 466.4$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(416 + 15 - 20)60}{53} = 465.3$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 30 + 0.6448 = 30.65$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 23 - 1.801 = 21.20$$

$$11 \ V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(378 + 33 - 25)60}{26 + 28} = 428.9$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(380 + 29 - 18)60}{54} = 434.4$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 28 - 1.519 = 26.48$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 26 - 1.119 = 24.88$$

$$12 \ V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(398 + 31 - 16)60}{30 + 35} = 381.2$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(406 + 19 - 29)60}{65} = 365.5$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 35 + 1.642 = 36.64$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 30 - 2.361 = 27.64$$

$$13 \ V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(390 + 25 - 22)60}{29 + 25} = 436.6$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(345+28-24)60}{54} = 387.8$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 25 - 0.6189 = 24.38$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 29 - 0.4123 = 28.59$$

$$14 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(443+27-18)60}{29+31} = 452$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(399+34-25)60}{60} = 408$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 31 - 1.324 = 29.68$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 29 - 1.195 = 27.81$$

$$15 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(345+38-30)60}{24+29} = 399.6$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(409+29-26)60}{53} = 466.4$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 29 - 0.3859 = 28.61$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 24 - 1.201 = 22.79$$

$$16 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(301+15-22)60}{18+25} = 410.2$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(350+15-22)60}{43} = 503.7$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 25 - 1.310 = 23.69$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 18 + 1.024 = 19.024$$

$$17 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(391+26-25)60}{24+27} = 461.2$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(359+30-29)60}{51} = 423.5$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 27 - 0.1417 = 26.86$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 24 - 0.1301 = 23.87$$

$$18 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(450+33-19)60}{29+23} = 535.4$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(395+28-25)60}{52} = 459.2$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 23 - 0.3919 = 22.61$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 29 - 1.569 = 27.43$$

$$19 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(305+17-16)60}{30+28} = 316$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(291+25-27)60}{58} = 298.9$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 28 + 0.4015 = 28.40$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 30 - 0.1899 = 29.81$$

$$20 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(335+29-30)60}{26+32} = 345.5$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(326+31-25)60}{58} = 343.5$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 32 - 1.048 = 30.95$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 26 + 0.1737 = 26.17$$

$$21 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(412 + 27 - 22)60}{30 + 29} = 424.1$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(284 + 33 - 17)60}{59} = 305.1$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 29 - 3.147 = 25.85$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 30 - 0.7074 = 29.29$$

$$22 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(368 + 38 - 22)60}{34 + 28} = 371.6$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(397 + 30 - 31)60}{62} = 383.2$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 28 + 0.1566 = 28.16$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 34 - 2.583 = 31.42$$

$$23 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(397 + 29 - 35)60}{30 + 27} = 360.9$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(414 + 26 - 28)60}{65} = 380.3$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 27 + 0.3155 = 27.32$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 30 + 0.9975 = 30.99$$

$$24 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(401 + 29 - 35)60}{28 + 30} = 420$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(356 + 18 - 15)60}{58} = 371.4$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 30 - 0.4847 = 29.52$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 28 - 0.7143 = 27.29$$

$$25 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(399 + 28 - 25)60}{25 + 27} = 463.9$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(403 + 30 - 18)60}{52} = 478.9$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 27 - 1.5035 = 25.49$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 25 - 0.3880 = 24.61$$

$$26 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(412 + 27 - 25)60}{30 + 29} = 421.0$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(422 + 25 - 15)60}{59} = 439.3$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 29 - 1.366 = 27.63$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 30 - 0.2850 = 29.72$$

$$27 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(386 + 30 - 26)60}{27 + 31} = 403.5$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(425 + 29 - 18)60}{58} = 451.0$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 31 - 1.463 = 29.54$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 27 - 0.5948 = 26.41$$

$$28 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(394 + 25 - 24)60}{29 + 24} = 447.2$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(368+19-28)60}{53} = 406.4$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 24 + 1.329 = 25.33$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 29 - 0.1342 = 28.87$$

$$29 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(377+27-18)60}{30+26} = 413.6$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(408+22-30)60}{56} = 428.6$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 26 + 1.119 = 27.12$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 30 - 1.306 = 28.69$$

$$30 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(390+30-28)60}{28+22} = 470.4$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(425+27-15)60}{50} = 524.4$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 22 - 1.373 = 20.63$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 28 - 0.2551 = 27.75$$

The Volume ( $V_e$ ) In The Eastbound And Westbound ( $V_w$ ) Direction Can Then Be Obtained From The Expression For Wadata Market Route (off-peak)

$$1 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(296+25-9)60}{24+20} = 425.5$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(311+21-12)60}{44} = 436.4$$



$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 20 - 1.237 = 18.76$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 24 - 2.256 = 21.74$$

$$2 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(315 + 33 - 15)60}{29 + 25} = 370$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(309 + 20 - 18)60}{54} = 345.6$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 25 - 0.3472 = 24.65$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 29 - 2.919 = 26.081$$

$$3 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(389 + 27 - 12)60}{30 + 27} = 425.3$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(401 + 23 - 18)60}{57} = 427.4$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 27 - 0.7019 = 26.298$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 30 - 2.116 = 27.88$$

$$4 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(316 + 31 - 20)60}{25 + 29} = 363.3$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(299 + 26 - 15)60}{54} = 344.4$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 29 - 1.916 = 27.08$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 25 - 1.817 = 23.18$$

$$5 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(325 + 25 - 19)60}{22 + 26} = 413.8$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(350 + 18 - 14)60}{48} = 442.5$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 26 - 0.5424 = 25.46$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 22 - 0.8699 = 21.13$$

$$6 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(386 + 32 - 17)60}{31 + 28} = 407.8$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(419+26-20)60}{59} = 432.2$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 28 - 0.8329 = 27.17$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 31 - 2.207 = 28.79$$

$$7 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(334+29-15)60}{27+24} = 4409.4$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(361+21-18)60}{51} = 428.2$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 24 - 0.4204 = 23.58$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 27 - 2.052 = 24.95$$

$$8 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(343+30-16)60}{29+32} = 351.2$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(420+27-22)60}{61} = 418$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 32 - 0.7177 = 31.28$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 29 - 2.392 = 26.61$$

$$9 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(403+22-25)60}{25+27} = 461.5$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(359+25-18)60}{52} = 422.3$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 27 - 0.9946 = 26.01$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 25 + 0.3900 = 25.39$$

$$10 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(380+27-13)60}{30+27} = 414.7$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(456+19-10)60}{57} = 489.5$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 27 - 1.103 = 25.897$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 30 - 2.026 = 27.97$$

$$11 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(408+30-18)60}{28+30} = 434.5$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(398+17-26)60}{58} = 402.4$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 30 + 1.342 = 31.34$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 28 - 1.657 = 26.34$$

$$12 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(381+29-30)60}{31+25} = 407.1$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(333+20-18)60}{56} = 358.9$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 25 - 0.3344 = 24.67$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 31 + 0.1474 = 31.15$$

$$13 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(396+25-16)60}{26+30} = 433.9$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(429+28-13)60}{56} = 475.7$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 30 - 1.892 = 28.11$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 26 - 1.245 = 24.76$$

$$14 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(420+30-18)60}{33+27} = 432$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(451+28-20)60}{60} = 459$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 27 - 1.046 = 25.95$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 33 - 1.667 = 31.33$$

$$15 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(405+22-16)60}{25+29} = 456.7$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(381+25-13)60}{54} = 436.7$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 29 - 1.649 = 27.35$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 25 - 6.349 = 18.65$$

$$16 \ V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(380 + 26 - 18)60}{30 + 26} = 415.7$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(412 + 21 - 20)60}{56} = 442.5$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 26 - 0.1356 = 25.86$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 30 - 1.155 = 28.85$$

$$17 \ V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(416 + 31 - 15)60}{33 + 28} = 424.9$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(431 + 33 - 25)60}{61} = 431.8$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 28 - 1.112 = 26.89$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 33 - 2.259 = 30.74$$

$$18 \ V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(378 + 28 - 22)60}{28 + 30} = 394.1$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(344 + 25 - 18)60}{58} = 363.1$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 30 - 1.157 = 28.84$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 28 - 0.9135 = 27.09$$

$$19 \ V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(410 + 18 - 14)60}{27 + 30} = 435.8$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(384 + 31 - 20)60}{57} = 415.8$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 30 - 1.587 = 28.41$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 27 - 0.5507 = 26.45$$

$$20 \ V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(364 + 27 - 23)60}{25 + 28} = 416.6$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(321 + 33 - 18)60}{53} = 380.4$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 28 - 2.366 = 25.63$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 25 - 0.5761 = 24.42$$

$$21 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(403 + 36 - 25)60}{31 + 26} = 435.8$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(388 + 28 - 21)60}{57} = 415.8$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 26 - 1.010 = 24.99$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 31 - 1.515 = 29.49$$

$$22 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(375 + 19 - 19)60}{25 + 29} = 416.7$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(411 + 25 - 26)60}{54} = 455.6$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 29 + 0.1317 = 29.13$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 25 - 0 = 25.0$$

$$23 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(334 + 27 - 16)60}{28 + 24} = 398.1$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(380 + 29 - 22)60}{52} = 446.5$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 24 - 0.9407 = 223.06$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 28 - 1.658 = 26.34$$

$$24 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(408 + 29 - 20)60}{26 + 28} = 463.3$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(347 + 15 - 14)60}{54} = 386.7$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 28 - 0.1552 = 27.85$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 26 - 1.166 = 24.83$$

$$25 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(390 + 33 - 12)60}{22 + 30} = 474.2$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(422 + 29 - 18)60}{52} = 499.6$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 30 - 1.321 = 28.679$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 22 - 2.657 = 19.34$$

$$26 \ V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(399 + 21 - 23)60}{29 + 27} = 425.4$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(450 + 32 - 15)60}{56} = 500.4$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 27 - 2.038 = 24.96$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 29 + 0.2821 = 29.28$$

$$27 \ V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(471 + 26 - 19)60}{27 + 33} = 478$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(386 + 29 - 12)60}{60} = 403$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 33 - 2.531 = 30.47$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 27 - 0.8787 = 26.12$$

$$28 \ V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(406 + 33 - 21)60}{30 + 29} = 425.1$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(388 + 26 - 18)60}{59} = 402.7$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 29 - 1.192 = 27.81$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 30 - 1.694 = 28.31$$

$$29 \ V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(455 + 35 - 16)60}{27 + 31} = 490.4$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(408+31-23)60}{58} = 430.4$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 31 - 1.115 = 29.89$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 27 - 2.325 = 24.68$$

$$30 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(425+33-17)60}{30+28} = 490.4$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(391+38-20)60}{58} = 423.1$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 28 - 2.553 = 25.45$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 30 - 2.104 = 27.89$$

The Volume ( $V_e$ ) In The Eastbound And Westbound ( $V_w$ ) Direction Can Then Be Obtained From The Expression For Air force base Route (off-peak)

$$1 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(356+23-22)60}{20.4+29.6} = 431$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(334+30-19)60}{49.6} = 417$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 29.6 - 1.583 = 28.02$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 20.4 - 0.1392 = 20.26$$

$$2 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(316+29-21)60}{22.3+25.3} = 408$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(341+20-23)60}{47.6} = 426.1$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 25.3 + 0.4224 = 25.72$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 22.3 - 1.177 = 21.12$$

$$3 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(356 + 22 - 20)60}{22.9 + 27.6} = 425.3$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(309 + 19 - 22)60}{50.5} = 363.6$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 27.6 + 0.4951 = 28.10$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 22.9 - 0.2822 = 22.62$$

$$4 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(383 + 20 - 19)60}{20.3 + 23.0} = 532.1$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(414 + 24 - 21)60}{43.3} = 577.8$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 23.0 - 0.3115 = 22.69$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 20.3 - 1.386 = 18.91$$

$$5 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(372 + 20 - 23)60}{22.1 + 25.8} = 462.2$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(399 + 22 - 25)60}{47.9} = 496.0$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 25.8 + 0.3629 = 26.16$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 22.1 + 0.3629 = 22.49$$

$$6 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(391 + 23 - 21)60}{23.5 + 19.8} = 544.6$$



$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(382+20-19)60}{43.3} = 530.7$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 19.8 - 0.1131 = 19.69$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 23.5 - 0.2204 = 23.28$$

$$7 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(386+23-22)60}{21.0+23.6} = 520.6$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(401+19-17)60}{44.6} = 542.2$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 23.6 - 0.2213 = 23.38$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 21.0 - 0.1153 = 20.89$$

$$8 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(406+19-21)60}{19.2+24.3} = 557.2$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(395+24-20)60}{43.5} = 550.4$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 24.3 - 0.4361 = 23.86$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 19.2 + 0.2154 = 19.42$$

$$9 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(384+18-15)60}{22.7+20.6} = 536.3$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(359+20-18)60}{43.3} = 500.2$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 20.6 - 0.2399 = 20.36$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 22.7 - 0.3356 = 22.36$$

$$10 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(367+18-20)60}{19.8+21.4} = 531.6$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(394+23-20)60}{41.2} = 423.1$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 21.4 - 0.3113 = 21.09$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 19.8 + 0.2257 = 20.03$$

$$11 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(381+20-23)60}{20.1+23.6} = 518.9$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(403+20-22)60}{43.7} = 550.6$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 23.6 + 0.2179 = 23.82$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 20.1 + 0.3469 = 20.45$$

$$12 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(369+22-21)60}{22.7+19.7} = 523.6$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(394+25-21)60}{42.4} = 563.2$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 19.7 - 0.4261 = 19.27$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 22.7 - 0.1146 = 22.59$$

$$13 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(376+23-20)60}{21.6+20.89} = 535.2$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(410+20-22)60}{42.49} = 576.1$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 20.89 + 0.2083 = 21.10$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 21.6 - 0.3363 = 21.26$$

$$14 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(353 + 23 - 19)60}{23.6 + 21.34} = 476.6$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(311 + 19 - 23)60}{44.94} = 409.9$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 21.34 + 0.5855 = 21.93$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 23.6 - 0.5036 = 23.10$$

$$15 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(378 + 25 - 22)60}{22.4 + 20.7} = 530.4$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(419 + 28 - 24)60}{43.1} = 588.9$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 20.7 - 0.4075 = 20.29$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 22.4 - 0.3394 = 22.06$$

$$16 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(403 + 22 - 19)60}{21.93 + 23.1} = 540.9$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(398 + 23 - 20)60}{45.03} = 540.9$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 23.1 - 0.3369 = 22.76$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 21.93 - 0.3328 = 21.60$$

$$17 \quad V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(384 + 20 - 23)60}{19.73 + 21.34} = 556.6$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(376+19-20)60}{41.07} = 547.9$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 21.34 + 0.1095 = 21.45$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 19.73 + 0.3234 = 20.05$$

$$18 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(390+22-23)60}{22.56+23.01} = 512.2$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(389+22-23)60}{45.57} = 423.1$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 23.01 + 0.1174 = 23.13$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 22.56 + 0.1171 = 27.89$$

$$19 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(379+20-17)60}{22.67+21.77} = 515.8$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(403+23-19)60}{44.44} = 549.5$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 21.77 - 0.4368 = 21.33$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 22.67 - 0.3490 = 22.32$$

$$20 V_e = \frac{(N_w + O_e - P_e)60}{T_w + T_e} = \frac{(401+24-21)60}{20.30+22.90} = 561.1$$

$$V_w = \frac{(N_e + O_w - P_w)60}{T_w + T_e} = \frac{(358+19-21)60}{43.2} = 494.4$$

$$T_w = T_w - \frac{(O_w - P_w)60}{V_w} = 22.90 + 0.2427 = 22.66$$

$$T_e = T_e - \frac{(O_e - P_e)60}{V_e} = 20.30 - 0.3208 = 19.98$$

## Appendix D

### ESTIMATION OF TRAVEL SPEED USING TRAVEL TIME AND DISTANCE FOR WADATA PEAK AND OFF-PEAK

$$D1: \text{Travel Speed (M/min)} = \frac{\text{RouteLength } h}{\text{TravelTime}} = \frac{11800}{29.46} = 400.5 \quad D1 = \frac{11800}{20.25} = 582.7$$

$$D2 = \frac{11800}{26.67} = 442.5 \quad D2 = \frac{11800}{25.37} = 465.1$$

$$D3 = \frac{11800}{25.64} = 460.2$$

$$D3 = \frac{11800}{27.09} = 435.6$$

$$D4 = \frac{11800}{25.45} = 463.7$$

$$D4 = \frac{11800}{25.13} = 469.6$$

$$D5 = \frac{11800}{28.94} = 407.7 \quad D5 = \frac{11800}{23.30} = 506.4$$

$$D6 = \frac{11800}{28.62} = 412.3$$

$$D6 = \frac{11800}{27.98} = 421.7$$

$$D7 = \frac{11800}{26.51} = 445.1 \quad D7 = \frac{11800}{24.27} = 486.2$$

$$D8 = \frac{11800}{29.43} = 400.9 \quad D8 = \frac{11800}{28.95} = 407.6$$

$$D9 = \frac{11800}{25.05} = 471.1 \quad D9 = \frac{11800}{25.70} = 459.1$$

$$D10 = \frac{11800}{27.65} = 426.8$$

$$D10 = \frac{11800}{26.93} = 438.2$$

$$D11 = \frac{11800}{25.15} = 469.2 \quad D11 = \frac{11800}{28.84} = 409.2$$

$$D12 = \frac{11800}{26.07} = 469.2$$

$$D12 = \frac{11800}{27.91} = 422.8$$

$$D13 = \frac{11800}{26.07} = 452.6$$

$$D13 = \frac{11800}{26.44} = 446.3$$

$$D14 = \frac{11800}{26.81} = 440.1 \quad D14 = \frac{11800}{28.64} = 412.0$$

$$D15 = \frac{11800}{26.01} = 453.7 \quad D15 = \frac{11800}{23.00} = 513.0$$

$$D16 = \frac{11800}{28.63} = 412.2 \quad D16 = \frac{11800}{27.36} = 431.3$$

$$D17 = \frac{11800}{27.55} = 428.3 \quad D17 = \frac{11800}{28.82} = 409.4$$

$$D18 = \frac{11800}{26.89} = 438.8$$

$$D18 = \frac{11800}{27.97} = 421.9$$

$$D19 = \frac{11800}{25.62} = 460.6 \quad D19 = \frac{11800}{27.43} = 430.2$$

$$D20 = \frac{11800}{28.92} = 408.0$$

$$D20 = \frac{11800}{25.03} = 471.4$$

$$D21 = \frac{11800}{23.84} = 494.9$$

$$D21 = \frac{11800}{27.24} = 433.2$$

$$D22 = \frac{11800}{26.35} = 447.8$$

$$D22 = \frac{11800}{27.07} = 435.9$$

$$D23 = \frac{11800}{25.09} = 470.3$$

$$D23 = \frac{11800}{24.70} = 477.7$$

$$D24 = \frac{11800}{26.55} = 444.4$$

$$D24 = \frac{11800}{26.34} = 447.9$$

$$D25 = \frac{11800}{27.08} = 435.8 \quad D25 = \frac{11800}{24.01} = 491.5$$

$$D26 = \frac{11800}{27.53} = 428.6 \quad D26 = \frac{11800}{27.12} = 435.1$$

$$D27 = \frac{11800}{26.92} = 438.3$$

$$D27 = \frac{11800}{28.30} = 416.9$$

$$D28 = \frac{11800}{26.92} = 431.6$$

$$D28 = \frac{11800}{28.06} = 413.9$$

$$D29 = \frac{11800}{25.57} = 461.5$$

$$D29 = \frac{11800}{27.29} = 432.4$$

$$D30 = \frac{11800}{29.39} = 401.5$$

$$D30 = \frac{11800}{26.67} = 442.5$$

ESTIMATION OF TRAVEL SPEED USING TRAVEL TIME AND DISTANCE FOR MODERN MARKET PEAK AND OFF-PEAK

$$\text{Travel Speed (M/min)} = \frac{\text{RouteLengt } h}{\text{TravelTime}}$$

$$E1 = \frac{13800}{22.82} = 604.7$$

$$E1 = \frac{13800}{25.13} = 549.2$$

$$E2 = \frac{13800}{24.39} = 565.8 \quad E2 = \frac{13800}{31.08} = 444.0$$

$$E3 = \frac{13800}{24.86} = 555.1$$

$$E3 = \frac{13800}{26.03} = 530.2$$

$$E4 = \frac{13800}{26.72} = 516.5$$

$$E4 = \frac{13800}{28.62} = 482.1$$

$$E5 = \frac{13800}{27.56} = 500.7 \quad E5 = \frac{13800}{26.51} = 520.6$$

$$E6 = \frac{13800}{32.21} = 428.4$$

$$E6 = \frac{13800}{27.13} = 508.7$$

$$E7 = \frac{13800}{24.28} = 568.4 \quad E7 = \frac{13800}{26.57} = 519.4$$

$$E8 = \frac{13800}{27.87} = 495.2 \quad E8 = \frac{13800}{28.95} = 476.7$$

$$E9 = \frac{13800}{27.79} = 496.6 \quad E9 = \frac{13800}{29.92} = 461.2$$

$$E10 = \frac{13800}{27.61} = 499.8$$

$$E10 = \frac{13800}{25.93} = 532.2$$

$$E11 = \frac{13800}{25.12} = 549.4$$

$$E11 = \frac{13800}{25.68} = 537.4$$

$$E12 = \frac{13800}{25.22} = 547.2$$

$$E12 = \frac{13800}{32.14} = 429.4$$

$$E13 = \frac{13800}{27.68} = 498.6$$

$$E13 = \frac{13800}{26.49} = 520.9$$

$$E14 = \frac{13800}{23.97} = 575.7 \quad E14 = \frac{13800}{28.75} = 480.0$$

$$E15 = \frac{13800}{25.61} = 538.9 \quad E15 = \frac{13800}{25.70} = 536.9$$

$$E16 = \frac{13800}{24.71} = 558.5$$

$$E16 = \frac{13800}{21.36} = 646.1$$

$$E17 = \frac{13800}{25.22} = 547.2 \quad E17 = \frac{13800}{25.37} = 543.9$$

$$E18 = \frac{13800}{24.66} = 559.6 \quad E18 = \frac{13800}{25.02} = 551.6$$

$$E19 = \frac{13800}{25.95} = 531.8$$

$$E19 = \frac{13800}{29.11} = 474.1$$

$$E20 = \frac{13800}{26.48} = 521.2 \quad E20 = \frac{13800}{28.56} = 483.2$$

$$E21 = \frac{13800}{26.57} = 519.4 \quad E21 = \frac{13800}{27.57} = 500.5$$

$$E22 = \frac{13800}{25.19} = 547.8 \quad E22 = \frac{13800}{29.79} = 463.2$$

$$E23 = \frac{13800}{31.89} = 432.7$$

$$E23 = \frac{13800}{29.16} = 473.2$$

$$E24 = \frac{13800}{25.39} = 543.5$$

$$E24 = \frac{13800}{28.41} = 485.8$$

$$E25 = \frac{13800}{28.28} = 545.9$$

$$E25 = \frac{13800}{25.05} = 550.9$$

$$E26 = \frac{13800}{31.99} = 431.4$$

$$E26 = \frac{13800}{28.68} = 481.2$$

$$E27 = \frac{13800}{25.79} = 535.1$$

$$E27 = \frac{13800}{27.98} = 493.2$$

$$E28 = \frac{13800}{27.30} = 505.5 \quad E28 = \frac{13800}{27.10} = 509.2$$

$$E29 = \frac{13800}{27.91} = 494.5$$

$$E30 = \frac{13800}{25.96} = 531.6 \quad E30 = \frac{13800}{24.19} = 570.5$$

ESTIMATION OF TRAVEL SPEED USING TRAVEL TIME AND DISTANCE FOR AIR FORCE BASE PEAK AND OFF-PEAK

$$\text{Travel Speed (M/min)} = \frac{\text{RouteLength } h}{\text{TravelTime}}$$

$$F1 = \frac{10200}{23.81} = 428.4$$

$$F1 = \frac{10200}{24.14} = 422.5$$

$$F2 = \frac{10200}{25.47} = 400.5$$

$$F2 = \frac{10200}{23.42} = 435.5$$

$$F3 = \frac{10200}{22.94} = 444.6$$

$$F3 = \frac{10200}{25.36} = 402.2$$

$$F4 = \frac{10200}{25.40} = 401.6$$

$$F4 = \frac{10200}{20.80} = 490.4$$

$$F5 = \frac{10200}{23.37} = 436.5$$

$$F5 = \frac{10200}{24.33} = 419.2$$

$$F6 = \frac{10200}{24.24} = 420.8$$

$$F6 = \frac{10200}{21.49} = 474.6$$

$$F7 = \frac{10200}{23.83} = 428.0$$

$$F7 = \frac{10200}{22.14} = 460.7$$

$$F8 = \frac{10200}{24.72} = 412.6$$

$$F8 = \frac{10200}{21.64} = 471.3$$



$$F9 = \frac{10200}{24.33} = 419.2$$

$$F10 = \frac{10200}{21.71} = 469.8$$

$$F11 = \frac{10200}{19.87} = 513.3$$

$$F12 = \frac{10200}{22.58} = 451.7$$

$$F13 = \frac{10200}{23.62} = 431.8$$

$$F14 = \frac{10200}{23.29} = 437.9$$

$$F15 = \frac{10200}{22.46} = 454.1$$

$$F16 = \frac{10200}{26.25} = 388.6$$

$$F17 = \frac{10200}{23.07} = 442.1$$

$$F18 = \frac{10200}{21.00} = 485.7$$

$$F19 = \frac{10200}{20.83} = 489.7$$

$$F20 = \frac{10200}{22.99} = 443.7$$

$$F9 = \frac{10200}{21.36} = 477.5$$

$$F10 = \frac{10200}{20.56} = 496.1$$

$$F11 = \frac{10200}{22.14} = 460.7$$

$$F12 = \frac{10200}{20.93} = 487.3$$

$$F13 = \frac{10200}{21.18} = 481.6$$

$$F14 = \frac{10200}{22.52} = 452.9$$

$$F15 = \frac{10200}{21.18} = 481.6$$

$$F16 = \frac{10200}{22.18} = 459.9$$

$$F17 = \frac{10200}{20.75} = 491.6$$

$$F18 = \frac{10200}{22.91} = 445.2$$

$$F19 = \frac{10200}{21.83} = 467.3$$

$$F20 = \frac{10200}{21.32} = 478.4$$

## Appendix E

### MULTIPLE LINEAR REGRESSION MODEL DEVELOPMENT USING SPSSAT 95% CONFIDENCE LEVEL, 0.05 INTERVAL LEVEL AND 78 DEGREES OF FREEDOM

#### Summary of Statistical Results of the Multiple Linear Regression Model Peak period

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.	95% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
<b>1 (Constant)</b>	<b>30.969</b>	<b>1.277</b>		<b>24.252</b>	<b>.000</b>	<b>28.424</b>	<b>33.515</b>
Ave. dwell time	.011	.007	.048	1.514	.134	-.003	.025
Route Length	.002	.000	1.118	22.077	.000	.002	.002
Time headway	-.283	.134	-.055	-2.106	.039	-.551	-.015
T-junction	-.139	.072	-.069	-1.930	.058	-.283	-.005
Vol. of traffic	-.002	.001	-.070	-1.914	.060	-.005	-.000
Travel speed	-.052	.002	-1.015	-	.000	-.055	-.048
				26.532			
No. of stops	-.047	.038	-.032	-1.235	.221	-.124	.029

a. Dependent Variable: Travel Time

$$T = 30.969 + 0.011X_1 + 0.002X_2 - 0.283X_3 - 0.139X_4 - 0.002X_5 - 0.052X_6 - 0.047X_7$$

#### Model Summary Result for Peak Hour Values

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.978 <sup>a</sup>	.956	.951	.52272

a. Predictors: (Constant), Number of stops, T- Junction, Time Headway, Average dwell time, Travel speed, Volume of traffic, Route length

**Summary of Statistical Results of the Multiple Linear Regression Model Off-peak**

Model	Unstandardized Coefficients		Standardized Coefficients Beta	T	Sig.	95% Confidence Interval for B	
	B	Std. Error				Lower Bound	Upper Bound
(Constant)	27.022	.541		49.983	.000	25.945	28.100
Ave. dwell time	.010	.006	.019	1.819	.073	-.001	.021
Route Length	.002	.000	.986	49.584	.000	-.002	.002
Time headway	-.018	.012	-.015	-1.570	.121	-.042	.005
T-junction	-.130	.030	-.053	-4.318	.000	-.190	-.070
Vol. of traffic	-.001	.001	-.025	-1.421	.160	-.003	.000
Travel speed	-.051	.001	-.812	-54.996	.000	-.052	-.049
No. of stops	.013	.013	.011	1.045	.300	-.012	.038

b. Dependent Variable: Travel Time

$$T = 27.022 + 0.010X_1 + 0.002X_2 - 0.018X_3 - 0.130X_4 - 0.001X_5 - 0.051X_6 + 0.013X_7$$

**Model Summary Result for Off-peak Hour**

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
2	.997 <sup>a</sup>	.994	.993	.23335

a. Predictors: (Constant), Number of stops, T- Junction, Time Headway, Average dwell time, Travel speed, Volume of traffic, Route length