KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI, GHANA

STUDY OF VEHICULAR TRAFFIC CONGESTION IN THE SEKONDI-TAKORADI METROPOLIS

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CHAPTER 1

1.0 INTRODUCTION

According to the Federal Highway Administration of the United States of America, Traffic Congestion is a condition on road networks that occurs as use increases, and is characterized by slower speeds, longer trip times, and increased vehicular queuing. The most common example is the physical use of roads by vehicles. When traffic demand is great enough that the interaction between vehicles slows the speed of the traffic stream, congestion is incurred. As demand approaches the capacity of a road (or of the intersections along the road), extreme traffic congestion sets in. When vehicles are fully stopped for periods of time, this is colloquially known as a traffic jam or traffic snarl-up.

Traffic congestion occurs when a volume of traffic or modal split generates demand for space greater than the available road capacity; this point is commonly termed saturation. There are a number of specific circumstances which cause or aggravate congestion; most of them reduce the capacity of a road at a given point or over a certain length, or increase the number of vehicles required for a given volume of people or goods. About half of United States of Americas' (U.S.A) traffic congestion is recurring, and is attributed to sheer weight of traffic; most of the rest is attributed to traffic incidents, road work and weather events (Federal Highway Administration,USA).

Traffic research still cannot fully predict under which conditions a "traffic jam" (as opposed to heavy, but smoothly flowing traffic) may suddenly occur. It has been found that individual incidents (such as accidents or even a single car braking heavily in a previously smooth flow) may cause ripple effects (a cascading failure) which then spread out and create a sustained traffic jam when, otherwise, normal flow might have continued for some time longer (Federal Highway Administration,USA).

1.1 BACKGROUND TO THE STUDY

Cities and traffic have developed hand-in-hand since the earliest large human settlements. The Same forces that draw inhabitants to congregate in large urban areas also lead to sometimes intolerable levels of traffic congestion on urban streets. Cities are the powerhouses of economic growth for any country. According to Bartone et al., (1994), around eighty percent of Gross Domestic Product (GDP) growth in developing countries is expected to come from cities. For the purpose of economic activities, it is imperative to facilitate movements. Transportation system provides the way for movements and medium for reaching destinations. Inadequate transportation system hampers economic activities and creates hindrances for development. In most of the developing countries which are overburdened by rising population and extreme poverty, increasing economic activities and opportunities in the cities result in rapid increase in urban population and consequent need for transportation facilities. Authorities in these countries often fail to cope with the pressure of increasing population growth and economic activities in the cities, causing uncontrolled expansion of the cities, urban sprawl, traffic congestion and environmental degradation.

1.2 STATEMENT OF THE PROBLEM

The backbone of urban activities is the urban transportation network. The transportation network of an urban area is usually designed to accommodate the transportation activities of urban people. With growing population and diversified land- use activities, transportation system needs to be updated or readjusted. Any lag between growing transportation demand and network capacity results in traffic congestion, thereby causing economic loss and environmental degradation.

Major reasons of such urban dilapidation are the inability to understand the factors causing problem and lack of proper planning to improve the situation. To cope with the situation, it is imperative to ensure proper use of available facilities and develop infrastructure through optimum utilization of resources. It is particularly true for developing countries like Ghana that because of scarcity of resources, planning provides scope for optimum utilization of available facilities and resources. For planning purposes, it is necessary to obtain quantitative visualization of the consequences of the planning and development policies for comparison among alternative options. Computer based models facilitate such visualization and evaluation of future consequences of planning options. Although such computer applications have some general structures, the models should be strategic and specifically developed for the area of interest. The planners of developing countries are severely constrained by unavailability of such planning tools (Habib, 2002).

The need for transportation model as a planning tool is particularly important due to the extent and characteristics of transportation systems. The demand for transportation is integrally related with economic activities, land-use, population and its distribution etc. Also transportation system development involves huge amount of money and substantial amount of time. Because of these reasons any decision regarding transport sector requires adequate planning, which should be justified by analysis on the basis of transportation models.

A public transport system must accommodate a very large number of individual trips. It's not possible to provide direct public transport routes to meet all requirements but it's possible to go a long way towards achieving this by providing a network of routes, so that passengers can make complex journeys by using a combination of routes.

Many transport systems consist of routes planned in isolation rather than as parts of coordinated networks. This is usually unsatisfactory for meeting the requirements of a significant proportion of travelers. Poor route planning may result in poor road coverage, an excessive requirement for interchange between routes, and irregular frequencies.

In developed countries like the USA, Canada etc, route networks have been designed to provide convenient links between all points where there is demand. Some have been designed to meet predetermined standards or criteria such as a maximum number of interchanges between routes on any journey. Route planning always lags in demand. In theory, market forces will eventually lead to an optimal transport system but in practice this evolution, which effectively is by trial and error, would take considerable time. And since cities are constantly growing and changing, the ideal route pattern will never evolve.

Indeed, even with a sophisticated planning capability, development of transport services will always tend to lag behind changes in demand. Transport planning in cities in developing countries is especially difficult, because of the rapid pace of change. Plans must be kept under regular review, and revised as necessary (World Bank Group, 2006).

Public transport planning may be based on transport demand and supply data, derived from operators own internal systems, and from surveys. Other planning data available to transport authorities may include overall transport plans and projections, land use plans, plans for private and public sector developments, traffic demand forecasts, and economic forecasts. Regular route revisions are necessary. In some cities route revisions are carried out regularly as a matter of routine but in other cities there have been virtually no changes for many years despite the city growing and changing considerably. For example in Kingston, Jamaica, a new central business district, New Kingston, was developed about eight kilometers from the original central area. For several years there was very little change to the network of bus routes, which was still focused on the original central area. Commuters traveling to New Kingston had to change buses during the course of their journeys (World Bank Group, 2006).

A route network may be designed to be operated on a fully commercial basis, with every route producing a profit, or there may be social objectives, requiring the provision of some unprofitable routes. The structure of the system, the degree of regulation and competition, and the extent, to which regulations are complied with, will influence the type of route network that is most appropriate.

In most cities, the main public transport corridors radiate outwards from the central area, with routes branching from these corridors to serve points on either side. The number of these branches will be partly influenced by the nature of the road system, and by policy and market forces. If people are not prepared to walk long distances, bus routes will need to penetrate further into residential areas than otherwise.

Similarly, if there are parallel roads along a corridor, a decision must be made whether or not to concentrate all routes along one road, or to split them between the two roads. The first alternative will give a higher frequency of service, and therefore less passenger waiting time. But it could mean greater average walking distance, and perhaps increased traffic congestion. The second will give lower frequency, and longer average waiting times, but shorter average walking distances.

In a city with a population of approximately one million or more the central area will normally cover a large area so that passenger's destinations are widely dispersed. Where the distances between these exceed acceptable walking distances, it is inappropriate for all routes to converge at a single focal point. There may therefore be several points, each constituting the focus of a number of radial routes, and possibly requiring another sub-network of routes connecting them.

A transport network may include a number of feeder bus routes, which feed passengers into trunk bus routes and to rail lines. These offer an alternative to operating a large number of different routes along a common corridor, each branching off to serve points off the main route. In certain circumstances, particularly in smaller towns, a hub-and-spoke route system may be appropriate. This means all routes meet at a central focal point, and passengers are able to travel between any two points in the city by transferring from one route to another. Where journey times are relatively short, and service frequencies are high so that transfer times are minimized, such a system may be acceptable. But in general, particularly for regular commuter traffic and where traffic congestion is a problem, a high proportion of indirect journeys are unacceptable (World Bank Group, 2006).

Vehicular routes themselves may take various forms. The basic and most common type of route is the end-to-end route, which operates between two points, following the same roads in both directions, except where one-way street systems necessitate minor deviations. Alternatively, a route may be circular, returning to the point of origin without traversing the same road twice. Circular routes are often found in sub-urban areas, sometimes circling an entire city. Inner-circle routes around city center areas are also common (World Bank Group, 2006).

For effectively dealing with traffic congestion and associated environmental problems, transportation planners need a tool to get a greater visibility of current and projected condition and comparative benefit of potential system improvement alternatives. In principle, strategic transportation planning models provide the best means of satisfying these requirements. With accurate database and careful specifications, such models are capable of affording planning insights that may not be obvious to the common sense. This thesis is devoted to study the Vehicular Traffic Congestion in the Sekondi-Takoradi Metropolis and evaluate some planning options to ease the Traffic Congestion in the Metropolis.

1.3 OBJECTIVES OF THE RESEARCH

The main objective of this research is to study the Vehicular Traffic Congestion in urban areas of Sekondi-Takoradi to help alleviate traffic congestion.

The specific objectives of the study include:

(i) To use secondary data provided by the Department of Urban Roads (DUR) Sekondi-Takoradi to identify areas in the Metropolis where Vehicular Traffic Congestion exist

(ii) To zone the Traffic Congested areas for analysis to identify which zone has the highest Vehicular traffic during the peak hours (6:00AM-9:00AM and 4:00PM-7:00PM)

(iii) To apply various indices and measures to quantify overall vehicular traffic volume on some selected road links within the Metropolis

(iv) To evaluate some planning options to ease Vehicular Traffic congestion in Sekondi-Takoradi

1.4 METHODOLOGY

The methodology used to study the Vehicular Traffic congestion in the Sekondi-Takoradi Metropolis is outlined below.

(i) Selection of study area

(ii) Zoning of the study area for analysis

(iii) Data on the type of count based on the link volume count, intersection volume count, link length and intersection dimension would be obtained from DUR Sekondi-Takoradi

(iv) The data would be analysed and presented using Excel broadsheet

(v) Conclusions and recommendations would be made based on the Excel output

(vi) Search on the internet will be used to obtain the related literature. Books from the main Library at KNUST and the Mathematics Department's library will be read in the course of the thesis

1.5 JUSTIFICATION OF THE RESEARCH

The Sekondi-Takoradi Metropolis (oil city) is the regional capital of the Western Region of Ghana and is among the top three mega cities in Ghana with a population of about 360,000 (GSS[1] provisional results urban localities, 2002). The Metropolis covers a land area of 385km² with Sekondi as the administrative headquarters. The Metropolis is bordered to the West by Ahanta West District, to the North by Mpohor Wassa East, to the East by Komenda-Edina Eguafo-Abrem and to the South by the Gulf of Guinea. The Metropolis is strategically located on the south-western coast of Ghana, about 280km west of Accra and 130km East of La Cote D'Ivoire. Between 1960 and 1984, the population grew rapidly from 152,607 to 249,371, at a rapid growth rate of 3.5% per annum ([2]STMA Website). With the discovery of crude oil in some environs of the Western Region, there is prediction of a faster urbanization and the Metropolis will have to accommodate future influx of population. The extent to which the Metropolis will be able to meet the challenge of rapid urbanization and continue to offer a favorable environment for further economic development remains a crucial question for the planners, engineers and decision makers. Striving for an efficient transportation system is a crucial requirement of the urban development strategy for the Sekondi-Takoradi Metropolis. Any constraints or bottleneck

[1] Ghana Statistical Service

[2] Sekondi-Takoradi Metropolitan Assembly

in this regard will seriously affect the economic potential of the oil city, especially in the context of global market and world trade. Flaws in transportation system in the Sekondi-Takoradi Metropolis are now pronounced as severe traffic congestion (official website of STMA). This study is motivated by the traffic congestion prevailing in Sekondi-Takoradi Metropolis as the situation is deteriorating rapidly with increasing urban population and economic activities.

Such traffic congestion has become an unbearable situation in the oil city. The extent of the problem can be accessed from the fact that during peak hours (6:00AM-9:00AM and 4:00PM-7:00PM) it takes more than an hour to travel a short distance which before the crude oil find took less than twenty minutes. The congested situation prevails almost whole day. In addition to other losses (economic losses, discomfort etc.), traffic congestion worsens the environmental condition, which is already extremely poor in commercial areas like the Takoradi Market Circle (the major commercial centre in the Metropolis). Several attempts have recently been made by the Sekondi-Takoradi Metropolitan Assembly (STMA), traffic police of the Youth Employment Scheme, Motor Traffic and Transport Unit (MTTU) of the Police Department etc. to improve the situation. Most of these measures fall in the category of short-term traffic management, which have been implemented on adhoc basis and in isolated ways, without adequate study. Also a lot of measures such as increasing the road network system, encouraging more public transport etc, which have been proved effective in other countries, have not been implemented yet.

To keep the Metropolis mobile in the future, long-term policies need to be implemented. It should be remembered that successful measures of other countries might not be as fruitful due to indigenous characteristics. For example, decisions like promoting cars through reduced taxes may have an adverse effect on transportation system as well as national economy.

Traffic composition and drivers' behavior in the Metropolis are unique in the world. Motorized vehicles are very prevalent in the Metropolis. Also, while developing long run policies, one has to be very careful in selecting the future modes of transportation. Many developed countries, especially European countries, have been vigorously promoting non-motorized modes like walking and cycling. It is well recognized that public transportation has the potential to play an important role in improving traffic and environmental situation.

For the purpose of developing a sustainable transportation system, long-term policies should be established. One of the major reasons of congestion is improper and imbalanced land-use. For congestion management, adequate considerations must be provided on this issue. The transportation system components, such as land-use, economic activity locations, selection of residential areas etc. are very much interrelated with one another. Any change in a single component of the system affects the other components as well. So to develop transportation policies and to reduce traffic congestion, the alternative options are required to be analyzed by using transportation model. However a complete Urban Transportation Model System (UTMS) for Sekondi-Takoradi is not available to the urban planners. It is deemed necessary to study the current vehicular traffic congestion in urban areas of Sekondi-Takoradi Metropolis and offer some recommendations to urban planners to help curb the rapid congestion problem in the Metropolis.

1.6 SCOPE OF THE STUDY

The study is designed to evaluate the Vehicular Traffic Congestion in the Metropolis and apply measures to quantify the overall traffic volume on some principal road networks and offer some planning advice to road engineers. In view of constraints, like computational facilities, time and information resources the study is restricted to the central urban portion (in and around the Takoradi Market Circle and some selected roundabouts and traffic light points) of Sekondi-Takoradi. It will also involve an evaluation of some selected transportation routes, which include improvement of road network. Again it is well recognized that changes in transportation system always have some long-term effects with corresponding land-use pattern changes. Such long term effects with changes in land-use patterns are out of the scope of this study.

1.7 ORGANISATION OF THE THESIS

The thesis is organized in five chapters, references and appendix. Chapter one covers an overview of transportation problems in relation to traffic congestion in the Sekondi-Takoradi Metropolis. Chapter two reviews the related literatures about transportation problems in general. It also includes summaries of prior research on urban transportation planning modeling. Chapter three covers the methodology of the study, which includes ways to quantify transportation system performance, particularly traffic congestion. Chapter four covers data collection, analysis and discussion. Chapter five gives the summary and conclusion of the study. It also makes some recommendations for future studies in this field.

1.8 SUMMARY

In this chapter, we considered the basic definition of Traffic Congestion as proposed by the Federal Highway Administration of the United States of America (U.S.A). We further outlined the basic background to our current study and stated our problem of interest (Traffic Congestion). The objectives, justification, scope and organization of the thesis were briefly outlined.

In the next chapter, we shall put forward pertinent literature in the field of transportation studies and traffic modeling.

CHAPTER 2

LITERATURE REVIEW

2.0 INTRODUCTION

This chapter presents a review of literature on transportation system with special emphasis on traffic congestion. An extensive literature survey of the documents on relevant researches and studies both in Ghana and oversees, has been performed. A review of literatures reveals that, only a limited number of studies have been accomplished in Sekondi-Takoradi Metropolis and no studies have so far been accomplished to quantify the traffic congestion in the Metropolis. Some ideas from this review have been incorporated in the current study.

2.1 TRANSPORT STUDIES IN GHANA

The Republic of Ghana is a country of almost twenty four (24) million people (GSS, 2010) located in West Africa. Ghana is the second largest producer of Cocoa in the world and this still forms a major part of its export industry although it has growing service and manufacturing sectors. The latest addition is the large crude oil reserves. Exploration has begun and this is expected to present a major economic boost to Ghana's economy. The capital city Accra and its surrounding region houses about four (4) million people creating significant transport challenges. As with most African countries, vast rural hinterlands also create significant transport challenges with important social dimension to them.

Commonly there are problems with an over reliance on road transportation for transporting both goods and freight, inadequate and poor condition of infrastructure, lack of funds for development and timely maintenance of transport infrastructure, and a lack of private sector interest in the provision of transport infrastructure. Ghana has made several efforts to attract the private sector to help rejuvenate its rail industry for over a decade. These have all proved unsuccessful. There are institutional deficiencies and inadequacies of well motivated human resources to undertake policy implementation and monitoring of projects. For instance, in the recent past, the Monitoring and Evaluation Department of the Ministry of Roads and Highways in Ghana had only four staff, one Land Cruiser and one Pickup. This unit however is responsible for monitoring the progress of works on over sixty thousand (60,000) kilometres of roads countrywide. Even though it is done with regional Road Agency offices, it is difficult to achieve what is desired (Appiah, 2009).

Regulation and enforcement are also challenging. In the road freight sector, operators can be carrying goods in excess of 70 tons with less than 6-axle trucks. The non-uniform application of axle load limits in the sub-region leads to the quick deterioration of such transit corridors.

Accra is still urbanising, with about 3.8% growth in the urban population compared with a national growth rate of 2.5%. There are significant management issues to be tackled on public transport with unrestricted access and a lack of standards. Growth in car and powered two-wheeler traffic combined with narrow roads, limited junction capacities and poorly managed road works contribute to heavy traffic congestion. Ghana is not alone in needing to tackle its road safety problems with about two thousand two hundred and thirty-seven (2,237) fatalities registered in 2009. The good news is that in spite of these problems there are several major transport initiatives currently underway to improve the situation (Appiah, 2009).

Road transport is by far the dominant carrier of freight and passengers in Ghana’s land transport system. It carries over 95% of all passenger and freight traffic and reaches most communities, including the rural poor and is classified under three categories of trunk roads, urban roads, and feeder roads. The Ghana Highway Authority, established in 1974 is tasked with developing and maintaining the country's trunk road network totaling thirteen thousand three hundred and sixty-seven (13,367) kilometres, which makes up 33% of Ghana's total road network of forty thousand one hundred and eighty-six (40,186) kilometres (DUR Sekondi-Takoradi, 2010).

Trunk roads in Ghana are classified as National roads, Regional roads, and Inter-regional roads, all of which form the Ghana road network. National roads, designated with the letter **N**, link all the major population centers in Ghana. Regional roads, designated with the letter **R**, are a mix of primary and secondary routes, which serve as feeder roads to National roads; while Inter-Regional roads, designated with the prefix **IR**, connect major settlements across regional borders. By virtue of National roads linking major cities in the country, they sometimes double as Regional and Inter-Regional roads. The **R40**, which connects Accra to Adenta through the Tetteh Quarshie Interchange, forms part of the **N4** which links Accra to Koforidua and Kumasi through the Tetteh Quarshie Interchange (DUR Sekondi-Takoradi, 2010).

With respect to this mode of transport, many people prefer to use the public means. Many of the town and cities in the country can be reached by the use of urvan buses known as "trotro" or taxis. For inter-regional transport bigger buses are normally used.

2.2 ROAD SAFETY SITUATION IN SEKONDI-TAKORADI METROPOLIS

Most of the infrastructural facilities in the Sekondi-Takoradi Metropolis, particularly those within the urban centers have been over stretched. There is rapid development taking place in the hinterland and significant numbers of these areas are without access roads (STMA, 2010).

The condition of the road network in the Metropolis stands at 51.6%Good, 28.2% Fair and 19.6% Poor. The total length of all weather roads in the Metropolis has been extended from 330.9km in 1996 to cover four hundred (400) kilometres. Areas such as Awuna Beach have been linked to the main Cape Coast road while Komfoeku and Assakae roads have been developed (DUR Sekondi-Takoradi, 2011).

Out of a total length of about two hundred and thirteen (213) kilometres of the urban roads, over one hundred and fifty (150) kilometres have been tarred, forty (40) kilometres of gravel road while twenty three (23) kilometres are of simple earth. Road construction works in the Metropolis have been grouped into seven main categories. These are Arterial Network development, Rehabilitation and Maintenance of Local roads, Roads in Depressed Areas, Roads in Newly Developed Areas, Rehabilitation of Feeder Roads as well as traffic management (STMA, 2011).

The roads in the high-income low low-density have a good network of surface dressed roads. However, most of these roads have seen little or no maintenance since they were constructed. These areas include Chapel Hill, Beach Road and Windy Ridge. Most section of the local roads have developed cracks and potholes (DUR Sekondi-Takoradi, 2011)

The local roads within the middle-low income high-density areas are mostly engineered. Drainage within these areas is generally poor and gullies are a common phenomenon on most of the roads. The level of socio-economic activities within these areas is moderate; however, there is a likelihood that these activities would increase rapidly with road improvement. These areas include West and East Tanokrom, part of Apremdu, Fijai and Effia. Traffic volume generally, on all the local roads is increasing with an Average Annual Daily Traffic (AADT) above 1500 vehicles (DUR Sekondi-Takoradi, 2011).

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Due to the presence of the Takoradi Harbour, fuel installation as well as numerous Timber firms have been located in the Region, the Metropolis have heavy-duty vehicles and these trucks constitute close to 12% of the traffic volume in the Metropolis (STMA, 2011).

A site at the Fijai by-pass is being developed into a terminal for these vehicles. The terminal occupies an area of 860m² and to close 45% of the land area has been cleared and is in use. The site for the heavy-duty trucks is hilly and requires cutting and leveling in order to create adequate parking space for the vehicles. The area is dusty and poorly drained. It also lacks basic services such as water, electricity and sanitary facilities (STMA, 2011).

The cargo station at Fijai and a minor one at Kwesiminstim will require priority attention in order to avert indiscriminate parking in the City by the trucks. Economic integration is being fostered on the Africa Continent and the plan to use the Takoradi Harbour to ferry goods and landlocked countries such as Burkina Faso requires that more of such terminals and warehouses be developed (STMA, 2011).

Three transport terminals for passenger vehicle have been developed. Two at Takoradi and one at Sekondi. They are to cater for on-street station and are to be privately managed. Vehicle waiting sheds or bus stops are completely absent in the city. Passengers, particularly patients from the hospital often have to wait for long periods under the scorching sun for cars.

There are adequate road signs, marking signals and good drainage facilities in the Central Business District (CBD) of Takoradi in particular. All the asphalt sections of the city from Central Takoradi to Effia-Nkwanta Hospital have pedestrian's walkways, pedestrian crossing and traffic lights. The city is poorly illuminated and non-motorized transport such as bicycle lanes are not in existence (STMA, 2011).

2.3 RESEARCH ON TRAFFIC PLANNING AND MANAGEMENT

Many studies relating to urban travel behavior and its relation to socio-economic variables of urban dwellers have been done in different countries. Some of them, which deal with traffic planning, management and related variables, are discussed below.

2.3.1 Urban Land Use Pattern

Owen (1966) pointed out that planners and engineers were designing large-scale urban development considering the salient features of transport problems. He mentioned two sides of the process. First, design process to achieve a good mix of work places and housing, served by conveniently located shopping, schools and other services in a pleasant environment. The second, semi-independent centers or clusters of activities to provide ready access to major highways or rail transits to ensure close links with the central city and abutting region. The transportation corridors help to bring about some degree of order in the movement of traffic among the multiple centers of the urban region and their points of access provide logical sites for concentrating commercial development. Japan planned its community development for a nationwide dispersal effort using the technique explained above. Both high speed rail and telecommunications are used to help spread the benefits of urbanization and reduce diseconomies of over concentration. Owen emphasized on the need for traffic simulation modeling for the design of large-scale urban development. He also suggested traffic optimization modeling as a tool for such process.

2.3.2 Choice of Travel Mode

Burton (1974) showed that three main factors were responsible for the choice of mode for person trips. These are:

(i) Characteristics of Journey that includes: Journey time/length and Journey purpose.

(ii) Characteristics of travelers that includes income and car-ownership.

(iii) Characteristics of transport system that includes relative travel time, relative travel cost, relative level of service and accessibility indices.

For modeling of any transport or traffic system, these are the variables on which calculation for optimization can be based.

2.3.3 Transport Modes - Performance, Planning and Management

Extensive research has been done in USA, UK, Australia and Japan on different transport modes to optimize their performance. A considerable amount of literature is available on this topic.

Case and Latchford (1981) examined characteristics of different public transport modes, mainly from the user's point of view, on the basis of information gathered from eight cities in South-East Asia. Heraty (1980) investigated the organization and operation of conventional buses and minibuses in the city of Kingston, Jamaica. Maunder and Fouracre (1983) investigated the operational characteristics of specialized bus services in two Indian Cities, Hydarabad and Delhi and in Bangkok, Thailand. Victor (1979) described some recent developments in mass transit modes. Fielding and Anderson (1983) and Jadaan (1988) investigated the system characteristics, usage and operations of urban public transport system and derived a set of indicators to represent all desirable dimensions of transit performance. World Bank (1986) developed another method specifically to evaluate the performance of reasonably well managed bus companies in developing countries.

Greenstein et al., (1988) investigated the transport situation in Quito, Ecuador and proposed a new planning of bus scheduling programme for the city. Umigar et al., (1988) examined the various management policy alternative within three broad ownership patterns - private, public-private mixed and public, in Indian bus transit system.

These studies provide idea about variables of traffic planning and management and parameter for evaluation of performance. They also give basic idea for analysis and optimization of mixed type of vehicles.

Young (1986) investigated computer-aided design in local street planning and management. The study described the relevance and application of procedures from the new information technology, especially computer aided design in planning and management of local street networks. It pointed out that those new techniques offered traffic planners new and perhaps more approximate means for using computers in their work.

Young et al., (1988) extensively described the application of Micro Computer in traffic system design. In the study they examined different types of software packages available in traffic system design together with their advantages, limitations and applicability.

Yi- Chin Hu and Schonfeld (1984) studied and developed a macroscopic model for Traffic Simulation and Optimization of regional highway networks. It was applied to the Maryland Eastern Shore network, where heavy recreational traffic created severe congestion and long queues. It was used to find out cost-effectiveness of route diversion as a substitute for new constructions on intercity networks - Where high demand peaks were infrequent**.**

Intelligent Transportation System (ITS) involves the integrated application of a range of technologies – computer, sensor, electronics, communications – and management strategies to transportation problems in order to increase the safety and efficiency of the surface transportation system.

2.3.4 An Overview

Urban planners are taking traffic engineering variables more seriously than ever before and also their understanding of the same are much clear now. They are giving more emphasis on the coordinated development of both land use and transport planning aspects.

In all the countries, including a developing country like Ghana, importance is given in the field of urban traffic planning and management. Methods for evaluating the performance of any transport system are becoming key interest to transport planners and a variety of methods are suggested by different researchers.

2.4 TRAFFIC MODELING

2.4.1 Overview

All road users are aware that traffic conditions vary widely over the road system. The situations in most of the cases may be unsatisfactory. Though all are concerned about the situation, their recommendations for its improvement vary from person to person. Traffic modeling represents one method of resolving some of these conflicts. It is directed towards the gain of an understanding, how the traffic system operates. Models are, however, developed for many purposes such as traffic flow-volume relationship study, traffic management, traffic plans, road-use planning etc. Traffic system models also vary from the most detailed or micro level to the regional or macro level.

To prevent the use of inappropriate models, the creation of models should be embedded within the context of a hierarchy framework and a defined development process. The defined process, during development, includes setting of criteria, objective and problem definition, system analysis, parameter estimation, validation and data collection. The final step in model building is application.

One of the most difficult part of model building is parameter identification. Morlok (1978) argued that the most popular approach was to use some form of deterministic 'fitting' process so that model parameters could be adjusted to provide best fit to the corresponding real world observations. A least square sense worked behind this argument.

There always exist some constraints on model application. The level of considerations for variables chosen is important. The higher level models are concerned with the problems of modes, destinations, general route choice and overall travel and congestion characteristics. The lower level models are concerned with number and types of lanes, traffic signaling, geometric design of road and fleet composition etc

2.4.2 Comments on Transportation Modeling Systems

This is a relatively new field of study. Currently there are very few systems known to be commercially available or used in transportation engineering practice on commercial basis. Some of the systems, which are operational and others, which are under development are discussed below. All of them are remained to be tested extensively under user environment.

LOGOIL, a rule based expert system that provides advice on shipment plans for crude oil distribution. It is the result of doctoral research of Auselano Braun at Polytechnic University at New York (Ritche et al., 1987).

TRAIL is an expert system that provides assistance to traffic engineers in designing traffic signal settings. It was developed by Carlos Zozaya Gorostiza and Chris Hendrikson in the Department of Civil Engineering at Carnegie Mellon University(Ritche et al., 1987).

EXPERT-UFOS is an expert system for large scale transportation network design problems that are evaluated using multiple conflicting criteria. The system addresses the design of single mode, fixed demand, and discrete equilibrium transportation network. The system was a part of doctoral dissertation by Shein-I Tung in the Department of Civil Engineering at University of Washington (Ritche et al., 1987).

TRANSTEP is a transport demand model to predict traveler responses to transport policies and practices. It is a flexible microcomputer based demand model suitable for the analysis of a variety of urban land-use/transport planning issues at either the strategic or detailed planning level (Young et al., 1988).

SATURN is a tool for testing the impacts of one-way streets, traffic control measures and bus-only streets. SATURN is an abbreviated form of 'Simulation and Assignment of Traffic in Urban Networks'. The model was developed by Institute of Transport Studies at University of Leeds. It is useful for the analysis and evaluation of traffic management systems over relatively localized road networks (Young et al., 1988).

MULATM is a traffic-planning model designed for studying local street networks. It can account for detailed street networks, including individual street and intersection characteristics, and can be used to study the effects of different control devises and measures such as street closers, roundabout, humps, 'slow points' etc. For an engineer or planner this model offers a systematic tool for the investigation of possible effects of alternate traffic management schemes, and the selection of appropriate plans to meet established goals and objectives (Young et al., 1988).

NETSIM is one of the most generally used micro-simulation models of traffic movement on networks. It is a microscopic model developed by United States Federal Highway Administration. It can be used to evaluate a wide mix of traffic control and management strategies (Young et al., 1988).

TRAFFICQ is developed by UK Department of Transport. This model intended for relatively small road networks, but which may contain complex traffic and pedestrian control techniques (Young et al., 1988).

TRANPLAN is a set of integrated programs for the transportation planning process. It encompasses the four-step travel demand model of trip generation, trip distribution, mode choice and trip assignment for both highway and transit systems. The public transit software utilizes coding and analysis techniques similar to the U.S. Department of Transportation's Planning System (UTPS).

NIS (Network Information System) is a flexible iterative graphic editor for displaying and maintaining spatial data, including highway and transit network descriptions and area boundary data.

TPMENU is a menu shell, which flexibly combines TRANPLAN and NIS and provides integrated user interface.

MEPLAN and TRANUS are economically based integrated land use-transportation modeling systems, which can address freight movement as well as passenger travel. These models integrate economic theory with operational planning methods (Rosenbaum and Koenig, 1997). The basis of the framework is the interaction of two parallel markets; one for land, one for transportation. The land portion of the model predicts volumes and locations of activities and their economic linkages with a formulation that explicitly consider cost of land and development. The economic linkages include good, services and labor. These are then used to predict travel demand both passenger and freight, which are assigned to modes and routes on the basis of travel impedance measures. The travel impedance then influences the location of activities in future periods.

2.5 CONVENTIONAL ANALYSIS AND QUICK RESPONSE MODELS

Before the 1970s, Origin-Destination (O-D) trip tables were obtained via statistical surveys, such as home interviews, license plate surveys and roadside surveys. The methods that use such survey data to determine real trip distributions are now called conventional analysis. The first large-scale cordon count (O-D table) was conducted in Chicago in 1916 (Easa, 1993a). Prior to World War II, information on the distribution of urban traffic was obtained using roadside interviews. Since surveys were conducted through sampling, it is impossible to determine the real trip information. Furthermore, with the evolution of society and with rapid changes in transportation demands, these surveys became harder to perform, and expensive with respect to time, manpower, money and effort. Another drawback of conventional analysis is that, as the land-use changes, these data soon become out-dated. In addition, in most cases, an assignment of this matrix to the network cannot reproduce observed flows. Three main types of models are considered in the conventional analysis: Fratar models, opportunity models and gravity models. These were evaluated by Easa (1993a).

The emphasis on transportation system management in the early 1970s increased the need for studying small urban areas in detail. Some cheaper and quicker-response theory and methods for synthesizing trip tables from more conveniently available information have been developed since then. According to the purpose of these models, they can be classified into the following subgroups: National Co-operative Highway Research Program (NCHRP) Simplified Techniques, Traffic Count-Based Models, Self-Calibrating Gravity Models, Partial Matrix Techniques, models using GIS data, Heuristic Methods and Facility Forecasting Techniques. There are also some special application models, for example, freeway trip distribution, pedestrian trip distribution and special purpose trip-distribution models. Examples of special purpose trip-distribution models include choice models (employing individual travelers instead of the zones as the unit of observation), continuous models (that ignore the zones altogether when the changes in land-use patterns are small), simultaneous models (that simultaneously analyse trip distributions and other planning steps).

2.6 TRAFFIC COUNT-BASED MODELS

In reality, the problem on a given network is a dynamic (time-dependent) system.

The analytical traffic flow process on such networks can be simplified to study some density function that satisfies certain differential or difference equations of the continuation type (Lyrintzis et al., 1994, Zhang et al., 1995), or can be treated by dynamic programming (DP) approaches (Janson, 1995). In practice, however, this dynamic system is very hard to study to obtain a desired solution. In order to derive O-D trip tables from count-based information, the traffic flow is usually considered in its static (time-independent) or stationary state. There is some evidence to support such an idea. First, the study of O-D trip tables is motivated by the purpose of reducing the congestion problem. In the case of congestion, however, the distribution of traffic flow is dominated by the user equilibrium principle discussed in the next section. Moreover, it can be shown that the flow pattern is independent of time if the system satisfies an equilibrium condition. Second, if the system is considered during a very short time period, it can be approximated as a static system. In addition, the stationary treatment of dynamic systems can be thought as a first step toward problem simplification, and frequently, this reveals a more detailed structure of the problem.

Among all types of easily derived data, traffic counts (link volumes in a network) perhaps contain the most important information about O-D distributions. A variety of analytic models have been developed to establish O-D trip tables based on traffic counts along with other information. Based on the theory (or principle, or hypothesis) used, these models may be divided into the following types (Easa, 1993b; CTR, 1995).

2.6.1. Gravity-Based Models

These models are sometimes called Parameter Calibration models, and represent the original idea of establishing trip distributions. In these models, the entries of the O-D matrix are assumed to be a function of the traffic count and other parameters.

Regression techniques and the flow conservation law are applied to calibrate the parameters such that the differences between observed volumes and established volumes are minimized. The models are divided into linear (Low, 1972; Holm et al., 1976; Gaudry and Lamarre, 1978; Smith and McFarlane, 1978) and nonlinear (Rolillhard, 1975; Hogbag, 1976) regression models.

2.6.2. Equilibrium Models

These models are based on the principle of user optimization of traffic flow, called the "Equilibrium Principle" or "Wardrop's Principle" (Wardrop, 1952). These include LINKOD (Nguyen, 1977a-b; Gur, 1980), SMALD (Kurth et al., 1979), and Linear Programming (LP) (Sivanandan, 1991; Sherali et al., 1994a-b).

2.6.3. Entropy Models

Minimum Information and Maximum Entropy models are included in this group and can be converted to a type of gravity models. In these models, the probability of a particular trip distribution occurring is assumed to be proportional to the number of the states (entropy or disorder) of the system. The derived O-D table is purported to be the most likely one that is consistent with information such as length and free speed of the links contained in the link flows. The pioneers of these models, ME2, are Wilumsen (1978) and Zuylen (1978, 1979). Many improvements and combinations with other theory have been conducted since then, and a great deal of testing on these models has been performed. These results have been summarized in the review papers of Easa (1993b) and CTR (1995).

2.6.4. Statistical Models

These models take into account inaccuracies on the observed O-D flows, row and column sums and traffic counts. This group includes the Constrained Generalized Least Squares (CGLS) model (McNeil, 1983), and Constrained Maximum-Likelihood (CML) models (Geva, 1983; Spiess, 1987; Walting and Maher, 1988; Walting and Grey, 1991). Another model, called MEUSE, standing for Matrix Estimation Using Structure Explicitly (Bierlaire and Toint, 1995), which uses both historic data and parking data as input, can be partially included in this subgroup. Statistical models are not as popular in practice as compared with equilibrium and entropy models.

2.6.5. Neural Network Models

Muller and Reinbardt (1990) introduced the neural network approach to determine O-D trip table from traffic counts. In a loose sense, this approach is based on the concepts derived from research into the nature of the brain. The procedure in this approach includes "learning" and "optimization" components. The model may be mathematically described as a directed graph with three characteristics. 1) A state of variable associated with each node; 2) a weight assigned to each link; and 3) a transfer function defined for determining the state of each node as a function of its bias and weights of its incoming links. Yang, Akiyamma and Sasaki (1992) adopted a feed-forward neural network for synthesising O-D flow for a four-way intersection and a short freeway segment. Chin, Hwang and Pei (1994) described a neural network model for generating O-D information from flow volumes. There still exists a need for further testing these models.

2.6.6. Fuzzy Weight Models

Instead of the "all or nothing" assumption made in most models, Fuzzy Weight approaches apply some kind of "fuzziness" to the link data (Xu and Chan, 1992a-b).

Fuzziness indicates probability, but is quite different in nature. Different types of fuzziness have been tested on the network of the Eastern Highway Corridor. The model is relatively new, and additional case studies and experimentation are recommended for evaluation.

2.7 EQUILIBRIUM-BASED MODELS

The User Equilibrium Principle, also known as Wardrop's (first) principle or user-optimal assignment principle, was originally used to guide the traffic flow assignment process. It requires that all routes having positive flows between any O-D pair should have equal traffic cost, and this cost must not exceed the traffic cost on any other unused route between this O-D pair. Mathematically, estimating the O-D trip tables from link volumes can be thought of as an inverse problem of transportation assignment. Therefore, the equilibrium-based O-D matrix estimation problem may be described as determining an O-D matrix such that, when this matrix is user-optimally assigned to the network, it reproduces the observed O-D travel times. Since the correspondence between equilibrium link flow patterns and equilibrium O - D travel times for the standard equilibrium problem is "one-to-one" (Yang et al., 1994), it consequently reproduces the observed link flows.

Nguyen (1977) exploits Wardrop's user-equilibrium principle for route choice and formulates a deterministic network equilibrium approach. He shows that, if the set of observed link flows is at equilibrium, the solution matrix can be found by solving the following optimization problem with respect to variables *v* and *t*

Nguyen's Model 0 (NM0)

$$\underset{v,t}{Min}\ \mathrm{F}\ (\mathrm{v},\ \mathrm{t}) = \sum_{a\in A}\int_0^{v_a} f_a(x)dx + \sum_i \sum_j \bar{\mathrm{u}}_{ij}\, t_{ij} \qquad [2.1a]$$

Subject to:

$$\sum_r h_{r_{ij}} = t_{ij},\ \forall i,j \qquad [2.1b]$$

$$\sum_{r_{ij}} d_a, r_{ij} = v_a,\ \forall a \qquad [2.1c]$$

$$\sum_{ij} \bar{\mathrm{u}}_{ij}\, t_{ij} = \sum_a f_a\ (\bar{v}_a)\bar{v}_a \qquad [2.1d]$$

$$h_{r_{ij}} \geq 0, t_{ij} \geq 0$$

Here f_a (*x*) is the volume-delay function for link *a*, t_{ij} is the travel demand between origin *i* and destination *j*, v_a is the assigned flow on link *a*, $h_{r_{ij}}$ is the flow on route *r* connecting origin *i* and destination *j*,

$$d, r_{ij} = \begin{cases} 1 & if\ link\ a\ is\ on\ route\ r\ between\ i\ and\ j \\ 0 & otherwise, \end{cases}$$

$\bar{v}_a$ is the observed link flow, and $\bar{u}_{ij}$, the observed inter-zonal accessibility (travel time on any used route between zone *i* and zone *j* due to the equilibrium assumption).

As shown by Nguyen (1984), for each link *a* ∈*A*, the problem NM0 has a unique optimal solution $\overset{*}{v}_a$ because the objective function is strict convex in *v*. The optimal solution $\overset{*}{v}_a$ is consistent with the observed link flow $\bar{v}_a$, *a* ∈*A*, if the observed link flow pattern is at equilibrium. However, the problem NM0 may not have a unique O-D matrix solution because that it is not strictly convex in the variable *t* (Sheffi, 1985).

Namely, there are many possible O-D matrices that produce the same set of observed O-D travel times of observed link flows when assigned to the network.

Nguyen's theoretical model was operationalised during the course of a Federal Highway Administration Project in which the LINKOD system of models were developed (Turnquist and Gur 1979; Gur et al., 1980). The LINKOD system is comprised of two major components: SMALD and ODLINK. SMALD (Kurth et at., 1979) is a small area trip distribution model that determines a trip table for a subarea. This table is used to overcome the under-specification problem of Nguyen's formulation and has been extensively tested and verified by Han, Dowling, Sullivan and May (1981), Han and Sullivan (1983), and Dowling and May (1984). To obtain a unique O-D matrix, a target O-D matrix $\bar{t}_{ij}$ is assumed to be available. Different criteria have been suggested for choosing among all the O-D matrices that produce the observed link flows. In the LINKOD model (Gur 1980), the estimation problem is formulated as

NM1

$$\min \sum_{ij}(t_{ij} - \bar{t}_{ij})^2 \qquad [2.2]$$

subject to *t* being optimal to NM0.

Another model is suggested by Jornsten and Nguyen (1980) that chooses the most likely matrix among the optimal solution set by solving the following optimization problem,

NM2

$$\max \sum_{ij} -t_{ij} \left\{ log\left(\frac{t_{ij}}{\bar{t}_{ij}}\right) - 1 \right\} \qquad [2.3]$$

subject to *t* being optimal to NM0.

In the existing literature, two requirements, namely, to reproduce the observed O-D travel times and to reproduce the observed link flows, have been used. These two requirements are equivalent when the observed network is in equilibrium. The equivalence relationship, however, will not hold when the set of observed link flows is not an equilibrium solution (Yang et al., 1994).

Both NM1 and NM2 have a bi-level programming structure that poses computational difficulties for large-scale networks (Fisk 1989, Fisk and Boyce 1983). LeBlanc and Farhangian (1982) suggested a partial dualization method for solving NM1 (Sheffi, 1985). The partial dualization method involves updating a Lagrange multiplier by iteratively solving a Lagrangian minimization problem. A similar method for solving NM2 was also suggested by Jornsten and Nguyen (1980) and Nguyen (1984). Both of these methods require iteratively solving program NM0, and are computational demanding. Yang et al., (1992b) have shown how to integrate existing methods such as the generalized least squares technique with an equilibrium traffic assignment approach using a Stackelberg leader-follower optimization model. An attempt is made for uncertainties in both the target O-D matrix and in the traffic link counts, and a heuristic solution method is proposed because of the inherent difficulty in solving moderate to large sized problems of this type.

It has been shown by Yang et al., (1994) that Nguyen's bi-level optimization models can be transformed into a single convex program. When the observed link flow pattern is in equilibrium, the original model is demonstrated to be equivalent to a reduced system of linear equations. By exploiting the properties of the system's feasible region, simpler methods, such as a least squares technique, can be used to obtain an O-D matrix that, when user-optimally assigned to the network, will reproduce the observed link flows.

The models mentioned above are based on improving and modifying Nguyen's systems. Other models based directly on the user-optimal principle are also developed. One of them is to apply Linear Programming (LP) theory to estimate O - D trip tables from the observed link flows (Sherali et al., 1994a; Sivanandan, 1991).

2.8 LINEAR PROGRAMMING MODELS

Linear programming theory and technique have been successfully applied to various transportation problems almost since its early beginning. A famous example is given by Dantzig (1951) to adapt his simplex method to solve (Hitchcock's) transportation problem. The terminologies, such as transportation/assignment problems, and allocation problems, have become a standard in these contexts since then (Bazaraa et al., 1990).

Linear programming methods were first used to study O-D distributions in the 1970s (Colston, 1970). The developed approaches, unfortunately, were not successful in practice. An alternative linear programming approach has been proposed recently (Sivanandan, 1991; Sherali et al., 1994a-b) based on a non-proportional assignment and user-equilibrium principle. The basic idea and technique used in this modeling approach may be described as follows.

Consider a road network. Let N be the set of nodes including centroids, A be the set of corresponding directed links or arcs, and let OD be the set of O-D pairs that comprise the trip table to be estimated. Let x_{ij} be the estimation of flow originating at i and destined for j, and

$\bar{f}_a$ be the observed link flow for each link $a \in A$. Let p_{ij}^k, k = 1,……,n_{ij}, represent all the n_{ij} paths between each O-D pair (i, j)∈OD , and x_{ij}^k be the contribution of x_{ij} to the path p_{ij}^k for each k = 1,…. n_{ij}. Assume that the link travel time/cost c_a (v_a) is a (strictly) increasing function of flow v_a , let c_{ij}^k=$\overline{c}$·p_{ij}^k denote the cost on route k between O-D pair (i, j) for k = 1,…., n_{ij}, and let $\overset{*}{C}_{ij} = \min\{ c_{ij}^k, k = 1, \ldots, n_{ij}\}$. Then based on the user-optimal principle, the following linear programming model may be constructed.

Minimize

$$\sum_{(i,j)\in OD} \sum_{k=1}^{n_{ij}} \hat{c}_{ij}^k \, x_{ij}^k \qquad [2.4a]$$

subject to

$$\sum_{(i,j)\in OD} \sum_{k=1}^{n_{ij}} (p_{ij}^k) \, x_{ij}^k = \bar{f} \qquad [2.4b]$$

$$x \geq 0 \qquad [2.4c]$$

where

$$\hat{c}_{ij}^k = \begin{cases} c_{ij}^k \;\; if \; k \in K_{ij} \\ M_1 c_{ij}^k \; if \; k \; \in K_{ij} \end{cases} \qquad [2.4d]$$

and where M_1 > 1 is a constant, and K_{ij} is the observed inter-zonal accessibility defined by K_{ij}= {k∈ $\{1, \ldots, n_{ij}\}$:c_{ij}^k=$\overset{*}{c}_{ij}$}, for each (i, j)∈ OD

It has been shown by Sherali et al. that the observed link flow pattern is at an equilibrium if and only if the objective value of [2.8] is equal to $\bar{C}_{total}$ =$\sum \bar{c}_a \, \bar{f}_a$, the total observed system cost.

In order to take the internal inconsistencies of input data and the prior trip table into account, some penalized terms are added to the objective function and the following LP and LP (TT) models are considered, respectively.

LP:

Minimize

$$\sum_{(i,j)\in OD} \sum_{k=1}^{n_{ij}} \hat{c}_{ij}^{k}\, x_{ij}^{k} + Me \cdot (y^{+} + y^{-}) \qquad [2.5a]$$

Subject to

$$\sum_{(i,j)\in OD} \sum_{k=1}^{n_{ij}} (p_{ij}^{k}) x_{ij}^{k} + (y^{+} + y^{-}) = \bar{f} \qquad [2.5b]$$

$$x \geq 0, y^{+} \geq 0, y^{-} \geq 0 \qquad [2.5c]$$

LP (TT):

Minimize

$$\sum_{(i,j)\in OD} \sum_{k=1}^{n_{ij}} \hat{c}_{ij}^{k}\, x_{ij}^{k} + Me \cdot (y^{+} + y^{-}) + M_{\sigma} \sum_{(i,j)\epsilon \overline{OD}} (Y^{+} + Y^{-}) \qquad [2.6a]$$

subject to

$$\sum_{(i,j)\in OD} \sum_{k=1}^{n_{ij}} (p_{ij}^{k}) x_{ij}^{k} + (y^{+} + y^{-}) = \bar{f} \qquad [2.6b]$$

$$\sum_{k=1}^{n_{ij}} x_{ij}^{k} + \left(Y_{ij}^{+} - Y_{ij}^{-}\right) = Q_{ij} \qquad \forall (i,j) \in \overline{OD} \qquad [2.6c]$$

$$x \geq 0, y^{+} \geq 0, y^{-} \geq 0, Y^{+} \geq 0, Y^{-} \geq 0. \qquad [2.6d]$$

Here, $\overline{OD} \subseteq OD$ is a subset of O-D pairs for which a partial prior (target) trip table information is available and M and M_{σ} are some positive penalty parameters. The authors investigated on how large these penalty coefficients should be for the purpose of achieving desired solutions. Instead of using the (standard) Simplex Method, a Column Generation Algorithm (CGA) is developed for solving LP (TT), in order to reduce the computational effort for practical problems. The models have been tested on a real network of Northern Virginia.

In practice, it is commonly the case that not all of the link volumes of the network are available. The LP models have been improved to take care of the case of missing volume (Sherali et al., 1994b). The idea used in this situation is to update the travel time/cost by solving some linear and nonlinear programming sub problems iteratively. Both the original and improved versions have been tested and evaluated on some real networks (Sivanandan et al., 1996).

2.9 SUMMARY ON O-D LITERATURE

Different approaches have been investigated for estimating O-D trip tables in the last several decades. Conventional analysis is very expensive in practice. It is hard to reproduce the observed flows using these techniques, and the trip tables often become outdated. As a consequence, quick response models become of great relevance in transportation planning.

Among quick response models, the one based on traffic counts is very popular and pervasive. The problem is beset with a great deal of complexities, and various approaches have been employed to overcome them.

Gravity-based models require considerable data, and are relatively more likely to have their results become outdated. This makes these models unattractive. LINKOD type models incorporate the desired equilibrium assignment concept, but their nonlinear nature leads to the issue of excessive computational effort for deriving acceptable solutions to practical problems. The entropy-based models pose restrictions on data, give little weight to prior information, and need refinements for incorporating the equilibrium principle. Statistical models take into account the stochastic nature of the data and the problem. However, they have not been adequately tested. In addition, the stochastic theory used itself sometimes makes the problem more complicated for practical purposes. Both neural network and fuzzy set approaches still need to be verified regarding their practical viability. Moreover, in-depth theoretical studies are themselves needed before these approaches can be justified for use in practice.

Linear programming models and algorithms have been widely used in various applications, including transportation and assignment problems. Using this approach to estimate the O-D trip matrix from link volumes, however, is relatively new. The approaches have some advantages such as a simpler formulation, and for the case of all link volumes being available, an established theory guaranteeing finite convergence. On the other hand, the approach approximates the random nature of the data and the problem, and the resulting O-D table often has many zeros because of the “extreme point” optimality principle. (This is somewhat alleviated when using prior trip table information.) Moreover, in the case of missing volumes, the approach iteratively updates the travel cost on missing data links and then minimizes the total cost, which leads to a problem of excessive computational effort.

Therefore, there is a need to improve the LP model so that it can take care of inaccuracies in input data in practice, interpret both user behavior and user-optimal principles in a reasonable manner, and reduce the computational effort in generating practical acceptable solutions.

2.10 CAPACITATED ARC ROUTING PROBLEM (CARP)

The CARP is closely related to the Rural Postman Problem (RPP) and was first introduced by Golden and Wong (1981). It is an important problem in the area of arc routing since it considers the capacity restrictions of the vehicles involved, which make it more applicable for real life applications. The routing of waste collection vehicles, snow removal vehicles and street sweepers are good examples of CARPs.

Golden and Wong (1981) describes the CARP as follows: consider an undirected graph **G = (V, E)** with a vertex set **V**, an edge set **E** and a set of required edges **R** ⊆ **E**. A fleet of k homogeneous vehicles of capacity **W** are based at a designated depot vertex v_0. Each edge of the graph (v_i, v_j) incurs a cost c_{ij} and has a demand q_{ij} associated with it. The subset **R** of edges must be serviced by a vehicle and the remaining edges of **E** may be traversed any number of times. The CARP consists of determining a set of vehicle routes of minimum total cost, such that each trip starts and ends at the depot, each required edge is serviced by a single trip and during one traversal and the total demand for each trip does not exceed vehicle capacity **W**. The graph or network on which the CARP is based may be undirected, directed or mixed depending on the road network topology and operating policies involved.

Eiselt and Laporte (1995) proposed an integer linear programming formulation for the undirected CARP by replacing each edge with two arcs creating a directed formulation of the CARP that is presented as follows:

$$x_{ijk} \triangleq \begin{cases} \mathbf{1} \text{ if edge } (v_i, v_j) \in \mathbf{A} \text{ is traversed from } v_i \text{ to } v_j \text{ by vihicle k,} \\ \quad \text{where } k = \{1, \dots m\}, i \neq j \\ \mathbf{0} \text{ otherwise} \end{cases}$$

$$y_{ijk} \triangleq \begin{cases} \mathbf{1} \text{ if edge } (v_i, v_j) \in \mathbf{A} \text{ is serviced by vihicle k while traveling from } v_i \text{ to } v_j, \\ \quad \text{where } k = \{1, \dots m\}, i \neq j \\ \mathbf{0} \text{ otherwise} \end{cases}$$

$c_{ij} \triangleq$ The cost or distance of edge (v_i, v_j)

$q_{ij} \triangleq$ The demand of edge (v_i, v_j)

W $\stackrel{\Delta}{=}$ Capacity of the vehicles

S $\stackrel{\Delta}{=}$ A given vertex set

$$\min \sum_{k=1}^{m} \sum_{(v_i,v_j)\in \boldsymbol{A}} c_{ij}x_{ijk} \tag{2.1}$$

subject to

$$\sum_{(v_i,v_j)\in \boldsymbol{A}} x_{jik} - \sum_{(v_i,v_j)\in \boldsymbol{A}} x_{ijk} = 0 \qquad \forall\, v_i \in \boldsymbol{V}, \mathrm{k} = 1, \dots, \mathrm{m} \tag{2.2}$$

$$\sum_{k=1}^{m} (y_{ijk} + y_{jik}) = \begin{cases} 0 \; if \; q_{ij} = 0 \\ 1 \; if \; q_{ij} > 0 \end{cases} \qquad \forall\, (v_i, v_j) \in \boldsymbol{A} \tag{2.3}$$

$$x_{ijk} \geq y_{ijk} \qquad \forall\, (v_i, v_j) \in \boldsymbol{A}\,, k = 1, \dots., m \tag{2.4}$$

$$\sum_{(v_i,v_j)\in A} q_{ij}y_{ijk} \leq W \qquad \forall\, k = 1, \dots., m \tag{2.5}$$

$$\sum_{v_i,v_j\in S} x_{ijk} \leq |S| - 1 + n^2u_k^S \qquad \forall\, S \subseteq V\{v_i\}; S \neq \emptyset; k = 1, \dots.m \tag{2.6}$$

$$\sum_{v_i\in S} \sum_{v_j\notin S} x_{ijk} \geq 1 - w_k^s \qquad \forall\, S \subseteq V\{v_i\}; S \neq \emptyset; k = 1, \dots.m \tag{2.7}$$

$$u_k^s + w_k^s \leq 1 \qquad \forall\, S \subseteq V\{v_i\}; S \neq \emptyset; k = 1, \dots.m \tag{2.8}$$

$$u_k^s, w_k^s \in \{0,1\} \qquad \forall\, S \subseteq V\{v_i\}; S \neq \emptyset; k = 1, \dots.m \tag{2.9}$$

$$x_{ijk}, y_{ijk} \in \{0,1\} \qquad \forall\, (v_i, v_j) \in \boldsymbol{A}\,, k = 1, \dots., m \tag{2.10}$$

In this formulation, the objective function (2.1) minimises the total cost induced by the *k* vehicles. Constraints (2.2) are flow conservation equations for each vehicle. Constraints (2.3) ensure that service arcs correspond to those with a positive demand. Constraints (2.4) state that an arc is serviced by a vehicle only if it is traversed by the same vehicle. Constraints (2.5) enforce capacity restrictions of vehicle *k*. Constraints (2.6) to (2.9) ensure that the solution does not contain any illegal subtours.

The basic CARP can sometimes be too simplistic to model accurate representations of real world instances, leading to various variants of the CARP.

2.10.1 Capacitated Arc Routing Problem with Intermediate Facilities (CARPIF)

The CARPIF, first introduced by Ghiani et al., (2001), requires that a vehicle need to unload or replenish at Intermediate Facilities (IFs). For the Waste Collection Problem (WCP), a vehicle starts in the morning at an assigned depot. Waste is collected along the streets until the vehicle's capacity is reached, after which the vehicle needs to dump the waste at the nearest dumping site (IF), which may or may not include the depot.

Ghiani et al., (2001) and Polacek et al., (2007) solve this problem by adding a subset ***I*** of intermediate facilities to the CARP. Constraints are added such that the waste collected between the depot and first IF, or between two IFs may never exceed the vehicle's capacity **W**.

2.10.2 Capacitated Arc Routing Problem with Turn Penalties (CARPTP)

The basic CARP assumes that all turns are allowed and are not time consuming, but this may not be the case when routes have to be operated within a city. Some turns can be considered forbidden, others more time consuming or dangerous, especially for large waste collection vehicles. U-turns may be impossible to make due to narrow streets or forbidden by traffic rules. Even right turns at robots or busy intersections may be more time consuming and should therefore be penalized.

Belenguer et al., (2006) provides a method for including turn penalties in the CARP based on the work of Benavent and Solver (1999). This method allows the solving of the problem by adding a penalty cost associated with each turn to the objective function.

2.10.3 Stochastic Capacitated Arc Routing Problem (SCARP)

The SCARP can be defined as a problem having some element of uncertainty. The uncertainty can for instance be the demand of the customer or the travel times of the vehicles. In the Waste Collection Problem the stochastic component refers to the demand of the customers and is treated as a decision variable in the problem (Chu et al., 2006).

2.10.4 Periodic Capacitated Arc Routing Problem (PCARP)

In waste collection problems it is not uncommon for municipalities to schedule service only on certain days for instance only twice a week. This period can vary for area to area depending on the population and demand of the given areas. Daily removal may be too expensive and trips will rather be planned over a multi-period time frame (Chu et al., 2006).

In order to make a model for the WCP more realistic, a problem formulation will have to be extended to include IFs and turn penalties.

2.11 SOLUTION APPROACHES

According to Winston and Venkataramanan (2004) problems that can be solved in polynomial time are typically solved to optimality using efficient algorithms and exact methods.

Golden and Wong (1981) demonstrated that even finding a near optimum (within 50%) solution to an approximate, restricted version of the CARP of a cost less than 1.5 times the optimal is NP-hard (Non-deterministic Polynomial-time hard). Given that the CARP is NP-hard it becomes necessary to use heuristics or metaheuristics to solve the CARP. However literature indicates several exact solution approaches for the CARP. Hirabayashi and Nishida (1992) proposed a Branch and Bound algorithm and Belenguer and Benavent (2003) proposed a Cutting Plane algorithm. Belenguer et al., (2006) extended the cutting plane algorithm for the mixed CARP. However, exact method are still limited to small instances of the CARP and can seldom cope with additional characteristics of real world waste collection problems. This again emphasises the importance of using heuristics or metaheuristics to solve larger instances of the CARP.

2.11.1 Heuristics

Heuristics are approximate techniques used to determine good feasible solutions for problems that are difficult or impossible to solve to optimality. Winston and Venkataramanan (2004) state that heuristics are characterized by using a greedy approach to obtain good solution in efficient time. Heuristics make incremental improvements to an existing solution by neighbourhood changes or local searches. Heuristics only allow movements that will improve the objective function (increase for a maximise, decrease for a minimise). As a result they tend to get trapped in a local optima and fail to find a global optimum[3].

Figure 2.1 indicates how a problem can have many different local optima's which may or may not be the global optimum. Depending on where the heuristic starts different solutions can be obtained. Starting at *a*, it can only improve until local optimum 1 is reached.

Whereas, starting at *b* will result in improvements up to the global optimum, indicating that heuristics cannot guarantee certainty about how close the solutions are to the global optimum.

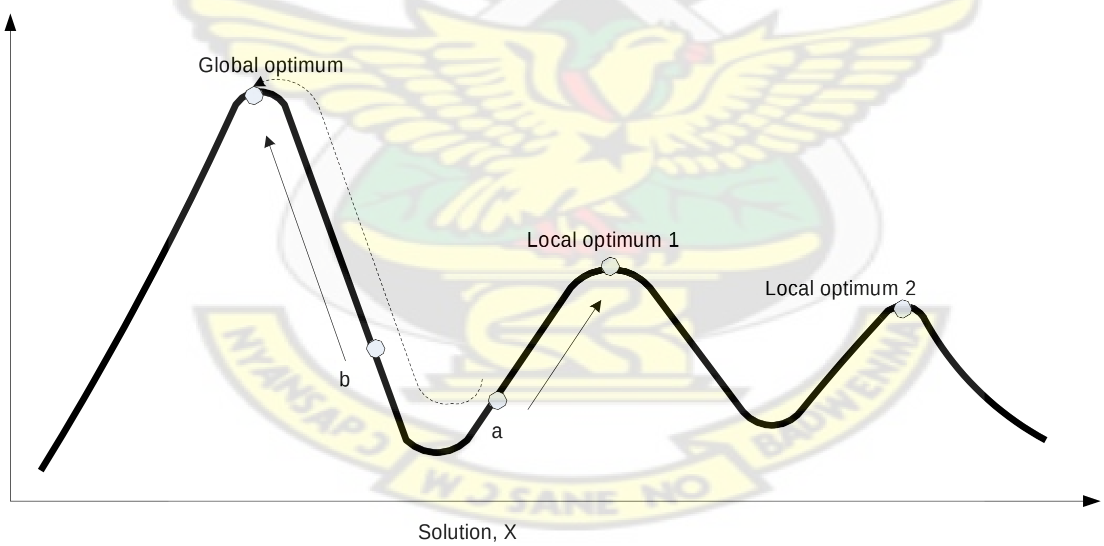

Figure 2.1: Local vrs Global optimum

[3] A global optimum is a feasible solution such that no other solution has a superior objective function value

2.11.2 Metaheuristics

Metaheuristics are a subset of heuristics that are based on intelligent search techniques which can over-come the problem of being trapped in a local optimum. This is achieved by accepting solutions that may not be an improvement or by considering several solutions at a time (Winston and Venkataramanan, 2004).

Metaheuristics search through the entire solution space, not simply excepting the first local optimum. They keep on searching for an improved solution, increasing the probability of finding a global optimum. Referring back to Figure 2.1 starting at point *a* it can reach the global optimum by excepting worse solutions.

The four metaheuristics that will be investigated further are Simulated Annealing (SA), Genetic Algorithms (GAs), Tabu Search (TS) and Variable Neighborhood Search (VNS).

2.11.3 Simulated Annealing (SA)

First introduces as a technique to solve complex non-linear optimisations problems, SA emulates the physical process of aggregating particles in a system as it is cooled. By slowly lowering temperature, the energy exchange allows true equilibrium in each stage until the global minimum energy level is reached (Winston and Venkataramanan, 2004).

SA randomly generates feasible moves and calculates the net objective function improvement that these changes will bring about. Since the Waste collection Problem (WCP) is a minimization problem a decrease in the objective function will result in the acceptance of the move. An increase in the objective function will result in the acceptance of the move according to a certain probability function, which may result in a worse solution. This ensures that the algorithm does not get stuck in local optima but searches through the entire solution space in the pursuit of a better solution.

2.11.4 Genetic Algorithms (GAs)

GAs utilizes ideas from biology such as a population of chromosomes, natural selection for mating, offspring production using crossover and mutation for diversity. GAs begins by randomly generating an initial population of strings of chromosomes. These strings represent possible solutions to the given problem. Each solution is evaluated by measurable criteria that result in a fitness (usually the objective function value) being associated with each string. The selection of parents is probabilistically chosen from the current solution by the principle of survival of the fittest: the most fit has the greatest chance of being chosen.

Reproduction of parents occurs such that the offspring consist out of a recognisable portion of both parents. The offspring undergoes mutation to randomly alter its genetic makeup to avoid being trapped in a local optima. The offspring becomes part of the new generation of solutions (Winston and Venkataramanan, 2004).

Lacomme et al., (2006) use a Memetic Algorithm (MA) to solve the CARP. This Memetic Algorithm is a genetic algorithm hybridised with a local search. Moreover, the MA addresses several extensions of the CARP like mixed networks, parallel arcs and turn penalties. It provides excellent performance results on three sets of bench mark problems. Belenguer et al., (2006) further extended this MA to also address problems with several dumping sites. Prins et al.,

(2003) use a GA with population management to solve the CARP. Result obtained by the authors suggests that the GA is highly successful for solving the CARP and its extensions.

2.11.5 Tabu Search (TS)

The TS emulates heuristic rules people use in day-to-day decision making by making use of short term and long term memory. The short term memory prevents cycling around a local neighbourhood in the solutions space. Long term memory allows searches to be conducted in the most promising neighbourhoods. It moves away from a local optima by temporarily classifying some moves *tabu* or forbidden (Winston and Venkataramanan, 2004). The Tabu Search algorithm keeps track of the best solution found far and when the search stops it is reported as an approximate optima for the problem.

Hertz et al., (2000) use a TS algorithm called CARPET to solve the CARP; Greistorfer (2003) uses a Tabu Scatter Search metaheuristic; and Brandao and Eglese (2008) a deterministic TS algorithm. Ghiani et al., (2001) use the TS algorithm to solve the CARPIF.
All of the authors were able to provide high quality solution for benchmark problems.

2.11.6 Variable Neighbourhood Search (VNS)

Hansen and Mladenovic (2001) described the VNS as a metaheuristic that proceeds to a systematic change of neighborhoods within a possibly randomised local search algorithm.
A local search proceeds from an initial solution by a sequence of local changes. Each local change improves the value of the objective function until a local optima is found. The VNS avoids being trapped in a local optima through the systematic changes of neighborhoods.

VNS does not follow a trajectory but explores increasingly distant neighborhoods of the current incumbent (best feasible solution so far), and jumps from this solution to a new one, if and only if, an improvement has been made. In this way often favourable characteristic of the incumbent solution, e.g. the many variables that are already at their optimum value, will be kept and used to obtain promising neighbouring solutions.

Hertz et al., (2001) described an adaptation of a variant of the VNS, called Variable Neighbourhood Descent (VND) algorithm for the CARP. The VND algorithm proved highly successful for solving three sets of benchmark problems. On large instances the VND tend to perform better than the TS algorithm CARPET, proposed by Hertz et al., (2000), in terms of computational time and solution quality. Polacek et al., (2007) use the VNS to solve the CARP and extended it to solve the CARPIF. Excellent results were obtained on four sets of benchmark problems of which two included the extension of IFs. Again the VNS showed slightly better performance results for the CARPIF compared to the results that Ghiani et al., (2001) obtained through the use of a TS algorithm. Another major advantage of VNS is that high quality final solutions can be achieved independently from the quality of the initial solution. As a result of the highly successful results obtained on benchmark problems for the CARP, a VNS solution strategy is usually helpful in solving a WCP.

Amponsah (2003) used the Variable Search to solve a Capacitated Arc Routing Problem "The Collection of Waste in Developing Counties"

2.12 SUMMARY

In this chapter, we discussed pertinent and adequate literature in the area of heuristics.

In the next chapter, we shall put forward the methodology of the study.

CHAPTER 3

METHODOLOGY

3.0 INTRODUCTION

Traffic congestion is a consequence of disparity between transportation demand and supply. Demand for transportation in urban areas is an increasing phenomenon for the continuous increase in urban population and economic activities lagging behind the transportation supply. As a result, traffic congestion has already become a part of urban transportation system. Such traffic congestion not only causes problems to urban transportation activities but also causes degradation to natural environment by increasing the magnitude and intensity of air pollution. Efforts to eliminate traffic congestion completely from the transportation network may be unrealistic; rather the way to minimize traffic congestion is a challenge for transportation engineers and urban planners.

The methodology used to study the Vehicular Traffic congestion in the Sekondi-Takoradi Metropolis is described in the following sections. The study is based on one parameter that is; traffic congestion. The parameter would be estimated or computed and interpreted to determine the severity or otherwise of the current traffic situation in the metropolis and offer some planning advice to urban planners to help alleviate the traffic congestion problem. The steps which would be involved in the study are:

(i) Selection of study area within the jurisdiction of STMA

(ii) Zoning of the study area which include wards within the Metropolis for effective analysis of the traffic situation

(iii) Data on type of vehicular count (i.e. Master Station Classification Count, Screen Line Classification Count, Turning Movements Counts and Saturation flow studies) based on the link volume count, intersection volume count, link width and intersection dimension would be obtained from the DUR Sekondi-Takoradi for the study.

(iv) Various indices such as the Roadway Congestion index (RCI) would be employed to quantify the overall vehicular traffic volume within the Metropolis.

3.1 SELECTION OF STUDY AREA

3.1.1 Overview of the Study Area

The area selected for this study comprises forty-nine (49) square kilometres of central urban portion of Sekondi-Takoradi Metropolis. The main commercial and economic hub of the Metropolis is the Takoradi Market Circle. It covers an area of less than one kilometer. It is Ghana's best planned market. The market got its name due to the big circle in which it is situated. The stores of the market where built to form the shape. Inside the circle are buildings that house the market's administrative staff. This part of the Metropolis contains almost all major government and private commercial activities. Due to the recent discovery of crude oil in the Western Region of Ghana, there has been an influx of people in to the urban portions of the Metropolis. Due to lack of proper planning and control over land use activities, people from all over the country rush to this portion and made it a horde of residential, commercial and business centers. Traffic congestion problems are concentrated here and are much greater than other peripheral portions of the Metropolis.

3.1.2 Zoning of the Study Area for Analysis

For proper analysis of the study area, which is under the jurisdiction of the Sekondi-Takoradi Metropolitan Assembly (STMA), the study area is zoned in to five.

(i) Zone 1: Areas in and around the Takoradi Market Circle

(ii) Zone 2: Paa Grant roundabout near New Takoradi and the Takoradi Polytechnic (T-Poly) traffic light junction.

(iii) Zone 3: Effiakuma traffic light popularly known as Number Nine traffic light.

(iv) Zone 4: Tanokrom traffic light also known as Pipe Anor traffic light.

(v) Zone 5: Kwame Nkrumah Circle which is popularly referred to as Ajep roudabout.

The map of the study area (Sekondi-Takoradi) is shown below

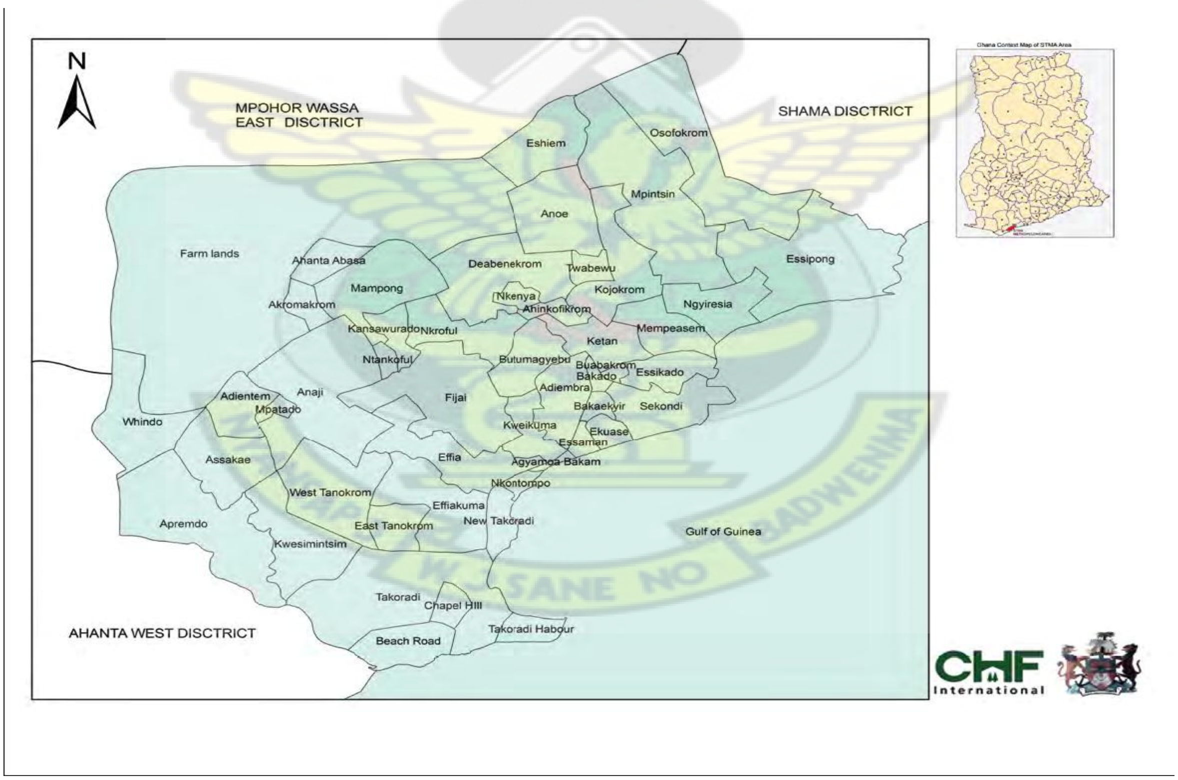

Figure 3.1 Map of the study Area

3.1.3 Study Area Transportation Network

The study is designed to determine the hourly traffic volume on the links of some road networks. The data collection procedure would take the numerical inventory of the road network as the number of road-way intersections or nodes, number of road links to be analyzed, connectivity of the nodes to form road links including length of each link in kilometer. For each individual link the number of lanes available in one direction, number of ways, average speed of all types of vehicles in the link, average speed of each individual type of vehicle in the link etc. would be considered for input.

The information about the road network would be obtained from DUR Sekondi-Takoradi. A total of 212.9km of road would be selected for the present study. Only the main roadway links, which are normally used for inter zonal movements would be taken into consideration in this study.

3.2 TRAFFIC VOLUME COUNT

The most important data are generated through the modern survey techniques like traffic volume count at different links and intersections. The extent of variation of traffic flow was ascertained by carrying out twelve-hour (6:00-18:00) weekday counts at five intersections such as Takoradi market circle, Paa Grant roundabout, Number nine, Pipe Anor and Ajep. By analyzing the twelve-hour volumes, the period of peak flows are assessed. Traffic volume counts are performed at major intersections and important links only in the period of peak flows as assessed by twelve-hour traffic volume count. The traffic volume is expressed as passenger car unit per hour (PCU/h). The following section describes the types of vehicular traffic counts that were conducted by the DUR in Sekondi-Takoradi.

3.2.1 Master Station Classification Count (MS)

The main objective of the Manual Traffic Counts was to obtained information on traffic volume and composition. Manual Classified Count was carried out for seven days at six locations in Sekondi-Takoradi. These were planned to give a good picture of the current traffic on the Sekondi-Takoradi town roads. The total number of vehicles (motorized and non-motorised) by type moving in each direction was registered. The counts were carried out for 24-hours each day. One enumerator registered vehicles (motorised and non-motorised) by type in one direction of the project road and the other enumerator also undertook the same exercise in the opposite direction. (DUR, Sekondi-Takoradi)

The 24-hours count conducted at these stations forms the basis for computing the Traffic Flow Characteristics, Traffic Variation Factors, Hourly Traffic Distribution, Traffic composition, Traffic Growth Rates at the Master Stations for each road and factors for adjusting the 12-hour counts to 24-hours.

The following classes of vehicles were used: Bicycles, Motor-cycles, Taxis, Private cars, Pick-Ups/Vans, Small Buses, Medium Buses, Large Buses, Light Trucks, Medium Trucks, Heavy Trucks, Truck-Trailer and Extra Large /Others.

3.2.2 Screenline Classification Counts (S)

Screenline classified counts were undertaken at 15 minutes intervals for a duration of 12 hours, on one weekday per location, at locations agreed within the operational frame work of DUR Sekondi-Takoradi. The total number of vehicles (motorized and non-motorised) by type passing in each location (station) every 15 minute interval was counted. One enumerator registered vehicles (motorized and non-motorised) in one direction of the project road and the other enumerator also undertook the same exercise in the opposite direction. The same vehicle classification system adopted for the Master Stations was utilized (DUR Sekondi-Takoradi, 2011).

3.2.3 Turning Movements Counts (T)

Turning Movement Counts were undertaken at 15 minute intervals for a duration of 12 hours, on one weekday per location agreed with DUR in Sekondi-Takoradi. Turning movement counts of all vehicles were registered at the junctions. The total number of vehicles (motorized and non-motorised) by type, that turned right, left or straight as they left the intersection, was counted. The same vehicle classification system adopted for the Master Stations was utilized.

3.2.4 Saturation Flow Studies (SF)

Saturation flow studies were undertaken during the AM and PM peak periods for a duration of 3 hours on one weekday per location at traffic signal locations agreed with DUR in Sekondi-Takoradi. Saturation Flow Study was undertaken at intersections controlled by traffic signals. In order to ensure saturation flow conditions, the survey was conducted only when vehicles exceeding four (4) had queued on the red phase of the approach lane. The time each vehicle takes to cross the white line when the red phase changes to green phase was recorded. Two (2) enumerators were stationed at each approach to record the time each vehicle took to cross the white line in each direction of the approach lane. This exercise was conducted for a minimum of eight cycles for each direction. One enumerator recorded the time each vehicle took before it crossed the stop line on the green, while the other enumerator took note of the first and last vehicle in the queue before the green and observes the time from a stop watch. Saturation flow studies were undertaken on each approach lane of the intersection.

3.3 WAYS TO QUANTIFY CONGESTION

A number of studies have been carried out by a number of researchers and professional organization to develop Congestion Indices. Pioneers of such studies are National Cooperative Highway Research Program (USA); Texas Transportation Institute (TTI), and Federal Highway Administration etc. A number of indices have also been proposed but they are mainly for freeways, corridor analysis or arterial roads etc. For regional or area wide analysis such type of indices cannot be used directly but the theme can be translated from a particular scope to a broader perspective. The congestion indices selected for this study are described as follows:

3.3.1 Roadway Congestion Index (RCI)

The overall regional Volume/Capacity ratio is a useful indicator of regional congestion (Shrank and Lomax, 1998). Shrank and Lomax define their "Roadway Congestion Index", RCI, as a weighted average Volume/Capacity ratio comprising Freeway and Principle Arterial components. The equation is:

$$\text{RCI} = \frac{\left(\frac{FV^2}{FLM}+\frac{AV^2}{ALM}\right)}{(13000*FV+5000*AV)} \qquad (3.1)$$

Where,

FV = Regional Freeway Volume, Vehicle-miles / day

AV = Regional Arterial Volume, Vehicle-miles / day

FLM = Regional freeway Lane-miles

ALM = Regional Arterial Lane-miles

To further illustrate the significance of RCI, it is useful to define,

FC = Freeway Nominal Capacity = 13000 * FLM veh-mile/day

AC =Arterial nominal Capacity = 5000 * ALM veh-mile/day.

Here 13000 and 5000 are freeway and arterial capacity per lane per day respectively. It should be understood that nominal capacity is not the maximum capacity rather it is a capacity close to the threshold of significant congestion. Further it must be emphasized that FC and AC thus defined are not the capacity defined by the Transportation Research Board (TRB), which refer to a point or screen line along a roadway rather than a region as a whole (Mallinckrodt, 2001).

Using definition of nominal capacity, the RCI, equation (1) can be written as

$$\text{RCI} = \frac{\left[\left(\frac{FV}{FC}\right)*FW+\left(\frac{AV}{AC}\right)*AW\right]}{[FW+AW]} \qquad (3.2)$$

Where,

FW = 13000 * FV

AW = 5000*AV

Expression in this form may be recognized as the weighting coefficients in a weighted average of freeway and arterial volume to capacity ratios. The ratios for these particular coefficients are not clear. Nevertheless the resulting RCI has a close relationship to congestion and perhaps it was on the basis, the weighting was chosen.

For the present study on Sekondi-Takoradi, the road network is not well classified. Again this study would be carried out for a two to three-hour peak period rather than whole day. So according to the suggestion of TTI, if the equation (3.2) for RCI is modified for the present study it stands as

$$\text{RCI} = \frac{\sum\left[\left(\frac{LV}{LC}\right)*LW\right]}{\sum LW} \tag{3.3}$$

Where,

LV = Link volume in Vehicle-km in peak hour = Vehicle per peak hour * Link Length.

LC = Link nominal capacity = Total capacity in vehicle per peak hour.

LW = (Capacity per Lane per Peak hour)*LV

If, for the whole network, capacity per lane per peak hour is taken as 650 (as per HCM[4], 1994), then after generalization it stands as;

$$\text{RCI} = \frac{\sum\left[\left(\frac{LV}{LC}\right)*(650)*LV\right]}{\sum 650*LV}$$

$$= \frac{\sum\left[\left(\frac{LV}{LC}\right)*LV\right]}{\sum LV}$$

$$= \frac{\sum\left[\left(\frac{LV^2}{LC}\right)\right]}{\sum LV}$$

$$\text{RCI} = \frac{\sum\frac{(Vehicle\ per\ Peak\ Hour*Link\ Length)^2}{(Link\ Capacity*Link\ Length)}}{\sum(Vehicle\ per\ Hour*Link\ Length)}$$

[4] Highway Capacity Manual

$$\text{RCI} = \frac{\sum \frac{(Vehicle\ per\ Peak\ Hour)}{(Link\ Capacity)} * (Vehicle\ per\ Peak\ Hour * Link\ Length)}{\sum (Vehicle\ per\ Peak\ Hour * Link\ Length)}$$

Here the RCI stands as the network weighted average volume capacity ratio, which indicates the index value of extra vehicle kilometer travel needed due to congestion in peak hours.

3.3.2Travel Rate Index (TRI)

The Travel Rate Index is a way of looking at travel conditions in peak periods (Schrank and Lomax, 1999). It focuses on travel time rather than more traditional measure-speed. The TRI indicates how much longer it takes to make a trip than would be the case if trip occurred in free-flow conditions. For example, a TRI value of 1.3 indicates that it takes 30 percent longer time to make a trip than it would take if travel occurred at free-flow speed. In general TRI equation stands as a weighted average of peak period travel on freeway and arterial streets.

$$\left(TRI = \frac{\frac{Freeway\ Peak\ Period\ Travel\ Rate}{Freeway\ Free\ Flow\ Travel\ Rate} * Freeway\ Peak\ VMT + \frac{Freeway\ Peak\ Period\ Travel\ Rate}{Freeway\ Free\ Flow\ Travel\ Rate} * Freeway\ Peak\ VMT}{Freeway\ Peak\ VMT + Arterial\ Peak\ VMT} \right)$$

Where VMT= Vehicle Miles Traveled

This equation could be modified for the present study to determine TRI of a network as follows:

$$\left(TRI = \frac{\sum \frac{Peak\ Period\ Travel\ Rate}{Free\ Flow\ Travel\ Rate} * Peak\ Period\ Vehicle\ Kilometer\ Travel}{\sum Peak\ Period\ Vehicle\ Kilometer\ Travel} \right)$$

Here individual link vehicle-kilometer travel is increased by a factor equal to the ratio of congested and free flow travel time. Actually it gives the value of network weighted average congested to free flow travel time ratio.

3.3.3 Multimodal Congestion Index (MCI) or Volume-Capacity Index (VCI)

According to Mallinckrodt (2001), adhering as closely as possible to the TRB Highway Capacity Manual, the definition of '*effective regional capacity or RC'*, herein for the purpose of congestion mitigation, can be stated as follows:

For congesting subsystems:

RC = the maximum volume of traffic, persons or vehicle kilometer per peak hour, which is under the prevailing conditions, can reasonably be expected to be supported by the subsystem at an acceptable or better level of congestion. Operating conditions specifically include public acceptance as well as managerial controls.

For non-congesting sub-systems:

RC = the maximum volume of traffic, persons or vehicle kilometer per peak hour, which under the prevailing operating conditions, can reasonably be expected to be diverted from congesting sub-systems. Operating conditions specifically include public acceptance as well as managerial controls.

VCI *Defined:* These definitions lead to define the Multimodal "Volume / Capacity Index" (VCI) as follows:

$$\text{VCI} = \frac{RV_S - RV_{nc}}{RC_c}$$

RV_s= Total (all Modes) System Demand Volume, Vehicle- kilometer per peak hour.

RV_{nc} = Summed effective volume (Vehicle-kilometer per peak hour) of non-congesting elements or links.

RC_c = Summed Effective capacity (Vehicle-kilometer per peak hour) of all congesting sub-systems.

Here the definition (Mallinckrodt, 2001) is changed from persons to vehicle to simplify the calculation according to the objectives of present study.

3.3.4 Congestion Severity Index (CSI)

It is used by Federal highway Administration Authority (FHA, USA) in reporting the results of system analyses using 'Highway Performance Monitoring System' data. The CSI has units of roadway delay per million vehicle kilometer of travel. For present study, if only peak period is considered rather than daily basis and the index is determined for thousand vehicle-kilometer travel, then the equation of CSI would stand as follows:

$$\text{CSI} = \left(\frac{Total\ Delay\ (Vehicle{-}hours) per\ Hour}{Total\ Vehicle{-}Kilometer\ Travel\ in\ Thousand\ per\ Peak\ Hour}\right)$$

It indicates the loss of Vehicle-hour per Thousand Vehicle-Kilometer travel in Peak Hour.

It can easily be converted to delay per vehicle-km travel.

3.3.5 Traffic Growth Rate

Traffic growth rates would be determined by comparing traffic data collected at the same locations in two different years (i.e. in the past year and the current year). In the case of Sekondi-Takoradi Metropolis, the last data collection was done in July 2003 and the present in November 2008. The formula used in the computation of the traffic growth rates from the previous traffic data obtained by the Department of Urban Roads (DUR) Sekondi-Takoradi is discussed below

$$P_F = P_P(1+r)^n$$

Where P_F= Traffic in the year n (i.e. the current year of 2008)

P_P= Traffic in the past year (i.e. the past year of 2003)

r = Rate of growth in decimals

n = Number of years between the previous and present traffic data

This actually measures the growth in traffic over a period of time within an area.

3.3.6 Mobility Level

Sometimes the mobility level of an individual link is measured by volume-capacity ratio.

Such type of measure is proposed by Houston-Galveston Council of Traffic Modeling (HGAC, 1998), which is shown in Table 3.1.

Level of Mobility	Volume / Capacity
Tolerable	< 0.85
Moderate	>= 0.85 < 1.00
Serious	>= 1.00 < 1.25
Severe	>= 1.25

Table 3.1: Scale of Different Mobility Levels

This type of measure divides the roadway lengths of the network into a number of classes, expressed as a percentage of total lengths according to mobility levels.

3.4 Summary

This chapter described the overall methodology for the study of the Vehicular transportation situation in Sekondi-Takoradi Metropolis through the sections of transportation review, selection of study area and selection of transportation system performance. The details of the study area where traffic congestion is eminent together with method of zoning and selection of road network were described. In transportation system performance sections, the concepts and definitions of various system performance parameters were illustrated. Based on the concepts and methods described in this chapter, an urban transportation study for the Metropolis would be established and applied to analyze traffic congestion situations within the Metropolis.

The next chapter is devoted for data collection and analysis.

CHAPTER 4

DATA COLLECTION, ANALYSIS AND DISCUSSION

4.0 INTRODUCTION

A lot of survey works were performed by the Department of Urban Roads (DUR) in Sekondi-Takoradi Metropolis. All data collected and used in the study were obtained from DUR Sekondi-Takoradi. The results of the data obtained have been summarized into tables and graphs to clarify the road traffic and transport patterns in the Metropolis. The analysis of results of the various field studies are discussed below.

4.1 MASTER STATION CLASSIFICATION COUNTS

Data from the Manual Classification Counts were collated and analysed to obtain traffic flow characteristics, variation factors, hourly distribution factors, traffic composition and traffic growth rates.

4.1.1 Traffic Flow Characteristics

Summary results of the traffic flow characteristics for the Master Stations studied in Sekondi-Takoradi Metropolis is shown in Table 4.1.The table indicates the average AM-peak and PM-peak volumes, the average daily 12-hour volumes, average 24 hour volumes and the various traffic variation factors based on the average 24 hour totals. The results show that the average 12-hour daily flows at the Master Stations form more than 68% of the total average of the 24 hour flow.

Table 4.1: Traffic Flow Characteristics at the Master Stations in Takoradi

Descriptor	MS1 Liberation road, Near Obuasi Road	MS2 Sekondi Road, Near Goil Station	MS3 Sekondi By-Pass, Near Tanokrom	MS4 Agona Nkwanta Road, West of PTC	MS5 Kansaworado /Apramdo By-pass, Near St Francis School Junction	MS6 Axim Road, Near Air Force Base
AM Peak-Hour Volume	730 (7.40%)	1756 (6.67%)	1590 (6.04%)	2108 (7.67%)	735 (8.58%)	1616 (7.74%)
PM Peak-Hour volume	839 (8.50%)	1769 (6.72%)	1643 (6.24%)	1946 (7.08%)	606 (7.08%)	1643 (7.87%)
12-Hour (06:00-18:00) Weekday Total Volume	7879 (79.90%)	19753 (75.03%)	18008 (68.39%)	20236 (73.62%)	6510 (76.02%)	16298 (78.06%)
24-Hour Weekday Total Volume	9862 (100.00%)	26327 (100.00%)	26332 (100.00%)	27487 (100.00%)	8563 (100.00%)	20880 (100.00%)

From Table 4.1, MS4 (Agona Nkwanta Road, West of PTC) recorded the highest 24 hour traffic of 27487 veh/day, followed by MS3 (Sekondi By-Pass, Near Tanokrom) with 26332 veh/day, MS6, MS1 and MS5 respectively.

MS4 registered the highest AM-peak and PM-peak of 2108 (7.67%) and1946 (7.08%) respectively for the morning and evening. The AM and PM peak flows of station MS2, however registered the second highest AM and PM peak flows recording 1756 and 1769 per day for the morning and evening period respectively

4.1.2 Variation Factors at Master Stations in Sekondi-Takoradi

From the 7-day, 24 hour manual classified count organized by DUR Sekondi-Takoradi, an average 24 hour daily traffic was calculated using Excel. The total average 24 hour traffic for each Master Station was divided by the average total 12 hour count to obtain the Variation Factor (VF) for the various Master Stations. Table 4.2 shows the variation factors obtained at the various Master Stations.

Table 4.2: Traffic Variation Factors at Master Stations in Sekondi-Takoradi

Station / Descriptor	**MS1** Liberation road, Near Obuasi Road	**MS2** Sekondi Road, Near Goil Station	**MS3** Sekondi By-Pass, Near Tanokrom	**MS4** Agona Nkwanta Road, West of PTC	**MS5** Kansaworado /Apramdo By-pass, Near St Francis School Junction	**MS6** Axim Road, Near Air Force Base	**MS1** Liberation road, Near Obuasi Road
12 hrs to 24hrs	1.25	1.33	1.46	1.36	1.32	1.28	1.33
AM Peak-Hour to 24hrs	13.51	14.99	16.56	13.04	11.65	12.92	13.78
PM Peak-Hour to 24hrs	11.76	14.88	16.03	14.13	14.13	12.71	13.94
Typical 1-hr: AM Flows (10:00-11:00) to 24 hr flows	14.30	15.27	16.56	17.75	16.19	16.56	16.10
Typical 1-hr: PM Flows (04:00-05:00) to 24 hour flows	11.76	15.10	16.42	14.39	15.14	13.90	14.45

4.1.3 Hourly Traffic Distribution

The Excel output in Table 4.3 and Figure 4.1 shows the hourly distribution of traffic during the 24 hour count at the Master Stations in Sekondi-Takoradi.

Figure 4.2 shows the cumulative hourly distribution of traffic

HOUR OF DAY	MS1		MS2		MS3		MS4		MS5		MS6	
	% TOTAL	% CUM	% TOTAL	% CUM	% TOTAL	% CUM	% TOTAL	% CUM	% TOTAL	% CUM	% TOTAL	% CUM
6:00-7:00	2.35	2.35	4.05	4.05	4.69	4.69	4.33	4.33	4.39	4.39	3.9	3.9
7:00-8:00	5.35	7.7	6.67	10.72	5.57	10.26	7.67	12	8.58	12.97	6.52	10.42
8:00-9:00	6.84	14.54	6.45	17.17	5.93	16.19	7.3	19.3	7.41	20.38	7.74	18.16
9:00-10:00	7.4	21.94	6.53	23.7	5.89	22.08	6.13	25.43	6.71	27.09	6.37	24.53
10:00-11:00	6.99	28.93	6.55	30.25	6.04	28.12	5.63	31.06	6.18	33.27	6.04	30.57
11:00-12:00	6.76	35.69	6.2	36.45	5.49	33.61	5.2	36.26	5.27	38.54	6.2	36.77
12:00-13:00	7.14	42.83	6.08	42.53	5.18	38.79	5.33	41.59	5.59	44.13	6.06	42.83
13:00-14:00	6.39	49.22	6.3	48.83	5.08	43.87	5.38	46.97	5.41	49.54	6.41	49.24
14:00-15:00	7.41	56.63	6.48	55.31	6.04	49.91	5.82	52.79	5.96	55.5	6.64	55.88
15:00-16:00	7.86	64.49	6.38	61.69	6.16	56.07	6.8	59.59	7.08	62.58	7.12	63
16:00-17:00	8.5	72.99	6.62	68.31	6.09	62.16	6.95	66.54	6.6	69.18	7.19	70.19
17:00-18:00	6.91	79.9	6.72	75.03	6.24	68.4	7.08	73.62	6.84	76.02	7.87	78.06
18:00-19:00	5.53	85.43	6.66	81.69	5.94	74.34	7.08	80.7	6.72	82.74	6.25	84.31
19:00-20:00	4.09	89.52	5.42	87.11	5.44	79.78	5.22	85.92	5.33	88.07	4.16	88.47
20:00-21:00	3.03	92.55	3.9	91.01	4.71	84.49	3.99	89.91	3.72	91.79	2.91	91.38
21:00-22:00	2.14	94.69	2.61	93.62	3.47	87.96	2.43	92.34	2.6	94.39	2.01	93.39
22:00-23:00	1.34	96.03	1.68	95.3	2.71	90.67	1.59	93.93	1.6	95.99	1.43	94.82
23:00-24:00	0.9	96.93	0.94	96.24	1.67	92.34	0.95	94.88	0.77	96.76	0.88	95.7
0:00-1:00	0.5	97.43	0.55	96.79	1.07	93.41	0.57	95.45	0.43	97.19	0.62	96.32
1:00-2:00	0.35	97.78	0.31	97.1	1	94.41	0.37	95.82	0.2	97.39	0.41	96.73
2:00-3:00	0.26	98.04	0.25	97.35	0.77	95.18	0.28	96.1	0.18	97.57	0.43	97.16
3:00-4:00	0.31	98.35	0.31	97.66	1	96.18	0.35	96.45	0.24	97.81	0.48	97.64
4:00-5:00	0.6	98.95	0.65	98.31	1.53	97.71	0.95	97.4	0.6	98.41	0.78	98.42
5:00-6:00	1.05	100	1.68	100	2.32	100	2.57	100	1.6	100	1.57	100
TOTAL NO. OF VEHICLES	9862		26327		26332		27487		8563		20880	

Table 4.3: **Percentage Hourly Distribution of Traffic in Sekondi-Takoradi**

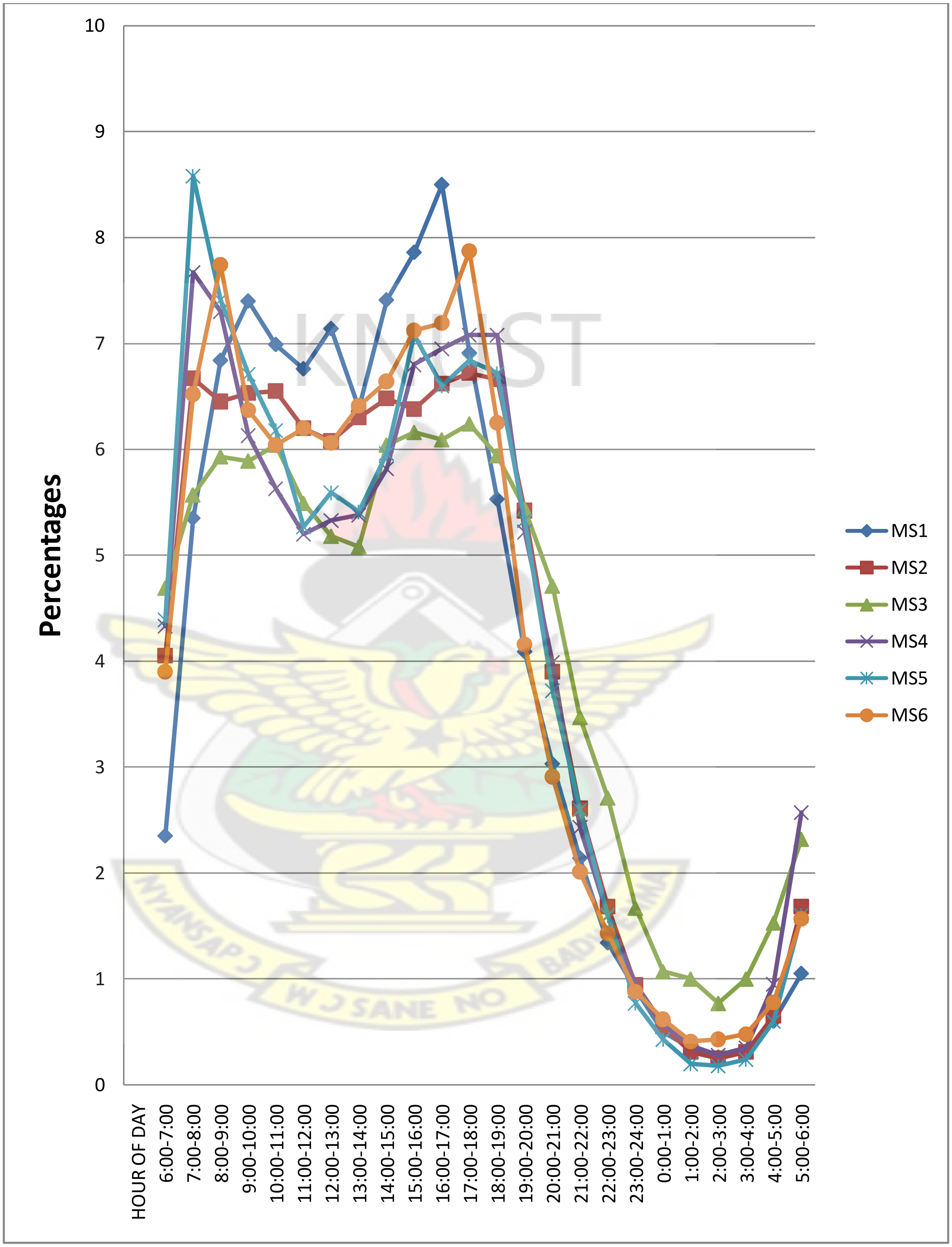

Figure 4.1: Percentage hourly Distribution of Traffic in Sekondi-Takoradi

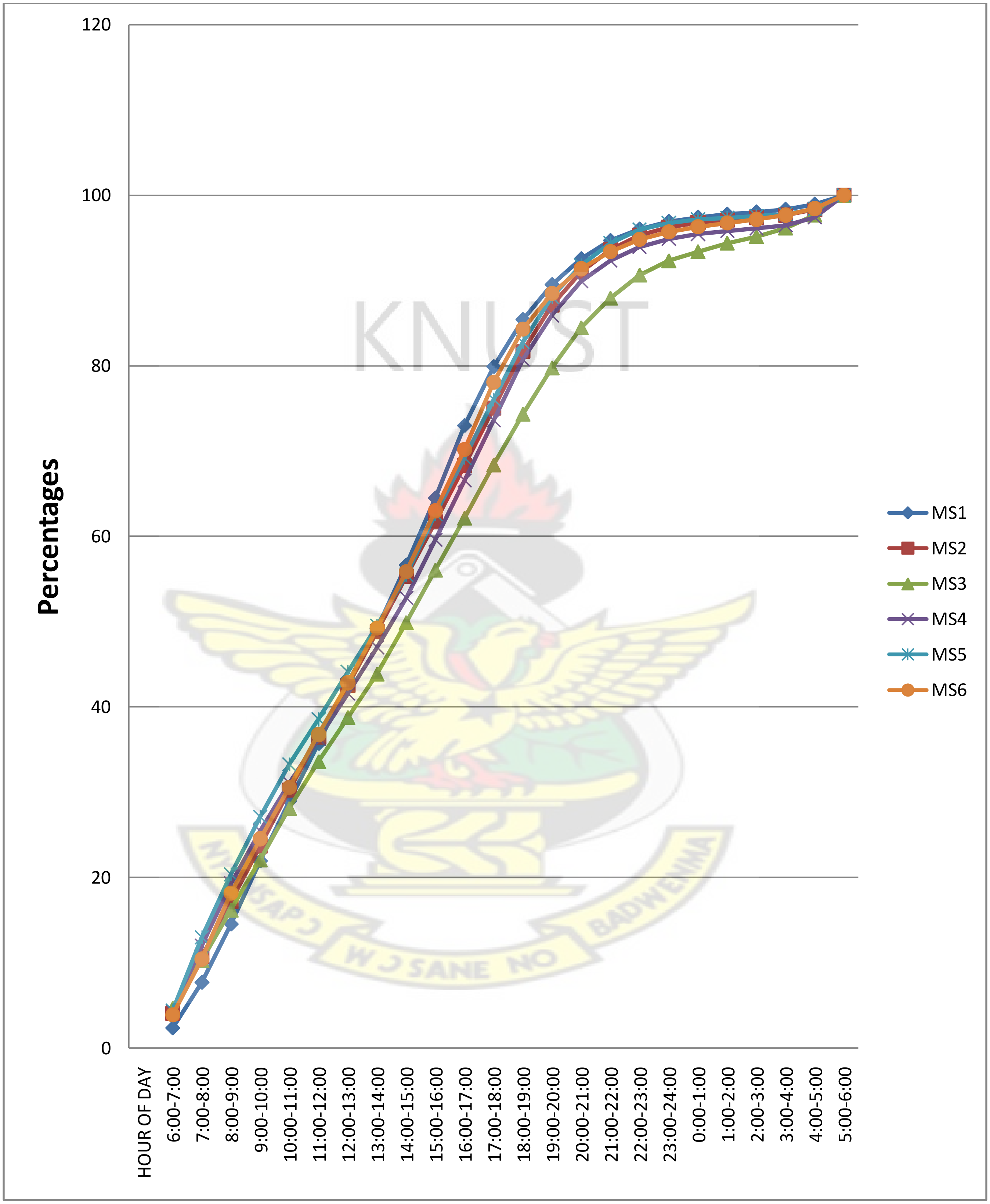

Figure 4.2: Cummulative Percentage Hourly Distribution of Traffic in Sekondi-Takoradi

4.1.4 Traffic Composition

Table 4.4 shows the summary results of the traffic composition at the six number Master Stations in Sekondi-Takoradi. As shown from the traffic data obtained, taxis recorded the highest percentage of traffic followed by private cars at all the Master Stations.

MS1 (Liberation Road, Near Obuasi Road) registered the highest percentage of taxis which was 58.55% of the total traffic, followed by MS2 with 46.04%, MS4 recording 44.11%, MS5 (42.07%), MS3 (38.17%) and MS6 (31.81%) respectively.

The traffic compositions by vehicle type are also shown in Table 4.4. The traffic composition by vehicle type is also shown in Figure 4.3 whereas Figure 4.4 shows percentage composition of vehicles by Master Stations.

Table 4.4: Percentage Composition of Traffic at Master Stations in Sekondi-Takoradi

Station	Bicycles	Motor Bikes	Taxis	Cars	Pickup /Van /4WD Vehicles	Small Bus	Medium Bus/ Mammy Wagons	Large Bus	Light Truck	Medium Truck	Heavy Truck	Truck Trailer	Extra Large Truck And Others
MS1	5.26	3.11	58.55	19.77	9.98	2.02	0.20	0.10	0.53	0.34	0.02	0.01	0.11
MS2	2.30	2.48	46.04	19.36	10.49	14.49	1.15	0.50	1.34	0.55	0.23	1.06	0.01
MS3	5.55	3.46	38.17	12.46	5.94	27.44	2.91	0.79	1.48	0.58	0.46	0.58	0.18
MS4	4.50	2.24	44.11	17.31	10.10	15.90	1.23	0.51	1.74	0.56	0.64	1.14	0.02
MS5	6.42	3.10	42.07	20.63	12.76	5.08	1.49	0.30	4.98	0.85	0.83	1.41	0.07
MS6	6.33	3.64	31.81	22.31	17.99	9.11	1.73	1.73	1.92	0.80	0.75	1.79	0.08

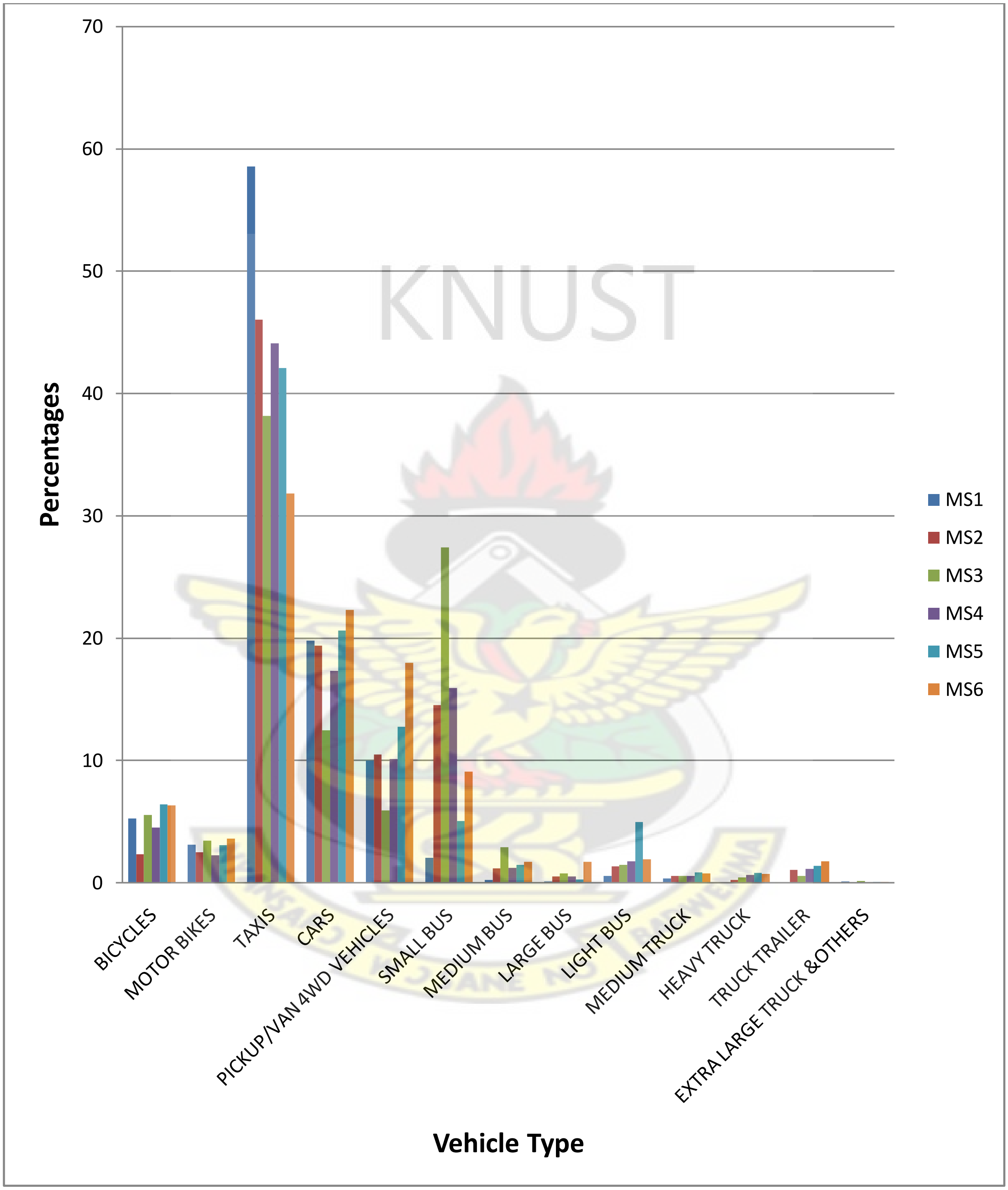

Figure 4.3: Percentage Composition of Traffic by Vehicle type at the Master Stations in Sekondi-Takoradi

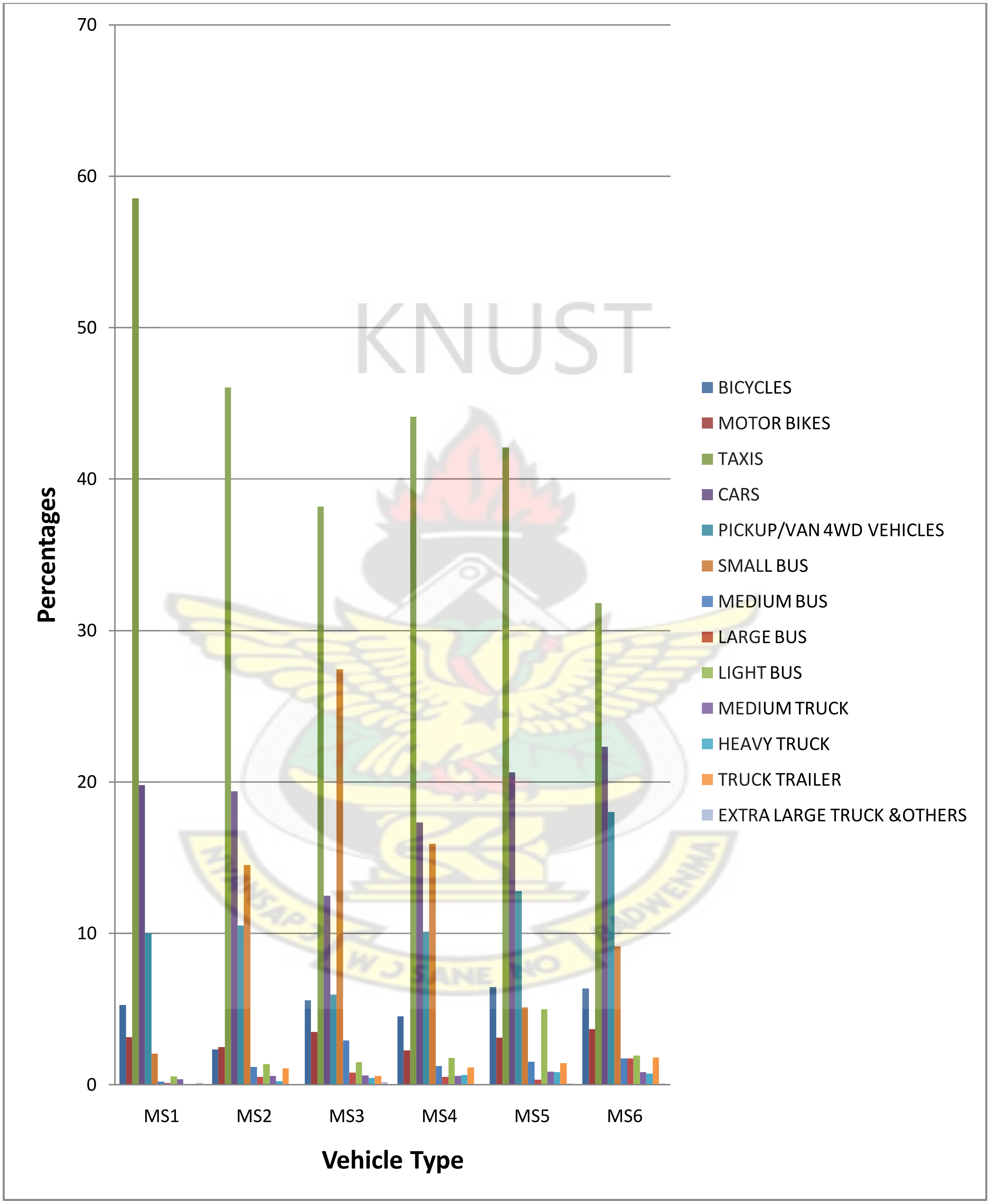

Figure 4.4: Percentage Composition of Vehicles by Master Stations (Both Directions)

4.1.5 Traffic Growth Rates at Master Stations

Traffic growth rates were determined by comparing traffic data collected at the same location (stations) both in the past year (2003) and in the present year (2008). The formular used in the computation of the traffic growth rates from the previous data obtained from DUR Sekondi-Takoradi is discussed below

$P_F = P_P(1+r)^n$

Where P_F= Traffic in the year n (i.e. the current year of 2008)

P_P= Traffic in the past year (i.e. the past year of 2003)

r = Rate of growth in decimals

n= Number of years between the previous and present traffic data

From above then it implies that

$$r = \left[\frac{P_F}{P_P}\right]^{1/n} - 1$$

Since the previous traffic data obtained for the study routes, was collected in the year 2003, the n value used in the computation of the traffic growth rate between the year 2003 and 2008 is 5. The Excel output in Table 4.5 provides a comparison of the traffic volumes and their corresponding traffic growth rates recorded at the Master Stations in Sekondi-Takoradi Between the years 2003 and 2008.

Table 4.5: Traffic Growth Rates at Master Stations in Sekondi-Takoradi

Location	Adjusted 24-Hour Volume		% Increase	% Annual Growth Rate
	Traffic Data in the year 2003	Traffic data in the year 2008		
MS1	-	9862	-	-
MS2	28504	26327	-7.64	-1.57
MS3	23757	26332	10.84	2.08
MS4	-	27487	-	-
MS5	-	8562	-	-
MS6	17150	20880	21.27	4.01

Two of the Master Stations (MS3 and MS6) experienced positive traffic growth and MS2 experienced negative growth while information for comparison of the other Master Stations (MS1), MS4 and MS5) was unavailable. The highest growth rate was r=4.01% occurring at MS6 on the Axim Road, near Air force Base, followed by r=2.08% at MS3 on the sekondi By-pass Road, near Tanokrom. A negative growth rate of r= -1.57% occurred at the MS2 on the Sekondi Road, near Goil station. From the three Master stations, the traffic growth rate for Sekondi-Takoradi generally experienced a positive growth rate of r=1.51%

4.2 Screenline Classification Count

According to DUR Sekondi-Takoradi, Screenline count were undertaken at 43 stations in Sekondi-Takoradi. The traffic data obtained from the screenline counts was analysed to determine the AM and PM peak hours. The summary results of the traffic volumes at the screen line stations for the AM and PM peak hours have been presented in Table 4.6.

The percentage traffic composition of the peak hours have also been presented in Figures A1-A43 of Appendix A.

Table 4.6: Summary Results of Screenline Traffic Volumes in Sekondi-Takoradi

Station No.	Location Description	AM Traffic Volumes		PM Traffic Volume	
		Peak Hour	Total 3hr AM Peak Period	Peak hour	Total 3hr PM Peak Period
S1	John Sarbah Road	594	1360	524	1306
S2	Kitson	707	1421	678	1430
S3	Ashanti Road	369	801	393	962
S4	John Sarbah	650	1136	979	2173
S5	Liberation Road	956	2592	1011	2659
S6	Hayford Road	1144	2733	784	1816
S7	Wiaso Road	264	452	294	777
S8	John Sarbah Road	1660	3212	1292	3822
S9	Agona Nkwanta Road	1831	4484	1702	4377
S10	Agona Nkwanta Road	1976	5207	2802	6567
S11	Agona Nkwanta Road	934	1970	940	2780
S12	Sekondi By-Pass	991	2283	1088	3193
S13	Cape Coast Road	886	1709	947	2680
S14	Liberation Road	1714	4757	1710	4277
S15	Axim Road	445	1064	544	1545
S16	Cape Coast Road	880	2023	764	1949
S17	Sekondi Road	1710	4213	1265	3653
S18	New Takoradi Road	564	1355	391	1080
S19	Accra Road	318	716	336	893
S20	John Sarbah Road	1724	3440	1277	3715
S21	Liberation Road	931	2388	1003	2619
S22	Electricity Road	695	1914	629	1565
S23	Harbour Road	307	812	287	793
S24	Electricity Road	499	972	476	1207
S25	Harbour Road	367	1081	409	881
S26	Axim Road	1350	3048	1569	4089
S27	Accra Road	492	1159	483	1300
S28	African Road	601	1196	477	1117
S29	African Beach Hotel Road	154	316	171	468
S30	Discove Hill Road	296	701	324	818
S31	Sekondi By-Pass	973	2423	797	1766
S32	Sekondi By-Pass	1465	4048	1424	3378
S33	Sekondi By-Pass	763	2051	756	2135

Table 4.6(continued) Summary Results of Screenline Traffic Volumes in Sekondi-Takoradi

Station No.	Location Description	AM Traffic Volumes		PM Traffic Volume	
		Peak Hour	Total 3hr AM Peak Period	Peak hour	Total 3hr PM Peak Period
S34	Ketan Road	431	1010	266	726
S35	Inchaban Road	869	2338	873	2292
S36	Poasi Road	529	1463	515	1507
S37	Fijai	686	1643	496	1387
S38	Effia Road/CDH Road	563	1172	308	761
S39	Takoradi Poly Road	942	2384	822	2228
S40	East Tanakrom Road	671	1585	536	1321
S41	Kansaworada Apremdo By-Pass	590	1228	408	1156
S42	Anaji Estate Road	723	1657	569	1505
S43	Tanokrom Road	1075	2594	1195	3417

From Table 4.6, S10 on the Agona Nkwanta Road recorded the highest peak hour traffic during the AM and PM period with peak volume of 19760vehs/hr and 2802 vehs/hr respectively, followed by S9 which recorded 1831 vehs/hr on the Agona Nkwanta Road during the AM peak period and S14 (Liberation Road) with 1710 vehs/hr

4.3 Turning Movement Counts

According to DUR Sekondi-Takoradi, Turning Movement Counts were undertaken at 45 number designated intersections. The traffic data obtained from the Turning Movement Counts was analysed for the assessment of the junction capacity and traffic safety. The summary results of the Turning Movement Counts at intersections during the peak hours (i.e. 6:00AM-9:00AM and 4:00PM-7:00PM) have been presented in Table 4.7

From the calculation of peak hour flows, it was realized that the intersection with the largest peak hour volume in Sekondi-Takoradi was 4533 veh/hr and this occurred at the Sekondi

Road/Takoradi Poly Road intersection (T27) in the morning, followed by 4181 veh/hr in the evening which occurred at Sekondi By-Pass/Ntankoful Road Junction (T36).

The AM and PM Peak hour volumes obtained at all the junctions studied are shown in Table 4.7.

Table 4.7: Summary Results of Total Approach Volumes at Intersection During Peak Hours in Sekondi-Takoradi

Station No.	Location Description	AM Peak-Hour Volumes	PM Peak-Hour Volumes
T1	Agona Nkwanta Road/ Kasanworado Apremdo By-Pass	2008	1508
T2	Agona Nkwanta Road/ Kwesimintsim Road	3492	3213
T3	Agona Nkwanta Road/ Airport Ridge Road	3298	2663
T4	Axim Road/ John Sarbah Road	3996	3898
T5	Liberation Road/ Hayford Road	2793	2535
T6	Collins Avenue/ Summer Road	1204	1191
T7	Summer Road/ Kitson Road	1027	855
T8	Collins Avenue/ Ahanta Road		
T9	Ahanta Road/ Liberation Road	1262	741
T10	Kitson Avenue/ Ahanta Road	735	1061
T11	Kitson Avenue/ Mampong Road	1789	2408
T12	Mampong Road/ Liberation Road	1234	1623
T13	Mampong Road/ Collins Avenue	672	905
T14	Collins Avenue/ Ashanti Road	1422	2038
T15	John Sarbah Road/ Collins Avenue	2074	2397
T16	Kumasi Road/ Kitson Avenue	703	1096
T17	Kumasi Road/ Collins Avenue	745	677
T18	Accra Road/ Liberation Road	4340	3923
T19	John Sarbah Road/ Market Circle North	1131	2283
T20	Liberation Road / Market Circle	839	1105
T21	Market Circle/ Ashanti Road	944	941
T22	John Sarbah Road/ Market Circle South	1273	875
T23	Liberation Road/ Market Circle Junction West	1195	1003

Table 4.7 (cont'd): Summary Results of Total Approach Volumes at Intersection During Peak Hours in Sekondi-Takoradi Metropolis

Station No.	Location Description	AM Peak-Hour Volumes	PM Peak-Hour Volumes
T24	Old Ashanti Road/ Market Circle North	1207	959
T25	African Beach Hotel Road/ Atlantic Hotel Road	1929	1047
T26	Atlantic Hotel Road Roundabout	863	880
T27	Sekondi Road/ Takoradi Poly Road	4533	2360
T28	Sekondi Road/ Adiembra Road/ Poasi Road	1421	2974
T29	Adiembra Road/ Fijai Road	3492	1262
T30	Poasi Road/ Lagoon Road	695	630
T31	Boundary Road Junction	2426	2099
T32	Sekondi By-Pass/ Fijai Junction	1332	1418
T33	Adiembra Road/ Ketan Road	1100	1138
T34	Sekondi By-Pass/ Ketan Road	1389	1900
T35	Kasanwurodo By-Pass/ Sekondi By-Pass	1533	1366
T36	Sekondi By-Pass/ Ntankoful Road	3616	4181
T37	Sekondi By-Pass/ Effiakuma Road	1728	1824
T38	Sekondi By-Pass/ Tanokrom Road	2978	4303
T39	West Tanokrom Road off Tadisco Road	1639	1577
T40	Anaji/ Sekondi By-Pass Road	1595	2025
T41	Kasanwurodo Apremdu By-Pass/ Namibia Road	2580	2411
T42	Kasanwurodo Apremdu By-Pass/ Westline Road	1443	942
T43	Kasanwurodo Apremdu By-Pass/ Assakae Road	1176	937
T44	Kumasi Road/ Liberation Road	1059	1262
T45	Kitson Road/ John Sarbah Road	1799	2001

4.4 Link Volume Count

Traffic volumes were obtained for 20 links in the period of peak flows (6:00AM-9:00AM and 4:00PM-7:00PM) and compared with the actual capacity of those links. Table 4.8 represents the hourly average traffic volume expressed as PCU/h and the volume/capacity ratio at different links. The highest traffic volume was found in Kwesimetim to Ajep link (6567 PCU/h) whereas the lowest one was observed at New site to Number nine link (1306 PCU/h). However, the highest volume/capacity ratio was observed as 5.47 in Kwesimetim to Ajep link where as the lowest one was observed as 1.09 in New site to Number nine link. At all the links, motorized vehicles were dominant. It is evident that at all the stations where counting was done, the major portion of vehicles was Taxis.

Table 4.8: Comparison of Actual Volume to the Link Capacity

LINK NAME	ACTUAL VOLUME(PCU/H)	CAPACITY (PCU/H)	VOLUME/ CAPACITY RATIO
PAA GRANT → MARKET CIRCLE	3822	1200	3.19
AJEP →MARKET CIRCLE	2659	1200	2.22
AXIM ROAD → MARKET CIRCLE	3715	1200	3.1
HARBOUR ROAD → MARKET CIRCLE	4277	1200	3.57
NEW TAKORADI→PAA GRANT	1430	1200	1.2
HARBOUR ROAD→PAA GRANT	1565	1200	1.3
T-POLY JUNCTION→PAA GRANT	5327	1200	4.44
AJEP→PAA GRANT	2680	1200	2.23
ANAJI→NUMBER NINE	3089	1200	2.57
FIJAI→NUMBER NINE	4059	1200	3.38
TANOKROM→NUMBER NINE	3193	1200	2.66
NEW SITE→NUMBER NINE	1306	1200	1.09
T-POLY→TANOKROM	3228	1200	2.69
ANAJI→TANOKROM	3378	1200	2.82
AJEP→TANOKROM	3639	1200	3.03
KWASIMETIM→AJEP	6567	1200	5.47
AXIM ROAD→AJEP	4089	1200	3.41
EFFIA-NKWANTA→T-POLY JUNCTION	3653	1200	3.04
SEKONDI→EFFIA-NKWANTA	4377	1200	3.65
FIJAI→EFFIA-NKWANTA	1816	1200	1.5

4.5 Average Traffic Volume Count per Zone in the Period of Peak Flows

From Table 4.9 and Figure 4.48, the Zone with the highest traffic volume count during the morning (AM) peak hours was recorded at Zone 5 followed by Zone 1, Zone 4, Zone 2 and Zone 3 respectively. Zone 5 still recorded the highest in the evening (PM) peak hours followed by Zone 4, Zone 1, Zone 2 and Zone 3 respectively.

Table 4.9: Summary results of Average Traffic Volume per Zone

Name of Zone	Zone Description	Average AM Peak Hour Volume	Average PM Peak Hour Volume
Zone 1	Areas in and around Takoradi Market Circle	2267	2180
Zone 2	Paa Grant roundabout and T-Poly Junction	1919	1705
Zone 3	Effiakuma traffic light	1414	1346
Zone 4	Tanokrom traffic light	2089	2369
Zone 5	Kwame Nkrumah circle	3138	3985

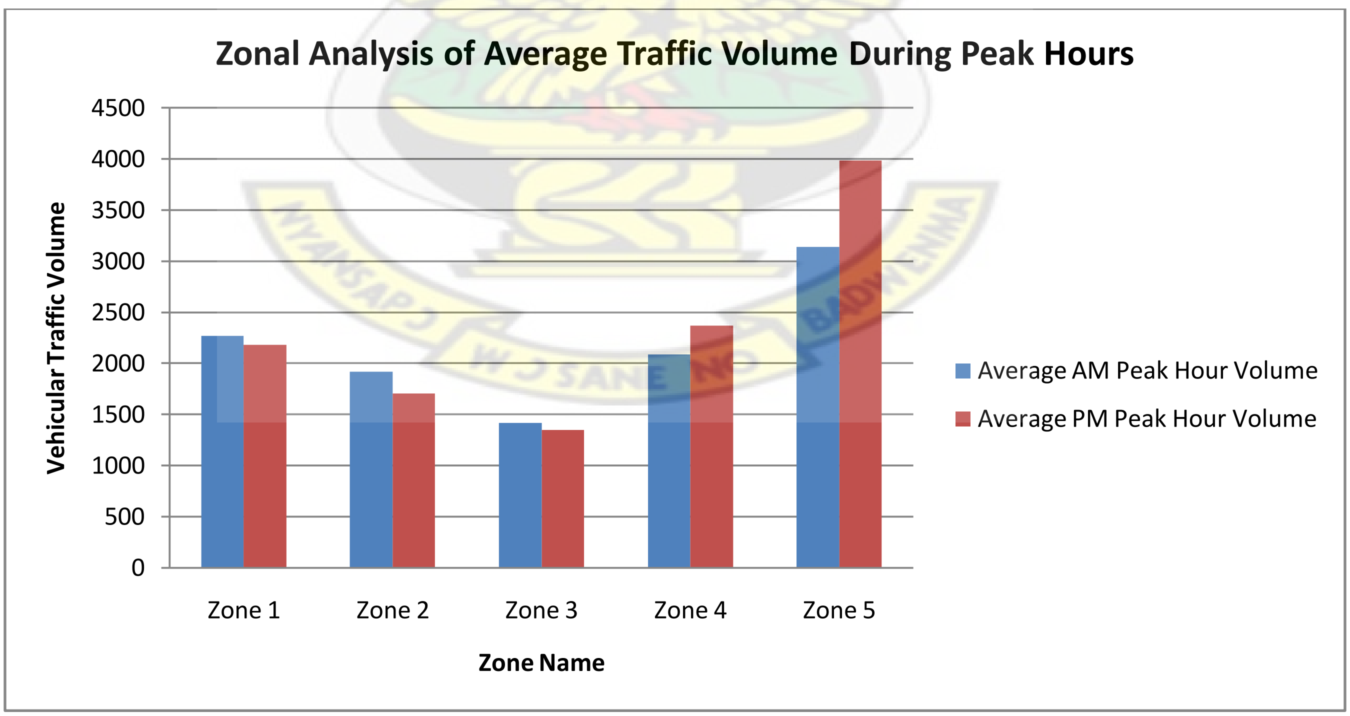

Figure 4.5: Average Traffic Volume per Zone During Peak Hours

4.6 Roadway Congestion Index (RCI)

The Roadway Congestion Index (RCI) was found to be 3.18 for the selected road network using Excel shown in Table 4.10. An RCI of 3.18 according to Table 3.1 indicates the severity of the traffic congestion situation within the Metropolis. A Roadway Congestion Index (RCI) of 3.18 indicates that the extra vehicle kilometer travel due to congestion in peak hours is about 218%. The RCI stands as the network weighted average volume capacity ratio and is calculated as

$$\text{RCI} = \frac{\sum \frac{(Vehicle\ per\ Peak\ Hour)}{(Link\ Capacity)} * (Vehicle\ per\ Peak\ Hour * Link\ Length)}{\sum (Vehicle\ per\ Peak\ Hour * Link\ Length)}$$

Table 4.10: Calculation of RCI

COL 1	COL 2	COL 3	COL 4	COL 5	COL 6	COL 7	COL 8
LINK NAME	ACTUAL VOL.(PCU/H)	CAPACITY (PCU/H)	LINK LENGTH(KM)	COL 2*COL 4	COL 2/COL 3	COL 5*COL 6	RCI= $\sum COL7 / \sum COL5$
PAA GRANT → MARKET CIRCLE	3822	1200	0.55	2102.1	3.19	6695.19	
AJEP →MARKET CIRCLE	2659	1200	0.7	1861.3	2.22	4124.33	
AXIM ROAD → MARKET CIRCLE	3715	1200	0.43	1597.45	3.1	4945.44	
HARBOUR ROAD → MKT.CIRCLE	4277	1200	0.8	3421.6	3.56	12195.15	
NEW TAKORADI→PAA GRANT	1430	1200	0.65	929.5	1.19	1107.65	
HARBOUR ROAD→PAA GRANT	1565	1200	0.48	751.2	1.3	979.69	
T-POLY JUNCTION→PAA GRANT	5327	1200	0.25	1331.75	4.44	5911.86	
AJEP→PAA GRANT	2680	1200	1.31	3510.8	2.23	7840.79	
ANAJI→NUMBER NINE	3089	1200	0.4	1235.6	2.57	3180.64	3.18
FIJAI→NUMBER NINE	4059	1200	1	4059	3.38	13729.57	
TANOKROM→NUMBER NINE	3193	1200	0.38	1213.34	2.66	3228.5	
NEW SITE→NUMBER NINE	1306	1200	0.3	391.8	1.09	426.41	
T-POLY→TANOKROM	3228	1200	0.6	1936.8	2.69	5209.99	
ANAJI→TANOKROM	3378	1200	0.46	1553.88	2.82	4374.17	
AJEP→TANOKROM	3639	1200	0.23	836.97	3.03	2538.11	
KWASIMETIM→AJEP	6567	1200	0.57	3743.19	5.47	20484.61	
AXIM ROAD→AJEP	4089	1200	0.42	1717.38	3.41	5851.97	
EFFIA-NKWANTA→T-POLY JUNCTION	3653	1200	0.35	1278.55	3.04	3892.12	
SEKONDI→EFFIA-NKWANTA	4377	1200	0.64	2801.28	3.65	10217.67	
FIJAI→EFFIA-NKWANTA	1816	1200	0.57	1035.12	1.51	1566.48	
TOTAL				37308.61		118500.34	

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.0 CONCLUSIONS

Sekondi-Takoradi, a rapid growing Metropolis with non-controllable migration from peripheral outskirt in view to change the economic fortune due to the recent crude oil find aggravates the urban facilities of the inhabitants in limited infrastructures including narrow roads and streets of pre-urban and initial urban age. Increase of population creates tremendous traffic pressure on old narrow congested roads to provide excess transport facilities in the Metropolis. The following findings and observations were made during the study;

(i) The most heavily trafficked Master Station in Sekondi-Takoradi was MS4, located on the Agona Nkwanta road west of PTC R/A. It recorded a 12-hour weekday traffic of 20236 vehs/ day and 24-hour traffic of 27847 vehs/ day.

(ii) The highest peak hour traffic volumes of 2108 vehs/ hr and 1946 vehs/ hr was registered at MS4 during the AM and PM peak periods respectively. These peak hour volumes constituted 7.67% and 7.08% of the traffic during the AM and PM periods respectively.

(iii) Generally, the traffic variation factors for the Master Stations in Sekondi-Takoradi Metropolis did not differ very much from each other. Also the traffic patterns were similar in nature.

(iv) Taxis were the modal class of vehicles types in Sekondi-Takoradi, followed by Private cars, small vehicles and medium vehicles. Taxis were also the most popular modes of travel with a percentage composition ranging from 58.55% and 31.81% at the Master stations.

(v) Generally, the total hourly distribution of traffic at the Master Stations in Sekondi-

Takoradi increases rapidly from 6:00AM to 8:00AM. It then gradually increases to 18:00PM and then begins to decrease gradually till 4:00AM after which it increases again to 6:00AM. The cycle then begins again.

(vi) The highest growth rate of r= 4.01% occurred at MS6, Axim Road, Near Air-force Base and the lowest rate was r= -1.57% occurred at MS2, Sekondi Road, Near Goil Station.

(vii) At the Screenline stations the highest peak hour traffic volume of 1876 and 2802 veh/ hr, during the AM and PM period, at S10 Agona Nkwanta Road. This station also recorded the highest AM and Pm total volume of 5207 and 6567 veh/ hr respectively.

(viii) The busiest intersection in Sekondi-Takoradi under the study were T27 (Sekondi road and Takoradi Poly Junction, which registered the highest peak volume of 4533 veh/ hr during the AM peak volume and T38 (Sekondi By-pass and Tanokrom road), which registered the highest peak volume of 4303 veh/ hr during the PM volume

(ix) Zone 5 recorded the highest in the Average AM Peak Hour volume followed by Zone 1, Zone 4, Zone 2 and Zone 3. Zone 5 still recorded highest in Average PM Peak Hour volume followed by Zone 4, Zone 1, Zone 2 and Zone 3.

(x) The Roadway Congestion Index (RCI) of 3.18 was found for the selected road network within the Metropolis. A 3.18 RCI indicated the severity of traffic congestion in Sekondi-Takoradi metropolis.

5.1 RECOMMENDATIONS

To face the traffic congestion within the Sekondi-Takoradi Metropolis, authorities need to undertake initiatives through proper study applying engineering science of traffic management aided with computer models. It should utilize the knowledge of traffic engineers and involvement of experts, specialist and concern academicians. It will lead to the short term and long term solution for efficient traffic management in Sekondi-Takoradi. In this regard the following recommendations would be meaningful.

(i) The most vital and significant task to improve the vehicular traffic condition is to widen the roads that can be possible, because all the links are exceeding their capacity as shown by the study

(ii) Traffic management scheme/measures should be undertaken at the Central Business District (CBD) especially at the Takoradi Market Circle and the surrounding roads to improve traffic flow along that corridor

(iii) Intersection improvement designs should be undertaken at almost all vehicular intersections areas most especially the Sekondi By-pass and Tanokrom Road and its corridors to reduce delays and queues. Also, the efficiency of the Paa Grant Roundabout and its approaches in terms of delays, queues and capacity should be studied and analysed and if necessary redesigned to improve traffic flow.

(iv) As some of the roads are getting almost fixed, alternative actions for these roads should be taken. For example, the roads in and around the Takoradi Market Circle are almost in a fixed position and the widening of these roads is virtually impossible given the current trend of events. To develop these roads at the Market Circle, pressure would have to be extended to other sub-roads which are one way to two way to enable expansion works.

(v) A crucial decision have to be made by STMA to decentralize institutional and administrative premises to somewhat distant away from the most congested commercial zone (Market Circle), resulting in significant reduction in congestion.

(vi) STMA can enforce some rules on developing high-rise infrastructure. In that case the high-rise building should obviously provide multistoried parking facilities to help prevent parking on major streets which are already constrained by vehicular capacity.

(vii) Apart from the narrow roads which was observed in the CBD of Sekondi-Takoradi, it would be essential for authorities to remove floating shops, mobile hawkers, artisans and temporary traders from roads and roadsides to help ease traffic congestion.

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APPENDIX A

City: Sekondi-Takoradi	Location: John Sarbah Road	Station:S1

Both Directions

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	AM (Morning)	PM (Evening)
Bicycles	5.05	6.49
Motor Bikes	2.69	2.29
Taxis	62.79	55.34
Cars	16.33	20.99
Pickup/van/4WD vehicles	7.24	8.4
Small Bus	4.21	4.96
Medium Bus/Mammy Wagons	0.00	0.19
Large Bus	0.17	0.00
Light Truck	0.51	0.76
Medium Truck	0.84	0.19
Heavy Truck	0.00	0.38
Truck Trailer	0.17	0.00
Extra Large Trucks and Others	0.00	0.00
Peak Values	**594**	**524**

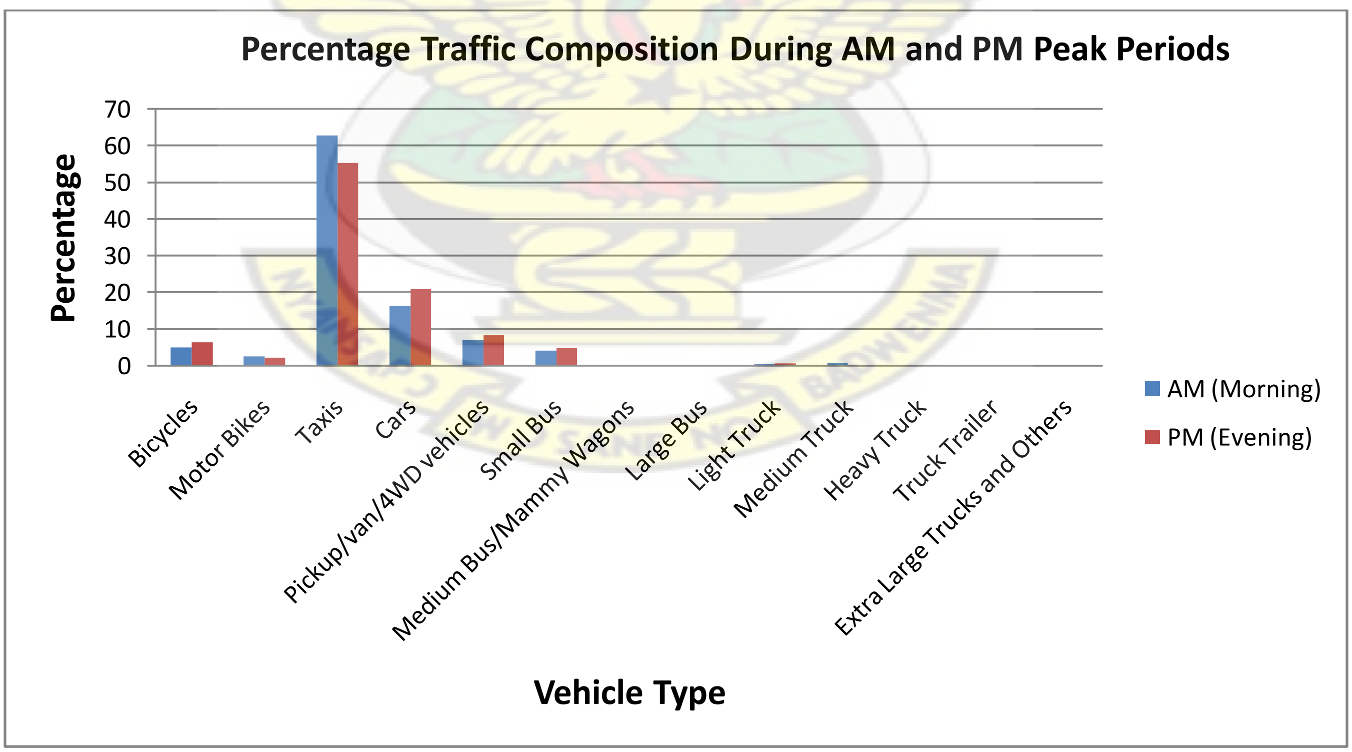

Figure A1: Percentage (%) Traffic Composition During AM and PM Peak Period for S1

City: Sekondi-Takoradi

Location: Kitson Road
Both Directions

Station:S2

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	AM (Morning)	PM (Evening)
Bicycles	6.08	6.93
Motor Bikes	2.83	3.69
Taxis	52.48	47.49
Cars	5.52	7.37
Pickup/van/4WD vehicles	2.83	4.72
Small Bus	28.71	28.61
Medium Bus/Mammy Wagons	1.13	0.59
Large Bus	0	0
Light Truck	0.42	0.29
Medium Truck	0	0.29
Heavy Truck	0	0
Truck Trailer	0	0
Extra Large Trucks and Others	0	0
Peak Values	707	678

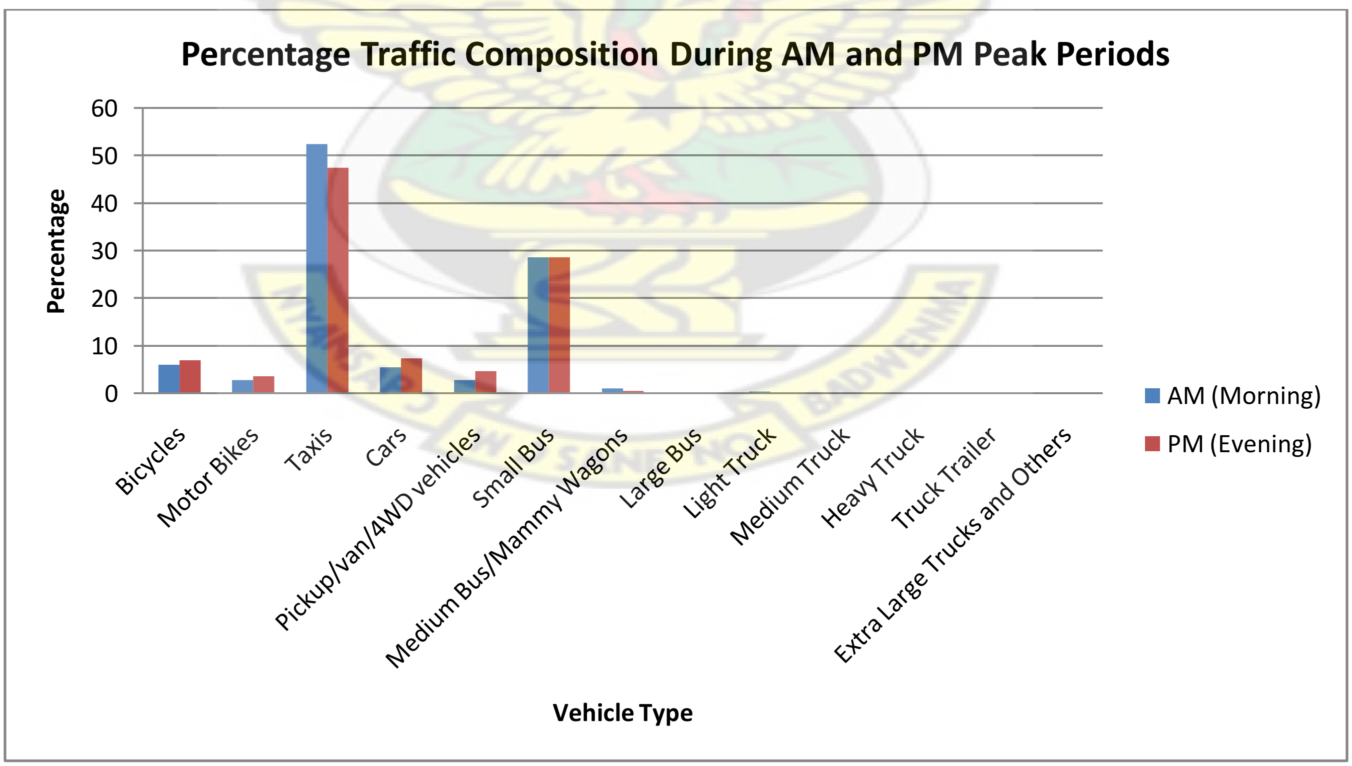

Figure A2: Percentage (%) Traffic Composition During AM and PM Peak Period for S2

City: Sekondi-Takoradi | Location: Ashanti Road Both Directions | Station:S3

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	**AM (Morning)**	**PM (Evening)**
Bicycles	0.81	7.38
Motor Bikes	0.54	3.56
Taxis	69.92	42.49
Cars	17.07	24.94
Pickup/van/4WD vehicles	7.32	14.25
Small Bus	2.17	4.33
Medium Bus/Mammy Wagons	1.08	0.76
Large Bus	0	0.25
Light Truck	1.08	1.53
Medium Truck	0	0.51
Heavy Truck	0	0
Truck Trailer	0	0
Extra Large Trucks and Others	0	0
Peak Values	369	393

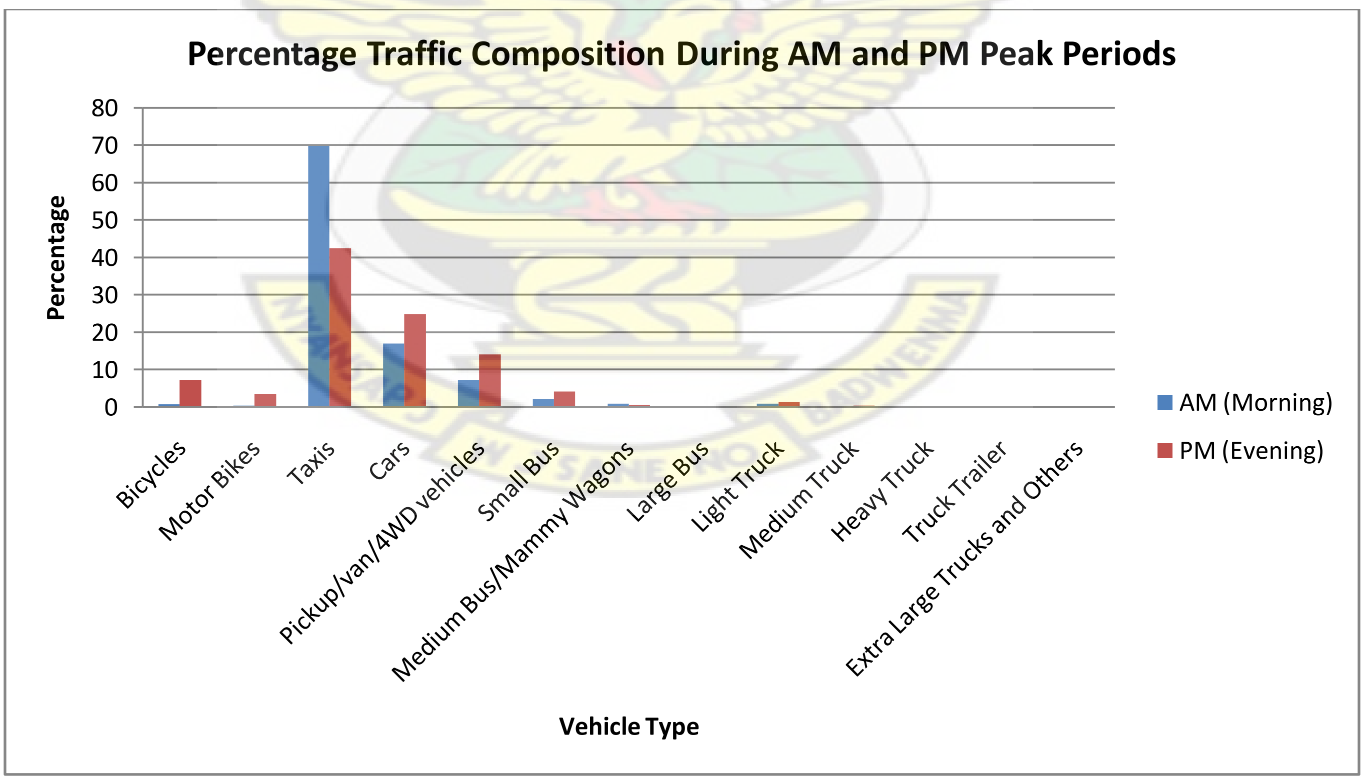

Figure A3: Percentage (%) Traffic Composition During AM and PM Peak Period for S3

City: Sekondi-Takoradi   Location: John Sarbah Road   Station:S4
Both Directions

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	**AM (Morning)**	**PM (Evening)**
Bicycles	8.46	9.09
Motor Bikes	4.46	2.66
Taxis	46.62	44.23
Cars	14.46	22.06
Pickup/van/4WD vehicles	9.38	6.44
Small Bus	8.62	15.02
Medium Bus/Mammy Wagons	5.54	0.31
Large Bus	0.62	0.1
Light Truck	0.31	0.1
Medium Truck	0	0
Heavy Truck	0	0
Truck Trailer	0	0
Extra Large Trucks and Others	1.54	0
Peak Values	650	979

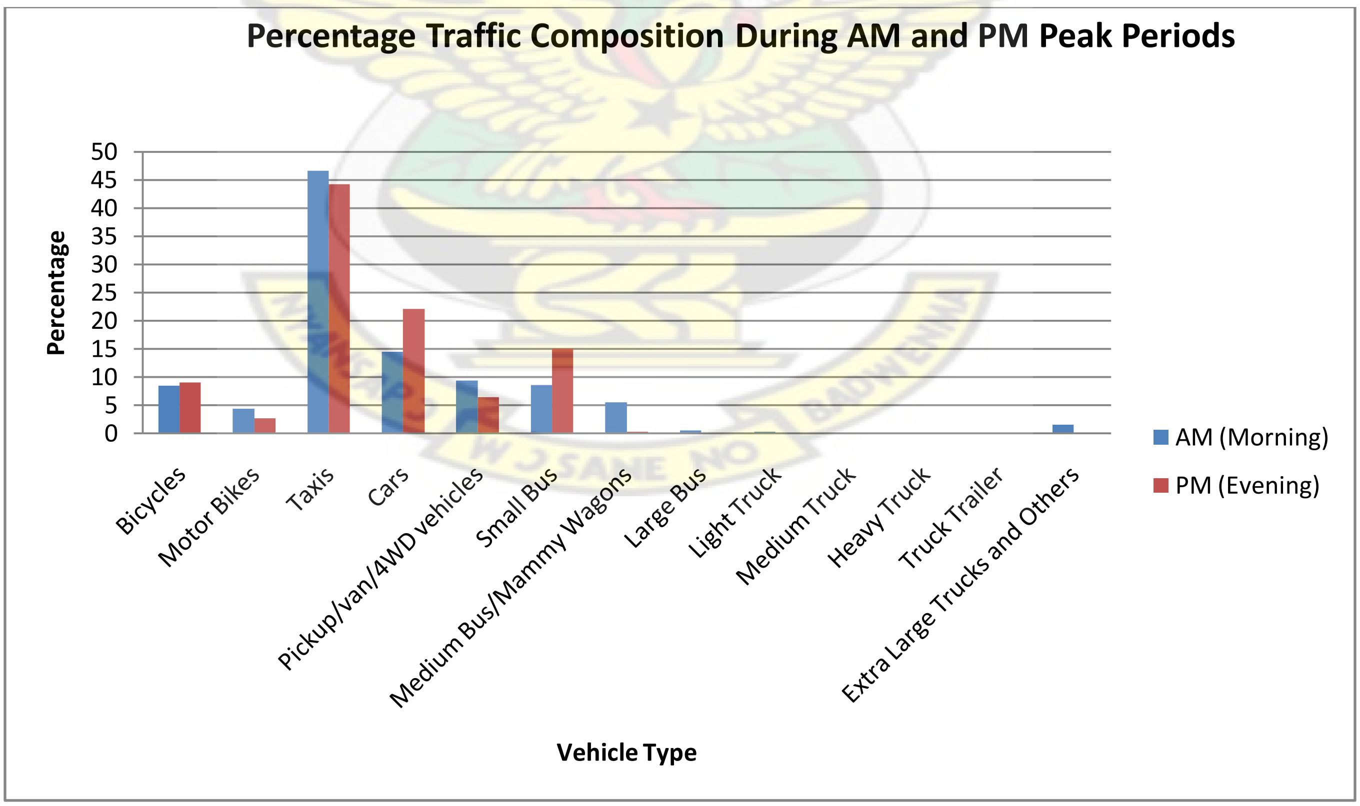

Figure A4: Percentage (%) Traffic Composition During AM and PM Peak Period for S4

City: Sekondi-Takoradi Location: Liberation Road Station:S5

Both Directions

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	AM (Morning)	PM (Evening)
Bicycles	3.87	4.15
Motor Bikes	0.94	0.69
Taxis	64.96	55.69
Cars	3.77	3.36
Pickup/van/4WD vehicles	3.03	3.76
Small Bus	22.8	31.95
Medium Bus/Mammy Wagons	0.1	0.1
Large Bus	0.21	0
Light Truck	0.21	0.3
Medium Truck	0.1	0
Heavy Truck	0	0
Truck Trailer	0	0
Extra Large Trucks and Others	0	0
Peak Values	956	1011

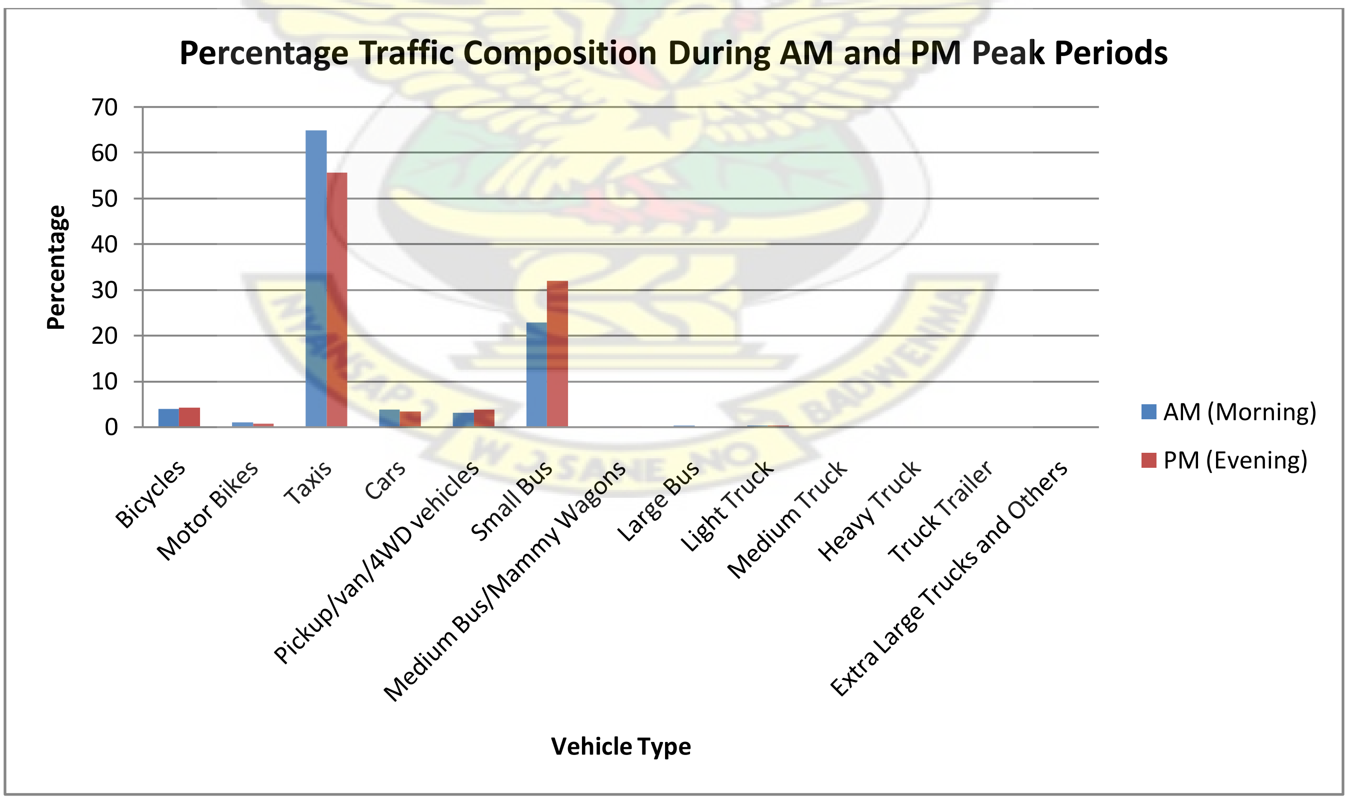

Figure A5: Percentage (%) Traffic Composition During AM and PM Peak Period for S5

City: Sekondi-Takoradi | Location: Hayford Road Both Directions | Station:S6

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	AM (Morning)	PM (Evening)
Bicycles	2.62	5.99
Motor Bikes	2.1	1.79
Taxis	30.51	22.58
Cars	20.37	15.31
Pickup/van/4WD vehicles	6.82	9.95
Small Bus	34.79	38.39
Medium Bus/Mammy Wagons	1.22	2.68
Large Bus	0.44	0.64
Light Truck	0.79	1.4
Medium Truck	0.35	1.02
Heavy Truck	0	0.26
Truck Trailer	0	0
Extra Large Trucks and Others	0	0
Peak Values	1144	784

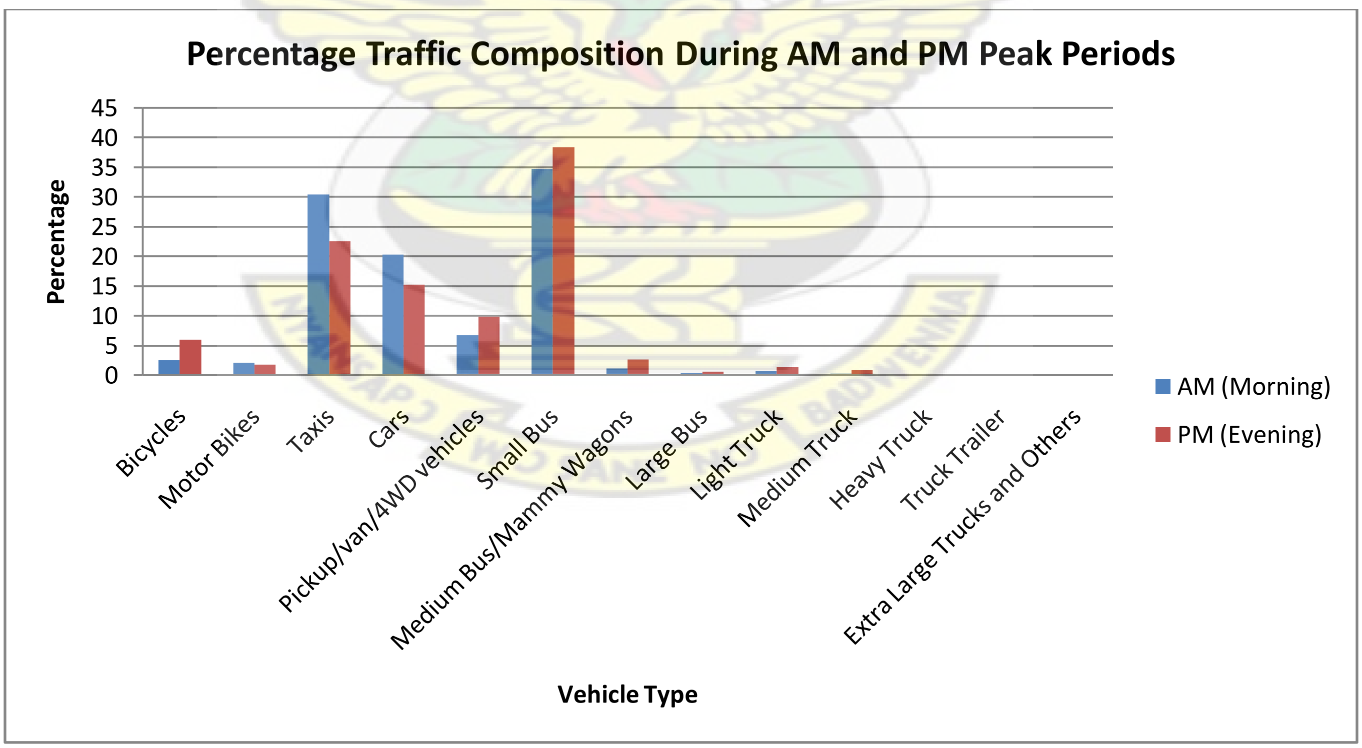

Figure A6: Percentage (%) Traffic Composition During AM and PM Peak Period for S6

City: Sekondi-Takoradi	Location: Wiawso Road Both Directions	Station:S7

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	AM (Morning)	PM (Evening)
Bicycles	17.8	13.95
Motor Bikes	6.44	8.16
Taxis	37.88	36.39
Cars	20.08	25.51
Pickup/van/4WD vehicles	14.02	12.93
Small Bus	1.52	1.36
Medium Bus/Mammy Wagons	0	0
Large Bus	0	0
Light Truck	1.52	1.02
Medium Truck	0.38	0.34
Heavy Truck	0	0.34
Truck Trailer	0.38	0
Extra Large Trucks and Others	0	0
Peak Values	264	294

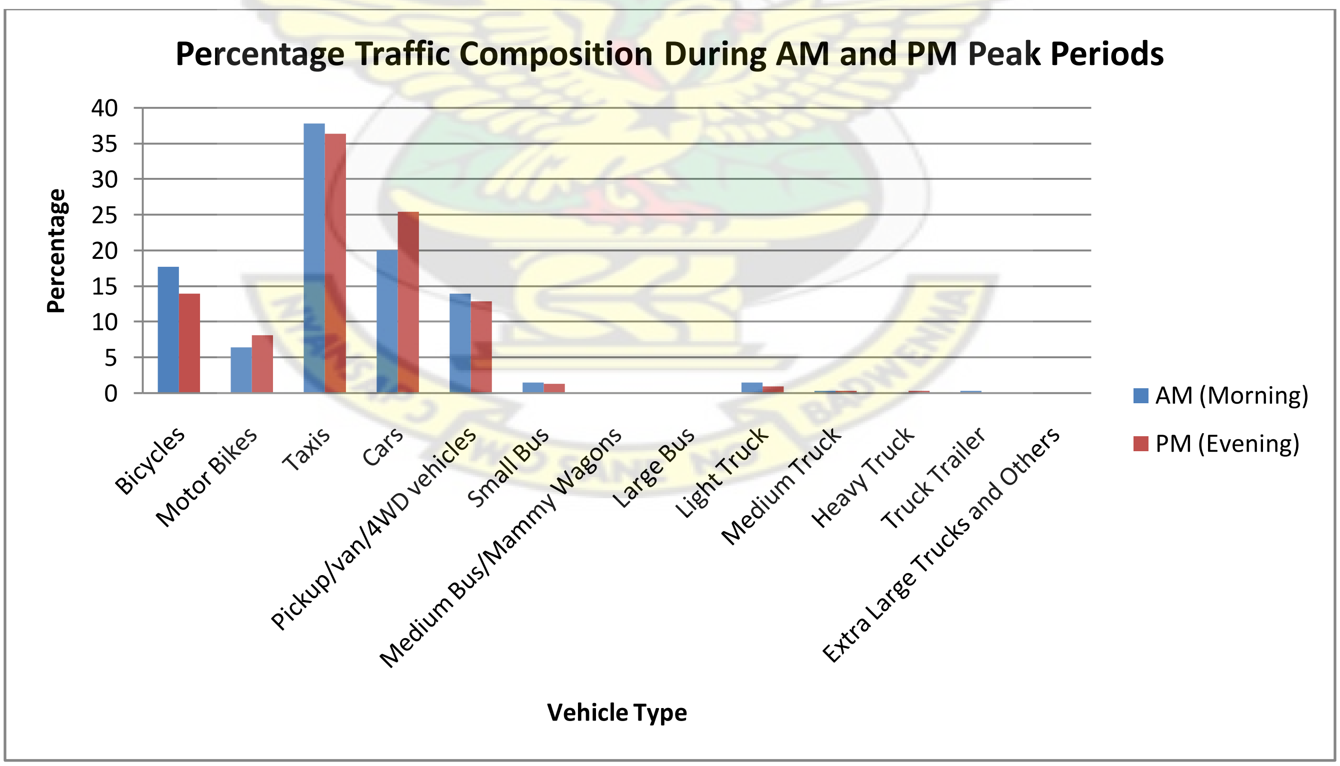

Figure A7: Percentage (%) Traffic Composition During AM and PM Peak Period for S7

City: Sekondi-Takoradi | Location: John Sarbah Road Both Directions | Station:S8

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	AM (Morning)	PM (Evening)
Bicycles	10.3	5.11
Motor Bikes	6.51	3.48
Taxis	37.89	35.29
Cars	15.54	23.92
Pickup/van/4WD vehicles	12.77	13.93
Small Bus	10.48	15.48
Medium Bus/Mammy Wagons	4.82	2.48
Large Bus	1.14	0.31
Light Truck	0.3	0
Medium Truck	0	0
Heavy Truck	0.06	0
Truck Trailer	0	0
Extra Large Trucks and Others	0.18	0
Peak Values	1660	1292

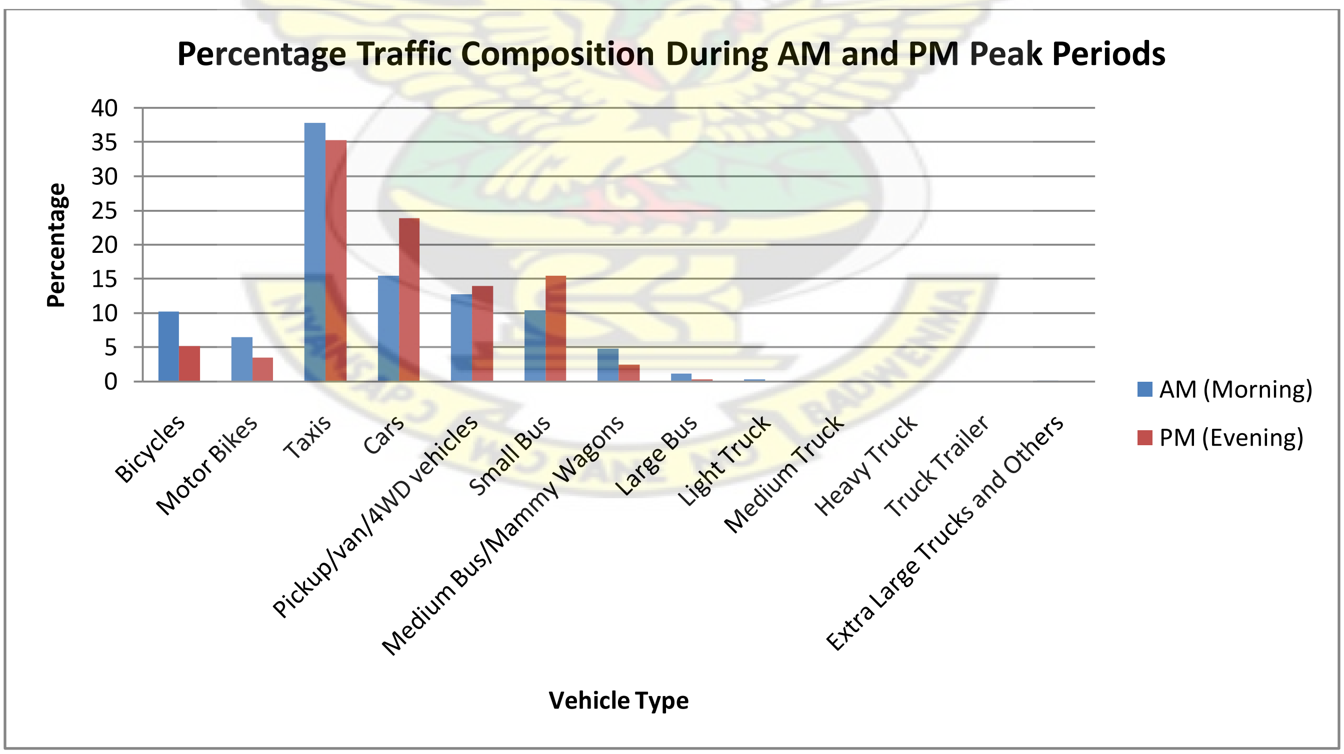

Figure A8: Percentage (%) Traffic Composition During AM and PM Peak Period for S8

City: Sekondi-Takoradi   Location: Agona Nkwanta Road Both Directions   Station:S9

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	AM (Morning)	PM (Evening)
Bicycles	4.7	4.35
Motor Bikes	3.66	3.76
Taxis	23.38	27.38
Cars	16.93	17.51
Pickup/van/4WD vehicles	11.8	9.81
Small Bus	19.06	21.09
Medium Bus/Mammy Wagons	2.84	6.05
Large Bus	2.62	1.41
Light Truck	3.82	3.06
Medium Truck	2.51	0.88
Heavy Truck	3.6	1.59
Truck Trailer	2.95	1.88
Extra Large Trucks and Others	2.13	1.23
Peak Values	**1831**	**1702**

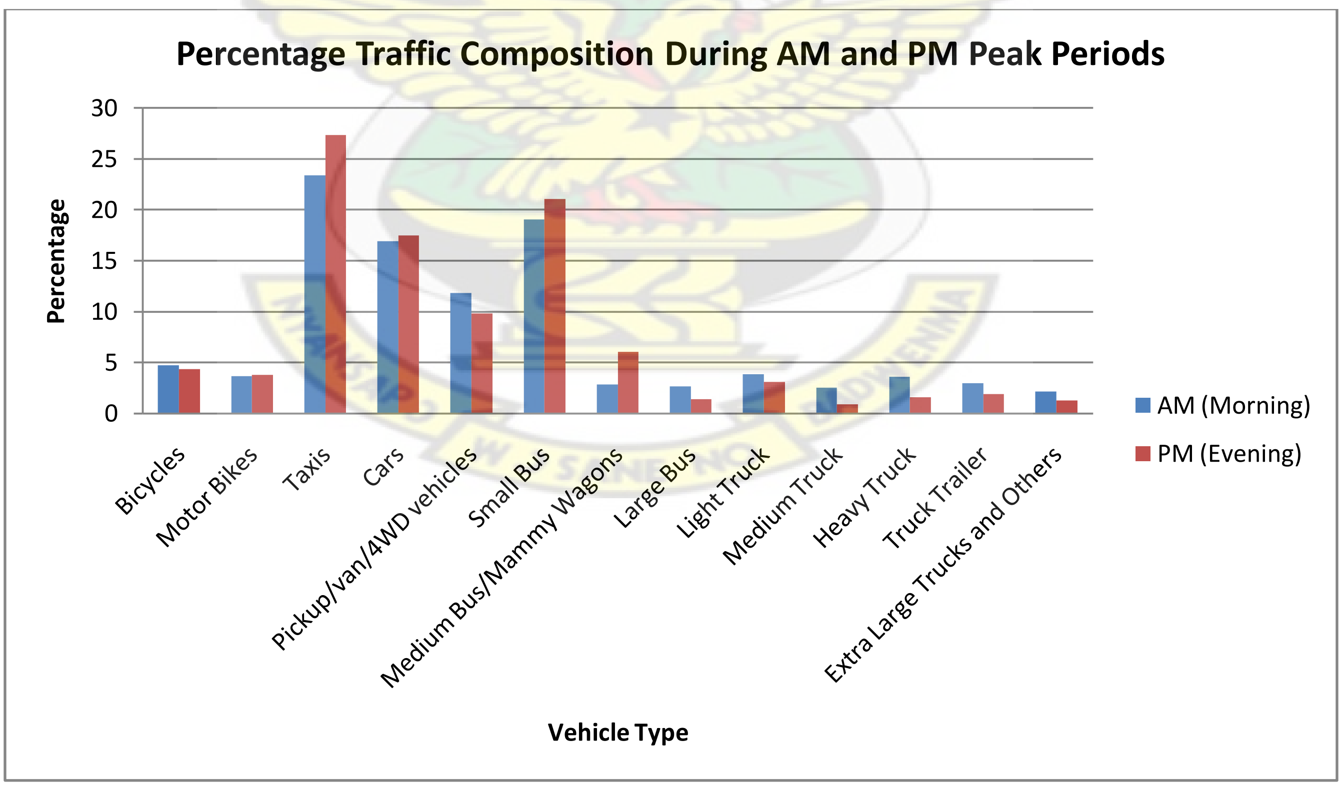

Figure A9: Percentage (%) Traffic Composition During AM and PM Peak Period for S9

City: Sekondi-Takoradi　　Location: Agona Nkwanta Road　　Station:S10
Both Directions

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	AM (Morning)	PM (Evening)
Bicycles	7.79	2.71
Motor Bikes	3.39	2.28
Taxis	26.52	23.34
Cars	8.2	14.38
Pickup/van/4WD vehicles	8.2	9.06
Small Bus	17.26	14.53
Medium Bus/Mammy Wagons	5.97	4.78
Large Bus	1.67	2.28
Light Truck	2.48	5.17
Medium Truck	1.06	4.78
Heavy Truck	0.51	4
Truck Trailer	1.06	3.78
Extra Large Trucks and Others	0.46	2.07
Peak Values	**1976**	**2802**

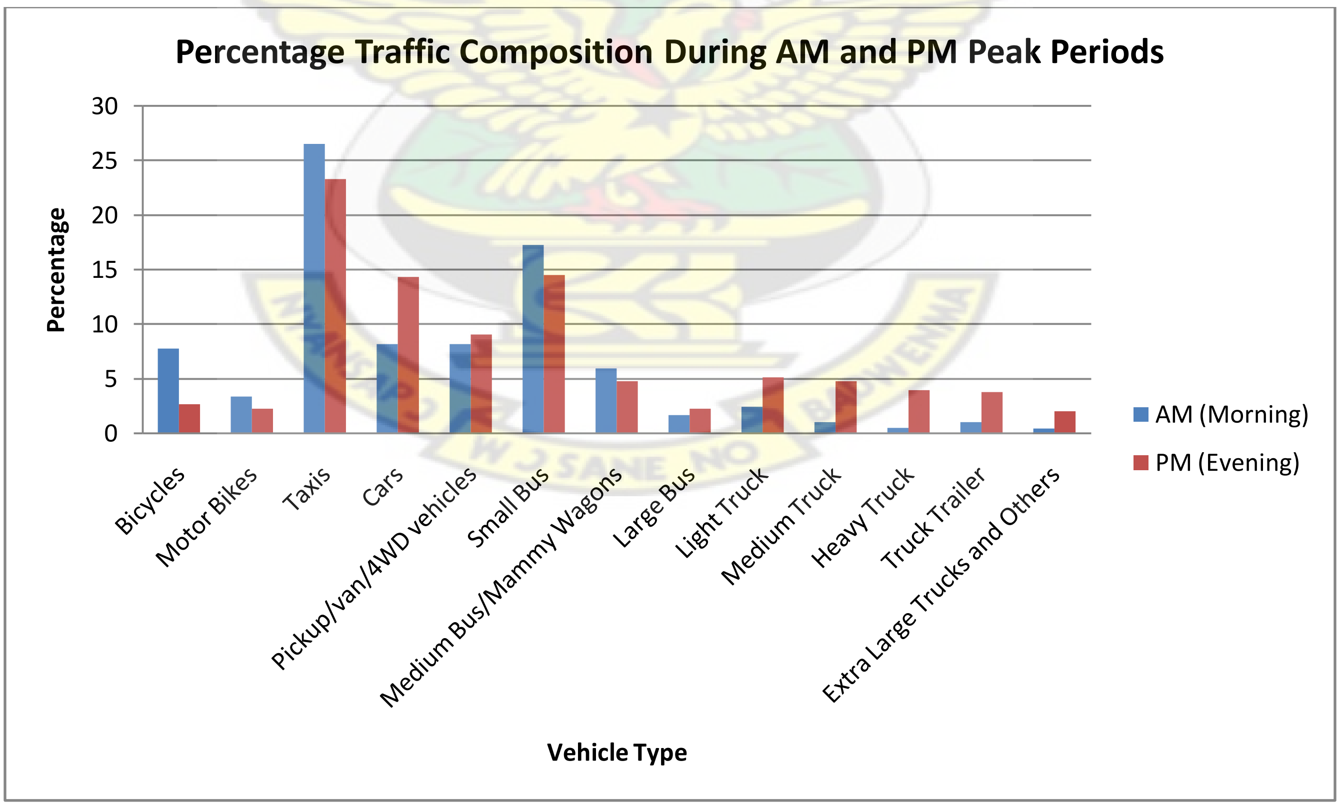

Figure A10: Percentage (%) Traffic Composition During AM and PM Peak Period for S10

City: Sekondi-Takoradi | Location: Agona Nkwanta Road Both Directions | Station:S11

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	AM (Morning)	PM (Evening)
Bicycles	0.96	5.11
Motor Bikes	3.1	3.4
Taxis	35.22	37.23
Cars	22.91	21.17
Pickup/van/4WD vehicles	16.92	10.85
Small Bus	17.88	18.62
Medium Bus/Mammy Wagons	0.32	0.96
Large Bus	0.11	0.85
Light Truck	1.71	1.17
Medium Truck	0.21	0.21
Heavy Truck	0.54	0.43
Truck Trailer	0.11	0
Extra Large Trucks and Others	0	0
Peak Values	**934**	**940**

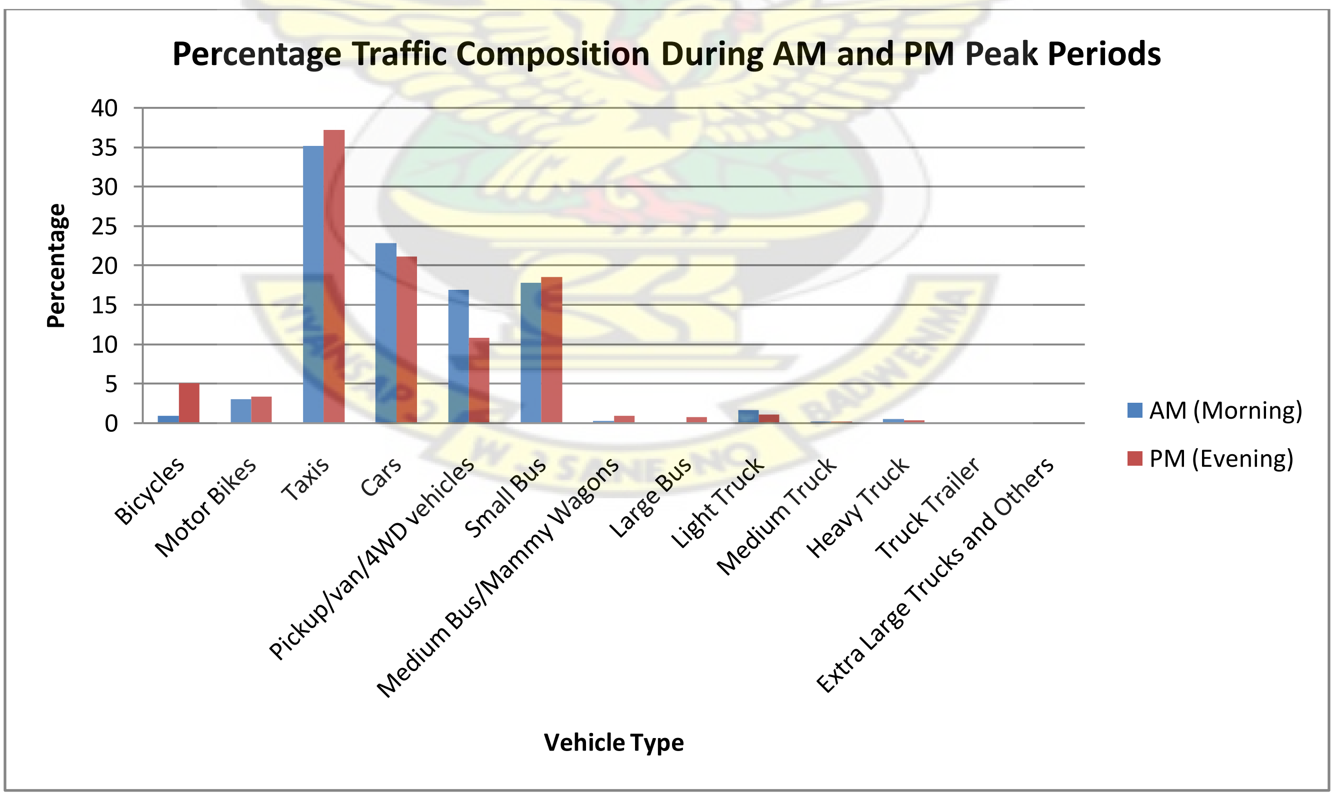

Figure A11: Percentage (%) Traffic Composition During AM and PM Peak Period for S11

City: Sekondi-Takoradi | Location: Sekondi By-Pass Both Directions | Station:S12

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	AM (Morning)	PM (Evening)
Bicycles	1.82	1.84
Motor Bikes	2.83	2.21
Taxis	36.02	35.11
Cars	23.21	20.31
Pickup/van/4WD vehicles	13.02	13.14
Small Bus	18.47	20.86
Medium Bus/Mammy Wagons	0.3	1.19
Large Bus	0	0.37
Light Truck	1.51	1.38
Medium Truck	0.4	1.01
Heavy Truck	1.11	0.92
Truck Trailer	1.31	1.65
Extra Large Trucks and Others	0	0
Peak Values	**991**	**1088**

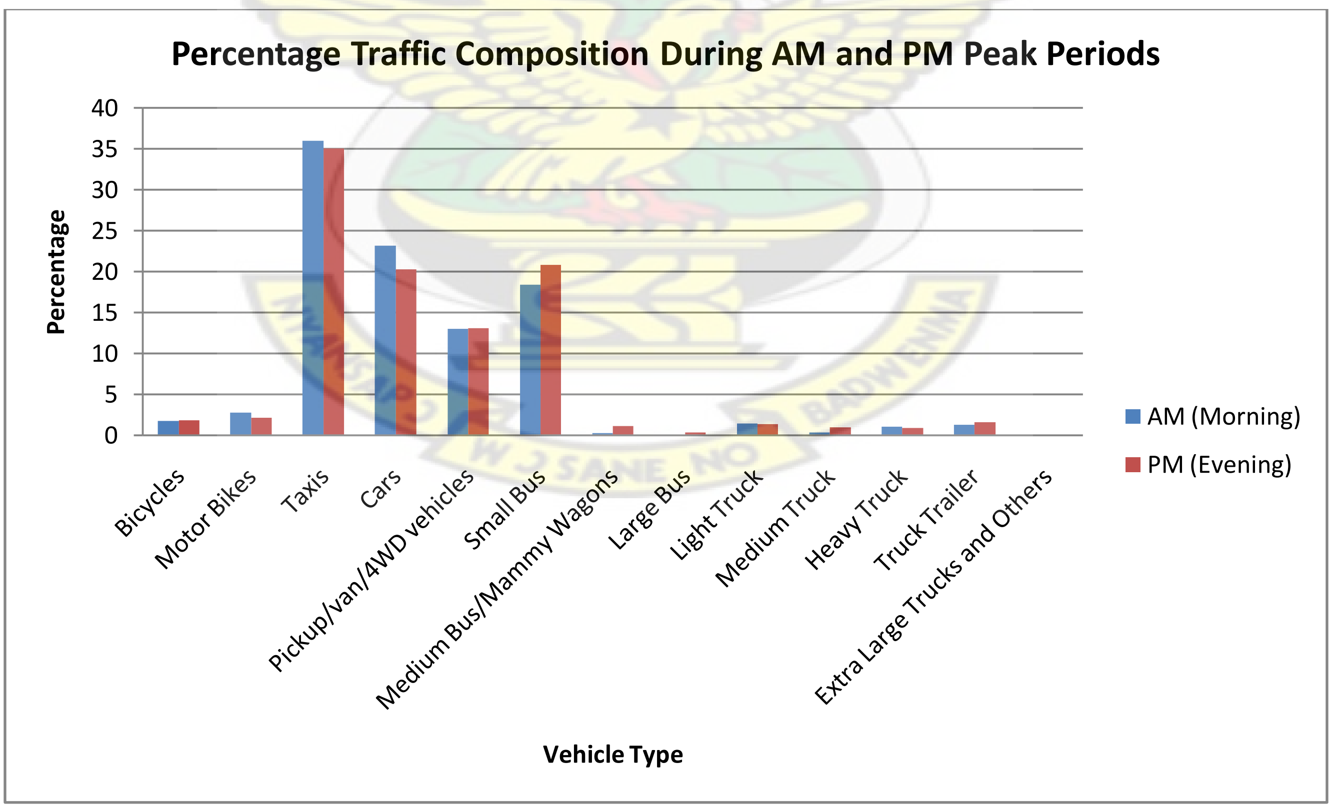

Figure A12: Percentage (%) Traffic Composition During AM and PM Peak Period for S12

City: Sekondi-Takoradi | Location: Cape-Coast Road Both Directions | Station:S13

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	AM (Morning)	PM (Evening)
Bicycles	5.3	8.03
Motor Bikes	2.71	3.7
Taxis	27.77	31.47
Cars	24.83	22.28
Pickup/van/4WD vehicles	15.91	14.15
Small Bus	10.38	10.03
Medium Bus/Mammy Wagons	3.27	3.8
Large Bus	1.13	0.53
Light Truck	2.82	2.75
Medium Truck	1.69	0.42
Heavy Truck	2.71	0.95
Truck Trailer	1.47	1.69
Extra Large Trucks and Others	0	0.21
Peak Values	**886**	**947**

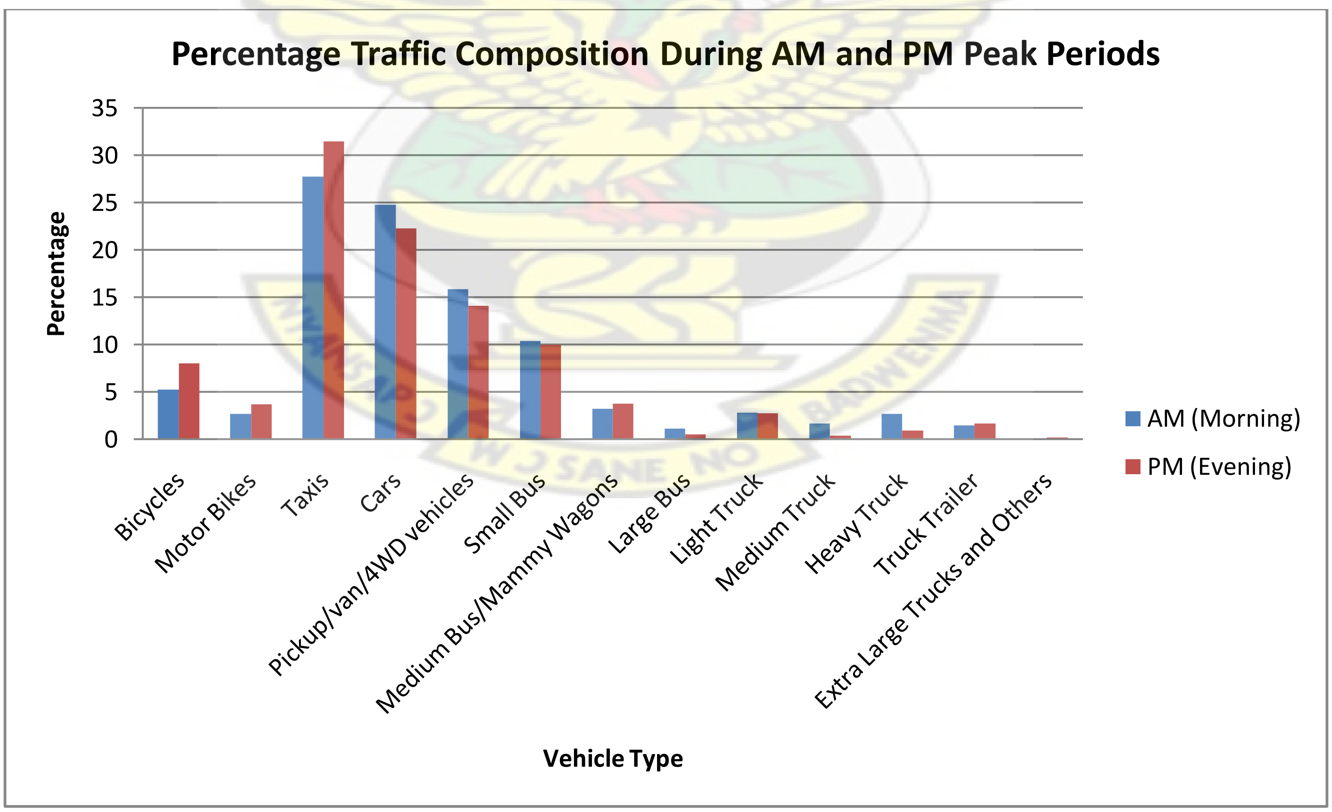

Figure A13: Percentage (%) Traffic Composition During AM and PM Peak Period for S13

City: Sekondi-Takoradi | Location: Liberation Road Both Directions | Station:S14

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	AM (Morning)	PM (Evening)
Bicycles	5.48	4.27
Motor Bikes	2.39	3.33
Taxis	50.88	46.67
Cars	5.95	7.6
Pickup/van/4WD vehicles	2.68	4.5
Small Bus	30.86	31.23
Medium Bus/Mammy Wagons	0.99	1.29
Large Bus	0.06	0.06
Light Truck	0.47	0.53
Medium Truck	0.23	0.29
Heavy Truck	0	0
Truck Trailer	0	0
Extra Large Trucks and Others	0	0.23
Peak Values	**1714**	**1710**

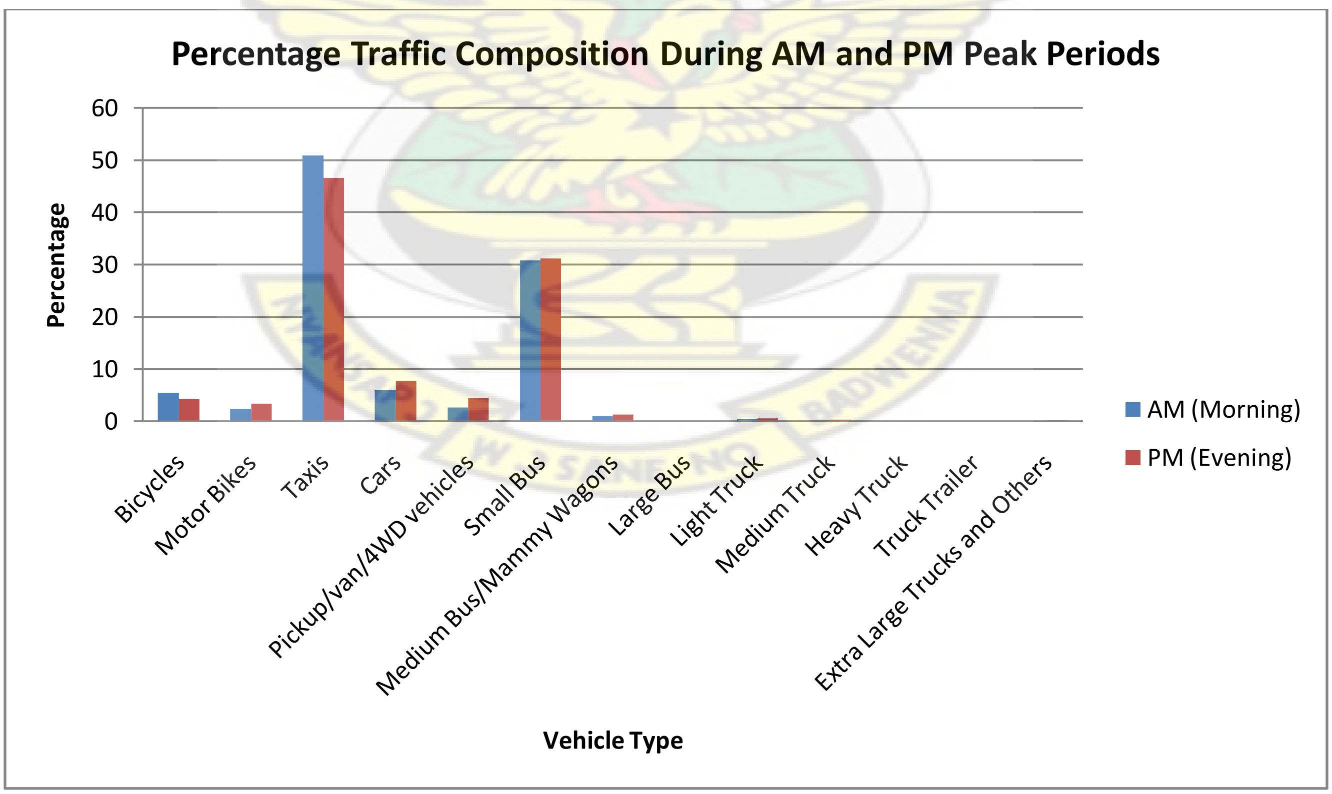

Figure A14: Percentage (%) Traffic Composition During AM and PM Peak Period for S14

City: Sekondi-Takoradi | Location: Axim Road Both Directions | Station:S15

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	AM (Morning)	PM (Evening)
Bicycles	7.42	5.88
Motor Bikes	3.15	2.02
Taxis	46.74	50.55
Cars	24.94	24.63
Pickup/van/4WD vehicles	11.69	11.21
Small Bus	2.92	2.76
Medium Bus/Mammy Wagons	0.67	0.37
Large Bus	0	0.55
Light Truck	2.27	1.65
Medium Truck	0	0.37
Heavy Truck	0.22	0
Truck Trailer	0	0
Extra Large Trucks and Others	0	0
Peak Values	**445**	**544**

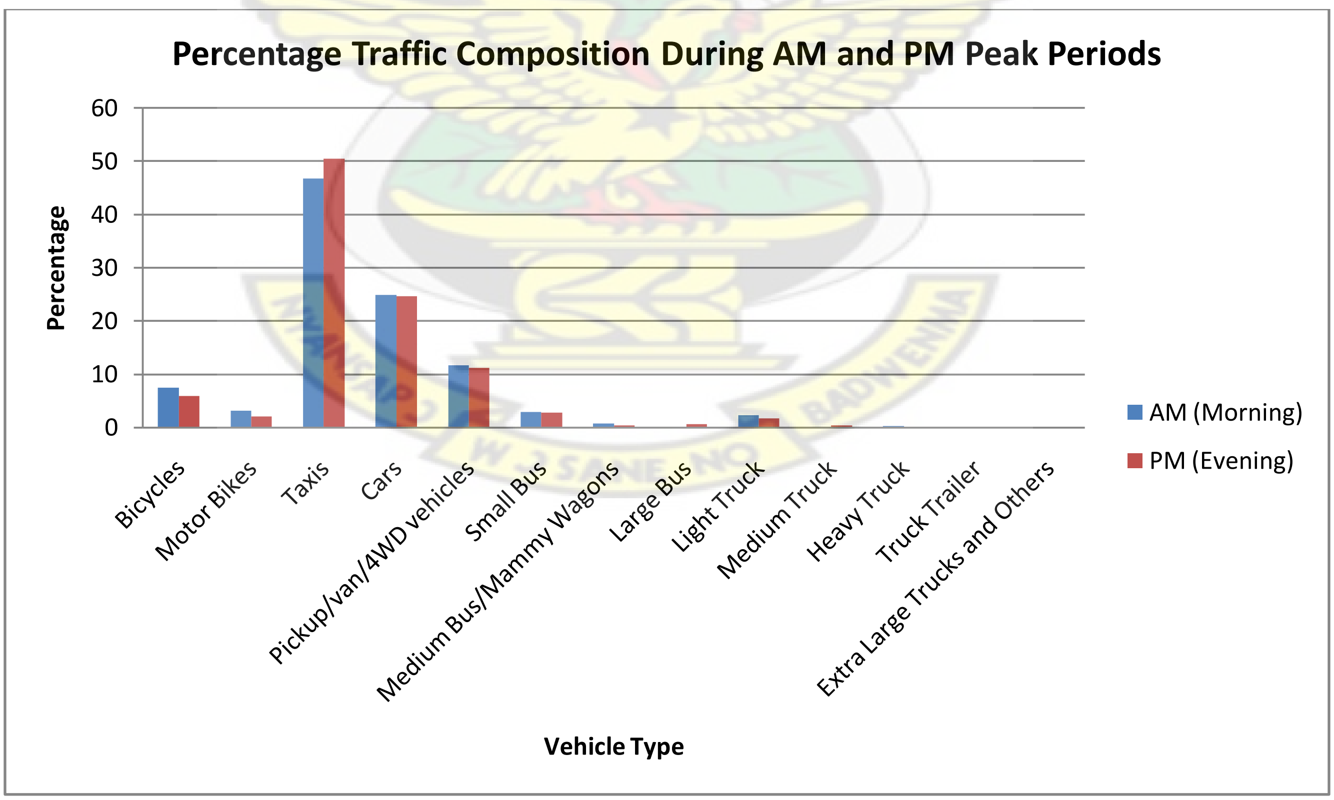

Figure A15: Percentage (%) Traffic Composition During AM and PM Peak Period for S15

City: Sekondi-Takoradi | Location: Cape-Coast Road Both Directions | Station:S16

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	AM (Morning)	PM (Evening)
Bicycles	4.25	4.58
Motor Bikes	2.5	4.58
Taxis	53.25	53.3
Cars	28.25	21.78
Pickup/van/4WD vehicles	6.25	9.46
Small Bus	2.25	5.16
Medium Bus/Mammy Wagons	0.75	0.29
Large Bus	0	0
Light Truck	1	0.29
Medium Truck	1.5	0.57
Heavy Truck	0	0
Truck Trailer	0	0
Extra Large Trucks and Others	0	0
Peak Values	**880**	**764**

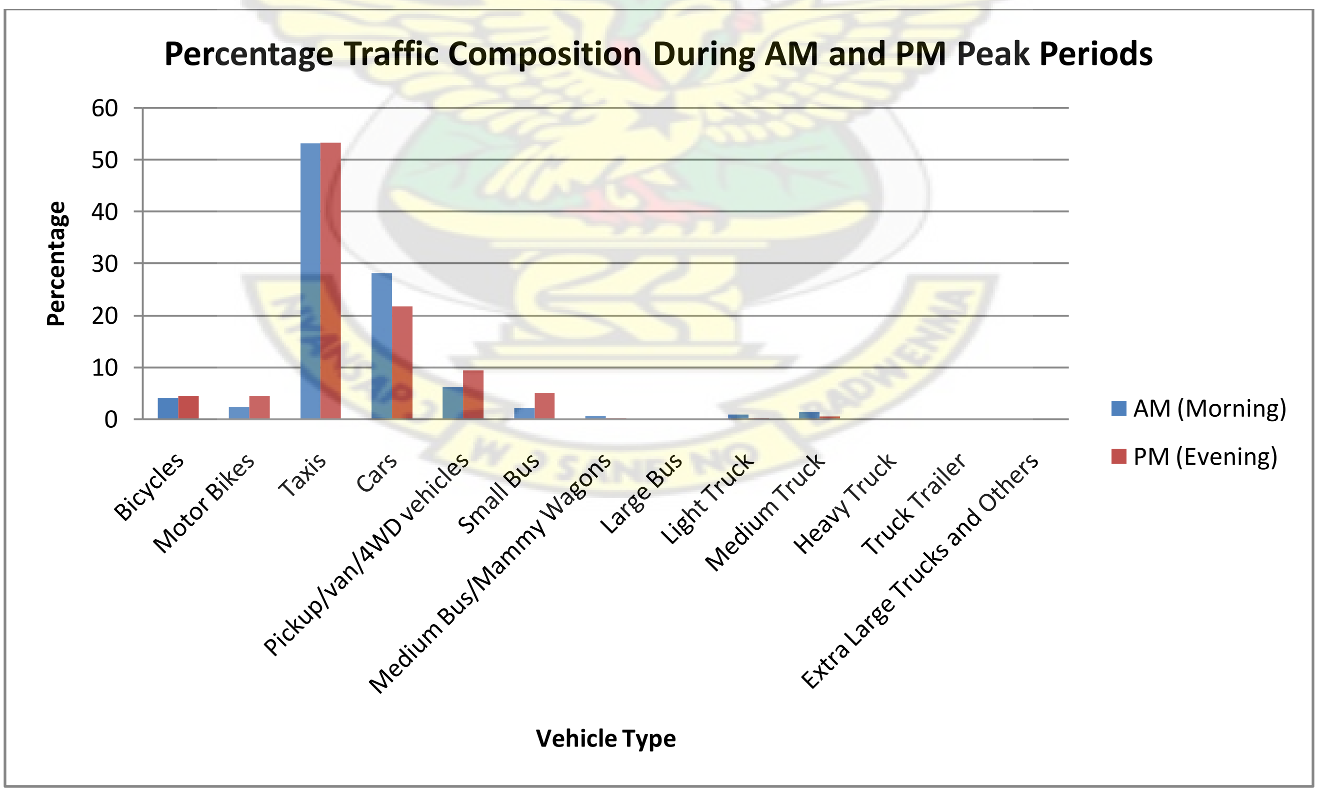

Figure A16: Percentage (%) Traffic Composition During AM and PM Peak Period for S16

City: Sekondi-Takoradi | Location: Sekondi Road Both Directions | Station:S17

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	AM (Morning)	PM (Evening)
Bicycles	3.33	2.69
Motor Bikes	1.64	2.45
Taxis	36.67	31.62
Cars	20.99	20.16
Pickup/van/4WD vehicles	6.96	12.49
Small Bus	23.16	22.37
Medium Bus/Mammy Wagons	2.69	3.24
Large Bus	0.64	0.79
Light Truck	1.23	1.98
Medium Truck	0.47	0.87
Heavy Truck	1.46	1.55
Truck Trailer	0.76	1.79
Extra Large Trucks and Others	0	0
Peak Values	**1710**	**1265**

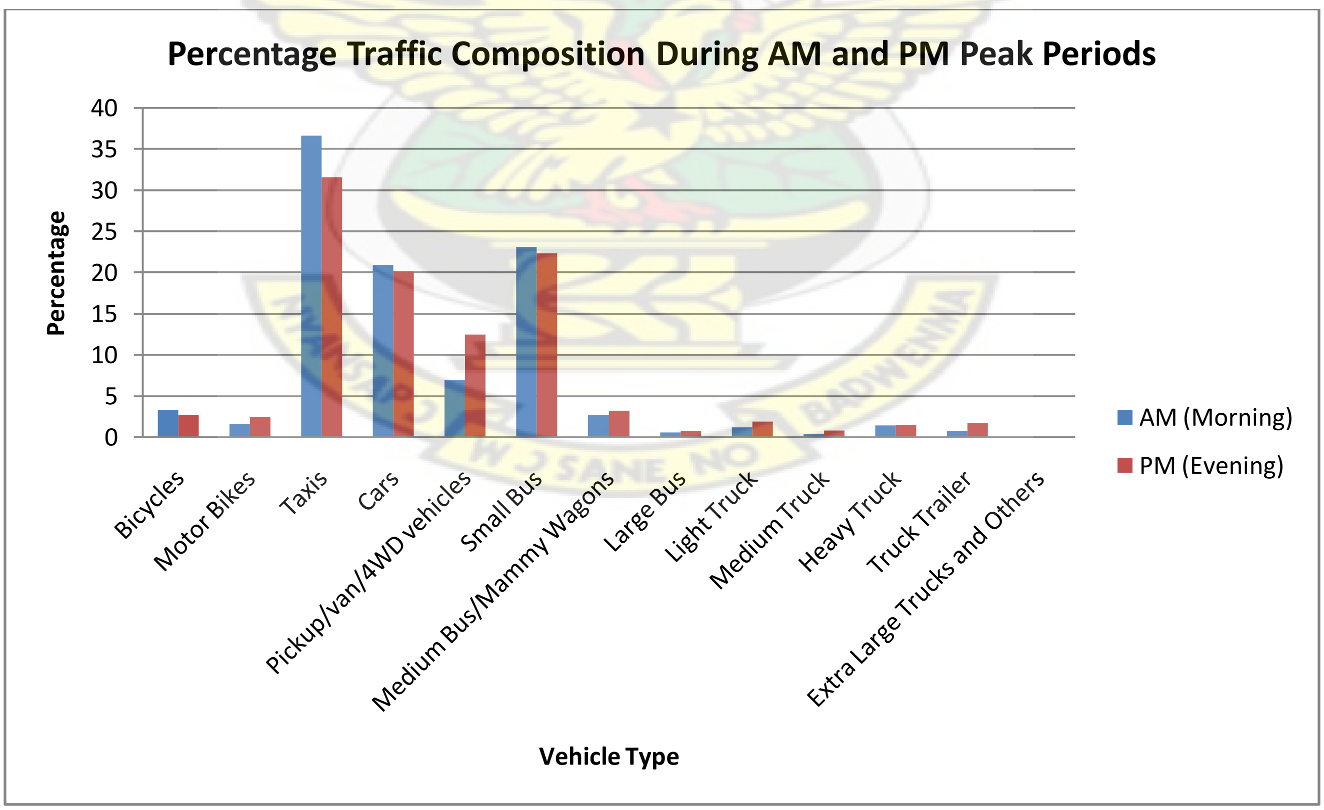

Figure A17: Percentage (%) Traffic Composition During AM and PM Peak Period for S17

City: Sekondi-Takoradi Location: New Takoradi Road Station:S18
Both Directions

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	AM (Morning)	PM (Evening)
Bicycles	10.07	7.42
Motor Bikes	5.86	5.12
Taxis	38.28	33.25
Cars	10.07	17.65
Pickup/van/4WD vehicles	8.06	11.25
Small Bus	17.03	7.42
Medium Bus/Mammy Wagons	2.93	2.81
Large Bus	0.92	0.77
Light Truck	1.28	3.07
Medium Truck	0.55	2.05
Heavy Truck	3.66	3.07
Truck Trailer	1.28	5.63
Extra Large Trucks and Others	0	0.51
Peak Values	**564**	**391**

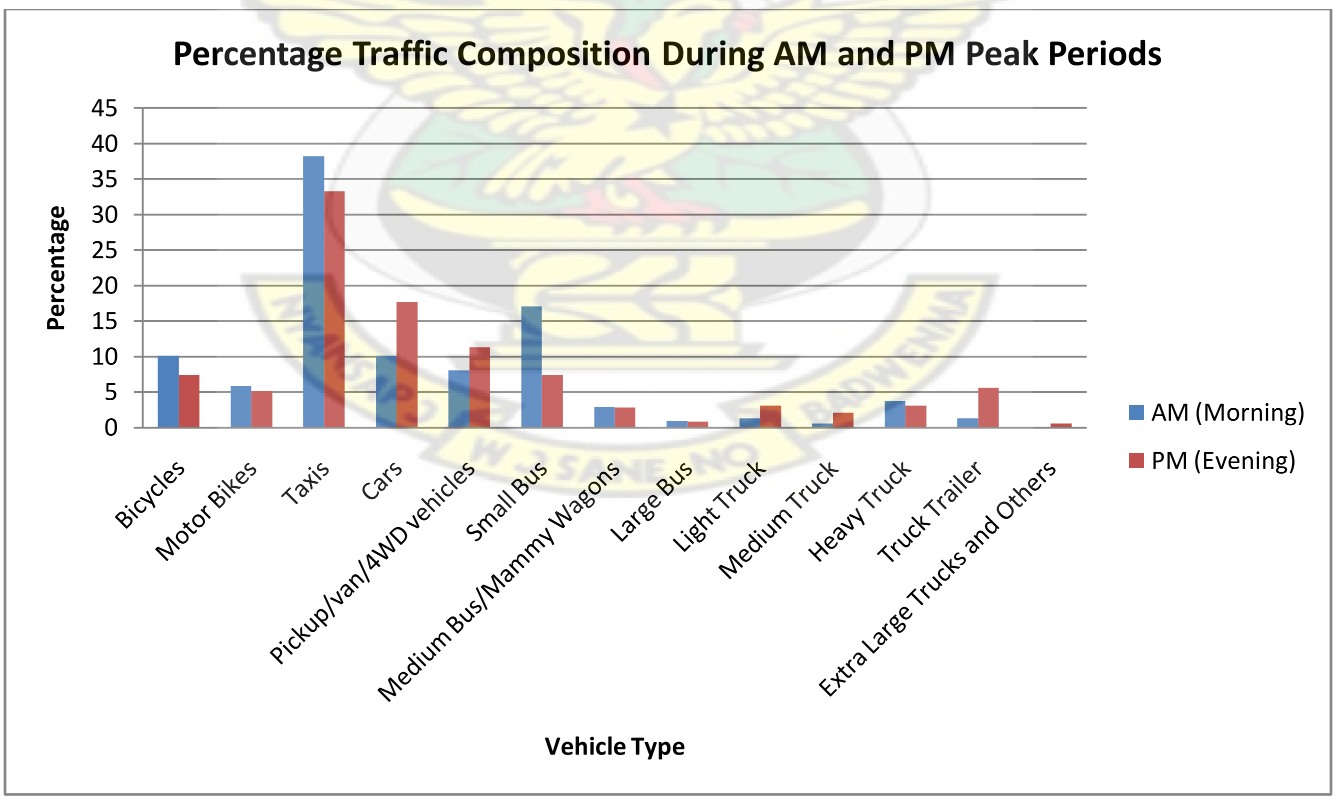

Figure A18: Percentage (%) Traffic Composition During AM and PM Peak Period for S18

City: Sekondi-Takoradi Location: Accra Road Station:S19

Both Directions

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	AM (Morning)	PM (Evening)
Bicycles	2.2	4.17
Motor Bikes	1.09	3.87
Taxis	27.99	29.46
Cars	31.45	32.74
Pickup/van/4WD vehicles	26.42	22.92
Small Bus	4.72	2.98
Medium Bus/Mammy Wagons	0	1.49
Large Bus	0	0
Light Truck	1.89	0.89
Medium Truck	1.26	0.3
Heavy Truck	0	1.19
Truck Trailer	0	0
Extra Large Trucks and Others	0	0
Peak Values	**318**	**336**

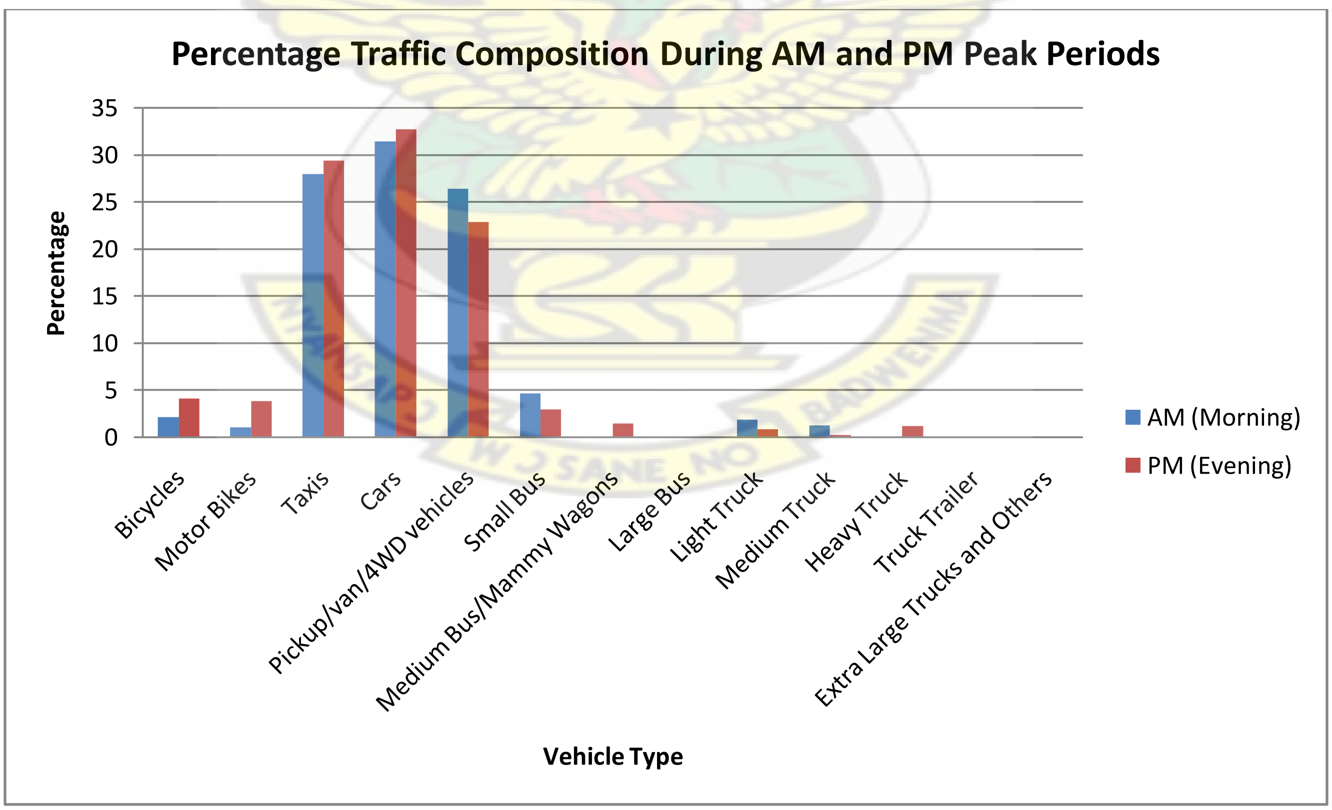

Figure A19: Percentage (%) Traffic Composition During AM and PM Peak Period for S19

City: Sekondi-Takoradi Location: John Sarbah Road Both Directions Station:S20

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	AM (Morning)	PM (Evening)
Bicycles	2.9	2.58
Motor Bikes	2.38	4.15
Taxis	44.78	51.37
Cars	13.57	19.89
Pickup/van/4WD vehicles	6.61	9.4
Small Bus	28.48	10.73
Medium Bus/Mammy Wagons	0.41	0.47
Large Bus	0.23	0.47
Light Truck	0.52	0.78
Medium Truck	0.12	0.16
Heavy Truck	0	0
Truck Trailer	0	0
Extra Large Trucks and Others	0	0
Peak Values	**1724**	**1277**

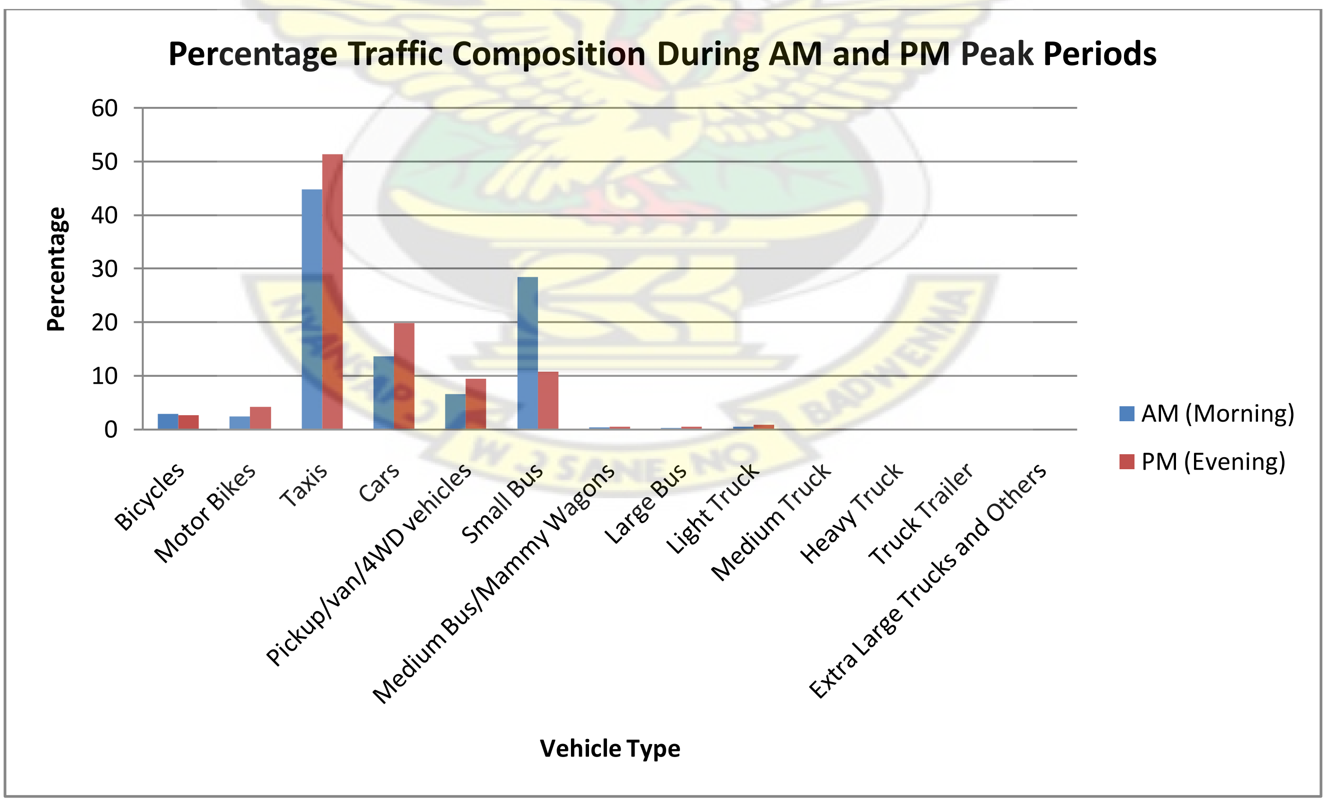

Figure A20: Percentage (%) Traffic Composition During AM and PM Peak Period for S20

City: Sekondi-Takoradi | Location: Liberation Road Both Directions | Station:S21

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	AM (Morning)	PM (Evening)
Bicycles	3.22	3.49
Motor Bikes	4.83	6.28
Taxis	52.2	43.07
Cars	22.34	25.02
Pickup/van/4WD vehicles	11.71	17.45
Small Bus	4.08	1
Medium Bus/Mammy Wagons	0.43	2.09
Large Bus	0	0.2
Light Truck	0.75	0.3
Medium Truck	0.43	1
Heavy Truck	0	0
Truck Trailer	0	0.1
Extra Large Trucks and Others	0	0
Peak Values	**931**	**1003**

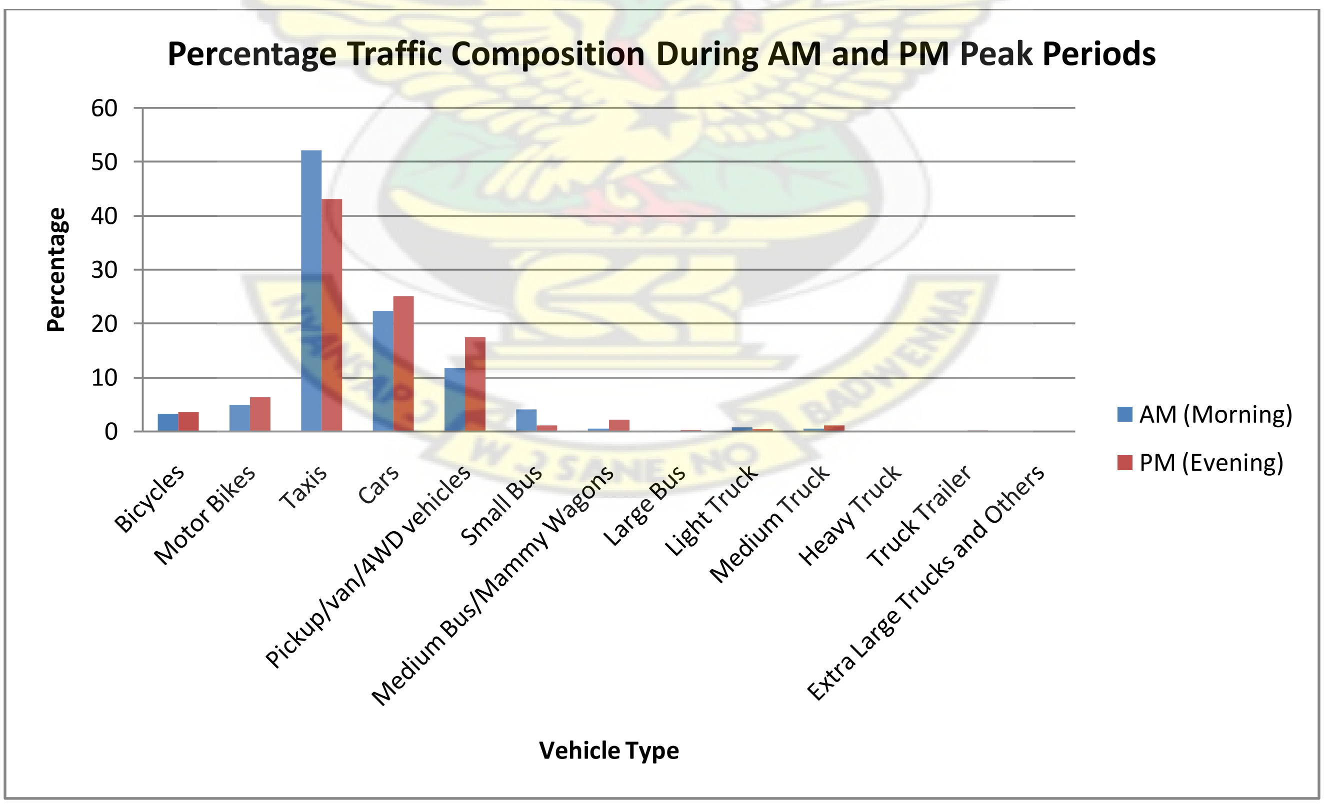

Figure A21: Percentage (%) Traffic Composition During AM and PM Peak Period for S21

City: Sekondi-Takoradi Location: Electricity Road Both Directions Station:S22

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	AM (Morning)	PM (Evening)
Bicycles	5.47	4.93
Motor Bikes	4.03	4.61
Taxis	32.95	31.16
Cars	37.84	27.5
Pickup/van/4WD vehicles	11.08	19.24
Small Bus	2.88	3.02
Medium Bus/Mammy Wagons	1.15	0.64
Large Bus	0.58	0.16
Light Truck	0.86	1.91
Medium Truck	0.43	1.59
Heavy Truck	0.72	0.64
Truck Trailer	2.01	4.61
Extra Large Trucks and Others	0	0
Peak Values	**695**	**629**

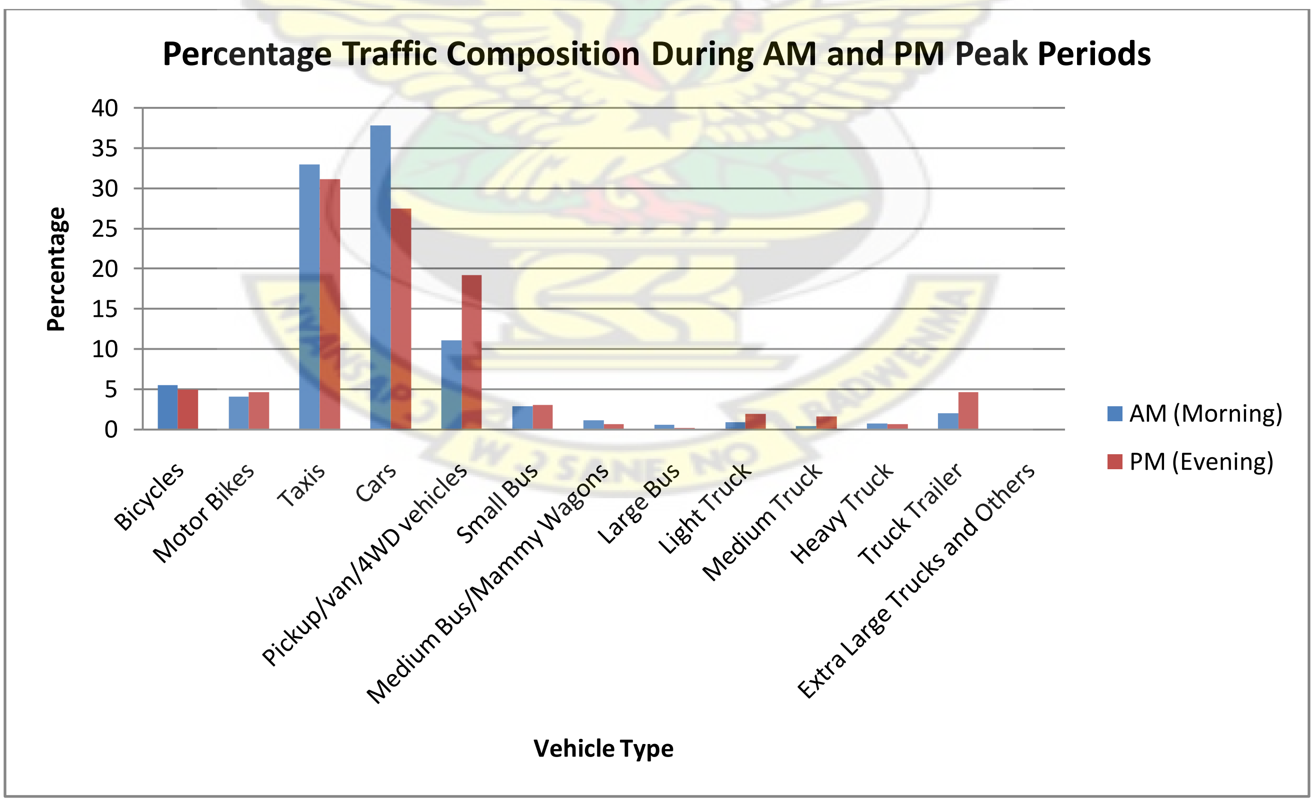

Figure A22: Percentage (%) Traffic Composition During AM and PM Peak Period for S22

City: Sekondi-Takoradi   Location: Harbour Road   Station:S23
Both Directions

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	AM (Morning)	PM (Evening)
Bicycles	16.61	8.01
Motor Bikes	11.4	6.62
Taxis	25.73	26.83
Cars	29.32	35.54
Pickup/van/4WD vehicles	7.82	11.85
Small Bus	0.65	0.7
Medium Bus/Mammy Wagons	1.95	1.39
Large Bus	0.33	0.7
Light Truck	0.65	1.39
Medium Truck	0	1.05
Heavy Truck	4.56	1.74
Truck Trailer	0.98	4.18
Extra Large Trucks and Others	0	0
Peak Values	**307**	**287**

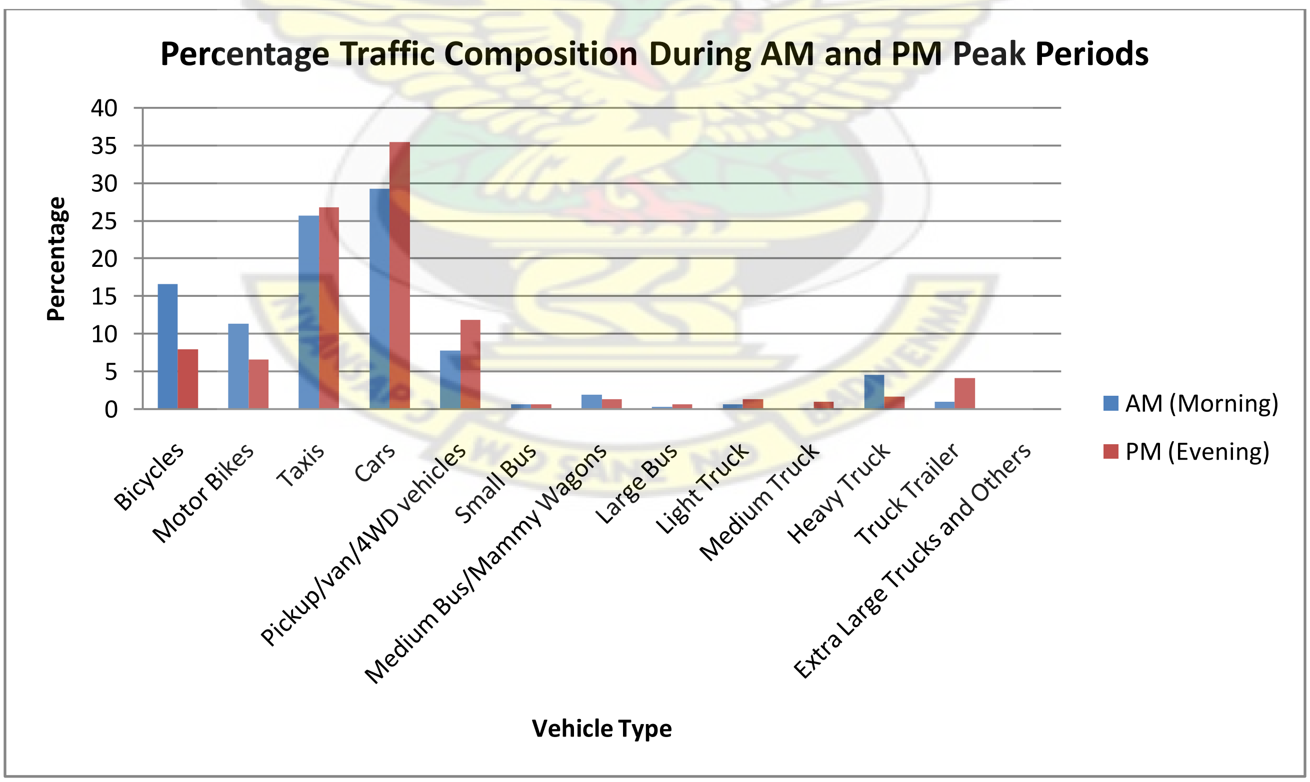

Figure A23: Percentage (%) Traffic Composition During AM and PM Peak Period for S23

City: Sekondi-Takoradi   Location: Electricity Road   Station:S24
Both Directions

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	AM (Morning)	PM (Evening)
Bicycles	4.41	2.52
Motor Bikes	2.81	2.94
Taxis	42.69	51.05
Cars	32.06	28.99
Pickup/van/4WD vehicles	10.62	9.66
Small Bus	3.21	1.68
Medium Bus/Mammy Wagons	0.6	0
Large Bus	0.2	0
Light Truck	1.2	0.84
Medium Truck	0	0.21
Heavy Truck	0.6	0.63
Truck Trailer	1.6	1.47
Extra Large Trucks and Others	0	0
Peak Values	**499**	**476**

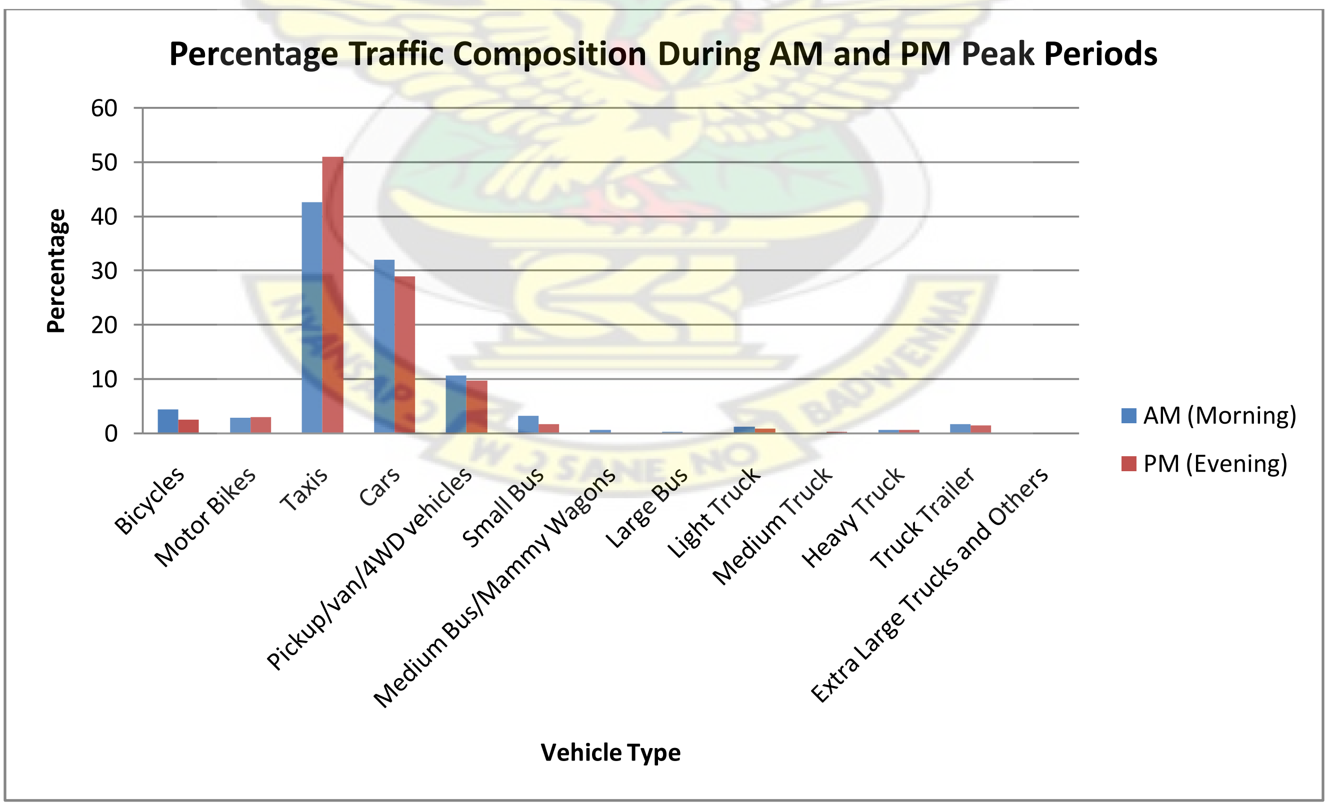

Figure A24: Percentage (%) Traffic Composition During AM and PM Peak Period for S24

City: Sekondi-Takoradi Location: Harbour Road Station:S25
Both Directions

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	AM (Morning)	PM (Evening)
Bicycles	2.72	2.2
Motor Bikes	2.18	2.2
Taxis	40.33	41.08
Cars	23.16	29.34
Pickup/van/4WD vehicles	20.16	15.16
Small Bus	1.09	1.96
Medium Bus/Mammy Wagons	0.27	0.98
Large Bus	0	0.24
Light Truck	1.36	2.93
Medium Truck	0.82	0.49
Heavy Truck	1.36	0.49
Truck Trailer	5.99	2.93
Extra Large Trucks and Others	0.54	0
Peak Values	**367**	**409**

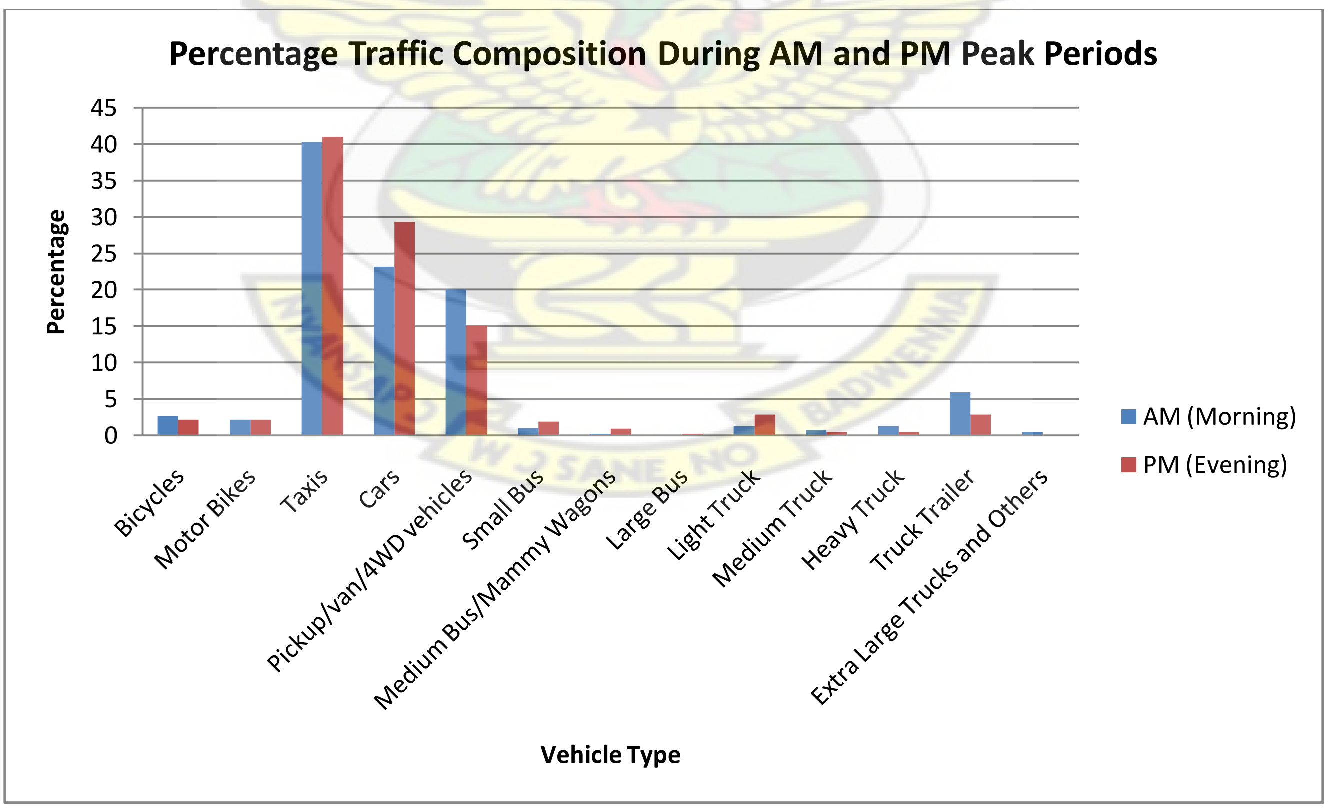

Figure A25: Percentage (%) Traffic Composition During AM and PM Peak Period for S25

City: Sekondi-Takoradi   Location: Axim Road   Station:S26
Both Directions

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	AM (Morning)	PM (Evening)
Bicycles	2.37	2.17
Motor Bikes	1.33	1.21
Taxis	34.74	34.03
Cars	28	26.32
Pickup/van/4WD vehicles	18.74	19.38
Small Bus	5.48	5.93
Medium Bus/Mammy Wagons	1.48	2.55
Large Bus	0.3	1.59
Light Truck	4.22	2.93
Medium Truck	0.59	1.57
Heavy Truck	1.48	1.34
Truck Trailer	1.26	1.91
Extra Large Trucks and Others	0	0.06
Peak Values	**1350**	**1569**

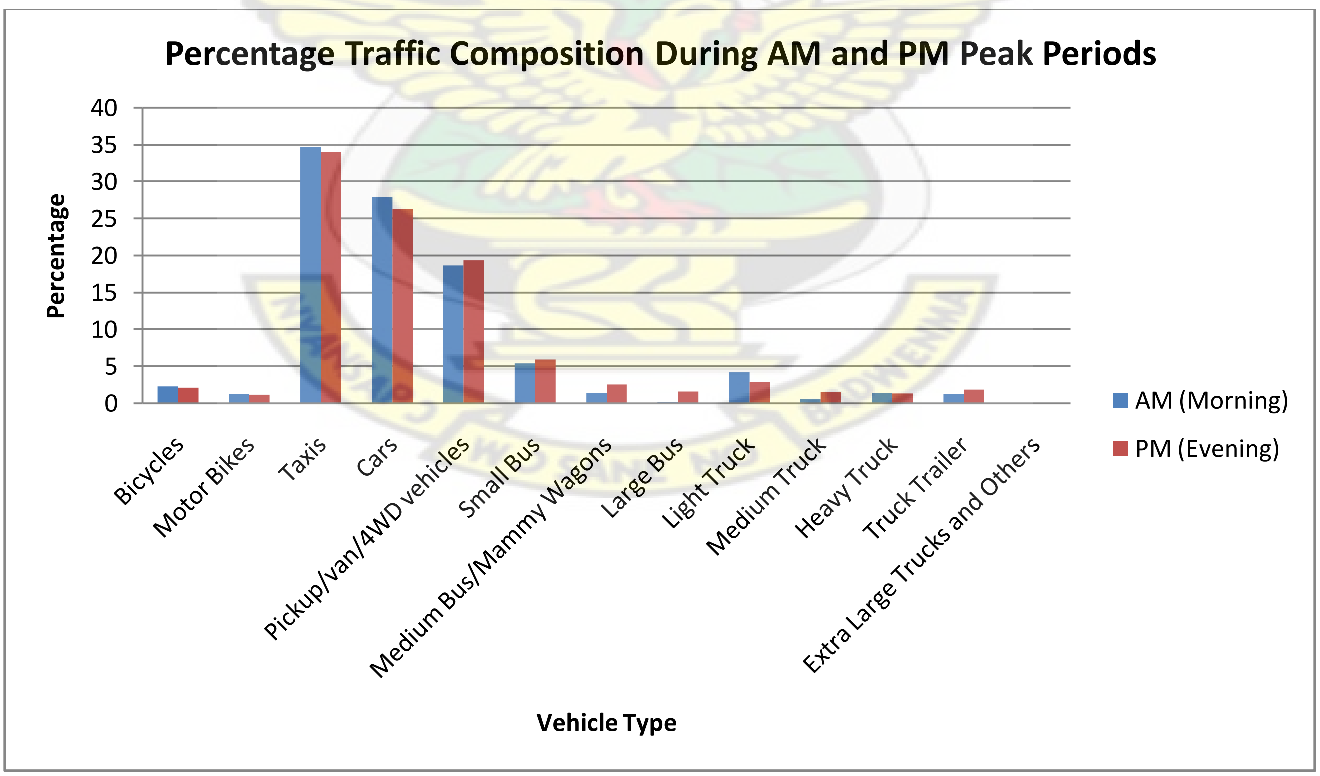

Figure A26: Percentage (%) Traffic Composition During AM and PM Peak Period for S26

City: Sekondi-Takoradi | Location: Accra Road Both Directions | Station:S27

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	AM (Morning)	PM (Evening)
Bicycles	3.25	5.81
Motor Bikes	1.02	0.83
Taxis	34.96	35.68
Cars	24.59	25.93
Pickup/van/4WD vehicles	29.07	28.22
Small Bus	3.66	1.87
Medium Bus/Mammy Wagons	0	0
Large Bus	0	0
Light Truck	2.44	1.45
Medium Truck	0.41	0.21
Heavy Truck	0.61	0
Truck Trailer	0	0
Extra Large Trucks and Others	0	0
Peak Values	**492**	**483**

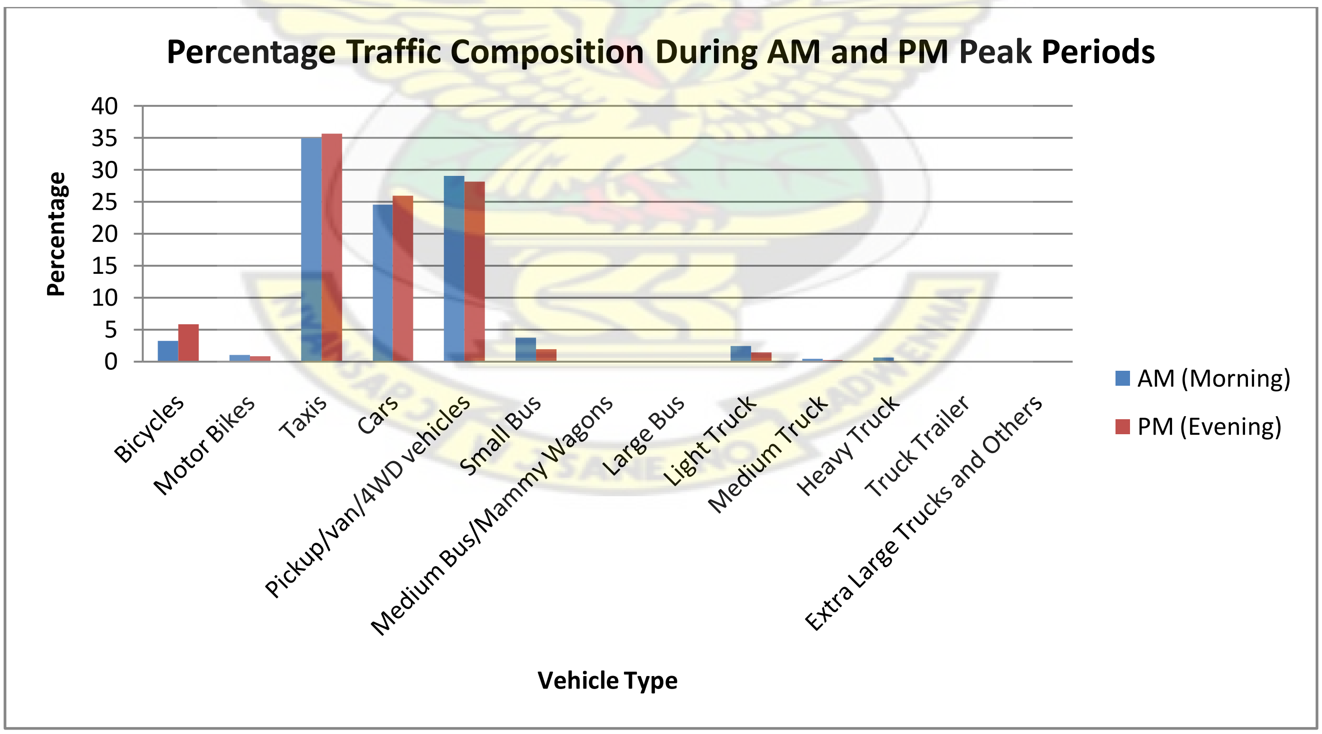

Figure A27: Percentage (%) Traffic Composition During AM and PM Peak Period for S27

City: Sekondi-Takoradi | Location: Africana Road Both Directions | Station:S28

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	AM (Morning)	PM (Evening)
Bicycles	5.66	3.35
Motor Bikes	1.5	2.52
Taxis	40.93	37.32
Cars	22.63	28.3
Pickup/van/4WD vehicles	21.13	17.82
Small Bus	3.33	3.98
Medium Bus/Mammy Wagons	1	2.31
Large Bus	0.17	0.21
Light Truck	1.16	1.05
Medium Truck	0	0.63
Heavy Truck	0.5	0.42
Truck Trailer	2	2.1
Extra Large Trucks and Others	0	0
Peak Values	**601**	**477**

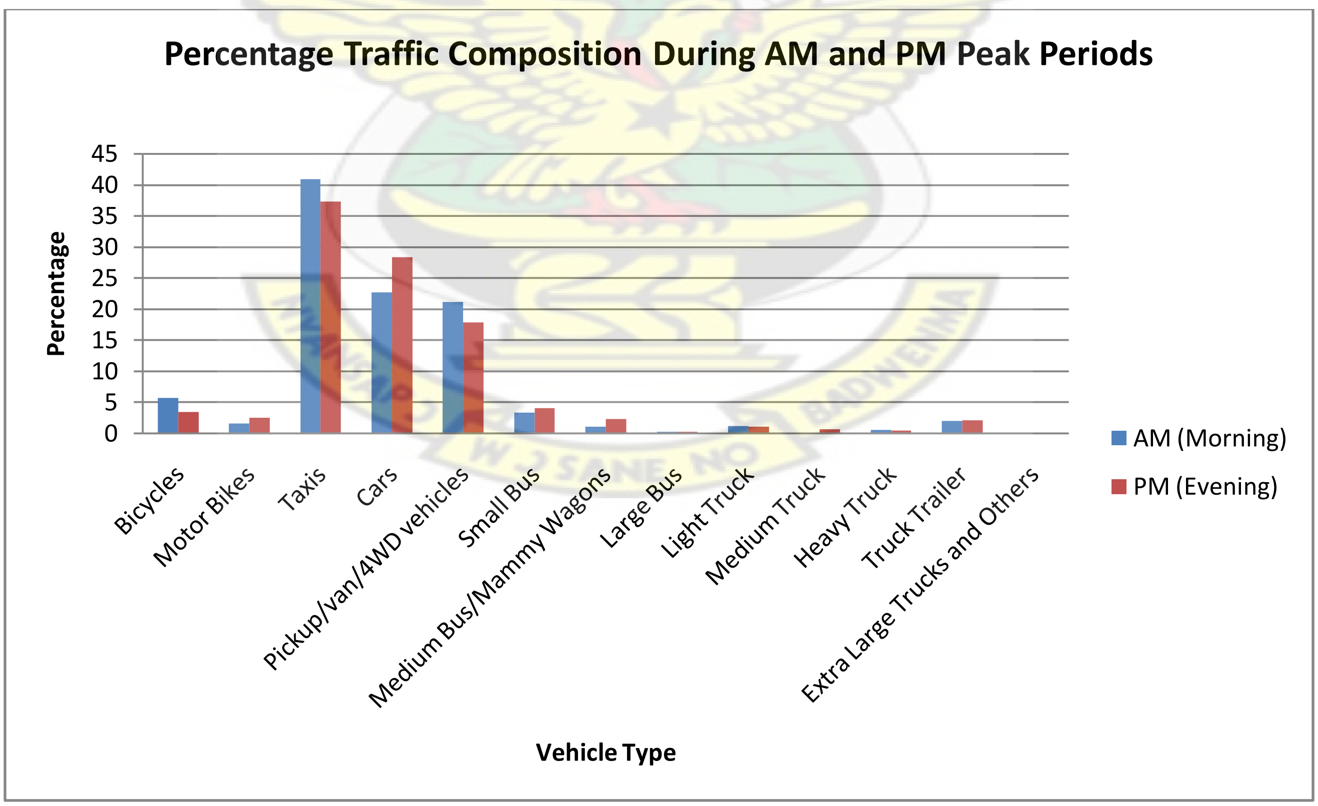

Figure A28: Percentage (%) Traffic Composition During AM and PM Peak Period for S28

City: Sekondi-Takoradi | Location: African Beach Hotel Road Both Directions | Station:S29

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	AM (Morning)	PM (Evening)
Bicycles	1.3	0.58
Motor Bikes	0.65	2.34
Taxis	38.96	39.18
Cars	22.73	23.39
Pickup/van/4WD vehicles	30.52	16.37
Small Bus	2.6	12.28
Medium Bus/Mammy Wagons	0.65	5.85
Large Bus	0	0
Light Truck	1.95	0
Medium Truck	0	0
Heavy Truck	0	0
Truck Trailer	0.65	0
Extra Large Trucks and Others	0	0
Peak Values	**154**	**171**

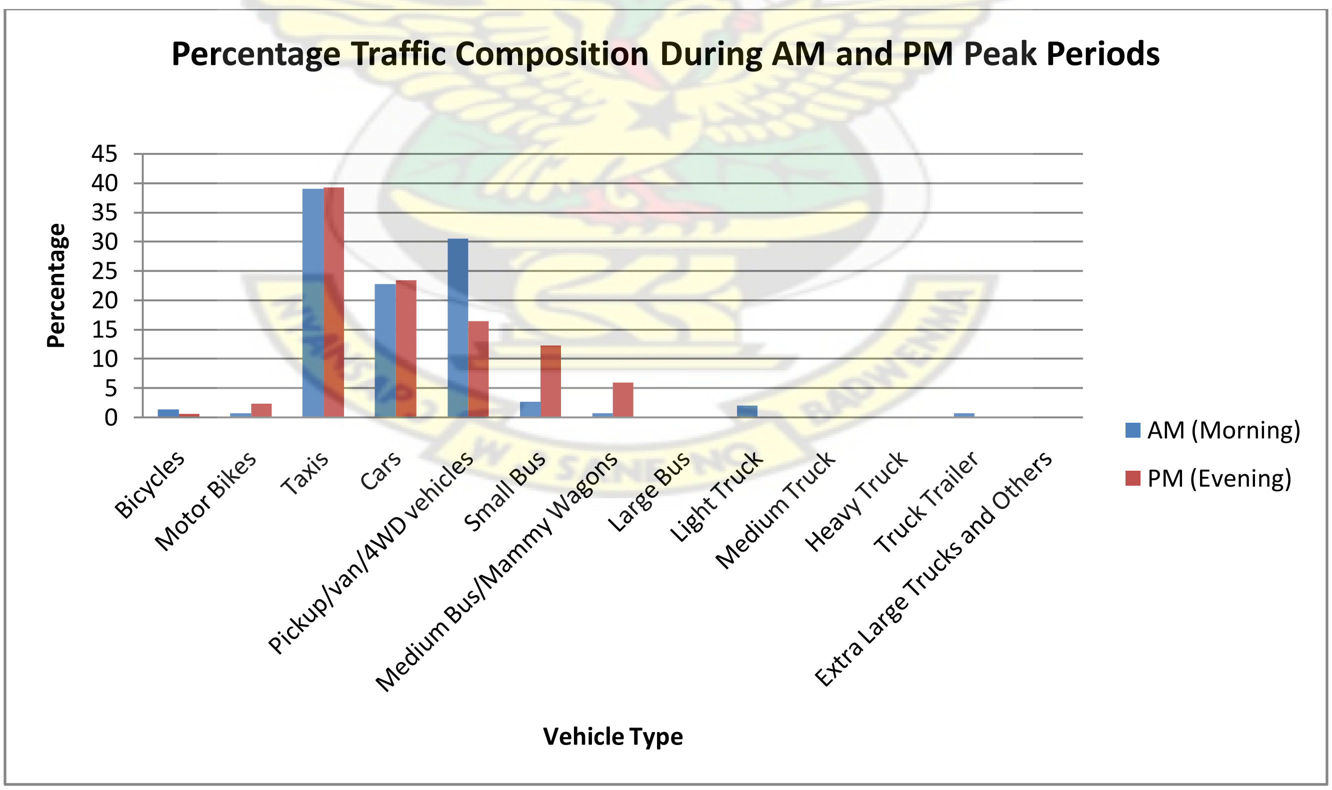

Figure A29: Percentage (%) Traffic Composition During AM and PM Peak Period for S29

City: Sekondi-Takoradi | Location: Discove Hill Road Both Directions | Station:S30

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	AM (Morning)	PM (Evening)
Bicycles	13.85	0.93
Motor Bikes	1.35	4.63
Taxis	33.45	38.27
Cars	20.61	23.77
Pickup/van/4WD vehicles	24.66	23.77
Small Bus	3.04	6.48
Medium Bus/Mammy Wagons	0	0
Large Bus	0.34	0
Light Truck	1.35	0.93
Medium Truck	0.68	0.93
Heavy Truck	0.68	0.31
Truck Trailer	0	0
Extra Large Trucks and Others	0	0
Peak Values	**296**	**324**

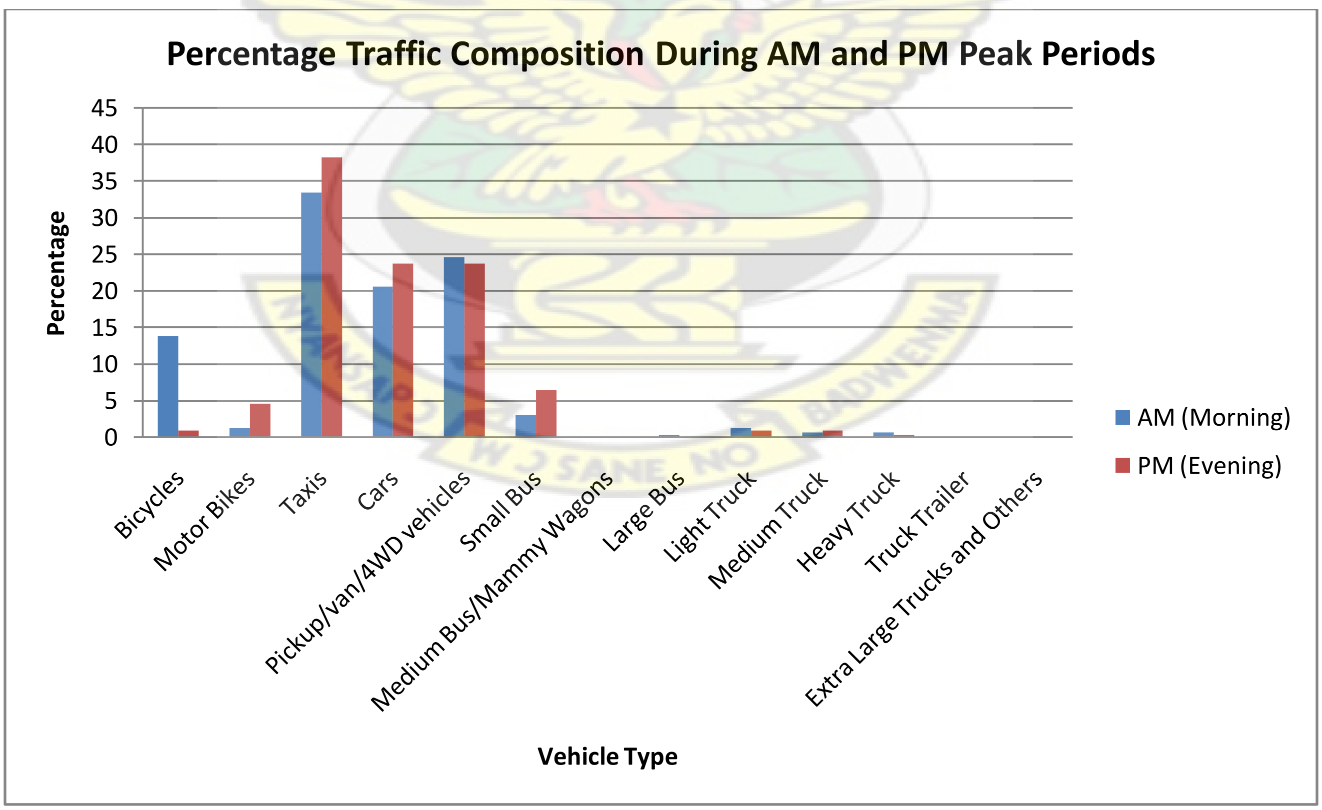

Figure A30: Percentage (%) Traffic Composition During AM and PM Peak Period for S30

City: Sekondi-Takoradi | Location: Sekondi By-Pass Both Directions | Station:S31

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	AM (Morning)	PM (Evening)
Bicycles	8.32	9.79
Motor Bikes	3.6	4.27
Taxis	13.98	15.43
Cars	15.21	13.17
Pickup/van/4WD vehicles	9.97	10.79
Small Bus	39.36	36.01
Medium Bus/Mammy Wagons	5.24	4.02
Large Bus	1.23	1.76
Light Truck	1.44	2.26
Medium Truck	0.41	0.63
Heavy Truck	0.82	0.38
Truck Trailer	0.21	1.13
Extra Large Trucks and Others	0	0.38
Peak Values	**973**	**797**

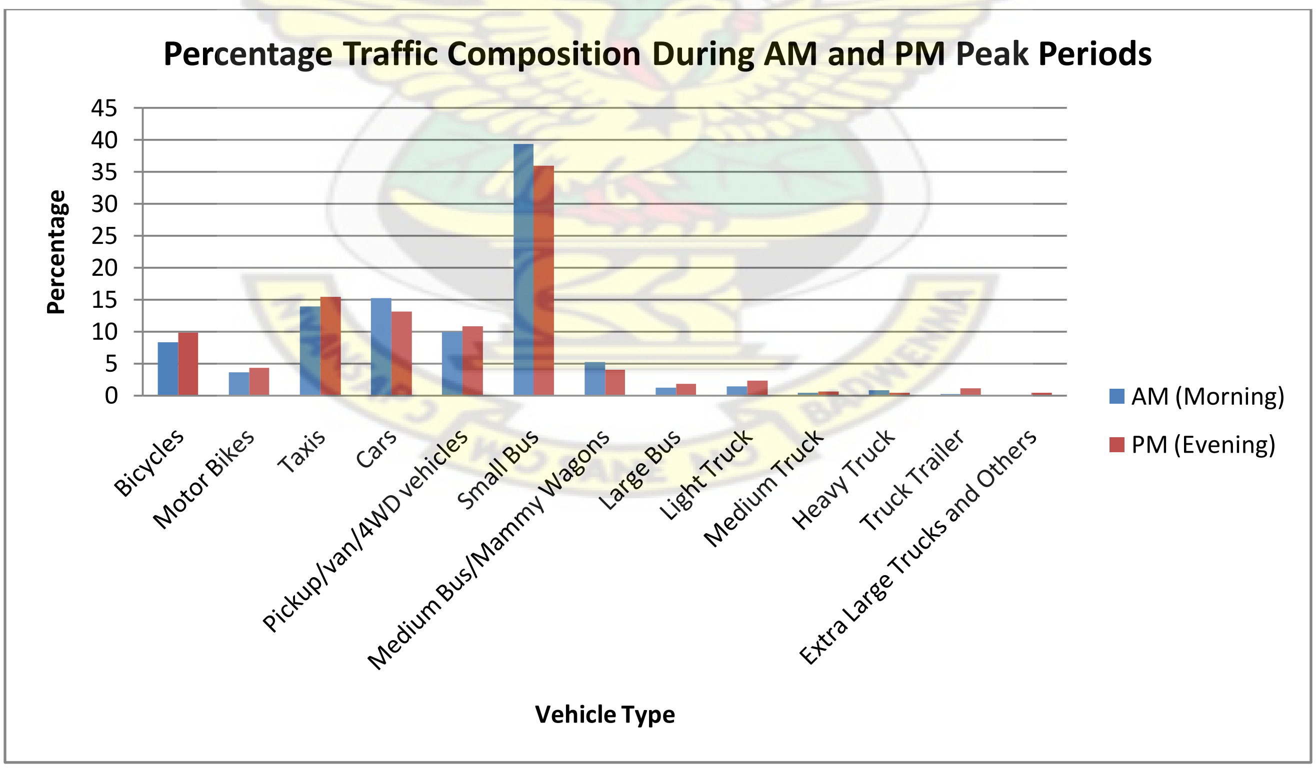

Figure A31: Percentage (%) Traffic Composition During AM and PM Peak Period for S31

City: Sekondi-Takoradi Location: Sekondi By-Pass Both Directions Station:S32

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	AM (Morning)	PM (Evening)
Bicycles	7.03	4.14
Motor Bikes	5.26	3.16
Taxis	18.02	17.77
Cars	16.31	16.15
Pickup/van/4WD vehicles	6.96	9.27
Small Bus	30.24	28.37
Medium Bus/Mammy Wagons	4.51	7.65
Large Bus	1.43	2.39
Light Truck	1.98	4.99
Medium Truck	3.07	2.11
Heavy Truck	3.69	1.54
Truck Trailer	1.43	2.25
Extra Large Trucks and Others	0.07	0.21
Peak Values	**1465**	**1424**

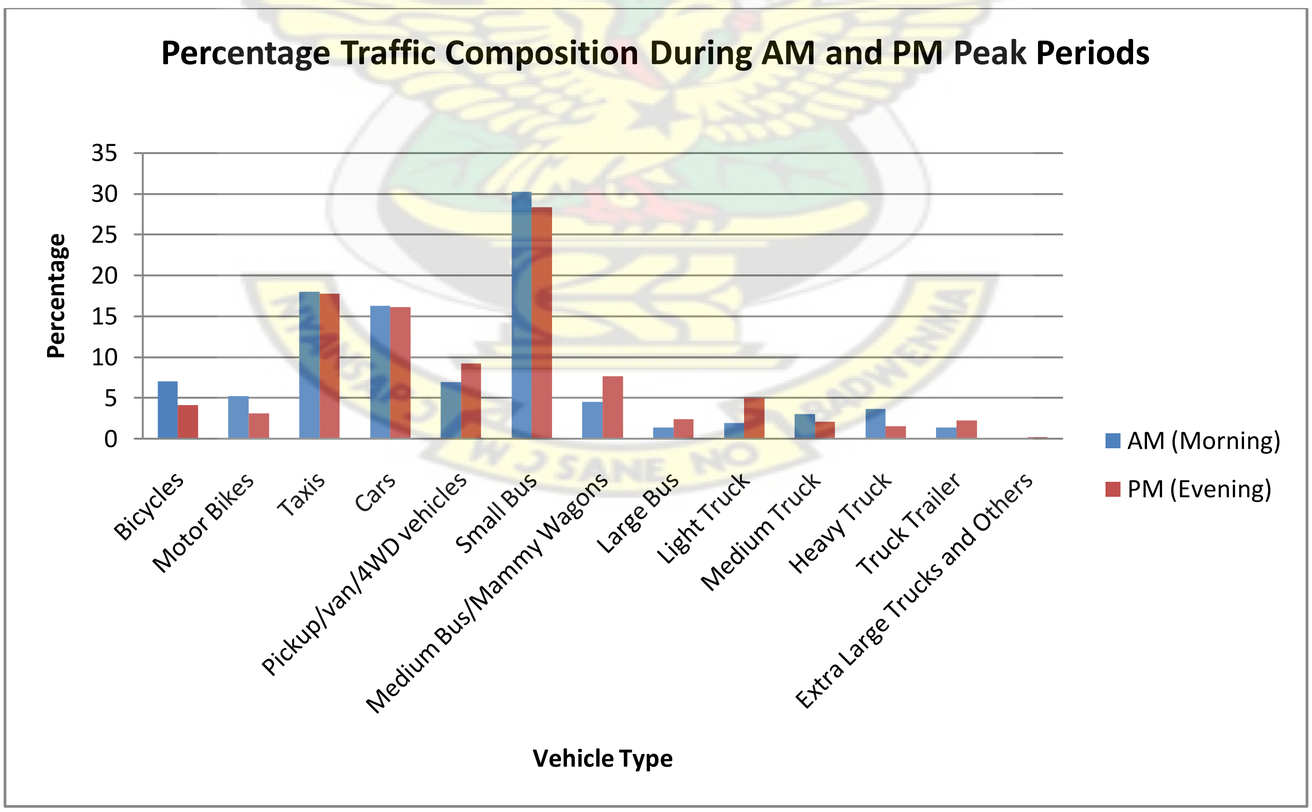

Figure A32: Percentage (%) Traffic Composition During AM and PM Peak Period for S3

City: Sekondi-Takoradi | Location: Sekondi By-Pass Both Directions | Station:S33

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	AM (Morning)	PM (Evening)
Bicycles	6.29	8.33
Motor Bikes	2.23	5.29
Taxis	12.19	11.64
Cars	11.93	12.96
Pickup/van/4WD vehicles	9.17	13.23
Small Bus	44.56	33.86
Medium Bus/Mammy Wagons	2.1	2.91
Large Bus	0.79	1.46
Light Truck	3.01	2.78
Medium Truck	1.05	0.93
Heavy Truck	4.46	2.65
Truck Trailer	2.23	3.97
Extra Large Trucks and Others	0	0
Peak Values	**763**	**756**

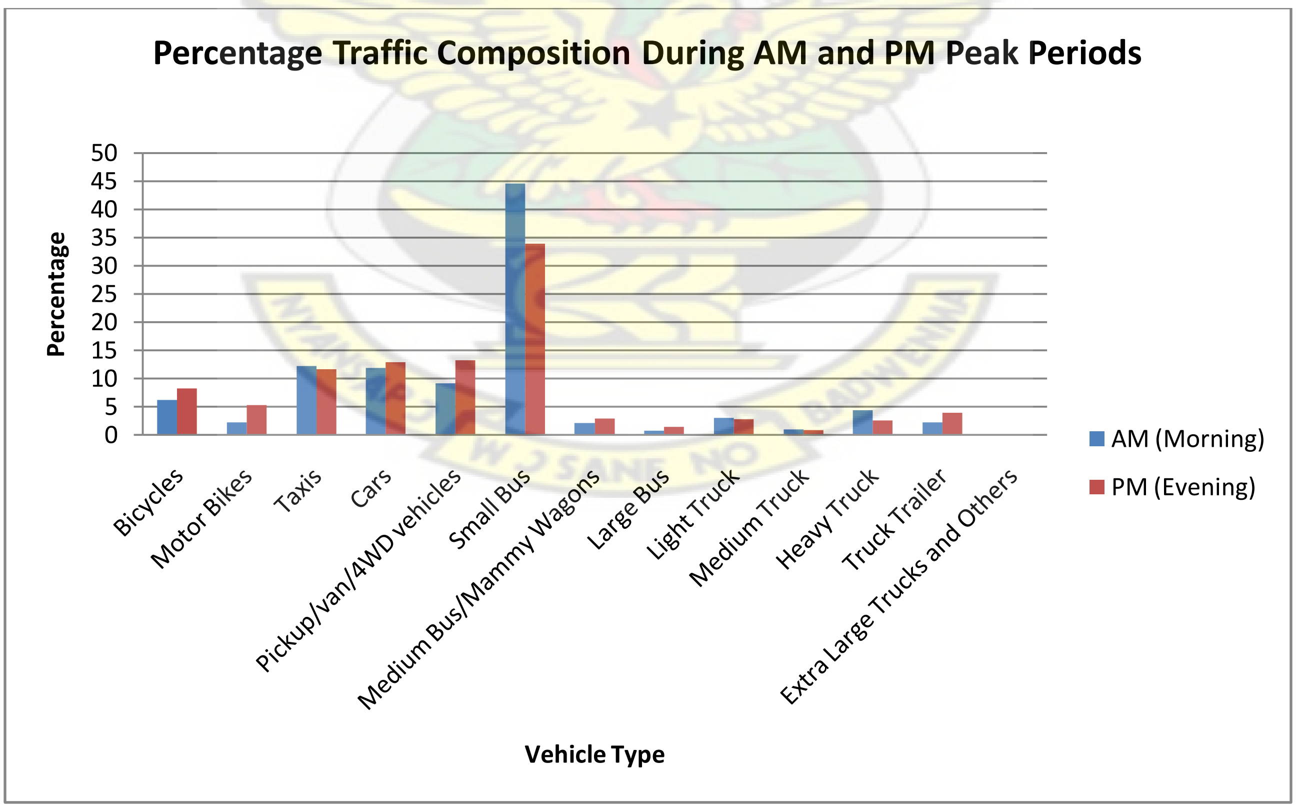

Figure A33: Percentage (%) Traffic Composition During AM and PM Peak Period for S33

City: Sekondi-Takoradi | Location: Ketan Road Both Directions | Station:S34

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	AM (Morning)	PM (Evening)
Bicycles	6.96	12.03
Motor Bikes	2.09	3.01
Taxis	64.5	52.63
Cars	11.14	11.28
Pickup/van/4WD vehicles	4.41	5.64
Small Bus	6.73	9.4
Medium Bus/Mammy Wagons	3.02	3.01
Large Bus	0.46	1.88
Light Truck	0.23	1.13
Medium Truck	0.23	0
Heavy Truck	0.23	0
Truck Trailer	0	0
Extra Large Trucks and Others	0	0
Peak Values	**431**	**266**

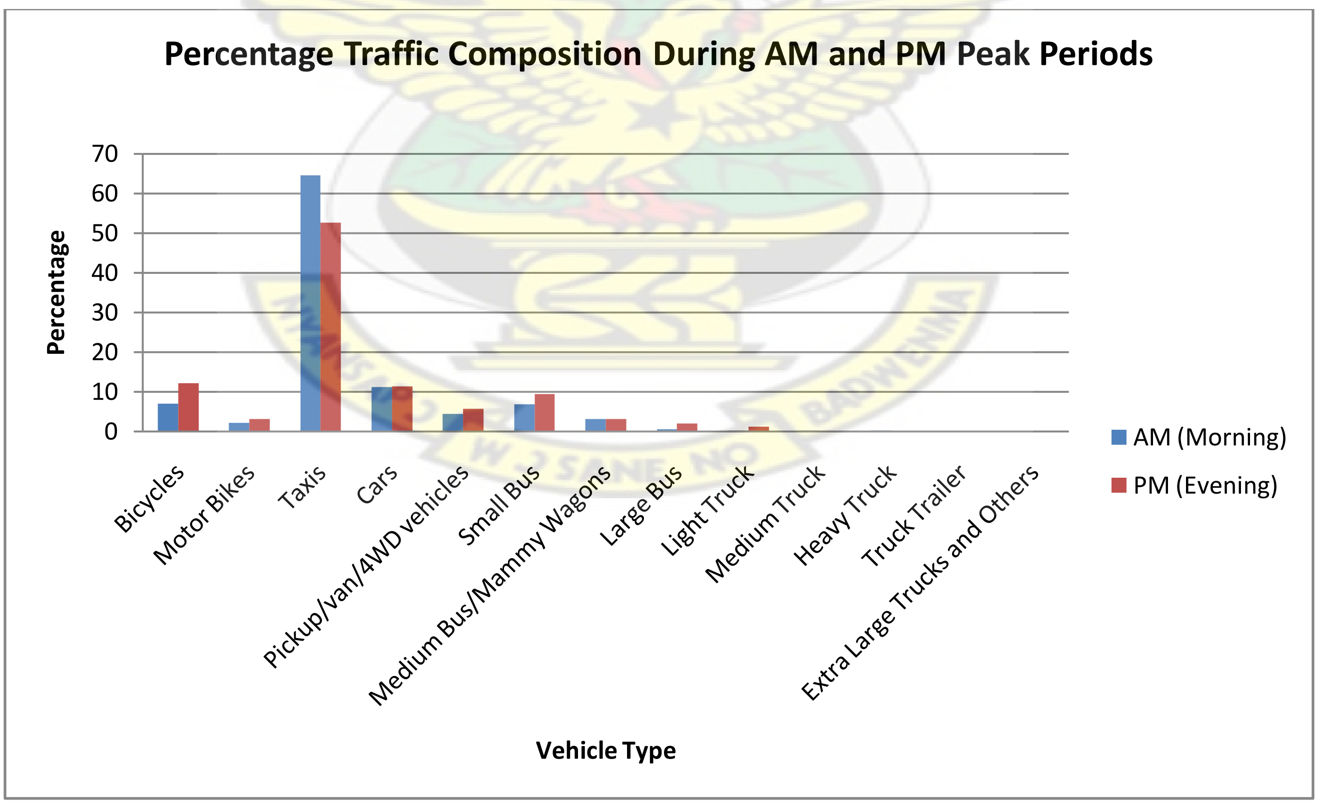

Figure A34: Percentage (%) Traffic Composition During AM and PM Peak Period for S34

City: Sekondi-Takoradi Location: Inchaban Road Station:S35

Both Directions

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	AM (Morning)	PM (Evening)
Bicycles	7.85	5.61
Motor Bikes	2.07	1.6
Taxis	32.11	26.69
Cars	17.03	16.84
Pickup/van/4WD vehicles	12.31	23.37
Small Bus	21.86	20.16
Medium Bus/Mammy Wagons	4.49	1.95
Large Bus	1.27	1.03
Light Truck	0.92	1.15
Medium Truck	0.12	1.57
Heavy Truck	0	1.03
Truck Trailer	0	0
Extra Large Trucks and Others	0	0
Peak Values	**869**	**873**

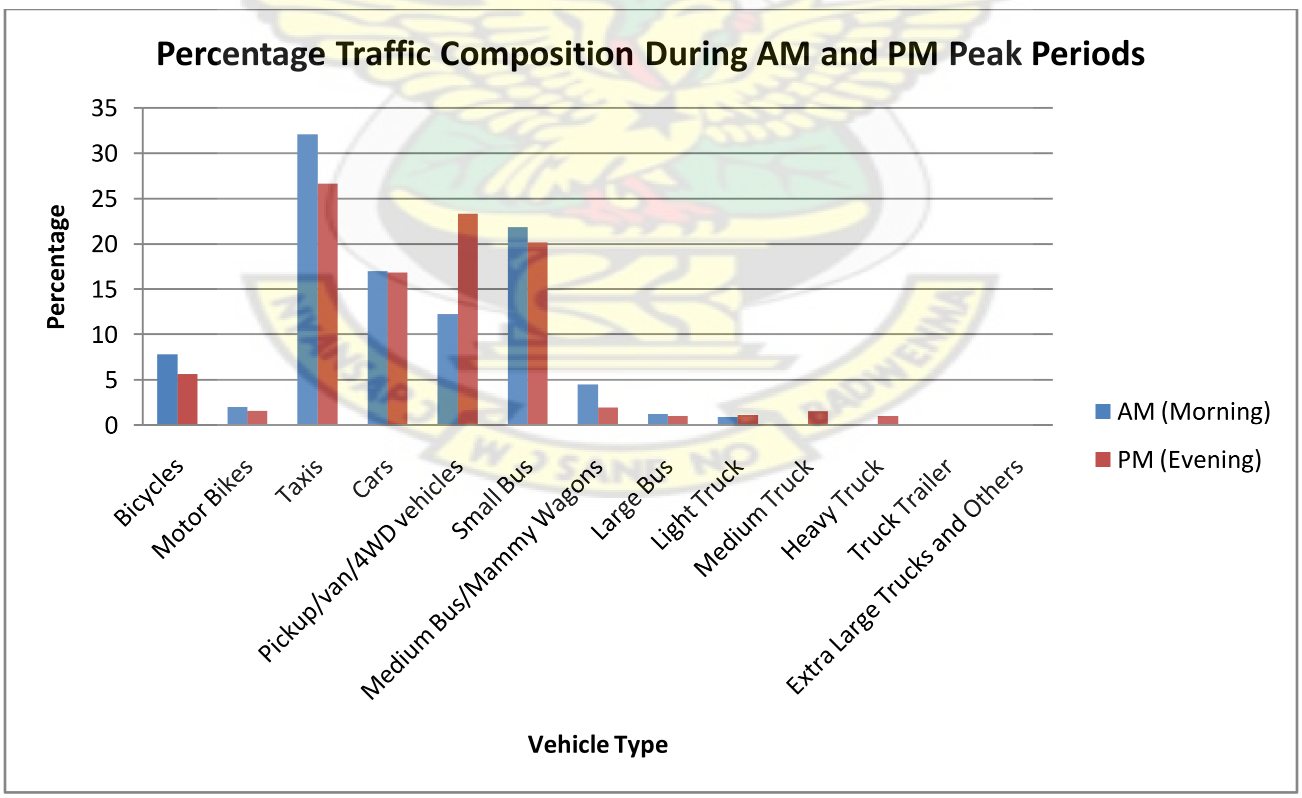

Figure A35: Percentage (%) Traffic Composition During AM and PM Peak Period for S35

City: Sekondi-Takoradi | Location: Poasi Road Both Directions | Station:S36

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	**AM (Morning)**	**PM (Evening)**
Bicycles	4.91	7.38
Motor Bikes	1.89	3.88
Taxis	37.05	34.56
Cars	17.01	17.67
Pickup/van/4WD vehicles	10.21	11.65
Small Bus	24.57	17.67
Medium Bus/Mammy Wagons	0.95	3.11
Large Bus	0.38	0.58
Light Truck	1.32	2.52
Medium Truck	0.57	0.78
Heavy Truck	0.57	0.19
Truck Trailer	0.57	0
Extra Large Trucks and Others	0	0
Peak Values	**529**	**515**

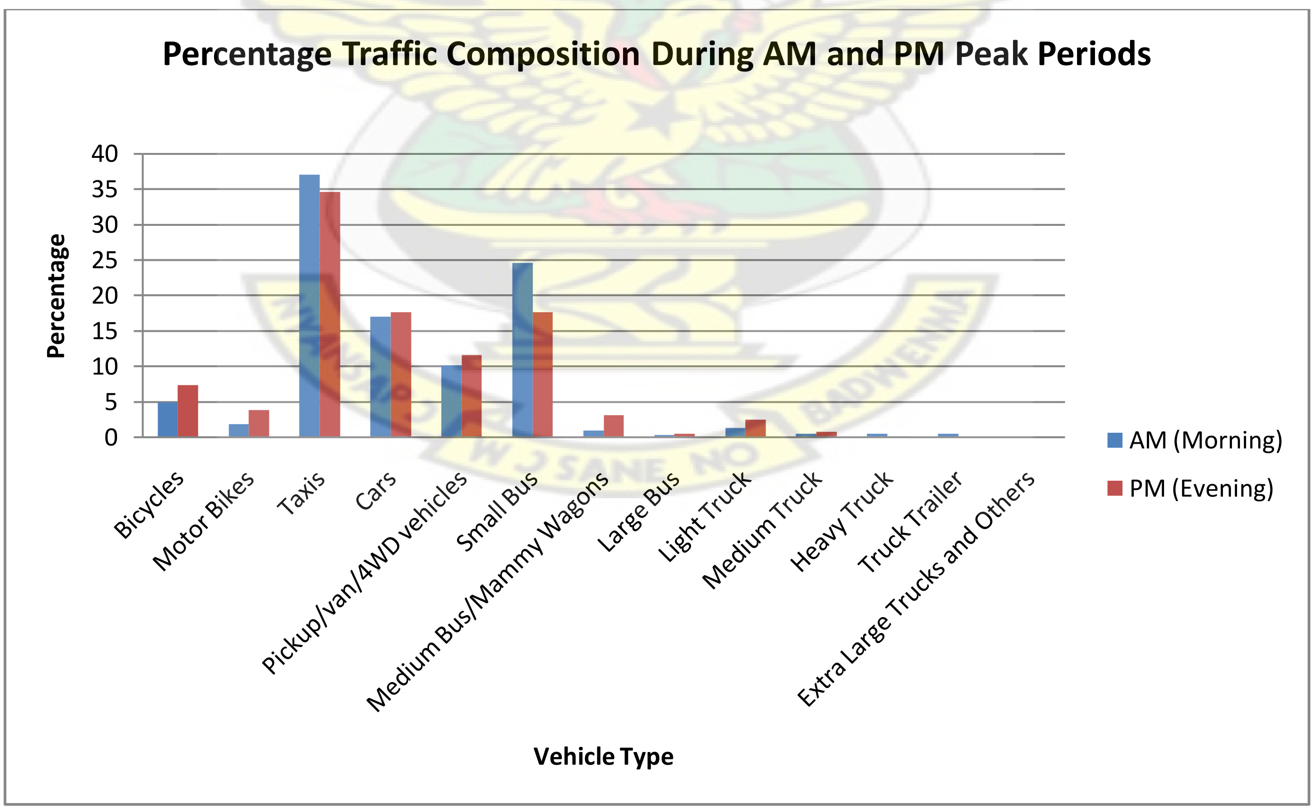

Figure A36: Percentage (%) Traffic Composition During AM and PM Peak Period for S36

City: Sekondi-Takoradi | Location: Fijai By-Pass Road Both Directions | Station:S37

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	AM (Morning)	PM (Evening)
Bicycles	7	3.43
Motor Bikes	1.02	2.82
Taxis	39.65	32.86
Cars	25.66	22.98
Pickup/van/4WD vehicles	10.5	15.12
Small Bus	7.58	9.07
Medium Bus/Mammy Wagons	2.04	1.21
Large Bus	1.02	0.81
Light Truck	0.87	4.03
Medium Truck	0.29	1.01
Heavy Truck	2.33	2.82
Truck Trailer	2.04	3.83
Extra Large Trucks and Others	0	0
Peak Values	**686**	**496**

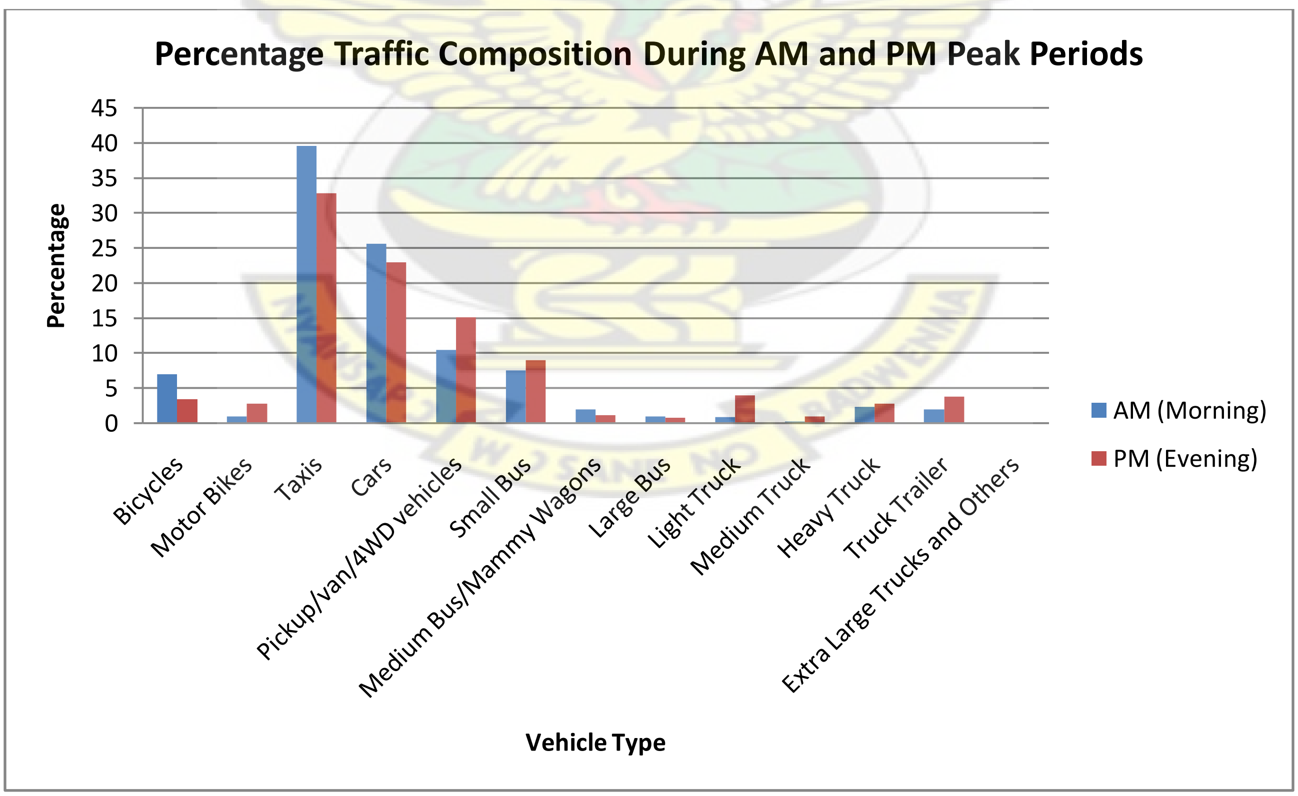

Figure A37: Percentage (%) Traffic Composition During AM and PM Peak Period for S37

City: Sekondi-Takoradi Location: Effia/CDH Road Station:S38
Both Directions

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	AM (Morning)	PM (Evening)
Bicycles	6.04	5.52
Motor Bikes	2.13	6.82
Taxis	30.2	27.92
Cars	28.77	29.55
Pickup/van/4WD vehicles	18.65	20.78
Small Bus	6.39	3.25
Medium Bus/Mammy Wagons	4.09	0
Large Bus	0	0
Light Truck	1.95	2.27
Medium Truck	1.24	1.95
Heavy Truck	0.36	1.3
Truck Trailer	0.18	0.32
Extra Large Trucks and Others	0	0.32
Peak Values	**563**	**308**

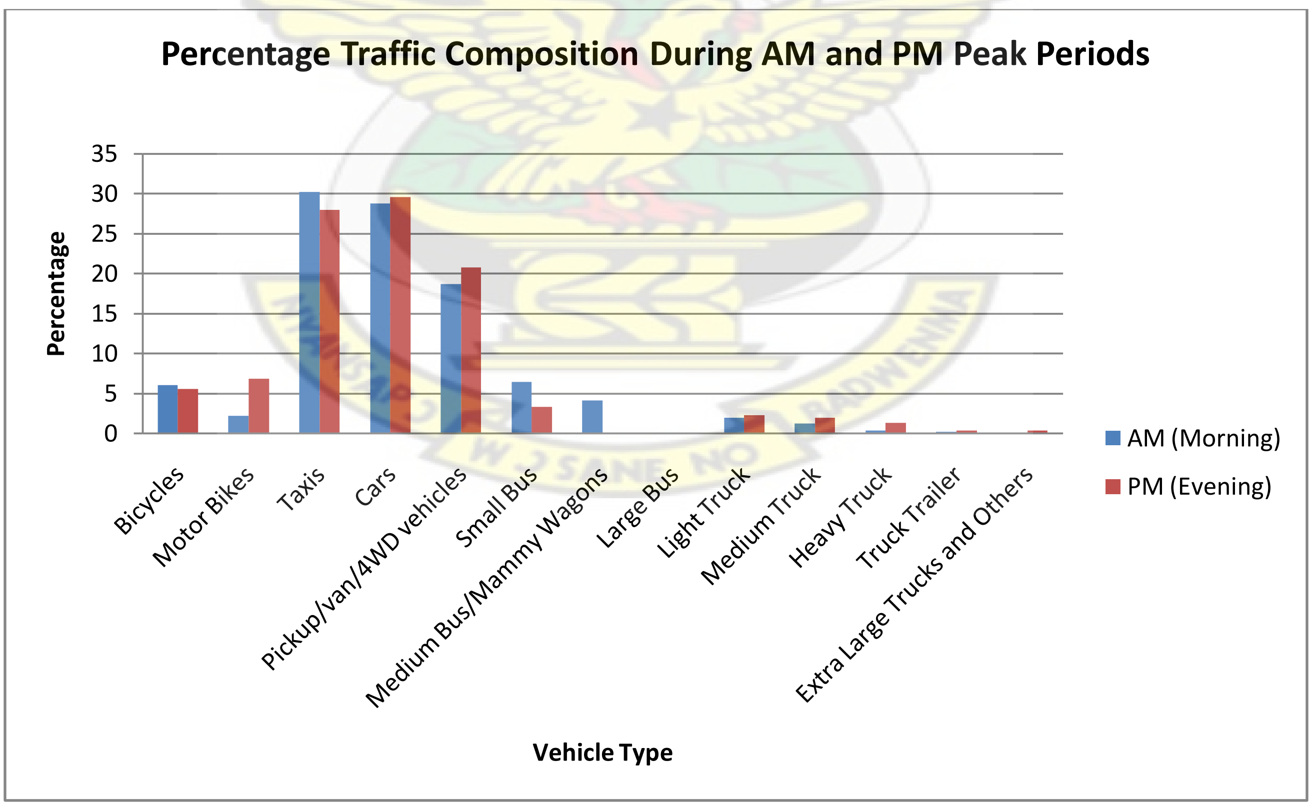

Figure A38: Percentage (%) Traffic Composition During AM and PM Peak Period for S38

City: Sekondi-Takoradi   Location: Takoradi Poly Road Both Directions   Station:S39

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	AM (Morning)	PM (Evening)
Bicycles	3.4	4.87
Motor Bikes	2.34	4.74
Taxis	63.59	54.5
Cars	18.37	22.26
Pickup/van/4WD vehicles	6.26	6.57
Small Bus	3.72	2.07
Medium Bus/Mammy Wagons	0.85	1.82
Large Bus	0.96	1.46
Light Truck	0.53	0.85
Medium Truck	0	0.49
Heavy Truck	0	0.24
Truck Trailer	0	0.12
Extra Large Trucks and Others	0	0
Peak Values	**942**	**822**

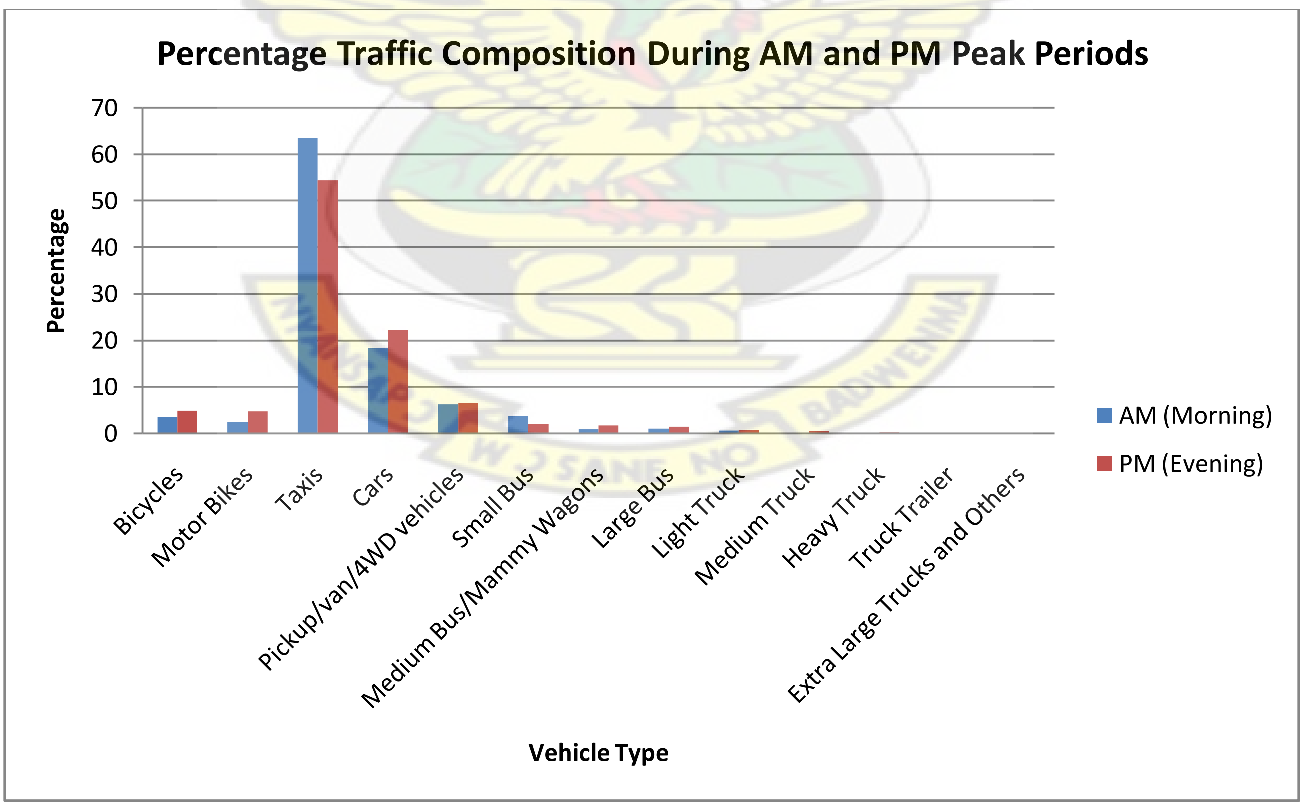

Figure A39: Percentage (%) Traffic Composition During AM and PM Peak Period for S39

City: Sekondi-Takoradi Location: East Tanokrom Road Both Directions Station:S40

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	**AM (Morning)**	**PM (Evening)**
Bicycles	2.83	3.54
Motor Bikes	2.09	4.1
Taxis	54.84	46.46
Cars	26.23	28.36
Pickup/van/4WD vehicles	8.49	9.7
Small Bus	2.24	5.41
Medium Bus/Mammy Wagons	1.04	0
Large Bus	1.19	1.12
Light Truck	0.89	0.56
Medium Truck	0	0
Heavy Truck	0	0.19
Truck Trailer	0.15	0.56
Extra Large Trucks and Others	0	0
Peak Values	**671**	**536**

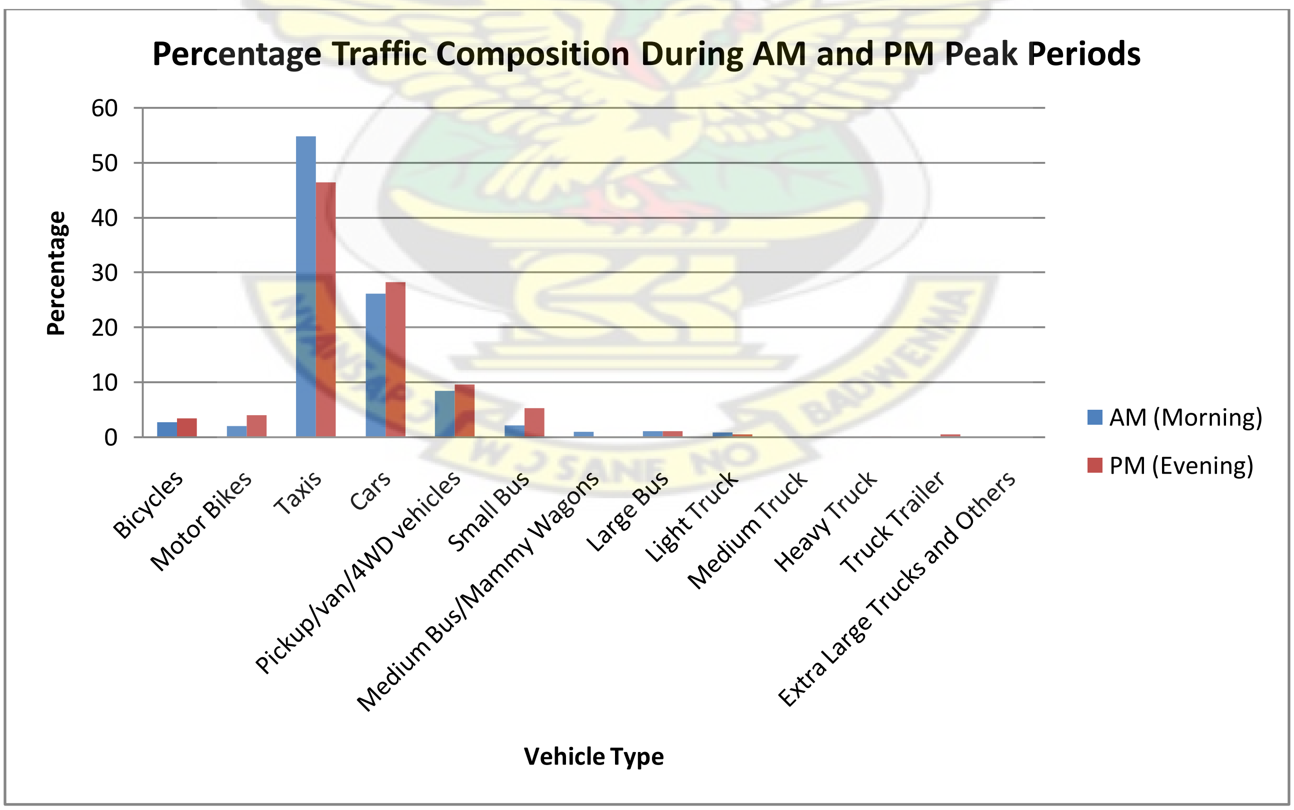

Figure A40: Percentage (%) Traffic Composition During AM and PM Peak Period for S40

City: Sekondi-Takoradi		Location: Kasanworado Apremdo Road Both Directions		Station:S41

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	AM (Morning)	PM (Evening)
Bicycles	10.34	13.48
Motor Bikes	3.56	3.68
Taxis	46.27	35.78
Cars	11.36	14.71
Pickup/van/4WD vehicles	11.19	8.58
Small Bus	9.49	9.31
Medium Bus/Mammy Wagons	0.85	2.21
Large Bus	0.34	0.49
Light Truck	3.05	5.64
Medium Truck	0.34	0.74
Heavy Truck	2.71	2.94
Truck Trailer	0.51	2.45
Extra Large Trucks and Others	0	0
Peak Values	**590**	**408**

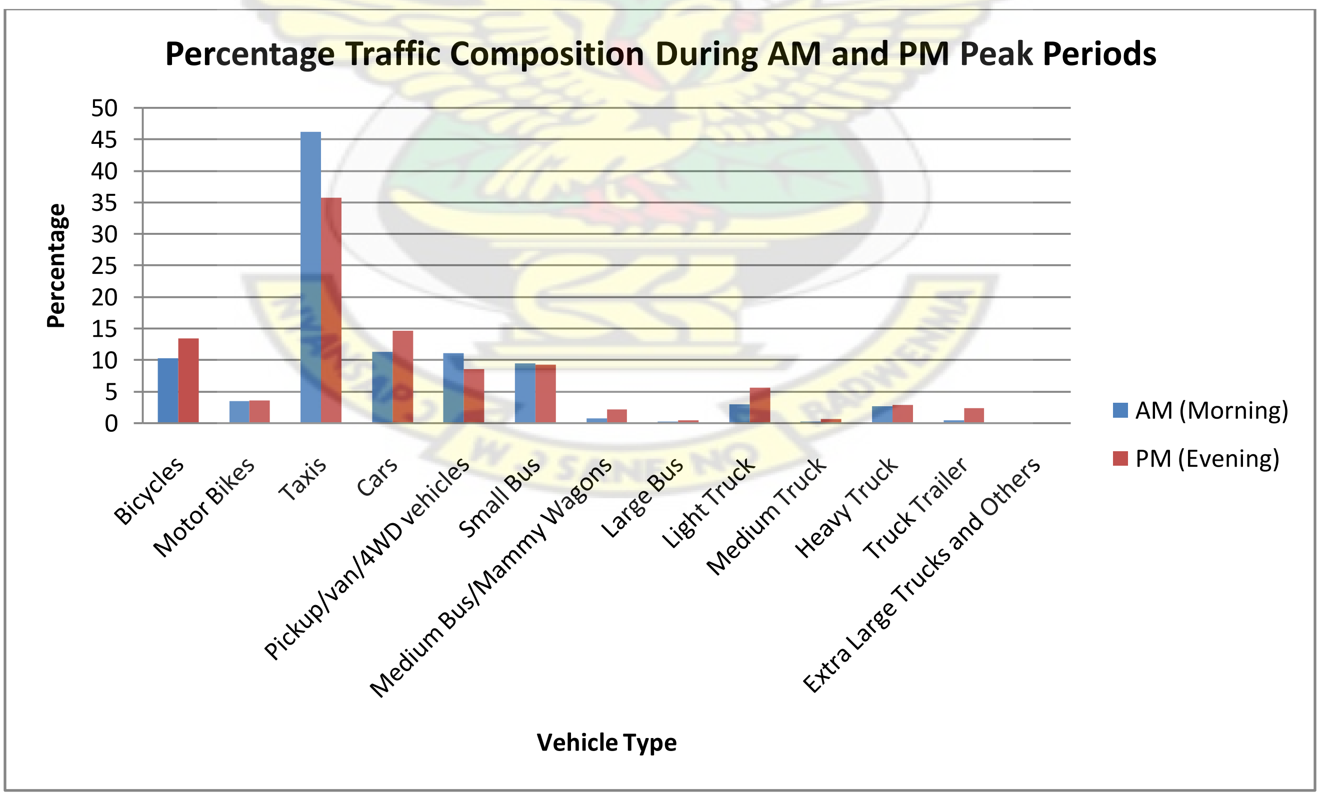

Figure A41: Percentage (%) Traffic Composition During AM and PM Peak Period for S41

City: Sekondi-Takoradi Location: Anaji Estate Road Both Directions Station:S42

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	AM (Morning)	PM (Evening)
Bicycles	7.33	10.9
Motor Bikes	4.15	3.16
Taxis	35.13	37.96
Cars	31.12	26.54
Pickup/van/4WD vehicles	11.89	8.96
Small Bus	5.81	9.84
Medium Bus/Mammy Wagons	2.63	0.53
Large Bus	0.69	0.35
Light Truck	0.83	1.58
Medium Truck	0.14	0
Heavy Truck	0.28	0.18
Truck Trailer	0	0
Extra Large Trucks and Others	0	0
Peak Values	**723**	**569**

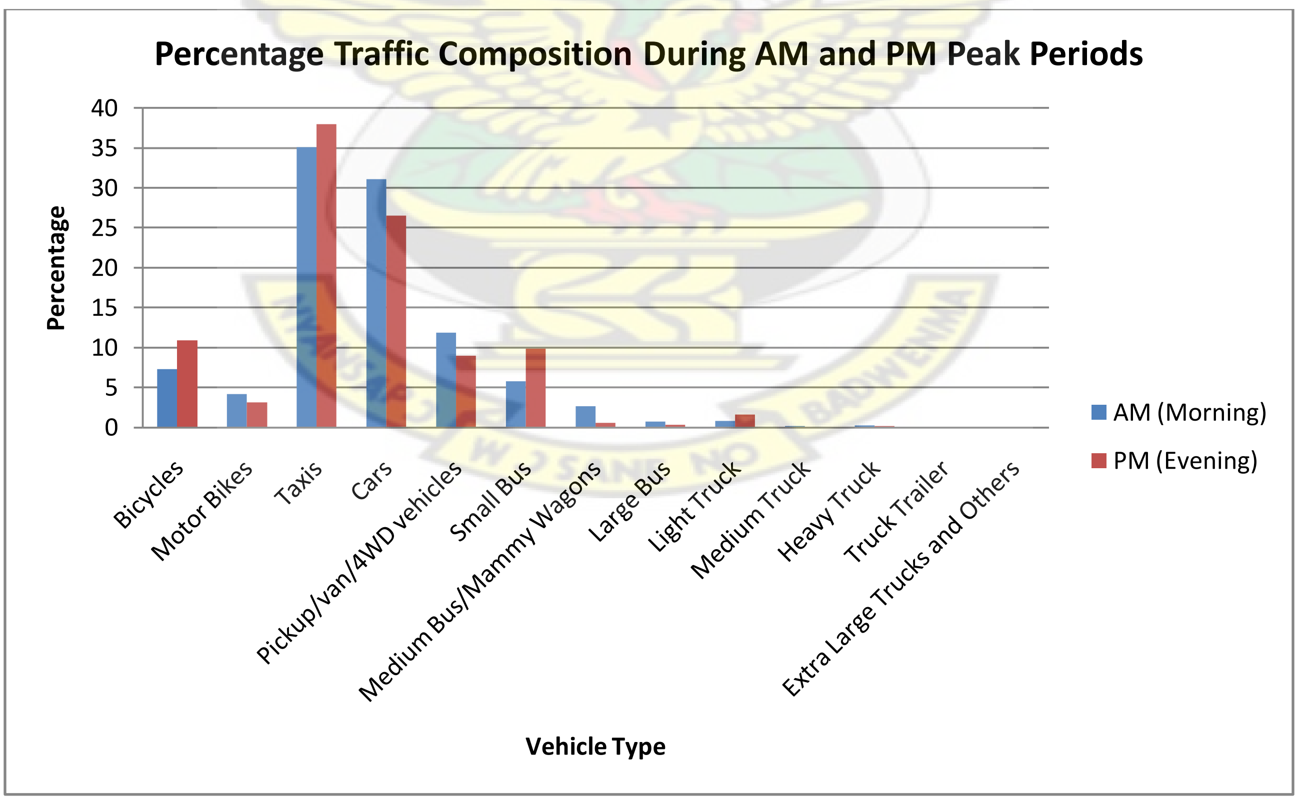

Figure A42: Percentage (%) Traffic Composition During AM and PM Peak Period for S42

City: Sekondi-Takoradi   Location: Tanokrom Road   Station:S43
Both Directions

Percentage (%) Traffic Composition During AM and PM Peak Period

VEHICLE TYPES	**AM (Morning)**	**PM (Evening)**
Bicycles	6.42	4.27
Motor Bikes	5.12	2.68
Taxis	48.84	41.17
Cars	25.95	27.95
Pickup/van/4WD vehicles	7.81	17.57
Small Bus	2.98	2.85
Medium Bus/Mammy Wagons	0.84	2.09
Large Bus	0.56	0.42
Light Truck	1.21	1
Medium Truck	0.09	0
Heavy Truck	0.09	0
Truck Trailer	0	0
Extra Large Trucks and Others	0.09	0
Peak Values	**1075**	**1195**

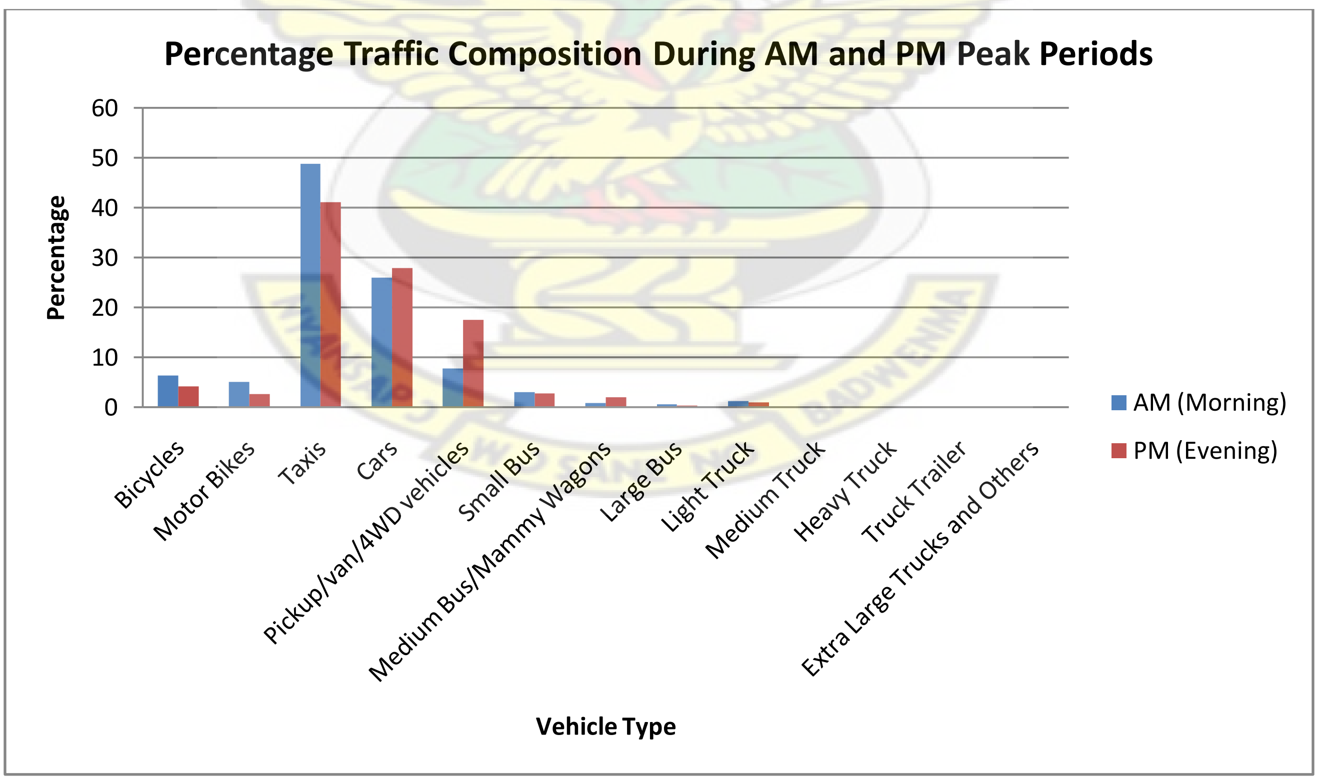

Figure A43: Percentage (%) Traffic Composition During AM and PM Peak Period for S43