Assessing the Impact of Vehicular Traffic on Energy Demand in the Accra Metropolis

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Traffic congestion is a great concern to many nations especially the developing ones. In this paper we examine the road traffic congestion construct. Mixed methods were used and analyzed using the Statistical Package for Social Scientists. Using the data from Ghana, we found that congestion has two main dimensions (i) narrowing of roads and (ii) artificial blockage of roads. From the analyzed data, it was established that, the congestions on our roads are being influenced by four-phase traffic theory, called BAM theory. This theory is the best used when dealing with intelligent traffic management systems.

INTRODUCTION

Traffic congestion in urban areas at crest hours has numerous repercussions on our national economy; one of them is augmented energy demand on transportation. Some potential elements in urban planning are transport and energy consumption. Reducing energy demand on transportation is a topic which is becoming increasing important as efforts to attain millennium goals and sustainable life styles as well as sustainable travel behaviour are being sought, yet proving intractable to achieve here in Ghana (Hickman and Banister, 2007).

Without well-developed transportation systems, logistics could not convey its return into full play. However, a good transport system in logistics activities could provide better logistics efficiency, reduce operational cost, and promote service quality. The improvement of transportation systems needs the effort from both public and private sectors. A well-operated logistics system could increase both the competitiveness of the government and enterprises (Tseng and Yue, 2005).

The transport sector plays a key role in economic development. In West Africa, the sector generates about six percent (6%) of total Gross Domestic Product (GDP) and about 4.8 percent of Ghana's GDP (Ghana Statistical service, 2007). However, inefficiency prevails due to the high cost of vehicle operation. In Ghana, roads are the predominant mode of transport accounting for about ninety-four percent (94%) of freight and ninety-seven percent (97%) of passenger traffic movements. The subsector is the most viable alternative apart from rail to transport, bulk commodities like manganese, bauxite, timber and cocoa. The railway network operates at limited capacity with low efficiency (Last, 2008). All the same, among the benefits that trains are expected to deliver to cities are capacity expansion of the current congested transportation infrastructure; reducing the geographical isolation of the towns within region; improving cohesion and quality of life in the city by stimulating the Ghanaian economy; and reducing the external costs of transportation in the region. Road transport presently represents sixteen percent (16%) of worldwide energy demand and forty-six percent (46%) of worldwide demand for petroleum products. Traffic information is incontestably important to all and sundry particularly for businesses in Ghana. With precise and current traffic information, a better traveling arrangement can be prepared which will translates to reduction in time and energy consumption (Poolsawat et.., al., 2009). The underlying issue for conducting this research was to find out how to minimize traffic and its adverse, yet fulfilling the demand for accessibility in support of the efficient distribution of goods and services in Ghana. This is to enhance economic and social goals. Thus the study aimed at assessing the impact of efficient logistics on urban transport energy demand. The rest of the paper is organized as follows: The next section present relevant review literature, following, we present our research methods and then continue with the presentation of the results and discussion. Finally we conclude the paper highlighting the findings, implications and potential recommendations.

LITERATURE REVIEW

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, this results in some congestion. As demand approaches the capacity of a road (or of the intersections along the road, extreme traffic congestion sets in (Downie, 2008). Palma and Lindsey, (2011) found that, Traffic congestion is common in large cities and on major highways and it imposes a significant burden in lost time, uncertainty, and aggravation for passenger and freight transportation cost which is esteemed at around half the wage rate (Small, 1992).

Traffic congestion occurs when a volume of traffic or modal split generates demand for space greater than the available road capacity. 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.

According to Baskar, (2009), owing to the ever-increasing traffic demand, modern societies with well-planned road management systems, and sufficient infrastructures for transportation still face the problem of traffic congestion. This results in loss of travel time, and huge societal and economic costs. Constructing new roads could be one of the solutions for handling the traffic congestion problem, but it is often less feasible because of political and environmental concerns.

According to Baskar (2009), Traffic congestion in highway networks is one of the main issues to be addressed by today’s traffic management schemes. Automation combined with the increasing market penetration of on-line communication, navigation and advanced driver assistance systems will ultimately result in intelligent vehicle highway systems (IVHS). Due to this, an extension to the current traffic control approaches, advanced technologies in the field of communication, control and information systems have been combined with the existing transportation infrastructure and equipment.

D‟Este (2000) concedes the importance of integrating congestion into the modeling of freight movements in urban areas, particularly as that is where congestion delays are concentrated. Taniguchi et al (1999), industrial a representation for determining the optimal size and position of these public logistics terminals which incorporates a „travel time performance function‟ on ordinary urban roads and expressways.

According to Baskar et al., (2009), congestion management and control methods are used to control the traffic flows and to prevent or reduce traffic jams, or more generally to improve the performance of the traffic system. Potential performance measures in this circumstance are throughput, travel times, safety, fuel consumption, emissions, reliability etc. Currently implemented traffic management approaches primarily make use of roadside based traffic control measures (such as ramp metering, traffic signals, dynamic route information panels and dynamic speed limits) and infrastructure-based equipment (including sensors and traffic control centres).

Transport in Ghana is consummate by road, rail, air and water. Ghana's transportation and communications networks are centered in the southern regions, especially the areas in which gold, cocoa, and timber are produced. The northern and central areas are connected through a major road system; some areas, however, remain relatively isolated (Wikipedia 2007). Earlier research by Tiwari (2002) found that, travel distinctiveness of big cities in high-income countries vary from those in low- and middle-income countries in the use of mass rapid transit and commuter rail systems. According to Tiwari et al., (2007) there are two kinds of traffic - homogeneous and non-homogeneous. Homogeneous traffic has stern lane control and has traffic entity types whose physical dimensions do not vary much.

According to APEC (2006), Japan prediction shows that, by 2030, oil is likely to continue to be the major energy source for the transport sector Whiles by that same duration road transport is projected to account for about eighty percent (80) of total transport energy demand. APEC's net oil import dependence will jump from the current 36 percent to 52 percent by 2030. Over the outlook period, energy demand in the transport sector is projected to grow at an annual rate of 0.4 percent per year, compared with the previous two decades at 2.5 percent per year. Energy demand for road transport is projected to increase by an annual rate of 0.2 percent, maintaining the largest share at around 78 percent of the total transport energy demand. Gasoline for passenger vehicles is expected to increase by 0.5 percent per year, compared with that of 2.6 percent in the previous two decades.

METHODOLOGY

The population of the study included all drivers in Accra Metropolitan Area as well as officials of Urban Roads, National Petroleum Authority, Driver Vehicle License Authority and Ghana Statistical Service. A convenience sample 500 personnel were interviewed out 1,658,937 being the population the metropolis. Both primary and secondary data were used in this study. A combination of various data collection techniques were utilized in this study including interviews, observation, documentary analysis and questionnaire administration. To gain a deeper understanding of the system, semi-structured interviews were used for the drivers. In other words, a series of questions were asked to cover specific interested areas without necessary following the pre-set questionnaire. Given the nature of the issues that were being investigated, a combination of quantitative and qualitative methods was used in the analysis of the study; with the qualitative tools being used more extensively. Data collected were analyzed using Microsoft Excel 2007 and Statistical Package for Social Scientist (SPSS).

RESULTS, PRESENTATION, ANALYSIS AND DISCUSSION

Causes of Road Traffic Congestion in Accra Metropolis

Form the data gathered it was found that congestion in Accra Metropolis are as a results of eight routes causes which is best grouped into four categories called ''BAM FACTORS'' of road congestion.

BAM FACTOR 1- Horizontal Causes of Congestions

Poor road network; Transportation engineers have long studied and addressed the physical capacity of roadways—the maximum amount of traffic capable of being handled by a given highway section. Capacity is determined by a number of factors: the number and width of lanes and shoulders of roads; merge areas at interchanges; and roadway alignment (grades and curves). These things are completely absent on the five highways understudied.

Road checkpoints; The several road checkpoints erected by Police officers also contribute to serious traffic congestions and further restrict the flow of the traffic on our roads.

Pedestrian obstruction; The missing crosswalks sometimes forces pedestrians to cross the roads at many different parts which eventually leads to congestions in different parts of the same road.

BAM FACTOR 2- Vertical Causes of Road Congestion

(i) Trading obstruction; are events that disrupt the normal flow of traffic, usually by physical impedance in the travel lanes. In addition to blocking travel lanes physically, events that occur on the shoulder or roadside can also influence traffic flow by distracting drivers, leading to changes in driver behavior and ultimately degrading the quality of traffic flow.

(ii) Narrow traffic lanes; Construction of roads with narrow lanes several years ago is now causing serious congestions in Ghana. With the width of most of our roads in Ghana, many of the modern heavy vehicles has a wider width reducing the lane widths on our roads. This can sometimes makes it impossible for some of the vehicles to overtake each other's and this tend to slow down the speed of vehicles on the roads especially in central Business Areas, Malam Road, Ofanko Road and the Sprintex road. On urban roads, where speeds are limited to 50kph, this can sometimes be slow down the speed of the vehicles to 5kph or lesser than that.

(iii) Reserved Parking lots; It was observed from most of these arterial roads that the various shops, offices and churches along it had either no or inadequate parking spaces. As a results of this, a lot their customers tend to park their cars along the shoulders of the road. Lack of pullouts, or designated stopping points for jitneys results in numerous interruptions to flow of the vehicles, even within non-conflicting streams of traffic which seriously contribute to the road congestion.

BAM FACTOR 3- Traffic Control Devices

Traffic control congestion; Intermittent disruption of traffic flow by control devices such as railroad grade crossings and poorly timed signals also contribute to congestion and travel time variability.

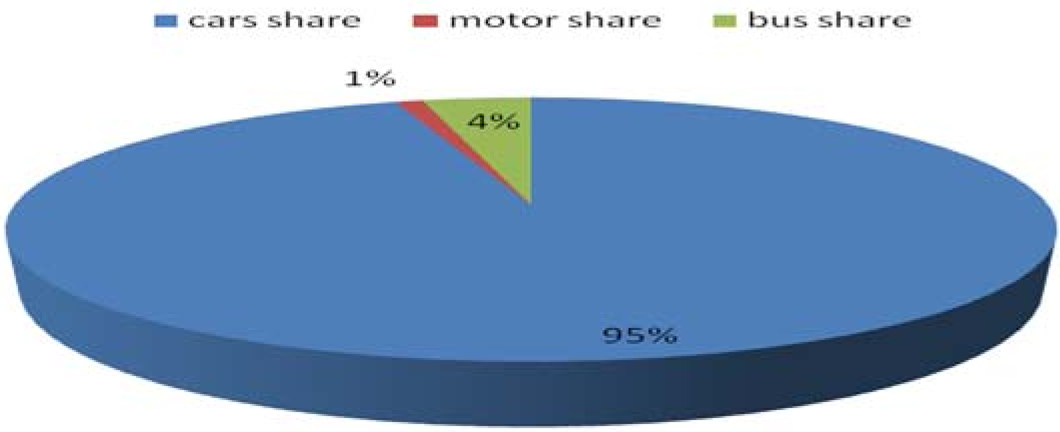
BAM FACTOR 4- Loading

Picking of Passengers along the road; In Accra most of the taxi and commercial minibuses (trotro) do not have permanent terminals and routes. They move around picking passengers along the routes. Landmarks may serve as route names or route termini. These taxis and trotro can also be boarded anywhere along the routes which is obviously causes road traffic congestion in the city.

URBAN TRANSPORT STRUCTURE

It is interesting to note from the data gathered that the cars (which consist of Private Motor Vehicles (PMV) and Commercial Motor Vehicles with their Consumption Capacities (CC) up to 2000 constitute about 95 percent on our roads whereas the buses and coaches which are able to pick an average of six times the number of passengers for the cars constitute only 4 percent (see Figure 1and Table 1) contributing to the traffic congestion on our roads which also resulting in high energy (fuel) demand and the delay in distribution of goods and services. Urban congestion is set to get worse under current trends of increases in these categories of cars for growth in traffic.

FIGURE 1
URBAN TRANSPORTATION STRUCTURE



Source: Field Survey, 2009

From Figure 1 and Table 1 (See Appendix), public transport buses and train services have declined in the face of increasing ownership to the use of personal cars, reducing the mobility of disadvantaged groups and the use of more fuel by these cars. The reasons accounting for this, is that, large municipal buses have been unable to compete effectively for trips to the Central Business Area (CBA) of Accra due to high levels of delay and inability to maintain any semblance of a regular schedule. Thus the traffic flow comprises of multitudes of "mini buses" type of public transportation vehicles intermingled with private saloon cars, trucks and taxis.

USAGE OF ROAD INFRASTRUCTURE

There are about 775 km of paved roads and 658.37 km unpaved roads (Table 2) and 75 km of the paved roads are the main arterial whilst the rest are minor arterial, collectors and local roads. These have been estimated to be 300 – 400kms.

TABLE 2
LENGTHS AND NATURE OF ROAD SURFACE

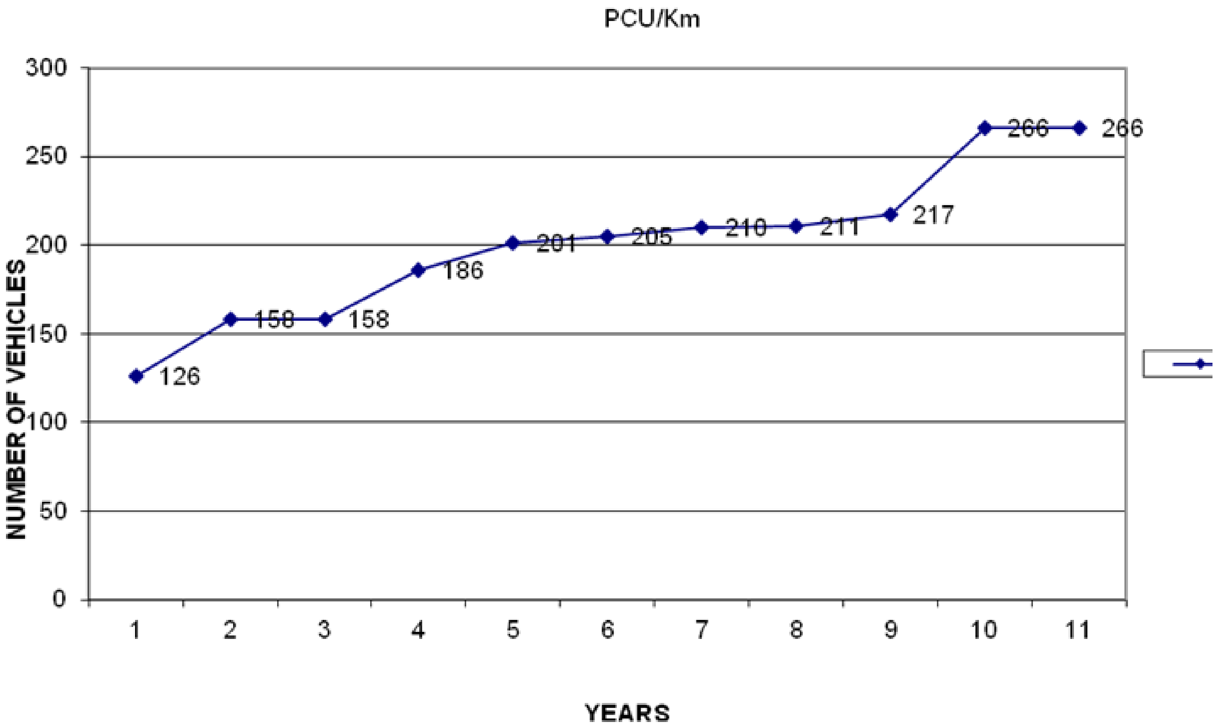
	Paved Roads		Unpaved Roads		Total
		%		%	
Accra	775 km	54	658.37 km	46	1433.37 km
Country	1935.10 km	47.6	2128.85 km	52.4	4062 km

Source: Department of Urban Road, 2002

According to classification of Department of Urban Road forty- five percent (45%) of Accra roads are in poor condition. This figure is higher than the national average of forty- three percent (43%). The primary road network in Accra radiates out from the Kwame Nkrumah Circle to Accra Central, Ofanko barrier, Medina, Spintex road, Malam Junction Road corridors. It is estimated that about eighty percent (80%) of vehicular traffic in Accra Metropolis has these road corridors as their destination. Peak hours Traffic is when the road network is heavily loaded and in the mornings it was found to range between

6:30 – 10:00 GMT. This is the most loaded morning period of traffic in the Accra Metropolis. Evening Peak Hour (EPH) traffic matrix in Accra metropolis was also found out to be ranging between 16:00 and 20:00 GMT and which is slightly longer than the morning period traffic.

FIGURE 2
ROAD OCCUPANCY OF VEHICLES



Source: Field Survey, 2009

Considering the usage of roads, figure 2 show the eleven year (1997-2007) period ratio of "the number of motor vehicles over total length of roads" in Accra Metropolis. For the (x-axis) – Numbers (1-11) in Figure 3, represent the years 1997-2007 whiles the vertical axis depicts the length of road, with most of these traffic occurring between, 2000-2007. The numbers of vehicles within that period (2000-2007) were much higher than 180 unit/Km, which were been taken as the highest limitation of the above ratio and this confirms that there are severe traffic congestion on the five arterial principal roads under study in Accra Metropolis. This is due to the growth of motor vehicles which were not controlled in Accra Metropolis and for that matter Ghana as a whole by the Driving and Vehicle Licensing Authority (DVLA) and this account for the congestion on our roads in Ghana.

Though each day there are more vehicles which are not driven on our roads in the Metropolis, the load on roads in the city is still very high as shown by the figure 2. Something has to be done to check this increasing passenger car per kilometer trend otherwise severe traffic congestion is going to occurred on our roads and this will be resulting in high fuel consumption, which is not due to an expansion of our economy but inefficiency in our logistics system.

URBAN TRANSPORT SERVICE LEVEL

TABLE 3
COMPARISON OF URBAN TRANSPORTATION SERVICE LEVEL

ROADS	DISTANCE FROM NKRUMAH CIRCLE (KM)	AVERAGE TRAVEL TIME WITHOUT TRAFFIC (MINUTES)	AVERAGE TRAVEL TIME WITH TRAFFIC (MINUTES)	CONGESTION COST
CBA	3.4	30	70	40
SPINTEX ROAD	16.4	45	105	60
MADINA	13.0	60	180	120
OFANKOR BARRIER	7.7	20	55	35
MALAM JUNCTION	8.7	75	148	73

Source: Modified from Urban Roads –Accra (2009)

Analysis of travel speed survey for the purposes of calibrating the traffic model and traffic management aspects, floating vehicle journey-time surveys were conducted in the five arterial-roads. Results for the average morning and evening peak hours are schematize in table 3 and detailed analyses of travel times for all road links are summarize in the Table 3. From Table 3, the distances of the five principal arterial roads under study and the congestion costs which is the difference between the times taking to travel in non-congestion route and time taking to travel on congested route. Looking at congestion cost is really significant cost for the metropolis and is consistent with the work of Small, (1992). Additional impacts of these congestion on motorized travel, includes the delay and the travel foregone, which are usually ignored, although they are often significant compared with costs that are considered, particularly in urban areas (Tiwari, 2007).

SUMMARY OF KEY FINDINGS

In summary, it is significant to note that without well-developed transportation systems, logistics could not bring its advantages into full play. Besides, a good transport system in logistics activities could provide effective distribution system in the economy, drastically reducing business operational costs, and promote service quality. The improvement of transportation systems needs the effort from both public and private sectors. A well-operated logistics system could increase both the competitiveness of the government and enterprises. From the above analysis it was established that, traffic congestions in Accra metropolis are influence by BAM theory which constitute eight root causes- Poor road network, Road checkpoints, Pedestrian obstruction, Trading obstruction, Narrow traffic lanes, Reserved parking lot, Picking of passengers and Traffic control congestion.

Also the absence of rail based transport system and inadequate city buses in Accra Metropolis has led to frequent use of cars leading to congestion in city roads. Public transport buses and train services have declined in the face of increasing use of cars, reducing the mobility of disadvantaged groups and causing extremely unpleasant traffic congestions leading to high energy demand.

The rapid increase in vehicles on roads without corresponding increasing in road space is causing heavy congestion in many parts of the city. During the past 10 years (1997-2007), the length of road has not seen any significant increase, while the number of road worthy vehicle registrations increased by more than double (Table 1). The imbalance in growth of road length and vehicle registration has resulted in most of the serious traffic congestion we see in our roads. The effect of this is more consumption of fuel energy on our roads which also have a negative effect on the economy because of government subsidy.

The cost of oil dependency are essentially a huge cost to a national economy (specifically that of Ghana) of various features of the world oil market that cause problem to a nation relying heavily on oil imports. There is a considerable scope to improve the fuel efficiency of vehicle fleets, not mainly through technological changes but also to some extend through consumer choices among the number of vehicle in system, vehicles size and types, maintenance culture and the use of right fuel. As a result, we should not expect to see dramatic changes in modal shares or in the nature of transport system. Furthermore, this unresponsiveness suggests that it is costly to reduce energy use in transport, relative to other economic activities, and thus the efficient policies will probably not extract as much energy savings (in percentage terms) from transport as from other sectors.

CONCLUSION AND RECOMMENDATION

Traffic congestion in the urban areas are one of the main logistics issues to be addressed by today's traffic management schemes. Congestion in the Accra Metropolis is translated into lost time, missed opportunities, lost worker productivity, distribution delay, and a general increased cost of energy in logistics activities. According to Baskar et al., (2009), constructing new roads could be one of the solutions for handling the traffic congestion problem, but it is often less feasible because of political and environmental concerns. An option would be to make more proficient use of the accessible infrastructure. Automation pooled with the rising market dissemination of on-line communication, routing and advanced driver support systems are some of the solution that will help us to achieve efficient logistics in urban areas.

Again, implementing these Automations in our transport systems will eventually result in intelligent vehicle highway systems (IVHS) that share out intelligence between roadside infrastructure and vehicles and in the longer term the most hopeful solutions to the traffic congestion problem found here in Ghana. Based on the extent to which the roadside and vehicle could work together (devoid of human driver involvement), we recommend the following different types of Automated Highway System (AHS) to be used on our roads to reduce the congestions as well as energy used to save cost in businesses and the nation as whole;

Autonomous vehicle systems: there should be a policy for all vehicles to be equipped with sensors and computers to operate without roadside infrastructure assistance and without coordination with neighboring vehicles.

Cooperative vehicle systems: Vehicles use sensors and wireless communication techniques to coordinate their maneuver's with neighboring vehicles without any roadside intervention.

Infrastructure-supported systems: Vehicles will communicate with each other and guidelines for decision making purposes are provided by the roadside infrastructure.

Infrastructure-managed systems: This will help vehicles indicate their desired actions such as lane changes, exits and entries to the roadside infrastructure. The roadside system then provides the instructions for inter-vehicle coordination of these maneuvers.

Infrastructure-controlled systems: This help the roadside infrastructure to takes entire control of the vehicle operations, monitors the traffic, and optimizes the vehicle operations in such a way that the network is utilized as well as possible.

Decongestion: It is a known fact that traffic is a function of land use. The implementation of a policy geared towards decongestion of the Central Business Area (CBA) through relocation of certain trading activities which attract considerable traffic will be a step in the right direction.

All these will enhance easily movement of transport and for that matter improve logistics activities in the Accra metropolis. Urban transportation efficiency is the key factor which determines the capacity of urban transportation systems and the balance between transportation demand and supply. The transportation input (i.e. construction of transportation facilities) cannot increase within a short period of time, but the demand of transportation is growing rapidly from the study. Therefore to improve the efficiency of urban transportation systems is the best way to effectively utilize the existing inputs, enhance the capacity of the systems and relieve traffic congestion in the Accra Metropolis.

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TABLE 1
SUMMARY OF ROADWORTHY VEHICLES IN ACCRA METROPOLIS

YRS.	MOTOR CYCLE A	PMV UP TO 2000CC 1	CMV UP TO 2000CC 2	PMV ABOVE 2000CC 3	CMV UBOVE 2000CC 4	TOTAL SHARE OF CARS B(1+2+3+4)	P/BUS AND COACHES	C/BUS AND COACHES	TOTAL SHARE OF BUSES C	TOTAL A+B+C
2003	2 063	78 654	39 154	25 806	17 570	161 184	262	6 030	6 292	**169 539**
2004	5 700	75 362	34 990	26 927	13 980	151 259	263	4 759	5 022	**161 981**
2005	2 485	85 497	37 072	28 689	12 496	163 754	335	4 993	5 328	**171 567**
TOTAL	**10 248**	**239 513**	**111 216**	**81 422**	**44 046**	**476 197**	**860**	**15 782**	**16 642**	**503 087**

Source: Modified From Ghana Statistical Services, 2009