# SUSTAINABILITY OF THE URBAN TRANSPORT SYSTEM OF KUMASI

By

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## DECLARATION

I hereby declare that this submission is my own work towards the M.Phil (Planning) and that, to the best of my knowledge, it contains no material previously published by another person or material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.



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## ABSTRACT

Sustainable transportation is of great importance in today's world, because of concerns regarding the environmental, economic, and social equity impacts of transportation systems. Sustainable development can be defined as the development that meets the needs of the present, without compromising on the future ability to meet the same needs. Sustainable transportation can be considered as an expression of sustainable development in the transport sector. This is because of the high growth of the transport sector's energy consumption and greenhouse gas emissions at the global scale, its impact on the economy, as well as, on social well-being. Since the mid-20th century, the negative side effects of urban transportation have become particularly apparent in the metropolitan areas of developed countries. Rising car ownership is increasingly causing loss of economic productivity, environmental degradation, and overall quality of life in cities. In developing countries, rapid urbanisation and motorization in the midst of insufficient investment in infrastructure have led to similar problems, often exacerbated by urban poverty and social exclusion. There is, therefore, a need to integrate sustainable transportation concerns into the activities of transportation planning.

Against this background, the study was designed to examine the sustainability of Kumasi's transport system. The selection of Kumasi as a case study was based on, factors including: its geographical location as the centre of major transportation routes, which facilitate movement to any destination in Ghana within a day; and its pivotal role as a bulk breaking centre for several commodities in transit to either the northern or southern parts of the country; all of which have led to the City experiencing a substantial volume of passenger and freight traffic. The main steps involved in the study were to: (i) develop a framework for measuring the sustainability of Kumasi's transport system; (ii) examine the present state of transportation in Kumasi using the developed sustainability indicators; and (iii) assess the sustainability of Kumasi's transport system using the "relative indicator" approach.

Using both primary and secondary data, collected from various sources, and from a comparative analysis of the transport systems of Mexico City, Istanbul, Bogota, and Lagos, with Kumasi, the study concluded that, the Kumasi's transport system is not sustainable. Specifically, the study found, among others,

1. The modal split of Kumasi's transport is largely skewed (74.2 percent) towards private cars, taxis, and minibus, all with low occupancy rates and high emissions. On the contrary, Bogota has a public transport modal share of 71 percent, Istanbul 19.36 percent, Mexico City 9 percent, and Lagos 2 percent, which are important for transport sustainability;

2. Kumasi has the lowest vehicle speed (16kph) and hence the most congested among the five cities. This situation is likely to further worsen, given that, private vehicle usage is predicted to increase by 1,388.4 percent (669,942) in 2022;

3. The carbon dioxide emissions per vehicle in the city of Kumasi exceeded that of all other cities indicating an unsustainable transport system. This is as a result of the large share (51.9 percent) of the total vehicle fleet in the City manufactured before 1993, and the fact that most vehicles are not fettered with catalytic converters.

To forestall the challenges of achieving sustainable transport in Kumasi, the study recommends four approaches, bearing in mind the need to balance the ability of the environment to sustain future quality of life, the ability of transport to serve economic development, and ability of society to fulfill their needs of accessibility freely. The recommendations involve: the promotion of non-motorized transport modes to improve mobility on road spaces and air quality in the city; the promotion of a roadway bus system and infrastructure to provide affordable, cost effective, space-efficient and environmentally friendly mode of motorized transport; and the creation of multi-nuclei centres as well as mixed use development to reduce the number of trips made to the Central Business District (CBD). Others include the introduction of a Traffic Demand Management (TDM) system, and the improvement in the energy efficiency of travel through the implementation of vehicle emission control standards and emission control devices, to control vehicle emission in the City.

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# CHAPTER ONE

# BACKGROUND OF RESEARCH

## 1.1 Introduction

Concerns about environmental quality, social equity, economic viability, and the threat of climate change have converged to produce a growing interest in the concept of sustainable development (Deakin, 2001). Sustainability and sustainable development have been the main themes of many international conferences, such as the UN Rio de Janeiro 1992 Earth Summit, the 1995 European Conference of Ministers of Transport, as well as the 1997 Kyoto Convention on Climate Change (Kassens, 2009). The most widely used definition of sustainable development, from the Brundtland Commission, is the basis of most definitions for sustainability in various national economies. Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED 1987). Since sustainable development became an international priority in the 1980s and 1990s, infrastructure sustainability has become a growing area of interest in practice, research and education (Jeon and Amekudzi, 2005).

Urban transport is one of the most important sectors having a direct bearing on sustainable development, because of the high growth of the transport sector's energy consumption and greenhouse gas emissions at global scale, its impact on the economy, and social well-being. Since the mid-20$^{th}$ century, the negative side-effects of urban transportation have become particularly apparent in the metropolitan areas of developed countries. Rising car volumes are increasingly causing loss of economic productivity, environmental degradation, and overall quality of life in cities. In developing countries, rapid urbanisation and motorization in the midst of insufficient investment in infrastructure have led to similar problems, often exacerbated by urban poverty and social exclusion. In the face of rising global population, continuing urbanisation and the emergence of mega cities, there is heightened urgency to apply solutions in the urban transport sector that contribute to sustainable urban development and to provide response to the issue of global warming. Actions to slow and ultimately reverse this phenomenon are warranted because of the need to mitigate local and national transport problems such as congestion, transport related air pollution, high accident rates, and high fatalities, which do not only affect the present generation but a source of worry for the generation unborn. By inference, therefore, sustainable transportation is a principal component of sustainable development, and thus, promoting sustainable urban transport goes a long way in ensuring sustainable development.

According to Imran and Low (2003), sustainable transport has three basic components: environment, society and economy, also known as the "triple bottom line". It helps to reduce environmental impacts of transport infrastructure (environment); contributes to economic prosperity by maximizing transport efficiency (economy); and enhances social well-being by providing greater mobility for people (society). The concept of sustainable transport has since become a growing area of interest to addressing the problems of urban transportation within the broader context of sustainable development, as evidenced by a growing number of initiatives around the world to define and measure sustainability in transportation planning (Jeon and Amekudzi, 2005).

Adopting the principles of sustainable transport becomes more important in the case of Ghana where the motor vehicle fleet, although relatively low in a global context, is growing at a fast rate, and private motor vehicle usage even faster. As at December 2010, the total registered vehicles (cumulative) had risen to 1,230,468, from a figure of 42,976 in 1995, an increase of about 22.6 per cent over the 15-year period or 1.41 per cent per annum (Adarkwa and Poku-Boansi, 2011). Coupled with this, is the overreliance on the road sub-sector, with its debilitating effects. Historically, priorities in Ghana's transport sector have been decided by short term imperatives and, at best, medium term plans. Virtually, all the investments in transport have been given a pro-road bias, with the view that because of their integrative nature, investments in roads would contribute positively toward poverty reduction. In Ghana, about 8.6 per cent of its budget is invested into transportation and about 99 per cent of this investment is dedicated to the road sub-sector, confirming the over reliance on the sector (National Transport Policy Report, 2008). In other words, large amounts of resources are spent on costly interventions, such as flyovers, ring roads, and urban highways, making driving even more attractive, and hence creating additional traffic.

## 1.2 Problem Statement

Kumasi by virtue of its geographical location is the centre of a major transportation, and facilitates movement to any destination in Ghana within a day. Much of Ghana's primary road network converges on Kumasi and as such acts as an important transport interchange point within the country. In addition, it has taken on the role of a bulk breaking centre for several commodities in transit to either the northern or southern parts of the country. Consequently, the city experiences a substantial volume of passenger and freight traffic.

Despite its importance, however, the city's transportation sector is faced with several problems. Traffic in Kumasi is characterized by heavy congestion (particularly during the peak periods), high vehicle emissions, heavy dependence on informal private bus services, weak implementation of traffic management measures, inadequate facilities for pedestrians and cyclists, poor road safety arrangements, and high accident rates (Poku-Boansi, 2008). In addition, automobile usage in the city has increased significantly, inducing very sprawled out and inefficient land use patterns. It is equally important to mention that, the city has not had its fair share of transport investments in spite of its unique location within the country. Consequently this has also affected the pattern of physical development within the city in the sense that, road infrastructure has always been behind physical development instead of the reverse (Adarkwa, 2011).

By revealing the existing urban transport situation of Kumasi, the overall picture shows that, 2,778,231 of all trips, especially to work are non-motorized (specifically walking), while 1,451,424 and 1,125,135 of all trips to work places and social places respectively are motorized (Poku-Boansi, 2008). While more than half of all trips are undertaken by pedestrians, there is no serious effort to plan for people on foot in Kumasi. Coupled with this is the fact that, the narrow footpaths provided along some major roads have been encroached on. Among motorized, transport the share of road based public transport is just 14 per cent (Poku-Boansi, 2008). Although this figure is relatively low, it indicates an increase in the proportion of trips undertaken by large occupancy buses (public transport) in recent times. Despite the fact that the proportion of private vehicles registered in the city over the 2004 - 2010 period has somewhat remained constant (averaging about 33 per cent per annum), it has, cumulatively, increased from

1,976 in 2004 to 26,229 in 2010 (Adarkwa and Poku-Boansi, 2011). Such a growth is substantial and can pose challenges in the management of traffic within the city, considering the restricted roadways and the absence of alternative transport modes.

From the foregoing, the transport sector exerts the greatest pressure on air quality in the city owing to emissions. Vehicles that ply the circulatory facilities are identified as the single largest source of air pollution in the Kumasi Metropolis (Agyeman-Bonsu et al., 2010) and the magnitude of this vehicular air pollution in the city keeps rising with the constantly rising numbers of vehicles. Moving cars usually emit gases such as Carbon Dioxide ($CO_2$), Carbon Monoxide (CO), Nitrogen Oxide (NO), Methane ($CH_4$) and Nitrous Oxide ($N_2O$) responsible for global warming (Agyemang-Bonsu et al., 2010). The total vehicular greenhouse emissions in the Kumasi Metropolis were estimated to rise from about 665 Gg in 2005 to 860 Gg in 2010. The components of $CO_2$, (the most influential gas on global warming) of the greenhouse emissions in Kumasi constituted about 97.6 per cent (Agyemang-Bonsu et al., 2010).

Another aspect of the sector in Kumasi is the fatality rate. The annual rate of transport-related mortality in Kumasi was 86 per 100,000, substantially higher than the corresponding rate of 20 per 100 000 in the USA and dramatically higher than the rate of 6.5 per 100,000 reported by the National Road Safety Commission of Ghana (London et al., 2002). Coupled with this is the lack of coordination between transport and land use planning. Development is taking place without consideration of transport needs resulting in the outward expansion of the City, making demand for transportation more complex.

The past approach of road construction and widening of roads is still continuing as the favoured remedy for traffic congestion and environmental improvement. Notable are the on-going completion of the inner ring road (the Anloga-Asokwa by-pass and Timber Gardens interchange and the Sofoline interchange), the connection of the existing radial roads as well as the dualisation of various roads. Such developments favor rapid motorization of transport to the detriment of modal diversity and non-motorized modes, such as walking and bicycles. These, rather than fostering real development, accelerate global climate change, increase air pollution, and weaken petroleum-importing economies, while often increasing inequality, social conflict, and poverty.

As can be gleaned from the foregoing and benchmarking them against the principles of sustainable transportation as put forward by Imran and Low (2003), the sustainability of the transport system of Kumasi appears to be threatened.

## 1.3 Research Aim and Objectives

Influenced by the above submission, the study investigates the sustainability of the transport system of Kumasi. To help achieve this aim, specifically, the study seeks to:

1. Develop an appropriate framework for measuring transport sustainability for Kumasi;
2. Examine the current state of transportation in Kumasi;
3. Examine the sustainability of the City's transport system; and
4. Draw conclusions and policy implications for sustainable urban transport in Kumasi.

## 1.4 Research Questions

Influenced by the foregoing objectives, the following research questions emerge:

1. How can the sustainability of Kumasi's transport system be measured?
2. What is the current state of Kumasi's transport system? and
3. To what extent is Kumasi's transport system sustainable?

## 1.5 Significance of Study

The significance of the research stems from, among others, the importance of transportation networks as a precondition for economic activity and social participation, in terms of moving people and goods, and a generator of wealth and employment. Consequently a research that seeks to address the problems of transportation; congestion, fuel consumption, vehicle emissions, and accidents, will not only make the transport system sustainable, but invariably, assist the national development effort towards achieving the Millennium Development Goals.

An important outcome of this study is an appropriate framework developed for measuring transport sustainability in Kumasi. Until this study, Kumasi's transport system had not been studied from the point of view of sustainability. Using the developed framework therefore, the sustainability of Kumasi's transport system can be measured and evaluated with more assertion. It is hoped that this provides some tangible features to city authorities and decision-makers, with easement in their assessment of cities effort towards achieving transport sustainability, and consequently sustainable development.

Although the growth of vehicle population and its associated effects in the city are obvious, based on past and current trends, the details about such projections are lacking. By measuring the performance of Kumasi's transport system against case cities using the developed rating scale, this study provides information required to formulate targeted and effective policies to manage vehicle growth and the resulting increases in congestion, accidents, fuel consumption, and vehicle emissions, with an ultimate aim of improving the performance of the city.

## 1.6 Limitations of the Study

The study encountered some difficulties, especially in the collection of data. An initial structure of this research included efforts to collect data on seven (7) indicators for measuring the sustainability of Kumasi's transport system. However, this could not be done due to the difficulty and unavailability of some data – transport cost and prices and affordability. The exclusion of such indicators limited the research to measuring five (5) indicators, namely, modal split, accessibility and mobility, risk and safety, resource use (fuel consumption) and transport emissions. Although this affected the study somewhat, it did not significantly affect the results of the study, as the 5 indicators measured, reflected the dimensions of the triple-bottom line (economic, social and environmental dimensions of transport sustainability). Also, although transport emissions and resource use were measured, latest data on them could not be obtained. However, trend data from 2000 to 2005, extracted from Agyemang-Bonsu et al. (2007), allowed for extrapolation of growth rates and subsequent projections, to obtain estimated data for the current year.

### 1.7 Organisation of Report

The report is organised into six (6) chapters as follows: Chapter one provides the background information and the statement of the problem. It examines the nature, causes, effect and the extent of the problem. The chapter also outlines the questions the study seeks to answer and the objectives to be achieved. In a sense, the chapter provides a foundation for the rest of the study.

Chapter two discusses the framework for measuring transport sustainability at the theoretical level, and provides a basis for the conceptual framework. Chapter three defines the research methodology applied in the study, including research design, sampling techniques, and the criteria for selecting suburbs for closer analysis. It also presents the various research methods employed in the collection of primary and secondary data, and the means of analysis and presentation.

Chapter four presents an overview of the present state of Kumasi's transport system. It considers issues on: accessibility and mobility in the city; the rate of resource use (fuel consumption); vehicle emissions; and risk and safety on the city's roads. An analysis of the current transport system in the light of sustainable transportation indicators is done in Chapter five, with the aim of assessing the sustainability of the city's transport system.

Chapter six summarises the main findings of the study and draws lessons for sustaining the transport system of Kumasi. Specific policy recommendations on sustainable urban transport for Kumasi are also identified in this chapter. The chapter also identifies possible areas for further research for areas that are not covered by the study but are seen to be key for the sustainability of Kumasi's transport system.

# CHAPTER TWO

# MEASURING SUSTAINABLE TRANSPORT SYSTEMS – A THEORETICAL PERSPECTIVE

## 2.1 Introduction

Following the wide acceptance of the sustainable urban development notion, finding an accurate way to assess and measure comparative sustainability levels of existing and future developments has become an important issue (Yigitcanlar and Dur, 2010), and this is not different from transport sustainability. Although there is no widely accepted, specified framework for evaluating progress towards sustainability, there is a substantial body of research that have proposed different methods for measuring sustainable transport systems. The focus of this chapter therefore is to explore these frameworks and to establish their point of mergence. This is to provide a framework within which the sustainability of Kumasi's transport system is measured.

To help adequately appreciate this, the chapter commences by exploring the nexus between sustainable development and transportation, which will pave way for a discussion of the concept, sustainable transportation, and the frameworks for measuring progress towards it. Consequently, the chapter is organised into seven major sections. The rest of this chapter is organised as follows. The second section explores the nexus between the concepts - sustainable development and transportation. Section three discusses the concept of sustainable transportation, which is followed by a review of the existing transport sustainability frameworks, and a synthesis of the frameworks in sections four and five respectively.  A conceptual framework, which conceptualizes the variables evolved from the review, and their relationships, to provide the research direction is presented in section six.  Section seven summarises the main points of the Chapter.

## 2.2 Sustainable Development and Transportation

As a starting point to developing a framework for measuring transport sustainability, this section of the chapter is devoted to a discussion of the two concepts – sustainable development and transportation.

### 2.2.1 Sustainable Development – Definitions, Dimensions and Measurability

Growing global concerns about environmental problems such as climate change, pollution and biodiversity loss and about social problems related to poverty, health, working circumstances, safety and inequity, have fostered sustainability approaches for industry. Although the concept of sustainability has been much discussed in literature, there is no general agreement on the definition of the term. This is reflected in the varying definitions and meanings given by different sectors or areas that try to incorporate in their activities, the concept of sustainability. Therefore, definitions of sustainability are connected to the values and value system of people making them (Koglin, 2009), and the context within which it is used. Despite the different definitions and approaches to sustainability, most academic researchers acknowledge the importance of the 'Brundtland Report' and use its definition of sustainable development as a starting point for further investigation. That is, essentially the process of change that allows current human needs to be satisfied without compromising the possibilities of future generations (WCED, 1987). Contained within this definition are two key concepts: (i) the concept of 'needs', in particular the essential needs of the world's poor, to which overriding priority should be giving; and (ii) the idea of limitations imposed by the state of technology and social organisation on the environment's ability to meet present and future needs (WCED, 1987). In this context, sustainability was directly linked to economic growth to be managed in such a way that natural resources were to be used to ensure the "quality of life of future generations". Progressing towards sustainable development implies that the objectives of increasing economic efficiency and material wealth must take into account social and environmental objectives. Explicit in the concept is a focus on inter-generational equity, implying that future generations should have opportunities similar to those now available. Sustainable development also puts emphasis on equity that applies both across and within countries (OECD, 2005).

In the extensive discussion and use of the concept since 1987 when the World Commission on Environment and Development presented their 1987 report, "Our Common Future", there has generally been recognition of three aspects of sustainable development. These are:

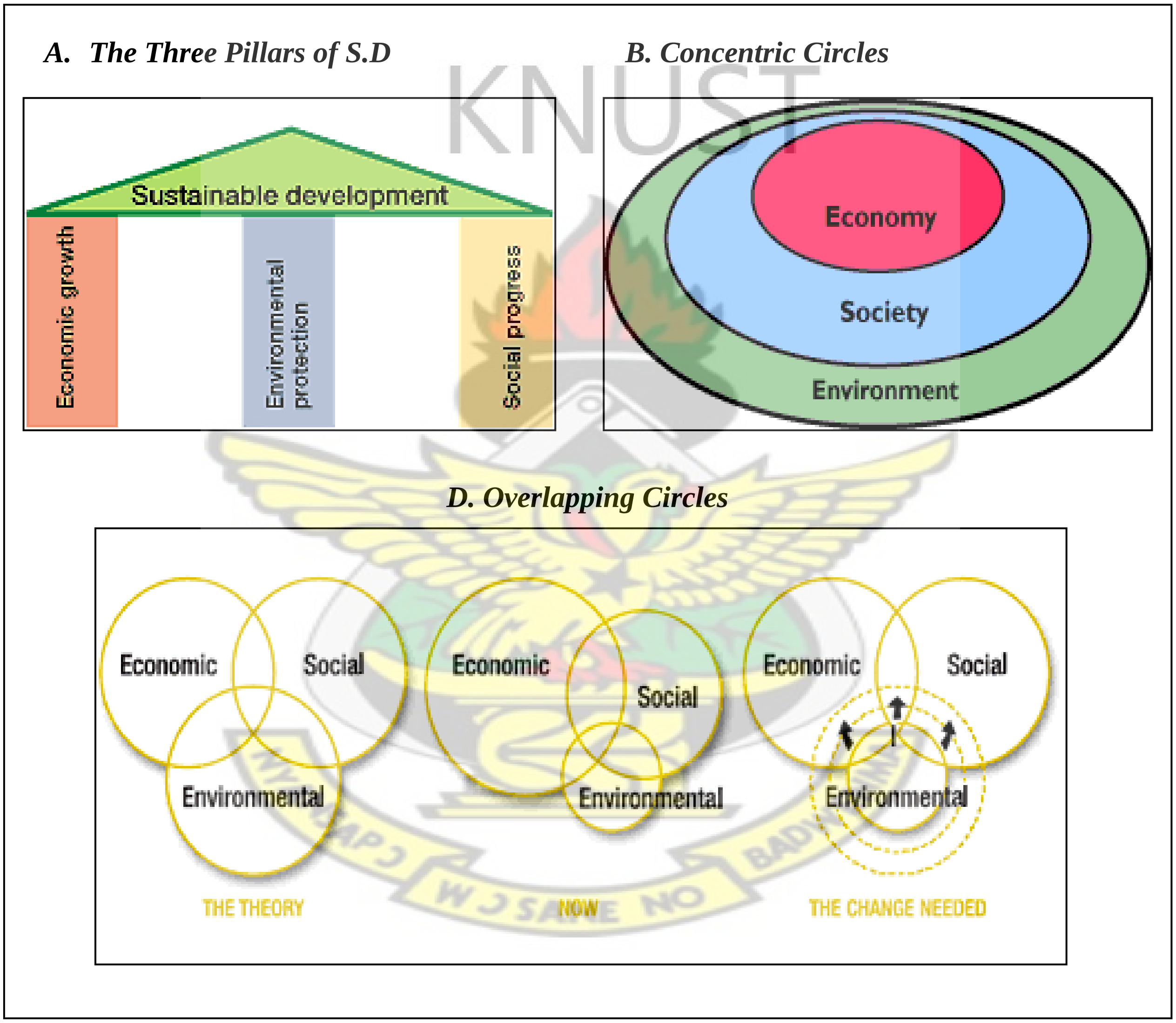
i. The Economic Perspective – sustainable development from the point of view of neoclassical economic theory is defined in terms of the maximization of welfare over time. Most economists simplify the maximization of welfare by identifying the maximization of utility derived from consumption. While this may be criticized as an oversimplification, it certainly includes many important elements of human welfare (food, clothing, housing, transportation, health and education services, etc.) and it has the analytical advantage of reducing the problem to a measurable single-dimensional indicator.

ii. The Ecological Perspective - unlike the economic dimension which provides no upper bound on economic growth, in an ecological perspective, sustainability involves limits on population and consumption levels. These limits apply to all biological systems. For the ecologist, then, sustainability is defined in terms of the maintenance of ecosystem resilience. This view of sustainability is clearly different from the human-centered conceptions put forward by the World Commission on Environment and Development and the consumption-based principles proposed by economic theorists. From an ecological perspective, both population and total resource demand must be limited in scale and the integrity of ecosystems and diversity of species must be maintained.

iii. The Social Perspective - advocates of sustainable development recognize the social component of development as an essential part of the new paradigm. In doing so, they are validating the importance of a much older perspective. Social equity, the fulfillment of basic health and educational needs, and participatory democracy are crucial elements of the social sustainability.

As reflected from the foregoing, development will not be sustainable unless the social, economic, and environmental dimensions of the concept are met or fulfilled. This has been depicted both graphically and mathematically. Mathematically, Sustainable Development is defined as (SD) = Ecological Sustainability + Social Sustainability + Economic Sustainability. Graphically, these dimensions have been drawn in variety of ways as 'pillars', as concentric circles, or as interlocking circles (Adams, 2006) (see Figure 2.1).

**Figure 2.1 the Graphical Representation of Sustainable Development**




*Source: Adapted from Adams, 2006.*

In the last few years, the concept of sustainable development has spread to all levels of society. This is evidenced by several attempts being made by international organisations, politicians, academics, as well as business persons to achieve sustainable development. According to

Neumayer (2003), this is not surprising, as *"sustainable development is like freedom or peace – that is, something to which no reasonable person would overtly object"*. The European Union (EU) since 2001 has been implementing a sustainable development strategy. Under this umbrella, EU environmental policies seek to ensure an environment that is productive, clean and healthy. At the Gothenburg Summit in June 2001, EU leaders launched a specific sustainable development strategy based on a proposal from the European Commission. The following priorities were set:



i. Combat climate change;
ii. Ensure sustainable transport;
iii. Address threats to public health, such as chemicals pollution, unsafe food and infectious diseases;
iv. Manage natural resources more responsibly and stop biodiversity decline;
v. Combat poverty and social exclusion; and
vi. Meet the challenge of an ageing population.

Among concrete actions that have been taken by the African Union (AU) with regards to Sustainable Consumption and Production (SCP) geared towards achieving the broader goal of sustainable development are as follows:

i. *Ten-Year Framework of Programmes on SCP:* The African 10 Year Framework Programmes on Sustainable Consumption and Production (African 10-YFP) has been launched. In June 2007, an expert group meeting was organized to review two draft study reports on ecolabeling. As a follow-up to the meeting, discussions and consultations were held between the AU Commission, ECA, UNEP and the Taskforce. Agreements on securing political endorsement, substantive development, coordination and mobilizing resources are currently being implemented.

ii. *Sustainable industrial development*: In July 2004, the AU endorsed the Africa Productive Capacity Initiative (APCI) as the NEPAD Sustainable Industrial Development Strategy.

iii. *Energy for sustainable development:* A multi-donor NEPAD Infrastructure Project Preparation Facility has been established at the African Development Bank (AfDB). The facility has provided funding for the preparation of several regional projects which are environmentally friendly, including oil pipeline, gas pipeline, hydroelectric power and power interconnection.

By the mid-1990s, the World Bank which was already claiming that it would only fund projects that were sustainable in economic, environmental, and social terms, defined sustainable development as a process by which current generations pass on as much, or capital per capita to future generations, with capital being defined as human-made, natural, social, and human (Serageldin, 1996, in Zegras, 2006). This definitional approach still clearly suffers from measurement challenges including, but not limited to, issues of how to measure the social capital stock. This brings to the fore the discussions of two schools of thought concerning sustainability – weak sustainability and strong sustainability – referred as economic paradigms of sustainable development (Neumayer, 2003). Advocates of weak sustainability argue that development is sustainable as long as the total value of capital is constant. This means the sum of natural and man-made capital must always give a total value that is constant at any time. In other words, it is based on the belief that what matters for future generations is only the total aggregate stock of man-made and natural capital, but not natural capital as such (Neumayer, 2003). Regarding strong sustainability, natural capital is non-substitutable (Neumayer, 2003), that is, it does not allow for the substitution of human capital for natural capital.

One of the crucial points from the viewpoint of the real world - and regardless of the definition of sustainable development adopted or the objectives implied - is how the concept should and can be translated from theory into practice to make it functional. Therefore the absence of, constraints, and/or threats to sustainability must be known and information made available on where we come from, where we are right now, and where we are heading with respect to certain objectives or defined criteria (Winograd and Farrow, 2006). In other words, there is the need to develop indicators for the system and its components to determine the direction in which we are moving or should or can move. Among other things, the report - "Our Common Future", presented guiding principles for sustainable development. Among other precepts, the report implied the need to develop indicators for monitoring long-term progress towards “meeting the needs of the present generation without compromising the ability of future generations to meet their own needs”.

Several conceptual frameworks have therefore been developed to guide the selection, development and use of sustainability indicators. They include: the Pressure-State-Response Model; the Basic Orienters Model; the Barometer of Sustainability Model; the Project-Based Model; the Problems and Components Model; and the Aggregation Model (refer to Winograd, M. and A. Farrow, 2006 for details).

2.2.2 Transport, Development and Sustainability

Transportation plays a very important role as far as the development of a country is concerned. It is regarded as a vital pre-requisite for development. According to Adarkwa (2003), transportation refers to the movement of people, goods or services between an origin and a destination for a predetermined purpose. On the other hand, transportation refers to all these movements as well as the entire system supporting them. This system comprises the physical, administrative and the legal structures required for the smooth running and administration of the entire process of movement. The basic function of transportation is the provision of accessibility.

Accessibility is a key ingredient of well-being and prosperity in contemporary societies. The ability of individuals, families, entrepreneurs and firms to exchange goods and services and interact with people on a regular basis, is crucial not only to economic life but also quality of life. With the growth of economic and social networks over the course of the past two centuries, and the spatial dispersion of activities, transportation has become a vital part of the systems providing access to those activities. It is also a crucial factor in economic growth and social interaction in most countries. By inference, efficient transport infrastructure and services is critical to the achievement of sustainable development. While the Millennium Development Goals (MDGs) do not specifically make reference to transportation issues, transportation projects and programs have an enormous impact on both the poverty alleviation and environmental sustainability goals (see for example DFID Transport Resource Center, 2003).

Despite these benefits attributable to enhanced transportation or mobility, there are externalities associated with it. According to OECD (2004), these externalities include increased pollution, emission of greenhouse gases, congestion, risk of death and serious injuries, noise and disruption of communities and ecosystems. These issues (the benefits and costs associated with transport) are discussed in more detail subsequently.

*2.2.2.1 Transport and Economic Growth*

Infrastructure sector, particularly transport, has large effects on the pattern of growth especially its geographical inclusiveness. DFID Transport Resource Center (2003) has identified three key benefits, contributed by the transport sector, towards economic growth. These benefits are: (i) support to food production and improved access to markets; (ii) access to employment; and (iii) source of employment. In rural areas, where the poor survive primarily on subsistence agriculture, addressing the needs of poor farmers should be the primary objective. Enabling poor farmers to grow different crops is widely seen as one of the most effective ways to reduce poverty and hunger. In this context there is evidence to show that road investments and improved access to transport services can be effective in lowering input prices and increasing agricultural production. The contribution that transport makes to final market prices varies with a range of factors such as commodity type, transport efficiency, marketing practices, and travel distance. Thus investment in transport infrastructure is likely to be most successful when accompanied by actions on other fronts to obtain cost reductions and encourage economic growth.

As a source of employment, the provision of transport services, including the construction and maintenance of transport infrastructure, generate demand for labor (often unskilled labor) and provides income-earning opportunities for the poor. If a transport project generates jobs for the poor who are otherwise unemployed or under-employed, it contributes to the reduction of poverty. According to Adarkwa (2011), since 1974, Kenya has constructed 12,000 km of rural feeder roads using labour based method, and has resulted in the creation of 20,000 man years of rural employment per year. Similarly, in the case of Ghana, between 1987 and 2001, 5,400 km of very poor rural roads had been rehabilitated, with 13 million person-days of employment been generated (Adarkwa 2011). Also in urban areas where public transport comes in myriad forms including small vehicles and non-motorised transport, the employment potential of the transport sector cannot be overlooked. Official employment figures for Lagos State, for example, suggest that almost 10 percent of the working age group is in the transport sector (DFID Transport Resource Center, 2003).

#### *2.2.2.2 Transport and Universal Primary Education, Gender Equality and Women Empowerment*

While there is a general acknowledgement of the relationship between transportation and access to education, there is very limited evidence that transport investments will actually increase school participation or enrollment rates. However, its role cannot be overemphasized as the quality of transport infrastructure can make an important contribution to enrollment levels, since it reduces both financial costs (lower fares in public transport and facilitation of non-motorised transport) and the opportunity by lessening the average time needed to cover the distance to school Holm-Hadulla, 2005). This role of transport is very critical as studies have shown that in spite of the long term benefits associated with education, the distance that children have to walk to reach their schools is the major cause of drop-outs in primary schools (I.T. Transport 1999, in DFID Transport Resource Center, 2003). Aside increasing enrollment rates, the quality of transport infrastructure has a positive impact on the quality of education and this, according to Holm-Hadulla (2005) can be attributed to two factors – (i) enhance teacher recruitment in and out of community; and (ii) monitoring teachers performance will considerably be easier , especially teacher absenteeism.

Further, transport infrastructure triggers an increase in gender equality, particularly in schools enrollment levels. A study of Morocco by Khandker et al. (1994 In Holm-Hadulla, 2005) shows that the presence of a paved road in the community, especially, influences the schooling outcomes of rural children. Thus in the absence of a paved road, 21 per cent of rural girls, as compared to 58 per cent of rural boys, ever attend school. If a paved road exists, the school participation rate increases to 48 per cent for girls and 76 per cent for boys. Comparative survival rates by grade are also affected. In the absence of a paved road in the community, girls drop out in larger proportions than boys even before completing the primary cycles. The presence of a paved road increases girls' survival rate, though only at the primary level.

Again, better access to farms, woodlots, water supply points, and markets, as considered by Holm-Hadulla (2005) is a first point of empowering women, as domestic transport for household needs, especially in developing countries, is almost exclusively performed by women.

### 2.*2.2.3 Transport and Increased Access to Health Services*

Similar to achieving universal basic education, access to health services may be as much influenced by factors of social accessibility, such as, gender relations, class, membership in cultural minority or other disadvantage groups, as well as preventive diseases that are the result of lack of clean water and good sanitation. Nonetheless, there is a clear association between levels of infant mortality, maternal health and malaria as well as other diseases prevention, and distance to health services. Wagstaff (2000, in DFID Transport Resource Center, 2005), indicated that, 10 percent increase in distance from hospital is associated with a 2 percent increase in all three mortality rates.

Women need access to a broad range of services during pregnancy and child birth, including emergency obstetrical care such as treatment of infections, hypertension, and obstructed labour, as argued by Holm-Hadulla (2005). Surveys conducted by DFID Transport Resource Center (2005) in a range of countries showed that, many women would like to deliver in a health facility but are unable to do so because of distance and lack of transport. This is compounded by the fact that, at least, one-third of rural women in developing countries live more than 5 km from the nearest hospital, making physical access to health facility a challenge. This underscores the importance of improved transport to enhancing maternal health.

In addition, efficient transport infrastructure both facilitates rapid response to emergencies and reduces the costs of regular visits to health facilities as well as delivery of medical services. This is captured by Holm-Hadulla (2005) as follows "…in order to eradicate tuberculosis from patients, therapy must be upheld for at least six months, and thus visits to the hospital must be made affordable and timely delivery of key medications must be ensured. Moreover, treatment of cerebral malaria requires immediate transport to a hospital; otherwise the fatality rate increases dramatically".

As can be gleaned from the foregoing, transport plays a critical role in helping contribute to economic development and social equity. In spite of these benefits, there are several problems, especially environmental concerns, associated with it, which threatens its sustainability and overall sustainable development. This is the focus of the next section.

### 2.2.3 Challenges of Transportation to Urban Development and Sustainability

Transportation problems are among the most pressing urban development problems and related environmental concerns in many cities. Many of these problems have been identified as threats to sustainable development (Zegras, 2006). Notable are: air pollution, traffic safety, sprawling urban development patterns, automobile dependence and its associated effects of traffic congestion and climate change, among others. This section discusses how transportation induces these problems, and their relationship with sustainable development.

#### *2.2.3.1 Sprawling Urban Development Patterns*

With the development of urbanisation at an unprecedented rate for decades, many cities are faced with a lot of challenges, especially in and around their core areas (inner cities). These problems include traffic congestion with its debilitating effects on air pollution and safety; crime; as well as poverty. The 'rich' especially, in their effort to escape these problems, usually find themselves in sub-urban areas, which provide ready access to open space, relatively cleaner and safer environment, as well as low land values (*Ql Lei, 2008).* This process is however, shaped by the capacity and requirements of urban transport infrastructural facilities, such as roads, transit systems or simply walkways. It is the latter that is the interest of this section, and has been a major determinant of the spread of cities especially in the advanced countries. This is confirmed by Land use theories, drawn from the pioneering work of Burgess, Hoyt, and Alonso who have established that urban dispersal is most likely to be channeled along transportation corridors that offer better accessibility, usually due to road construction or upgrading (Owusu-Ansah and O'Connor, 2009).

Studies on transport induced urban dispersal include Askew (2002) for Bangkok Metropolitan Area; Serra et al. (2004) for Rio de Jeneiro and Sao Paulo in Brazil; among many others. In many situations transport-induced dispersal has created concerns with uncoordinated, haphazard, as well as low density urban growth. Other associated outcomes include the contribution to the decay of the downtown areas, overly long journey to work, increase in car ownership, adding up to traffic congestion and air pollution in urban areas. Under this situation, the concepts of urban sustainable development and urban growth management within the context of sustainability have become the focus of interest. Bruekner (2000, in Ql Lei, 2008) summarises the effects of transport induced urban dispersal on urban sustainability. They go on to state that:

> *"Cities, it is claimed, take up too much space, encroaching excessively on agricultural land. Aesthetic benefits from the presence of open space are lost, and an allegedly scarce resource, namely farmland, is depleted. Excessive urban expansion also means overly long commute, which generate traffic congestion while contributing to air pollution. Unfettered suburban growth is also thought to reduce the incentive for redevelopment of land closer to city centers, contributing to the decay of downtown areas. Finally, by spreading people out, low-density suburban development may reduce social interaction, weakening the bonds that underpin a healthy society".*

As noted earlier, physical development or urban dispersal may be due to other factors other than transportation system. Other factors as identified by Owusu-Ansah and O'Connor (2009), especially in cities of developing countries are: local land ownership patterns, political structures, as well as regulatory systems.

To restrict urban sprawl or dispersal to promote sustainable urban development, several strategies, such as New Urbanism and Growth Management have been suggested (see for example, Talen, 2005; Grant, 2006; Grant and Perrot, 2009; Chakrabarty, 2001; Pollock, 2008).

*2.2.3.2 Transport Energy (Fuel) Consumption*

The current transportation system depends on nonrenewable fuels. Transportation and fossil fuels are currently inextricably linked; more than 60 percent of the 84 million barrels of oil consumed every day powers the world's cars, trucks, planes and other modes of transportation (World Economic Forum, 2011). According to Black (2005), the world has consumed approximately 1 trillion barrels of petroleum by motor vehicles for the past 100 years, and now consumes about

2.2 million tonnes of oil equivalent of energy each year. At present, consumption exceeds new discoveries by more than a 3:1 ratio.

Given that energy demand by the transport sector is likely to increase (forecasts by IEA suggests the world will consume about 40 percent more energy than it uses today by 2030), and conventional sources will not last beyond 2020, although there is significant petroleum out there (shale oil, oil sands, and tar sands), the sustainability of the sector seems threatened. Analysis of data on energy consumption helps to estimate the scale of environmental impacts of energy use, such as air pollution and global warming, as what goes into the fuel tank comes out of the exhaust pipe in the form of emissions. These impacts are explored in the subsequent sections.

*2.2.3.3 Contribution to Climate Change*

The transport sector being the fastest growing consumer of energy, as indicated in the previous section, by inference, makes it a major producer of greenhouse gases, a major cause of climate change. Climate change is considered as the number one global challenge facing humanity according to the Global Futures Studies and Research (2010). This is the case because of the several environmental concerns associated with it, such as, natural disasters (flooding), reduction in food yields, and consequently increasing global poverty. Although natural processes (volcanic eruptions, variations in the sun's intensity or very slow changes in ocean circulation) and other human activities (such as land use practices, landfills, septic and sewer systems and industrialisation, as well as agricultural practices) induce climate change, the transport sector is considered to be the major source of carbon emissions, a principal component of greenhouse gas. According to ADB (2009), transport is currently responsible for 13 percent of all world greenhouse gas (GHG) emissions, and 24.1 percent of global carbon dioxide (CO2) emissions from fuel combustion are transport related. Transport-related CO2 emissions are expected to increase 57 percent worldwide in the period 2005–2030.

Emissions from vehicles are classified into: Exhaust (Tail-pipe) emissions, and Evaporative emissions (Agyemang-Bonsu et al, 2010). Exhaust emissions include vehicle start-up emissions and running emissions, which occur when the vehicle is warmed up and operated in a hot stabilised mode. Evaporative emissions or vapour emissions consist entirely of volatile organic compounds (VOC). They consist of running losses when the vehicle is operating in a hot stabilised mode; hot soaks emission resulting from fuel evaporation (especially petrol) from the still-hot engine at the end of the trip; and diurnal emissions which result from evaporations of fuel from petrol tank when the vehicle is driven or in a steady state.

The burning of fossil fuels to power transportation vehicles releases greenhouse gases into the atmosphere, which contributes to increasing global average temperature and other climate changes. Greenhouse gases are emitted throughout the fuel cycle, from well to tailpipe. The use of petroleum-based fossil fuels for transportation is responsible, directly or indirectly, for more than one-fourth of U.S. emissions of carbon dioxide, the principal greenhouse gas emitted by transportation.

Climate change has significant impacts on biodiversity and food security, and developing countries are the most vulnerable to these impacts, though its contribution to greenhouse effect is relatively small (currently estimated at 3.2 percent of the world's Greenhouse Gases). Climate change causes frequent natural disasters, increases sea levels and distorts weather patterns which in turn affect the elements of the food production system – soil, water and biodiversity - making it difficult to achieve increases in food productivity. It is estimated that by 2015, climate change will reduce global wheat yields by 30 percent and rice yields by 15 percent while increasing their prices by 194 percent and 121 percent respectively (Global Futures Studies and Research, 2010). Flooding, desertification and drought considerably reduces food yields and the rise in sea levels, as a result of global warming melting ice caps and ice sheets make coastal agricultural lands unsuitable for farming due to increase in salinity levels and in some cases coastal lands being washed away.

According to Black (2005), the flooding of transit tunnels due to a rise in sea level, the failure of airplanes to take off due to high temperatures, the buckling of highways and railroad track, the flooding of coastal highways and railways, and the submersion of dock facilities are not problems that can be dismissed easily, as impacts of climate change. In other words, although the transport sector is seen as a major contributor to climate change, it is also hardly hit by the ramifications of climate change. These impacts of climate change have far reaching effects on the sustainable development of developing countries including their ability to attain the United Nations Millennium Development Goals by 2015 (UN, 2007).

*2.2.3.4 Urban Pollution*

The contribution of transportation to urban pollution can be categorised into air quality and noise. Transportation involves the combustion of fossil fuels to produce energy translated into motion. Pollution is created from incomplete carbon reactions, unburned hydrocarbons or other elements present in the fuel or air during combustion. These processes produce pollutants of various species, including carbon monoxide, soot, and various gaseous and liquid vapour hydro carbons, oxides of sulphur and nitrogen, sulphate and nitrate particulates, ash and lead. As at 2000, according to the Bureau of Transport Statistics, mobile sources accounted for 7 percent of sulfur dioxide emissions, 43 percent of nitrogen oxide emissions, 51 percent of carbon monoxide emissions, approximately 9 percent of particulates (particles up to 10 micrometers in diameter) and 31 percent of PM2.5, and 33 percent of volatile organic compounds (Cited in Black, 2005). The health consequences of urban air pollution are high; each year, suspended particulate matter (for which car exhaust is a major source) may account for 460,000 premature deaths (Doering 2002, In Lagan and McKenzie, 2004). It is also estimated that over 2 million people die annually due to the harmful effects of air pollution (GTZ, 2005).

In addition to having an immediate, localized impact on human health, pollutants from the transport sector contribute to regional environmental degradation. These environmental side effects are thought to be associated with long - range transport of air pollutants via ozone, peroxyacetyl nitrate (PAN), sulphuric acid, and other compounds. The effects include acidification, eutrophication, and forest and crop damage from exposure to ozone (Gorham, 2002).

The transportation system is a significant source of noise. Transportation noise originates from all motorized modes of transport. Examples of transportation- related sources of noise include engines, vehicle contact with pavement and other surfaces, horns, construction, brakes, and airplane takeoff and landing, to name a few. Loud noise and continuous noise are harmful to human health. The impacts include behavioral disorders, heart disease, and hearing loss. Noise also disturbs wildlife. Studies of the breeding and habitat of birds have found that higher volumes of traffic affect the nesting patterns of birds. Noise harms human health and wildlife and can damage the quality of life.

*2.2.3.5 Road Safety*

Road accidents are now widely recognized as a serious world health problem. According to ADB (2006), road accidents account for over 1.2 million deaths and as many 50 million injuries per year worldwide. This situation is more acute in developing countries, as it experiences about 85 percent of these fatalities. According to WHO (2004), road accidents were the ninth most important cause of years of life lost, out of a total of over 100 identified causes, around the world. Forecasts, however, suggest that, as a cause of death, road accidents will move up to the fifth place by 2030, resulting in an estimated 2.4 million fatalities per year (WHO, 2009), unless immediate action is taken.

In addition to the humanitarian argument, road traffic accidents have considerable impacts on world economies, especially developing countries that are frequently struggling with other developmental needs (WHO, 2009). Globally, it is estimated that, road accidents cost over US$500 billion each year, and cost governments between 1 percent and 3 percent of their gross national product (WHO, 2009). The huge economic losses from road accidents are undoubtedly hampering economic development.

While industrialized countries have systematically reduced the incidence and severity of road accidents through coordinated multi-sector remedial programs, problems continue to grow in the developing world, attributable to (i) the high proportion of two- and three-wheeled vehicles; (ii) traffic mix and road usage; (iii) high population density and number of pedestrians; (iv) underdeveloped infrastructure and institutions; and (v) rapid motorization (ADB Regional and Sustainable Development Department, 2006).

The foregoing hints that, transport's contribution towards sustainable development over the recent past has been negative. This situation is likely to further worsen in the future, if nothing is done about it.

In consonance with the aforementioned issues, the World Business Council on Sustainable Development (WBCSD, 2001), has identified seven goals towards which society should strive, to achieve sustainable development:

i. Reduce transport-related conventional emissions (carbon monoxide, nitrogen oxides, volatile organic compounds, particulates, and lead) to levels such that they cannot be considered a serious public health concern anywhere in the world;

ii. Limit transport-related greenhouse gas (GHG) emissions to sustainable levels;

iii. Significantly reduce the worldwide number of deaths and serious injuries from road crashes. Efforts to do this are particularly needed in the rapidly motorizing countries of the developing world;

iv. Reduce transport-related noise;

v. Mitigate transport-related congestion;

vi. Narrow the mobility “divides” that exist today (a) between the average citizen of the world’s poorest and the average citizen of the wealthier countries, and (b) between disadvantaged groups and the average citizen within most countries; and

vii. Preserve and enhance mobility opportunities available to the general population.

These lend credence to the relationship between the two concepts – sustainable development and transportation. In a sense, to make progress towards the achievement of sustainable development, it is vital to also look at ways of making the transport sector sustainable. The next section, thus, discusses the concept of sustainable transportation in details.

### 2.3 The Concept of Sustainable Transportation

In an attempt to reduce the ecological and social impacts of transportation as discussed in the previous section, the idea of sustainability has been integrated into the transportation planning process. Within this context, a number of questions must be answered – (i) what are the ranges of definitions of sustainable transportation; (ii) what indicators are used for measuring sustainable transportation; and (iii) what criteria are used for the selection of the indicators. Addressing these issues is an important step in progressing towards transport sustainability.

### 2.3.1 Definitions of Sustainable Transportation

To achieve sustainable transport system, it is important to define what sustainable transport is, and how it can be measured. The word sustainable transportation emerges in the immediate wake of the Brundtland report, with Replogle's (1987) paper at the 1988 Annual Meeting of the Transportation Research Board on "sustainable transportation strategies" for developing world, explicitly making the link between transportation, basic human needs, and environmental effects" (Zegras, 2006). Since then, there have been a growing number of efforts by researchers and agencies to define and measure sustainable transportation. A review of some alternative definitions developed by researchers and organisations involved in transport sustainability gives useful comparisons.

Schipper (1996, in Black, 2005) states that sustainable transport is transportation where the beneficiaries pay their full social costs, including those that would be paid by future generations. He further notes that changes in travel are associated with a number of prominent externalities, including accidents, air pollution, congestion, noise, damage to species habitat, increases in carbon dioxide production, and the importation of oil. It is these externalities, and not transportation or travel per se that threaten the sustainability of the system, according to Black (2005).

Transport is connected to mobility, which means that sustainable transport cannot be analysed without investigating mobility and mobility patterns, and this is what informs the definition given by the Massachusetts Institute of Technology and Charles River Associates in their report, "Mobility 2001" WBCSD (2001). The report defines sustainable mobility as "*the ability to meet the needs of society to move freely, gain access, communicate, trade and establish relationships without sacrificing other essential human or ecological values today or in the future*".

With the varying definitions associated with the concept, sustainable transport has been defined by others using specified parameters or criteria. According to Daly (1992, in Black, 2005), transport is sustainable if it satisfies three conditions: (a) the rate at which it uses renewable resources does not exceed their rates of regeneration; (b) the rate at which it uses nonrenewable resources does not exceed the rate at which sustainable renewable substitutes can be developed; and (c) its rate of pollution emissions does not exceed the assimilative capacity of the environment. Toth-Szabo et al. (2011), argue that in order to create sustainable transport, the volume of motorised traffic must be reduced, short trips should be made by walking or cycling and more trips should be made by public transport. This is because, modes of transport, such as public transport, walking and cycling have less impact on the environment than the personal motorized transport mode, the passenger car. Similarly, OECD (1996) defined sustainable transport using the following criteria:

- Access;
- Equity
- Health and safety;
- Individual responsibility;
- Integrated planning;
- Pollution prevention;
- Land and resource use;
- Education and public participation; and
- Fuller cost accounting.

Different from the above definitions, a review of the operational definitions of transport sustainability of the Organisation for Cooperation and Economic Development (OECD) and the World Bank, shows skewness towards the environmental dimension of sustainability. OECD defines sustainable transportation as *"transportation that does not endanger public health or ecosystems and meets the needs for access consistent: (a) with the use of renewable resources at or below their rates of regeneration; and (b) the use of nonrenewable resources below the rates of development of nonrenewable substitutes"*. Similarly, for the World Bank, a transport system is sustainable if: *"their rates of use of renewable resources do not exceed their rates of regeneration; their rates of use of non-renewable resources do not exceed the rate at which substitutes are developed; and Their rates of pollution do not exceed the assimilative capacity of the environment"* (cited in Jeon and Amekudzi, 2005).

Despite the varied definitions expressed by researchers, agencies and international organisations, they display a great degree of commonality. And in an attempt to be more comprehensive, the Centre for Sustainable Transportation (1998) in Canada states that a sustainable transportation system is one that:

i. *"Social Dimension"* - Allows the basic access needs of individuals and societies to be met safely and in a manner consistent with human and ecosystem health, and with equity within and between generations;

ii. *"Economic Dimension"* - Is affordable, operates efficiently, offers choice of transport mode, and supports a vibrant economy; and

iii. *"Environmental Dimension"* - Limits emissions and waste within the planet's ability to absorb them, minimizes consumption of non-renewable resources, limits consumption of renewable resources to the sustainable yield level, reuses and recycles its components, and minimizes the use of land and the production of noise.

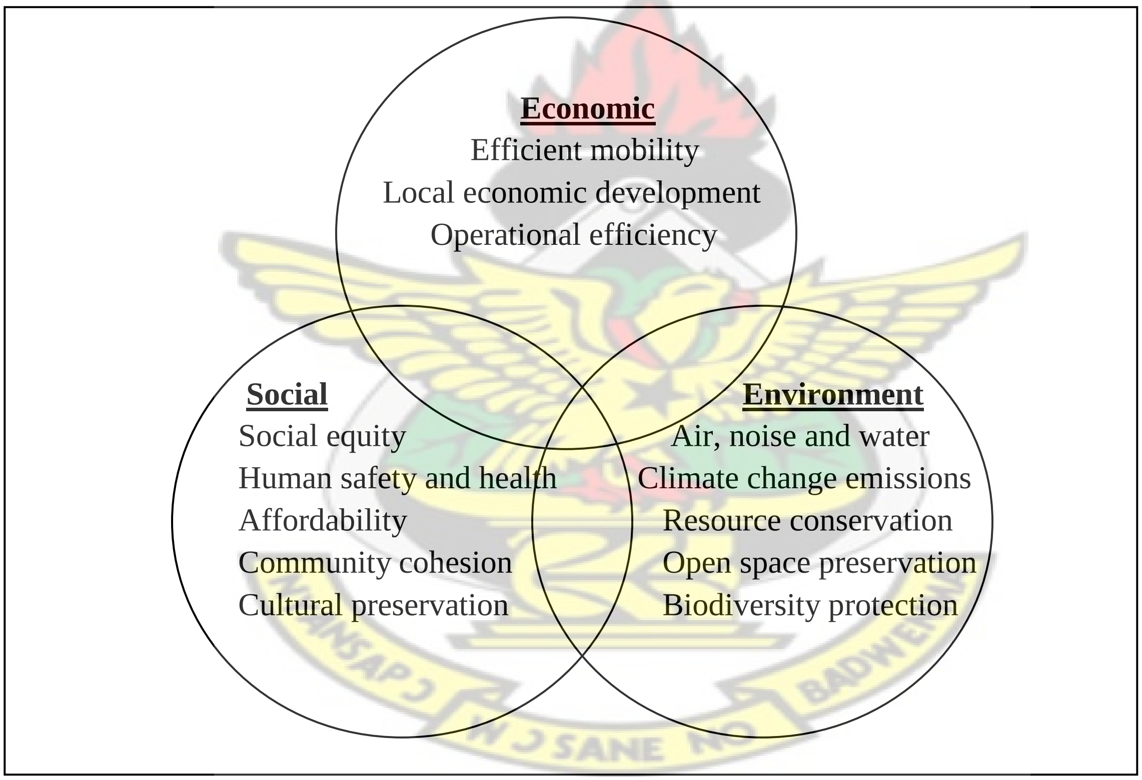
In a sense, while transportation system sustainability has been defined in various ways, there is emerging consensus that a sustainable transportation system must be safe, efficient in providing accessibility and mobility, and in enhancing economic productivity, without impacting the natural environment negatively – all in a manner that is equitable to those who use and are affected (either directly or indirectly) by the system (Amekudzi et al., 2009).

### 2.3.2 Dimensions of Sustainable Transportation

In evaluating the performance of transportation system towards sustainability, emphasis should not be given only to economic or social or environmental considerations, but all. According to Litman (2011), sustainable transportation is sometimes defined narrowly as simply environmental sustainability, concerned only with pollution reduction and habitat preservation, but is increasingly defined more broadly to include other goals. Conventional evaluation of transportation plans has focused largely on performance measures pertaining to transportation system effectiveness (i.e., congestion and vehicle miles traveled) as well as air quality impacts of the system. The term "triple bottom line" has therefore been coined to encourage sustainable transportation by evaluating performance on the basis of social, economic, and environmental impacts in order to ensure that transport strategies and investments will result in robust economic growth; better-than-before health of the environment; and improved quality of life for all citizens (Toth-Szabo et al., 2011). Using the triple bottom line as a yardstick, Jeon et al. (2010) also argued that, for transport system to be sustainable, it should at least capture attributes of system effectiveness and system impacts on economic development, environmental integrity, and the social quality of life. Litman (2011) translates these into sustainable transport goals – economic, social and environmental goals of transport sustainability (see Figure 2.2).



**Figure 2.2 – Sustainable Transport Goals**




*Source: Litman, 2011*

Figure 2.2 suggests that, although each goal fits into a specific category, they often overlap. For example, pollution is generally considered an environmental issue, but it also affects human health (a social issue), and fishing and tourism industries (economic issues) (Litman, 2011).

In the absence of a clear definition of what sustainable transport is, there have been several other proposals for the identification of indicators of sustainable transport. The next section, thus, reviews the various sustainable transportation indicators, with the aim of operationalising the term, sustainable transportation.

### 2.3.3 Sustainable Transportation Indicators

Transforming urban transport systems into sustainable urban transport systems is a long term process. It starts with a diagnosis of the current situation in the context of existing policies. Indicators can help in analyzing current sustainability levels and to support the planning and implementation of sustainable urban transport policies and investments. Performance assessment indicators define the transport system and describe the performance of the system; impact indicators can be used to assess, for example, the environmental and social impact of transport systems. Above all indicators allow the past, present and future changes in transport and its sustainability to be quantified. Littman (2006) defines indicators as "a variable selected and defined to measure progress towards an objective". He further argues that, indicators are useful for identifying trends, predicting problems, setting targets, evaluating solutions and measuring projects. In a sense, to monitor progress of transport, there is a need for a measuring tool based on sustainable indicators (Munier, 2005).

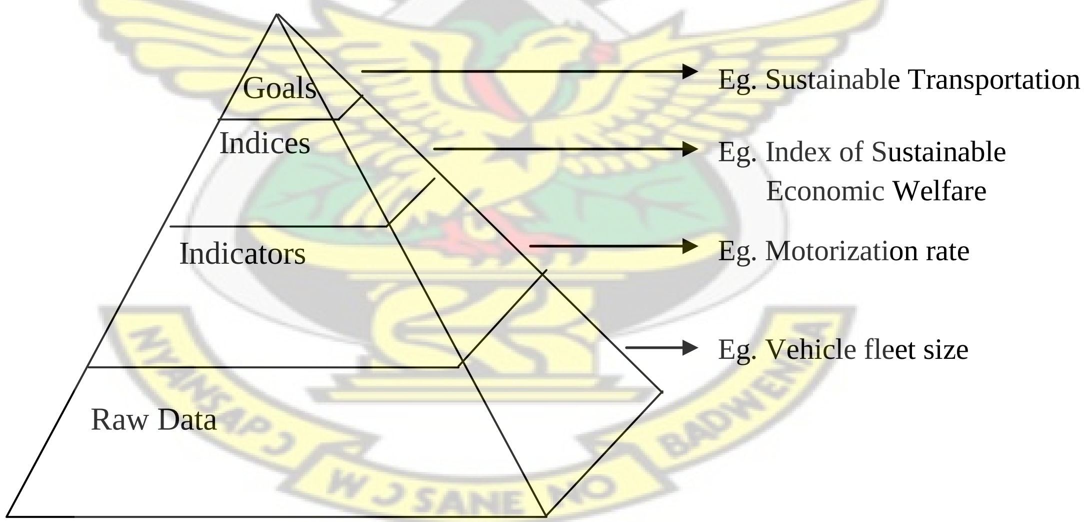
Indicators have been defined in terms of goals, objectives, targets and thresholds, as alluded by Litman (2011) that, indicators reflect societies' values and goals and become key drivers of change. This has been the basis of many definitions of indicators. Measuring sustainability with the help of indicators must be done on the basis of a definition of sustainability and a vision of how future urban regions and areas should be like. In other words, the framework of sustainability indicators has to be in line with a vision (Toth-Szabo et al., 2011). A number of transport objectives that appear regularly in cities' policy statements, according to OECD (2003, In Szabo et al., 2011) are:

i. Economic efficiency (short travel time, operating costs and direct payments);
ii. Safety (reducing the loss of life, injuries and damage to property resulting from transport accidents);

iii. Sustainable use of resources (the consumption of non-renewable fossil fuels, materials and land);
iv. Accessibility (number of destinations that are accessible against reasonable costs in terms of time and money);
v. Environmental protection (low noise, atmospheric pollution of differing kinds, vibration, visual intrusion, severance, fear and intimidation, and the loss of intrinsically valuable objects, such as flora and fauna, ancient monuments and historic buildings);
vi. Economic regeneration (reinforcing the land use plans of the area); and
vii. Equity (equal distribution of transport benefits).

Zegras (2006) represents these ideas in his "Sustainable Indicator Prism". As can be seen from Figure 2.3, within the hierarchy of the prism are goals, indices, indicators and raw data, as well as the structure of multi-dimensional performance measures or indicators (Zegras, 2006).

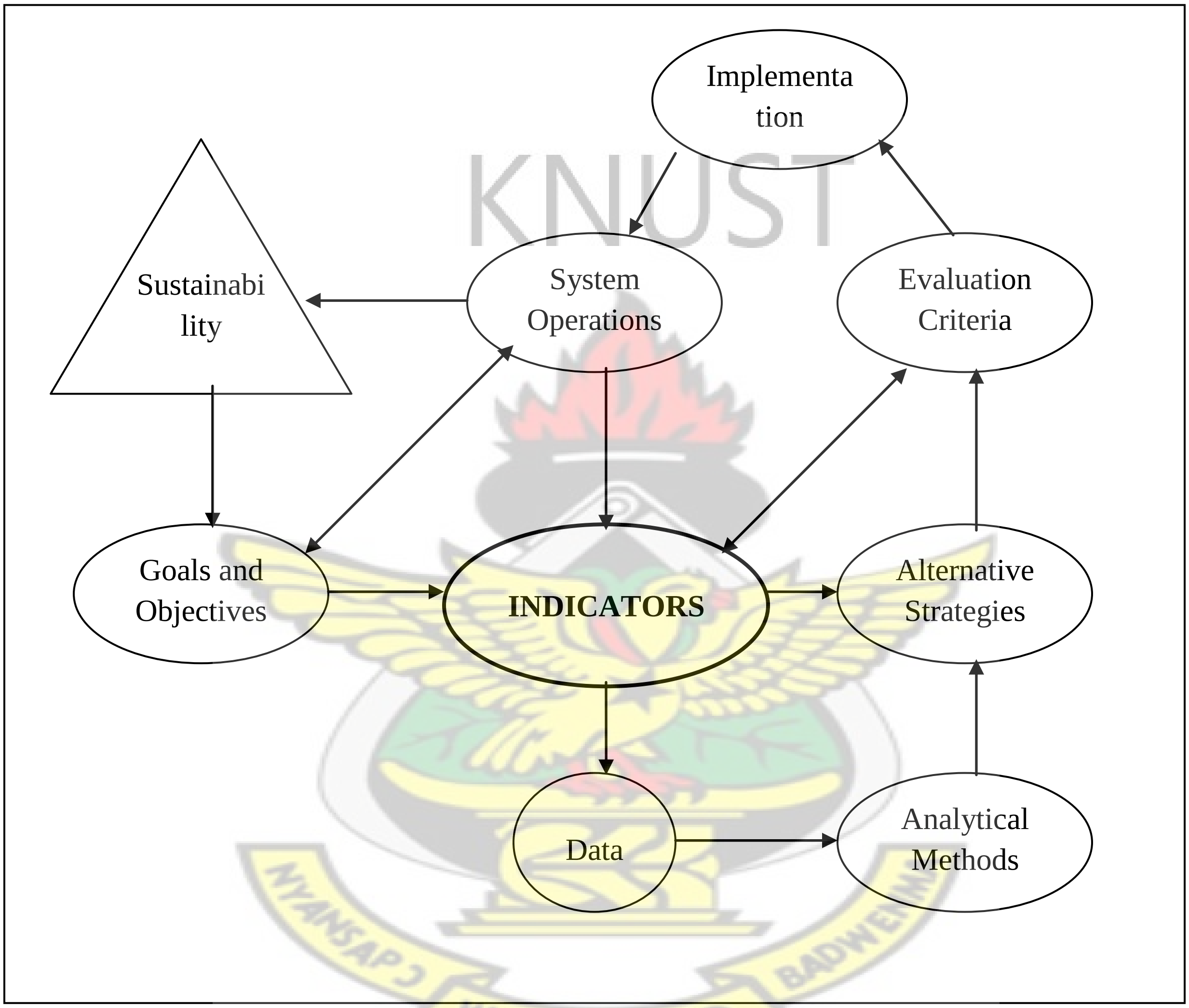
**Figure 2.3 – The Sustainable Indicator Prism**




*Source: Adopted from Zegras et al. (2004, in Zegras 2006)*

The role of indicators can therefore be situated within the context of Zegra's sustainability prism. This is because, developing an indicator informs the type of data, as well as the index or indices (which refers to a set of aggregated or weighted indicators), and ultimately achieving societal goals. Toth-Szabo et al. (2011) summarise the functions of indicators in three main ways – simplification, quantification and communication. This is depicted in Figure 2.4. Ultimately, the goal of developing a system of transportation indicators is to build powerful tools for policy making; these tools summarize trends and relationships that describe the most important activities, outputs, and side effects – both positive and negative – of transportation activities.

**Figure 2.4 – The Role of Indicators in Transport Sustainability**




*Source: Adopted from Meyer and Miller (2001, Cited in Zegras, 2006)*

2.3.4 Sustainable Transport Indicators by Category

Sustainable development is highly connected with the interplay of economic, social, and environmental indicators (refer to Figures 2.1 and 2.2). Within this context, evaluating transportation towards sustainability must reflect the "triple bottom line". This section describes the sustainable transportation indicators by category.

*2.3.4.1 Transport Economic Indicators*

Economic development refers to a community's progress toward economic objectives: such as increased income, wealth, employment, productivity, and social welfare (Litman, 2011). The purpose of an economic framework and indicators, therefore, is to monitor these parameters and to evaluate the economic impacts of transport policies (Toth-Szabo et al., 2011). In other words, economic indicators help to describe efficiency of the transport system and the benefits and costs for the society and individuals, which is often reflected in social welfare, and consequently GDP. However, relying on GDP as an indicator of economic sustainability has been criticized on a number of grounds (Litman, 2011):

i. "They only measure market goods and so overlook other factors that contribute to wellbeing such as health, friendship, community, pride, environmental quality, etc;

ii. These indicators give a positive value to destructive activities that reduce people's health and self-reliance, and therefore increase consumption of medical services, purchased rather than home-produced foods, and motorized transport; and

iii. As they are typically used, these indicators do not reflect the distribution of wealth (although they can be used to compare wealth between different groups)".

Litman (2011) recommends that, rather than net-gain in social welfare, sustainable transport economic indicators should reflect both the benefit of motor vehicle use, and the possibility that more motorised mobility reflects a reduction in overall accessibility and transport diversity. In addition, Schepelmann et al. (2010), suggest that the most realistic approach is to supplement GDP with additional environmental and/or social information. In order to make this kind of solution feasible there should be the establishment of an overarching and transparent indicator system for improving economic decision-making in support of sustainable development.

*2.3.4.2 Social Indicators*

Social indicators focus on the social impacts of transportation, and include equity, human health, community liveability and community cohesion, impacts on historic and cultural resources, as well as aesthetics (Litman, 2011). These parameters are often related with "quality of life" (Toth-Szabo et al., 2011). Although there is no universally accepted definition of quality of life, Toth-Szabo et al. (2010) refer to the term as "well being", "satisfaction" and happiness – related with the urban area, the public spaces.

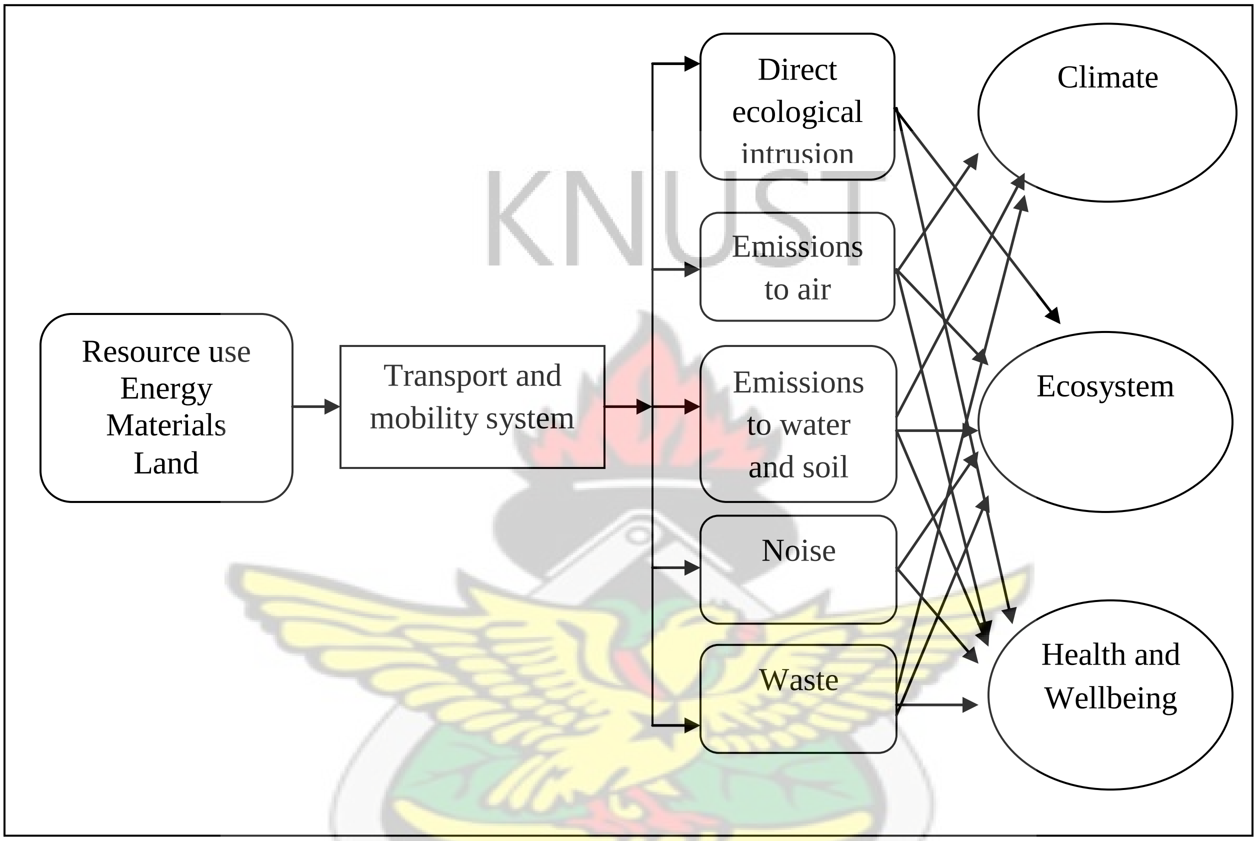
Transportation equity can be evaluated by comparing transport options, service quality, impacts and between different groups, particularly on economically, physically and socially disadvantaged people (Litman 2005). Transportation health impacts include accident injuries, pollution illness, and inadequate physical activity. Policies that increase non-motorized travel improve mobility for disadvantaged people and increase fitness tend to support sustainable transportation. Community livability and cohesion, according to Litman (2006) can be measured using surveys that evaluate impacts on the human environment, including interactions among neighbors, and how this affects property values and business activity. Historic and cultural resources can be evaluated using surveys which ascertain the value people place on them.

*2.3.4.3 Environmental Indicators*

Environmental sustainability is the most studied and developed in comparison with the economic and social concerns, as evidenced by works of Amekudzi and Meyer (2005), Amekudzi et al. (2009), Amekudzi et al. (2009), among others. Environmental indicators present the state of a particular environmental phenomenon that has significance beyond the property originally measured, and which requires little further explanation (OECD, 1999, in Toth-Szabo, 2011). According to Litman (2011), environmental impacts of transportation include *"various types of air pollution (including gases that contribute to climate change), noise, water pollution, depletion of nonrenewable resources, landscape degradation (including pavement or damage to ecologically productive lands, habitat fragmentation, hydrologic disruptions due to pavement), heat island effects (increased ambient temperature resulting from pavement), and wildlife deaths from collisions".*

Environmental impacts of transportation are differentiated by Rand et al. (2004) into inputs needed from the environment to the transport system, and the outputs from the transport system into the environment. In terms of the outputs, Rand et al. (2004) further differentiate them into two different types – the direct or immediate ones, and the indirect or secondary outputs (refer to Figure 2.5).

**Figure 2.5 Input-Output Framework of the Environmental Outcomes of Interest**




*Source: Adapted from Gudmundsson (2002, In Toth-Szabo, 2011)*

2.3.5 Criteria for Selecting Transport Indicator

Selection of indicators is generally based on certain internationally established and commonly used quality criteria. A review of indicator quality criteria of international organisations (OECD, EEA, EU and UN) by Dobranskyte-Niskota et al. (2007) reveal some commonalities with regard to indicators being representative of selected geographical or political area. "*Cost efficiency of indicators plays an important role for the OECD and UN indicator selections. For WHO, ethical value and usefulness of indicators are important criteria for the selection of indicators. The EU on the other hand considers balancing across different dimensions and mutual consistency within an indicator theme as important quality aspects. The EEA states that progress towards* *targets should be methodologically well founded, and the UN organization outlines that indicators should be within the capability of national governments to develop*" (Dobranskyte-Niskota et al., 2007). It can be inferred, therefore that, in selecting indicators, the accuracy within which the indicator measures the concept of interest, is critical. Zegras (2006) refer to this as "indicator validity".

Hart (1997, in Litman, 2011) recommends that, in selecting indicators, the following questions must be answered:

i. "Is it relevant to the community's definition of sustainability? Sustainability in an urban or suburban area can be quite different from sustainability in a rural town. How well does the direction the indicator is pointing match the community's vision of sustainability?

ii. Is it understandable to the community at large? If it is understood only by experts, it will only be used by experts.

iii. Is it developed, accepted, and used by the community? How much do people really think about the indicator?

iv. Does it provide a long-term view of the community? Is there information about where the community has been as well as where the community should be in 20, 30, or 50 years?

v. Does it link the different areas of the community? The areas to link are: culture/social, economy, education, environment, health, housing, quality of life, politics, population, public safety, recreation, resource consumption/use, and transportation.

vi. Is it based on information that is reliable, accessible, timely and accurate?

vii. Does the indicator consider local impacts at the expense of global impacts, for example, by encouraging negative impacts to be shifted to other locations?"

From the foregoing, indicators or performance measures must be developed to capture a community's broader vision which can be distilled into goals and objectives. It therefore becomes clear that performance measures or indicators for different regions (or other communities) may be different if their visions are different. There is thus no such thing as the correct performance measure in sustainability as much as there is/are the most appropriate measure(s) for capturing a particular vision (Jeon et al., 2010). Within this context, developing an appropriate framework for measuring transport sustainability in Kumasi would mean that, the vision and goals of its transport sector must be clearly stated, which will inform the indicators and data types for measurement. However, given the present status of any particular community, there may be superior and inferior visions or frameworks that can be adopted relative to moving rapidly toward sustainability (Jeon et al, 2010). These frameworks are reviewed to serve as general guiding principles for the development of indicators to measure the performance of Kumasi's transport sector towards sustainability. The subsequent section thus, discusses these initiatives.

## 2.4 Review of the Existing Transport Indicator Initiatives (Frameworks)

In order to determine a set of criteria by which Kumasi's transport system is evaluated, a review of existing transport indicator initiatives is necessary. It must be noted that, the individual sustainability indictors constitute a framework, a theoretical structure, systematizing data and information. The framework makes the interactions between different issues explicit (Munier, 2005). Differences among the organizations are thought to provide a sufficient degree of diversity and offer the overall comprehensive picture needed for the comparative analysis of indicator sets. A number of frameworks have been developed in this regard. This section, however, reviews 5 of these frameworks, and have been selected because of their wider use and applicability. These are discussed seriatim.

### 2.4.1 World Business Council for Sustainable Development (WBCSD)

The framework by WBCSD (2004) identifies 12 indicators, to measure the present and possible future state of sustainability of mobility, and how effective various approaches may be facilitating its improvement. These indicators have been informed by an earlier indicator sets developed by WBCSD (Mobility 2001), and modified through a combination of internal deliberations, studies of existing literature, as well as extensive consultations with stakeholders (WBCSD, 2004). Highlighting on the factors that were considered in the selection of the indicators, WBCSD (2004) notes that, "*these are indicators that ought to be central to any vision* *of sustainable mobility and the route to get there. They are the key dimensions that sustainable mobility systems should perform well on. They constitute a yardstick against which the effectiveness of various approaches can be measured".* These considerations confirm Zegras' "Indicator Validity", which refers to the accuracy within which the indicator measures the concept of interest (Zegras, 2006).

The indicators focus on the following themes: Accessibility; Financial outlay required of users; Travel time; Reliability; Safety; Greenhouse gas; emissions, Impact on the environment and on public well-being; Resource Use; Equity implications; Impact on public revenues and expenditure; and Prospective rate of returns to private businesses.

**Table 2.1 - WBCSD Framework for Sustainability Mobility**

| **Indicator Theme** | **Indicators** |
|---|---|
| Accessibility | - % of households having access to motorized personal vehicles;<br>- % of households located with a certain distance of public transport of given minimum quality. |
| Financial Outlay Required of Users | - Share of individual budget devoted to personal travel |
| Travel Time | - Average time required from origin to destination, including all switches of vehicle/mode and all "waiting time". |
| Reliability | - Variability in door-to-door travel time for "typical" mobility systems. |
| Safety | - The probability that an individual will be killed or injured in an accident while using a mobility system;<br>- Total number of deaths and serious injuries per year by category. |
| Security | - The probability that an individual will be harassed, robbed or physically assaulted during a journey. |
| Greenhouse Gas Emissions | - GHG emissions per time period measured in carbon-equivalent units. |

**Table 2.1 Continued**

| | |
|---|---|
| Impact on Environment and on Public Well-Being | - Emissions of $NO_x$, CO, Particulates, unburned hydrocarbons and lead per time period;<br>- Transport-related impacts on eco-systems (eg. Habitats, water) in addition to land use;<br>- Percentage of individuals exposed to various transport related noise levels over various time periods. |
| Resource Use | - Total transport-related use of particular fuel;<br>- % of a region's energy supply coming from outside the region or from insecure sources;<br>- Amount/share of land devoted to transportation activities;<br>- Total volume of material used by transport sector;<br>- Transport sector's share of total use; actual recycling rates. |
| Equity Implications | - Distribution of sustainable mobility values across different population groupings. |
| Impact on Public Revenues and Expenditure | - The level and change in levels of public capital and operating expenditures for providing transportation services and infrastructure. |
| Prospective Rates of Return to Private Business | - The prospective return on investment available to an efficient private business from offering particular mobility-related goods and services. |

*Source: WBCSD, 2004 (The Sustainable Mobility Project, Pg. 18-23)*

The indicators as presented in Table 2.1 provide a useful basis for measuring progress towards sustainable transportation or mobility. One identified flaw with this framework is the non-measurability of some major indicators such as "distribution of sustainable mobility values across different population groupings (equity implications). However, as acknowledged by WBCSD in the report, "just because something cannot be measured does not imply it should be ignored".

2.4.2 Victoria Transport Policy Institute's Framework

Another framework of transportation sustainability is the one developed by Litman (2007) from the Victoria Transport Policy Institute (VTPI). Littman (2009) concluded that, a single indicator is not adequate, but a set of indicators which should reflect various goals, objectives and impacts should be used. Litman groups his indicators into three major groups – economic, social, and environment, and further ranks them into: Most important; Helpful; and Specialized indicators. In terms of economic indicators, objectives such as increased income, wealth, employment, productivity and social welfare are identified. Social impacts include equity, human health, community livability (local environmental quality as experienced by residents and visitors) and community cohesion (the quality of interactions among community members), impacts on historic and cultural resources (such as historic sites and traditional community activities), and aesthetics. Whereas Environmental impacts include various types of air pollution (including gases that contribute to climate change), noise, water pollution, depletion of nonrenewable resources, landscape degradation (including pavement or damage to ecologically productive lands, habitat fragmentation, hydrologic disruptions due to pavement), heat island effects (increased ambient temperature resulting from pavement), and wildlife deaths from collisions (Litman, 2007) (see Table 2.2).

As indicated by Litman's Framework (2007) he identifies various sustainable transport indicators ranked by importance and type. The author suggests that for equity analysis, indicators can be disaggregated by demographic factors, so impacts on disadvantaged groups (people with disabilities, low incomes, children, etc.) are compared with overall averages.

**Table 2.2 – Recommended Indicator Set by VTPI**

| | Economic | Social | Environment |
|---|---|---|---|
| *Most Important (Should usually be used)* | - Per capita mobility (daily or annual person-miles or trips);<br>- Mode split<br>- Average commute travel time and reliability<br>- Per capita congestion cost<br>- Total per capita transport expenditure | - Per capita traffic crashes and fatalities<br>- Quality of transport for the disadvantaged<br>- Affordability (portion of household budget devoted to transport)<br>- Overall satisfaction rating of transport system<br>- Universal design | - Per capita energy consumption<br>- Energy consumption per freight ton-mile<br>- Per capita air pollution<br>- Per capita land devoted to transport facilities<br>- Air and noise pollution exposure and health damages<br>- Impervious surface coverage and storm water management practices |
| *Helpful (Should be used if possible)* | - Relative quality (availability, speed, reliability, safety and prestige) of non-motorised modes relative to motorised travel.<br>- Number of public services within 10-minute walk and job opportunities within 30-minute commute of residents | - Portion of residents who walk or bicycle sufficiently for health (15 minutes or more daily)<br>- Portion of children walking to school<br>- Community cohesion (quality of interactions among neighbours)<br>- Degree cultural resources are considered in transport planning) | - Community livability ratings<br>- Water pollution emissions<br>- Habitat preservation<br>- Use of renewable fuels<br>- Transport facility resource efficiency |
| *Specialized (Use to address particular needs or objectives)* | - Portion of households with internet access<br>- Change in property values | - Transit affordability<br>- Housing affordability in accessible locations | - Impacts on special habitats and environmental resources<br>- Heat island effects |

*Source: Litman, 2007*

2.4.3 Sustainable Transportation Performance Indicators (STPI)

STPI, authored by Gilbert et al., (2002), proposed 14 indicators, designed to show movement of transportation in Canada, towards or away from sustainability. These indicators reflect the economic, social and environmental aspects of sustainable transport, as shown in Table 2.3.

**Table 2.3 – STPI Framework for Sustainable Transport**

| **Framework Topic** | **Set of Indicators** |
|---|---|
| 1. Environmental and health consequences of transport | 1. Use of fossil fuel energy for all transport;<br>2. Greenhouse gas emissions from all transport;<br>3. Index of emissions of air pollutants from road transport; and<br>4. Index of incidence of injuries and fatalities from road transport. |
| 2. Transport activity | 5. Total motorized movement of people;<br>6. Total motorized movement of freight;<br>7. Share of passenger travel not held by land-based public transport; and<br>8. Movement of light-duty passenger vehicles. |
| 3. Land use, Urban form and Accessibility | 9. Rate of use of urban land. |
| 4. Supply of transport infrastructure and services | 10. Length of paved roads |
| 5. Transportation expenditures and pricing | 11. Index of relative household transport costs; and<br>12. Index of relative cost of urban transit; |
| 6. Technology adoption | 13. Index of intensity of the road vehicle-fleet; and<br>14. Index of emissions intensity of the road-vehicle fleet |
| 7. Implementation and Monitoring | |

*Source: Gilbert et al., 2002.*

Other additions to the indicators according to Gilbert at al. (2002) are on short term and long term bases. In terms of short term, the additions are: Net government expenditure on roads; share of total government transport expenditures going to ground-based public transport; travel by non-motorized modes in urban areas; and proximity of transport infrastructure to sensitive areas. The long term additions, on the other hand, focus on: modal split by urban zone; congestion index; transport related user charges; noise levels; as well as ecosystem fragmentation.

### 2.4.4 Transport and Environment Reporting Mechanism (TERM) Framework

TERM is an important initiative of the EU transport indicators and it is a jointly steered activity by the European Environmental Agency (EEA) and the European Commission. The major purpose of TERM is to monitor the progress and effectiveness of transport and environment integration strategies on the basis of a core set of indicators. These are selected to address the following policy issues (EEA, 2007):

i. Environmental performance of the transport sector;
ii. Management of transport demand and improvement of modal split;
iii. Spatial and transport planning coordination to match transport demand to the need for access;
iv. Optimizing the use of existing transport infrastructure capacity;
v. Moving towards a fairer and more efficient pricing system, which ensures that external costs are internalized;
vi. Implementation of cleaner technologies and efficiency of vehicles use; and
vii. Environmental management and monitoring tools to support policy- and decision-making.

The TERM indicators are focused on indicators tracking transport and environment integration in the European Union. These indicators are integrated in the so-called DPSIR framework, which depicts the indicators representing driving forces, pressures, state of the environment, impacts and societal responses. As it can be observed from Table 2.4, all indicators are divided into the two major groups and are composed of various data sources. The first group of transport and environment performance includes the components such as environmental consequences of transport, transport demand and intensity.

**Table 2.4a - Transport and Environment Reporting Mechanism (TERM) Indicators**

| Transport and Environmental Performance | |
|---|---|
| **Themes** | **Indicators** |
| Environmental consequence of transport | 1. Transport final energy and primary energy consumption and share in total by mode and fuel<br>2. Transport emissions of greenhouse gases (CO2 and N20) by mode<br>3. Transport emissions of air pollutants (NOx, NMVOCs, PM 10, Sox, lead and CO cursors) by mode<br>4. Exceedances of EU air quality standards for PM 10, NO2, benzene, ozone, lead and CO population exposed to exceedances of EU urban air quality standards.<br>5. % of population exposed to and annoyed by traffic noise, by noise category and by mode<br>6. Fragmentation of ecosystems and habitats<br>7. Proximity of transport infrastructure to designated areas<br>8. Land take by transport infrastructure by mode<br>9. Waste from road transport: number of end-of-life vehicles, number of used tyres |
| Transport demand and Intensity | *Passenger transport (by mode and purpose)*<br>1. Vehicle kilometer<br>2. Total passengers<br>3. Total passengers – km<br>4. Total passenger – km per capita<br>5. Passenger – km per GDP<br><br>*Freight transport (by mode and group of goods)*<br>1. Vehicle kilometer<br>2. Total passengers<br>3. Total passengers – km<br>4. Total passenger – km per capita<br>5. Passenger – km per GDP |

*Source: EEA (2002, in Dobranskyte-Niskota et al., 2007)*

The second group of determinants of the transport/ environment system tackles the components of spatial planning and accessibility, supply of transport infrastructure and services, transport costs and prices, technology and utilization efficiency and management integration.

**Table 2.4b - Transport and Environment Reporting Mechanism (TERM) Indicators**

| Determinants of the transport/environment system | |
|---|---|
| **Themes** | **Indicators** |
| Spatial planning and accessibility | 1. Regional access to markets: the ease (time and money) of reaching economically important asset (eg. Consumers, jobs), by various modes<br>2. Access to basic sevices: average passenger journey time and length per mode, purpose and location<br>3. Access to transport services (eg. Vehicle ownership and number of motor vehicles per household; % of persons in a location having access to transport node within 500 metres) |
| Supply of transport infrastructure | 1. Capacity of transport infrastructure networks, by mode and by type of infrastructure (motorway, national road, municipal road, etc)<br>2. Investments in transport infrastructure/capita by mode |
| Transport costs and prices | 1. Real change in passenger transport price by mode<br>2. Total amount of external costs by transport mode; average external cost per p-km and t-km by transport mode<br>3. Implementation of internalization instruments ie. economic policy tools with a direct link with the marginal external costs of the use of different transport modes<br>4. Fuel prices and taxes<br>5. Subsides<br>6. Expenditure on personal mobility per person by income group |
| Technology and utilization efficiency | 1. Overall energy efficiency for passenger and freight transport (per passenger-km and per tonne-km and by mode)<br>2. Emissions per passenger-km and emissions per tonne-km by mode<br>3. Occupancy of rates of passenger vehicles<br>4. Load factors for road freight transport (LDV, HDV)<br>5. Uptake of cleaner fuels and numbers of alternative-fuelled vehicles<br>6. Average age of the vehicle fleet<br>7. & of vehicle fleet meeting certain air and noise emission standard |
| Management integrations | 1. Number of member states that implement an integrated transport strategy<br>2. Number of member states with national transport and environment monitoring system<br>3. Uptake of strategic environmental assessment in the transport sector<br>4. Uptake of environmental management systems by transport companies<br>5. Public awareness and behaviour<br>6. Number of member states with a formalized cooperation between the transport, environment and spatial planning ministries |

*Source: EEA (2002, in Dobranskyte-Niskota et al., 2007)*

The indicators of TERM framework are projected to answer a set of policy questions aiming at more sustainable transport within an enlarged EU (EEA, 2002).

In addition to the foregoing frameworks developed by organisations, Jeon et al. (2008) have developed a multiple sustainability dimensional indexes to evaluate transportation planning options in a multi-criteria environment, using the performance indicators in Table 2.5.

**Table 2.5 - Sustainability Goals and Performance Measures**

| Sustainability dimension | Goals and Objectives | Performance Measures |
|---|---|---|
| Transportation System Effectiveness | A1. Improve mobility | A11. Freeway/arterial congestion<br>A12. Travel rate (minute/mile) |
| | A2. Improve System Performance | A21. Total vehicle-miles traveled<br>A22. Freight ton-miles<br>A23. Transit passenger miles travelled<br>A24. Public transit share |
| Environmental Sustainability | B1. Minimize GHG Effect | B11. $CO_2$ emissions<br>B12. Ozone emissions |
| | B2. Minimize Air Pollution | B21. VOC emissions<br>B22. CO emissions<br>B23. $NO_x$ emissions |
| | B3. Minimize Noise Pollution | B31. Traffic noise level |
| | B4. Minimize Energy Use | B41. Fuel consumption |
| Economic Sustainability | C1. Maximize Economic Development | C11. User welfare changes<br>C12. Total time spent in traffic |
| | C2. Maximize Affordability | C21. Point-to-point travel cost |
| | C3. Promote Economic Development | C31. Improved accessibility |
| Social Sustainability | D1. Maximize Equity | D11. Equity of exposure to emissions<br>D12. Equity to exposure to noise |
| | D2. Improve Public Health | D21. Exposure to emissions<br>D22. Exposure to noise |
| | D3. Increase Safety and Security | D31. Accidents per VMT<br>D32. Crash fatalities |
| | D4. Increase Accessibility | D41. Access to activity centers<br>D42. Access to open space |

*Source: Jeon et al., 2008.*

## 2.5 Synthesis of Transport Sustainability Frameworks

The review indicated that while a standard framework for evaluating progress toward transport sustainability did not exist, similar to its definitions, there are common indicators. Within this context, indicators are said to be common if they were captured at least by three of the frameworks. In cases where similar indicators were defined differently, they were considered identical, and thus grouped under a common theme. Using this criterion, a set of common transport sustainability indicators have been extracted from the complete indicator lists reviewed in the previous section. In all, 17 common indicators were identified under 8 themes (refer to Appendix 1). All the indicators being used in the 5 initiatives may be classified as economic, social, and environmentally related. Common indicators identified under these themes, which will be adopted in this study, are outlined in Table 2.6. It is however, important to mention that, the use of any of the measurement indicators in Table 2.6 will largely be dependent on the availability of data within the study time limits.

**Table 2.6 – Transport Sustainability Framework for Kumasi**

| **Sustainability Indicator** | **Variables** | **How Measured** |
|---|---|---|
| ***Economic*** | Transport Costs and Prices | Household travel cost |
| | | External cost of congestion |
| | Modal Split | % of transport use by mode |
| ***Social*** | Accessibility and Mobility | Average passenger travel time |
| | | Personal mobility |
| | Risk and Safety | Persons killed in traffic accidents |
| | | Persons injured in traffic accidents |
| | Affordability | Private car ownership |
| | | % of household income devoted to transport |
| ***Environmental*** | Resource Use | Fuel consumption |
| | | Lank take |
| | | Preservation of habitat |
| | Transport Emissions | $CO_2$ emission |
| | | Conventional pollutant emission |
| | | Noise pollution |

*Source: Based on Gilbert et al, 2002, EEA, 2002, WBCSD, 2004, Litman, 2007, Jeon et al., 2008*

Adopting these indicators to measure progress towards transport sustainability in Kumasi becomes very useful, considering the following characteristics of the City's transport sector:

i. About 52 per cent of all trips are non-motorised (Poku-Boansi, 2008), and yet, there is no serious effort to plan for people on foot in the City;
ii. Private vehicle registered in the City over the 2004 – 2010 period increased cumulatively from 1,976 to 26,299 (Poku-Boansi and Adarkwa, 2011);
iii. The sector accounts for about 70 per cent of emissions in the City, of which $CO_2$ components constitute about 97.6 per cent (Agyemang-Bonsu et al., 2010);
iv. High annual rate of transport related mortality;
v. Road construction is seen as favoured remedy to traffic congestion. Example is the on-going completion of the Inner Ring Road (Anloga-Asokwa By-Pass and the Sofoline-Interchange). This makes driving more attractive, and hence creates additional traffic.

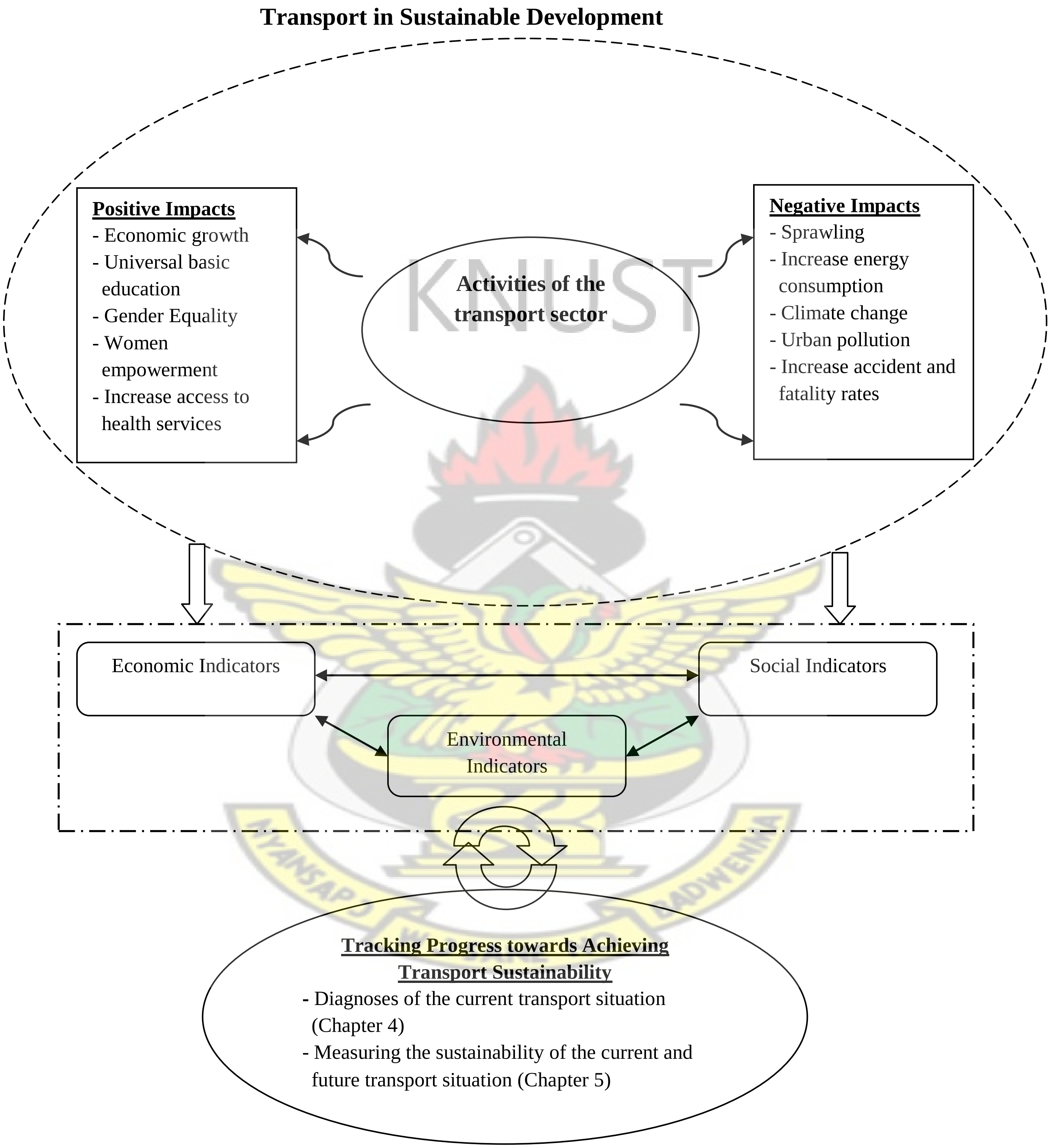
## 2.6 Conceptualizing Sustainable Transportation

This section provides the conceptual framework and attempts to define the key concepts of the study. An implicit argument made throughout sections 2.2.1, 2.2.2 and 2.2.3 is that, finding an appropriate framework for measuring progress towards transport sustainability is not possible until a relationship between both concepts – transport and sustainability – is established. From the argument, transportation has a direct bearing on sustainable development. This relationship is both positive and negative. For example, transportation is the medium through which:

i. Growth in economy is seen – in terms of support to food production and improved access to markets; access to employment; and source of employment;
ii. Accessibility to education and health services is ensured; and
iii. Gender equality and women empowerment is also ensured.

Similarly transport activities can affect sustainability through its contribution to climate change, urban pollution, increase energy consumption, increase accident and fatality rates, as well as sprawling urban development patterns. An urban transport sustainability framework is proposed in Figure 2.6 as a means of visualizing the identified positive and negative relationship between transport and sustainable development.

**Figure 2.6 – Conceptual Framework**




*Source: Author's Construct, 2011*

Consequently, to make progress towards the achievement of sustainable development, it is vital to also look at ways of making the transport system sustainable (that is, a transport system that does not leave problems or costs for future generations to solve). Moving from the "broader" sustainable development to sustainable transport requires indicators (reflecting the environmental, social and economic dimensions of sustainability) which ensure that, progress towards transport sustainability is made. Given its multidimensionality nature, a key to transport sustainability is that these three pillars, although interdependent, need to be mutually reinforcing.

In other words, an effective transport sustainability performance in this context requires all three pillars to have complementary rather than competing outcomes, indicated by the double headed arrow between the economic, environment and social dimensions, in Figure 2.6. These indicators provide the framework for tracking progress towards the achievement of sustainable transport system.

## 2.7 Summary of Chapter

The literature presented in this chapter covers a wide range of topics that suggest the nexus between the concepts of sustainable transportation and sustainable development, and the framework for measuring the progress towards transport sustainability. The basic messages that result from this literature search include the following:

1. Transport has a positive and negative relationship with sustainable development, and thus, to make progress towards the achievement of sustainable development, it is vital to also look at ways of making the transport sector sustainable;

2. Although there is no widely accepted definition of the term - sustainable transportation, it is seen as a transport system that meets the mobility needs of society, while also preserving and enhancing human and ecosystem health, economic progress, and social justice, now and for the future;

3. In operationalising sustainable transportation, a set of indicators, which must reflect or capture a community's vision, is necessary. This is represented in Figures 2.3 and 2.4;

4. The individual indicators constitute a framework with which the progress towards transport sustainability is measured. The frameworks presented in this chapter reflect the widely accepted "triple bottom line" of sustainable transport – economic, social and environmental dimensions.

Understanding the elements within the framework and their relationship, towards the achievement of transport sustainability require actions on how indicators can be better quantified and collected. These remain the strongest building blocks for a quantification methodology for assessing transport sustainability. However, there were no specific actions from the literature reviewed and hence it is from this premise that as part of investigating the sustainability of the transport system of Kumasi, the study seeks to identify a methodology in collecting and quantifying data. Addressing this will imply the following: (i) that the current state of Kumasi's transport system be examined; and (iii) the sustainability of the present and future state be assessed.

These issues are explored in subsequent chapters. The approach that is taken to present these issues in ways in which they can be measured and operationalised within the context of Kumasi, is provided in the next chapter.

## CHAPTER THREE

## RESEARCH APPROACH AND METHODOLOGY

### 3.1 Introduction

The issues discussed in the foregoing chapter offers a basic theoretical backdrop to the concept of sustainable transport. This chapter outlines the issues related to putting these ideas into practise, within the context of the study area, including: the research approach; data variables and measurements; data types and sources; inventories and investigations to be used in the collection of data for the study variables; as well as the framework for analyzing the data. In effect, the chapter provides a discussion of the decisions made in the research process.

### 3.2 Research Approach and Justification

The study adopted the case study approach in a generic sense. The case study approach was used because it offers the opportunity to investigate and understand the dynamics of a particular system (Yin, 1984). A hallmark of case study research is the use of multiple data sources, a strategy which also enhances data credibility. Data sources for this study included, but not limited to: published and unpublished reports, journals, interviews, direct observations, questionnaire/ survey schedules and direct measurements. In addition, the case study was selected because of the complexities of transport problems such as congestion, accidents, resource use, and vehicle emissions, among others, which the study seeks to explore.

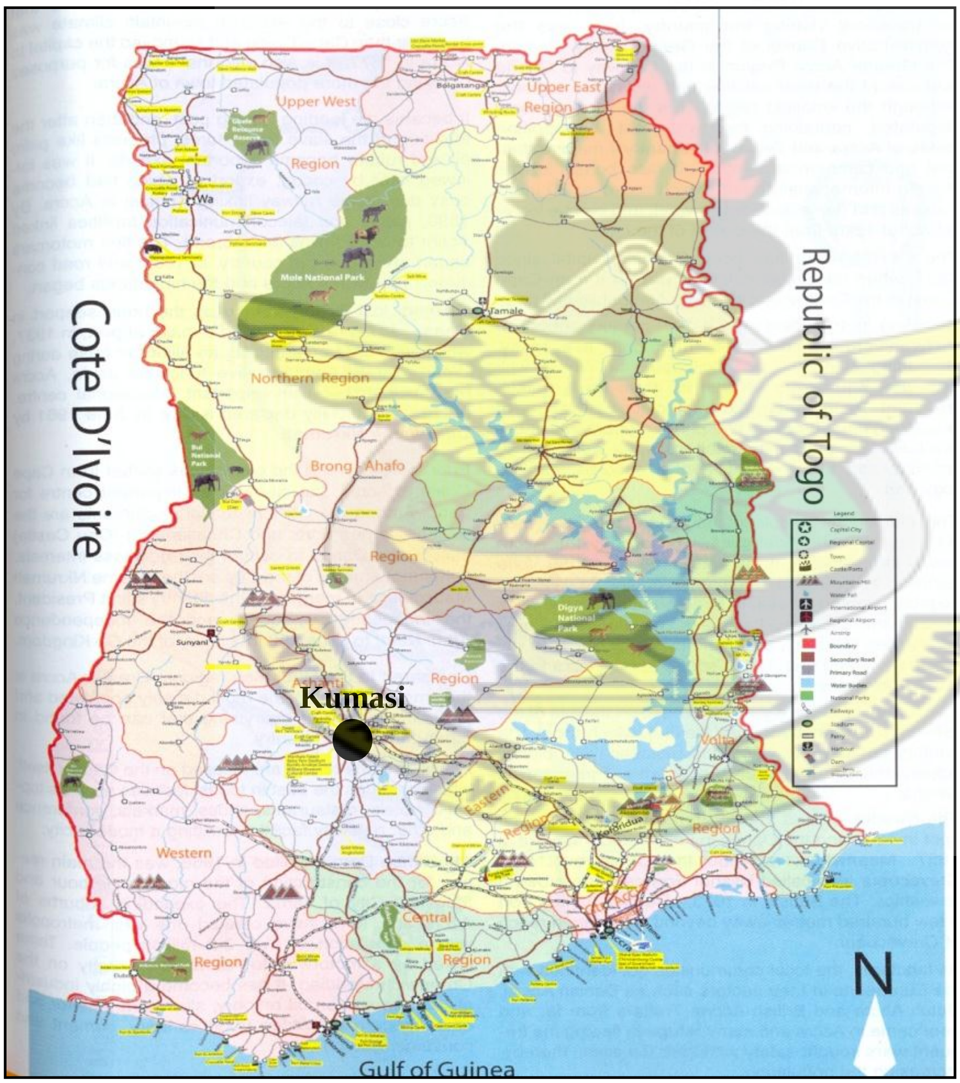
From Yin's definition, case study approach is useful when the study phenomenon is essentially contemporary. Urban transport is considered as having a direct bearing on sustainable development, which has been the main theme for many international conferences recently (Dakens, 2009), although the origin of the concept (sustainability) dates back to the early seventies. Considering that, there are three categories of case study, namely: explanatory, exploratory, and descriptive (Yin, 1984), it is useful to mention that, the exploratory approach was essentially adopted. The selection was guided by the overall study purpose, which was to explore the sustainability of the transport system of Kumasi.

### 3.3 Case Study Area and Justification

Kumasi provides a test ground for this study. The city, by virtue of its geographical location (central part of Ghana), is the centre of a major transportation, and facilitates movement to any destination in Ghana within a day. Its strategic location has also endowed it with the status of the principal transport terminal and has assured its pivotal role in the vast and profitable distribution of goods in the country and beyond. Much of Ghana’s primary road network converges on Kumasi.



**Figure 3.1 – Location of Kumasi as a Major Transport Hub of Ghana**




*Source: www.ghanadistricts.com*

In addition, it has taken on the role of a bulk breaking centre for several commodities in transit to either the northern or southern parts of the country. Its strategic location, a link between the north and south of the country, and as a capital of the Ashanti region makes it a brisk commercial and administrative center, and it is regarded as the commercial capital of Ghana (Adarkwa, 2011). The city, thus, experiences a substantial volume of passenger and freight traffic. The city has its share of problems created by an increasing number of private and commercial vehicles brought about by increases in the commercial and associated vehicular activities. Movement of people and goods is increasingly becoming complex and this is greatly affecting travel patterns. Consequently, Kumasi represents a true picture of Ghanaian cities, although each city has a unique character, in terms of their transportation system. These allow for an in-depth approach to finding appropriate strategies for sustainable urban transport.

### 3.3.1 Defining the Study Analysis Zones

Travel behaviour theory recognizes that daily travel choices are related to characteristics of the built environment such as residential density, employment density, mixed land uses, and street pattern. Although a considerable consensus has been reached with regard to the identified built environment measures on trip generation and mode choice, residential density is found to be the strongest predictor of travel behaviour. Leck (2006) confirms that, residential densities are found to be overwhelmingly significantly and negatively correlated with vehicle kilometers traveled, vehicle hours traveled, total vehicle trips, travel frequency, and on mode choice (walking, cycling, using private car, or public transport). Based on the foregoing, the study is conducted by dividing Kumasi into 6 Traffic Analysis Zones (TAZ) (as shown in Table 3.1), using residential density as a distinct factor, to facilitate data collection (refer to Appendix 2 for the distribution of residential densities for selected suburbs in the KMA). These sectors have varying densities and socio-economic characteristics that exhibit different traffic and travel characteristics. Despite the heterogeneity among sectors, individual suburbs have similar characteristics, and as such, are treated the same way as an aggregate group.

### 3.3.2 Selection of Suburbs for Closer Analysis

With these density stratifications, focal locations were selected for the field data to be collected. Based on the concentric nature of Kumasi's spatial pattern, two locations within each zone, representing the eastern and western or northern and southern sides of the zones, were selected, to ensure adequate geographic coverage by the overall respondent sample (see Figure 3.2). These locations are also found to be true representation of each zone. Consequently, a total of six suburbs were finally sampled for closer analysis (see Table 3.1).

**Table 3.1 – Sampled Study Communities for Closer Analysis**

| **Study Zones** | **Study Sites** |
|---|---|
| Sector 1 | Deduako (Kodiekrom) |
| Sector 2 | Ahodwo |
| Sector 3 | Kwadaso Estate |
| Sector 4 | Bohyen |
| Sector 5 | Aboabo |
| Sector 6 | Ayigya |

*Source: Author's Construct, 2012*

## 3.4 Units of Enquiry

The basic units of enquiry for the attainment of the study's objective were household heads, heads of transport related institutions, and to some extent transport unions in the Metropolis.

### 3.4.1 Household

Data on modal split were mainly obtained from this unit. Although every member of the household was capable of providing such information to some extent, the main focus of enquiry was the household head. However, in instances where the head of household was not available, the next of kin was used as proxy.

### 3.4.2 Transport Related Institutions

Institutions or bodies who supply and regulate the activities of the city's transport system were very important in undertaking this study. If sustainable transportation is to be achieved there should be a balance between the economic, social, environmental dimensions of the transport sector, as discussed in Chapter two (2). The data required from this group were mainly secondary in nature, namely emissions, congestion, resource use and safety. Also the perception of these institutions on the sustainability of the transport system was assessed. Specifically, the Urban Passenger Transport Unit (UPTU) of the Kumasi Metropolitan Assembly (KMA), the Drivers and Vehicle Licensing Authority (DVLA), the Environmental Protection Agency (EPA), as well as the Buildings and Road Research Institute (BRRI) were the main points of enquiry.

### 3.4.3 Transport Unions

Though the primary objective of the study is to investigate the sustainability of the City's transport system, it also takes into consideration planning approaches in making the system sustainable. Major players in helping achieve this objective or otherwise, are the Transport Unions, who supply transport services to a larger section of the population in the Metropolis. Data required from these unions were mainly their perception on mass-public transportation or large occupancy buses, which are vital to reducing congestion and consequently ensuring transport sustainability.

## 3.5 Household Sample Size Determination

Household sample size for the six suburbs was determined by using the mathematical formula as given by $n=\frac{N}{1+N(\propto)2}$ , where n is the sample size, N is the sample frame, α is the margin of error and 1, a constant (Refer to Appendix 3a on how "n" was determined). The total households of the various study areas were projected from the 2000 population and housing census results for a more realistic size. Using the inter censal growth rates for the various study sites, the household population was projected using the formula, $P_t=P_o(1+r)^t$.

Based on the calculations, a total sample size of 155 households was derived for the purposes of data collection. The sample size was based on the sum of the household population of all six suburbs, using a confidence interval of 92 percent. The numbers shown in Table 3.2 represents a pro rata breakdown of the overall minimum sample size for each study area.

**Table 3.2 – Sample Size Determination**

| Study Sites | Total Hh. (2000) | Inter Censal G.R (%) | Total Hh. (2012) | Minimum Sample Size |
|---|---|---|---|---|
| Deduako (Kodiekrom) | 563 | 5.8 | 1,107 | 6 |
| Ahodwo | 950 | 6.4 | 1,999 | 11 |
| Kwadaso Estate | 1,469 | 7.6 | 3,498 | 19 |
| Bohyen | 2,133 | 4.5 | 3,617 | 20 |
| Aboabo | 6,626 | 2.4 | 8,807 | 46 |
| Ayigya | 5,966 | 4.5 | 10,118 | 53 |
| **Total** | **17,707** | - | **29,146** | **155** |

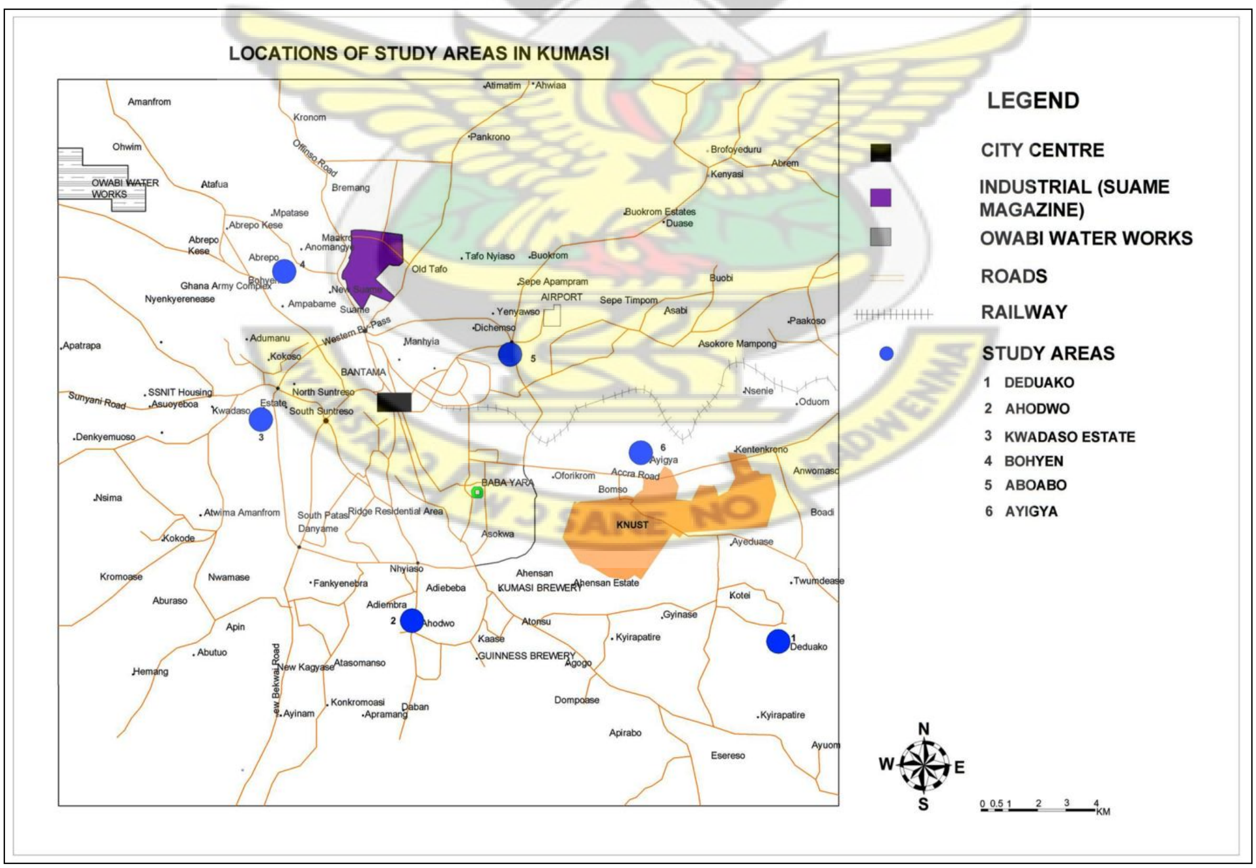
*Source: Population and Housing Census Report, 2000*

### 3.6 Sampling Techniques

The study adopted both non-probability and probability sampling. The non-probability sampling made use of purposive sampling. By this specific units were selected for the study due to their unique characteristics. In a sense, institutions were selected purposively, as they possessed the kind of information required needed to answer the research questions. This was also used in the selection of study roads, which was influenced by the availability of reliable accident and traffic data (ADT volumes), and road alignment details from as-built drawings and design reports.

Probability sampling, specifically the systematic sampling method, was employed at the household level. This is giving by the formula: K=N/n, where, "K" - the $K^{th}$ respondent to be interviewed after the first sample unit has selected randomly; "N" – the sample frame; and "n" – the sample size (Refer to Appendix 3b on how $K^{th}$ was determined for each community). Adopting this sampling technique, a house was used as a surrogate for household. In a sense, the total sampling frame for each community constituted the total number of houses within that community. This was possible especially in the low density areas, where each household occupied its own house. In Kodiekrom, every 32nd house or household or the next was interviewed. In Ahodwo and Kwadaso Estate, every 18th house and 44th house was interviewed respectively. On the other hand, in the high density areas, where a house was occupied by between two and eight households, a household was randomly selected for interview within a house that had been selected using the systematic sampling technique. In Bohyen, every 19th house was selected. In Aboabo and Ayigya, every 18th house and 22nd house was selected respectively. In all these instances, the initial house was randomly selected, but in some cases, it was taken to be the first house the interviewer saw as entering the community. The use of the systematic sampling over the other probability sampling techniques, in this study, stemmed from the fact that, it is highly representative of the population, unless certain characteristics of the population are repeated for every $n^{th}$ individual, which was not experienced in this study.

**Figures 3.2 – Location of Sampled Study Communities in Kumasi**




*Source: Author's Construct, 2012.*

### 3.7 Data Collection and Assembly

The study largely utilised quantitative data to address the research objectives. In doing so, several methods were employed in collecting such data, as discussed seriatim.

#### 3.7.1 Data Types

Variables believed to relate to transport sustainability in Kumasi were identified as follows: accessibility and mobility, risk and safety, resource use (fuel consumption), vehicle emissions, as well as transport affordability. This was primarily based on the literature reviewed. Data for the variables required in the study were both primary and secondary. Primary data in the context of this study refer to all field data that were gathered through surveys/inventories, as well as measurements and observations. The type of primary data collected included:

- Household level data – socio-economic data, information on daily trips and activities, vehicle ownership and characteristics, etc.;
- Institutional level data – road traffic crash data, vehicular traffic data, etc.
- Road geometric data – measurement of lane widths, shoulder widths, and the number of vehicle access points on the study roads.

Secondary data on the other hand refer to the data that were collected from journal articles, institutional reports, and maps. Secondary data included: fuel consumption data, vehicle emissions data, and traffic congestion data (speed data).

Even though both data types were considered, the study to a larger extent, relied on secondary data, since data especially on fuel consumption and emissions, could only be obtained in published form at the institutional level, giving several resource constraints. Primary data, however, were used to provide a better understanding of the data obtained from secondary sources, and allowed a deeper analysis to be done.

### 3.7.2 Data Sources

The main sources of primary data were household heads and heads of departments of the various institutions, as mentioned in Section 3.5. The secondary data on the other hand, were obtained from published and unpublished sources. Even though the study to a larger extent was a city level one, secondary data sources were largely at the national level. They were however used because of their relevance to the Kumasi. The secondary data required for the study were collected from various sources, primarily from the following:

- Population and Housing Census Report, 2000;
- Vehicular Emissions Inventory in Ghana, 2007;
- Strategic Environment Assessment of the Transport Sector Report, Ghana, EPA, 2007;
- National Transport Policy, Ghana, 2008;
- KMA Transport Action Plan for Kumasi, 2011; and
- Journal papers and book chapters on urban transport systems of Kumasi, such as “Rising Vehicle Ownership, Roadway Challenges, and Traffic Congestion in Kumasi, 2011”, among others.

### 3.7.3 Tools and Methods of Data Collection

Prior to administering the survey instruments, a pilot study involving a small sample of the study actor were conducted, in order to determine the clarity, validity, adequacy, relevance, suitability and length of the survey instruments. This was followed by an intensive field investigation from households in the sampled suburbs and the identified institutions to obtain relevant primary data. A combination of methods were used in the collection of data, taking into consideration all the actors who had been predetermined during the research design and confirmed during the pilot survey. Primary data were to a larger extent, obtained using both structured questionnaire schedules and semi-structured or interview guides.

- Structured Interview

Structured interview is a very formal interview following written questions. This was employed to solicit for information from household heads within the study areas. This required that, a representative sample size be determined to provide adequate responses for the analysis of the study variables. In this regard, population figures for the study areas were obtained from census records, and a sample size deduced, using the mathematical approach (refer to Section 3.6).

- Semi-Structured Interview

This was done in a more discursive manner than the extractive type of interview, where respondents just provide answers to structured interviews. During this stage, respondents were guided by a series of checklists.



Other methods employed in collecting the primary data included:

- Observations; and
- Inventory survey - undertaken on the major road network in the city, covering arterials, minor arterials and major collectors.

### 3.8 Analyses and Presentation of Data

This study primarily examines the sustainability of Kumasi's transport system, by identifying the various factors that affect the sustainability of the city's transport system. Data on study variables reflecting the current transport situation were analysed using Univariate and Bivariate Statistics. The univariate descriptive analysis was used to identify the characteristics of the current transport situation, taking into consideration the study variables. In analyzing this information, normal frequency counts and distributions were used to summarize data on the transport situation of Kumasi. Statistical application techniques such as means, median, and frequency distribution were employed in aiding the analysis of the data. Demographic characteristics, such as: household size, employment status, household income, and household vehicle ownership (which were identified as factors influencing the current transport situation), were analysed using univariate statistics.

Bivariate descriptive analysis (Correlation analysis), which is a sub-menu in the Statistical Package for Social Sciences (SPSS), was used to make inferences and establish the relationship that exists between the various study variables, and their strength to be determined simultaneously. The Pearson's Product Moment Correlation Coefficient was employed to examine the strength of the relationships. This was done for variables such as: vehicle population and congestion; congestion and fuel consumption; congestion and accidents; and fuel consumption and vehicle emissions.

In measuring the sustainability of the transport system of Kumasi, the "relative indicator" approach was used; implying that, a comparative analysis of the transport systems of Mexico City (Mexico), Bogota (Columbia), Istanbul (Turkey), and Lagos (Nigeria), with Kumasi's was done.



### 3.9 Summary of Chapter

This chapter has illustrated how the research seeks insight from a number of methods (published data, field counts, surveys and interviews) on an array of institutions and household dimensions to provide insight on sustainability of urban transport system in Kumasi. It also presents the analytical tools for the sets of data, needed to establish the relationship between the study variables. Data collected using the outlined methodology are analysed in the subsequent chapters.

# CHAPTER FOUR

# ANALYSES OF THE CURRENT TRANSPORT SITUATION IN KUMASI

## 4.1 Introduction

Assessing the sustainability of urban transport systems requires an understanding of the current state of the sector. This serves as input data with which the performance of the city's transport system is examined. The Chapter describes the current transport situation of Kumasi through a detailed analysis of the secondary and primary data collected for the study. This is tailored along the study variables: modal split; accessibility and mobility; transport emissions; risk and safety, and resource use (fuel consumption). Consequently, the chapter is structured into nine sections.

As a prelude to the main discussions, and in an attempt to identify the factors influencing the current transport system, Sections two (2) and three (3), following this introduction, focus on the demographic characteristics and the travel behaviour characteristics of households respectively. In Section four (4), empirical data on vehicle (fleet) characteristics within the city are presented; noting its growth pattern, its classification (in terms of types, age of production, and fuel type) as a basis for understanding the level of service of the city's roads, as well as its effects on fuel consumption, emissions, and accidents in the city. Section five (5) focuses on accessibility and mobility in the city, while Section six (6) is concerned with the rate of fuel consumption in the city. Analyses of the trends in vehicular emissions and accidents as an indicator of measuring the state of the environment and safety of Kumasi's transport system are captured in Sections seven (7) and eight (8) respectively. Section nine (9) summarises the Chapter, and provides a transition for the next Chapter. It is useful to mention that, the analyses of data in this chapter have been done in light of the approach and methodology outlined in Chapter three.

## 4.2 Demographic Characteristics

Even though a minimum sample size of 155 was calculated for the study, a total of 166 households fully participated in the Household Survey. In doing so, these households provided data about their household composition, vehicles owned and characteristics, as well as travel in the City. The purpose of this section, therefore, is to summarize the demographic and travel behavior characteristics of the participating households and to provide details highlighting how demographic variations in the households across the study areas are reflected in the travel behavior data (in Section 4.3), and ultimately the sustainability of the City's transport system. These characteristics are especially important for managing congestion and ensuring sustainability, because of the established relationship between household sizes, employment status, household income, and vehicle ownership, on the travel behaviour of household members (see for example Hanson, 1982; Soltani, 2005; and Potoplou and Kanaroglu, 2006).



### 4.2.1 Household Size

The significance of household size lies in the fact that, in most instances, it has a strong positive correlation with household trip rates (Hanson, 1982). The average household size of participating households was found to be 4.51 (see Table 4.1).

**Table 4.1 – Average Household Sizes of Study Communities**

| Study Communities | Household Sizes | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **N** | 1 | 2 | 3 | 4 | 5+ | Total | Mean |
| Kodiekrom | 10 | - | 20.0% | 30.0% | 40.0% | 10.0% | 100.0% | 4.20 |
| Ahodwo | 15 | 13.3% | 6.7% | 46.7% | 6.7% | 26.6% | 100.0% | 3.93 |
| Bohyen | 23 | 4.3% | 13.1% | 26.1% | 21.7% | 34.8% | 100.0% | 4.09 |
| Aboabo | 46 | 17.4% | 6.5% | 13.1% | 8.7% | 54.3% | 100.0% | 6.30 |
| Ayigya | 53 | 13.8% | 11.3% | 18.8% | 15.1% | 41.0 | 100.0% | 5.12 |
| Kwadaso Estate | 19 | 26.3% | 15.8% | 36.8% | 5.3% | 15.8% | 100.0% | 2.67 |
| **Total** | **166** | **13.9%** | **10.8%** | **23.5%** | **13.9%** | **37.9%** | **100.0%** | **4.51** |

*Source: Author's Field Survey, 2012*

As can be seen from Table 4.1, Aboabo and Ayigya recorded the highest of 6.30 and 5.12 respectively, which are higher than the City's average of 5 and the national average of 5.1 (Adarkwa and Poku-Boansi, 2011). These areas are mainly areas of tradition, and largely dominated by single storey compound houses including villages developed by or still separated from the city. Kwadaso Estate and Ahodwo areas recorded the least household sizes of 2.67 and

3.93 respectively. These areas, however, are high class residential areas dominated by low housing densities and occupied by senior government and company employees as well as wealthy business people and are in single household occupancy.

### 4.2.2 Employment Status

Employment status was obtained for household members aged 18 or older. As shown in Table 4.2, 57.5 percent of participating household members aged 18 and over were employed. Employment rates were higher in the low density areas than the high density areas. However, in terms of the number of persons working, the high density areas reported the highest. The highest proportions of employed respondents were reported by those in Ahodwo, Kodiekrom, and Kwadaso Estate, with about 80 percent, 80 percent and 70 percent respectively. The lowest proportions of employed respondents were reported in Bohyen (60 percent), Ayigya (50 percent), and Aboabo (50 percent), as shown in Table 4.2.

**Table 4.2 – Employment Status of Households**

| Study Communities | Household Workers | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4+ | Total | Mean |
| Kodiekrom | 23.8% | 30.9% | 35.7% | 4.8% | 4.8% | 100.0% | 0.8 |
| Ahodwo | 16.9% | 6.8% | 42.4% | 25.4% | 8.5% | 100.0% | 0.8 |
| Bohyen | 40.4% | 21.3% | 29.8% | 3.2% | 5.3% | 100.0% | 0.6 |
| Aboabo | 48.3% | 14.4% | 12.1% | 13.1% | 12.1% | 100.0% | 0.5 |
| Ayigya | 48.3% | 13.3% | 14.0% | 13.7% | 10.7% | 100.0% | 0.5 |
| Kwadaso Estate | 27.5% | 35.3% | 31.4% | 3.8% | 2.0% | 100.0% | 0.7 |
| **Total** | **42.5%** | **16.5%** | **19.5%** | **12.0%** | **9.5%** | **100.0%** | **0.6** |

*Source: Author's Field Survey, 2012*

### 4.2.3 Household Income

Household income estimates carried out revealed that, per household income for the study zones is estimated at GHS 1,012.5. In terms of income distribution, it was found that, households in the low density areas reported higher incomes than those in the middle and high density areas, which was an expected trend. Households in Ahodwo recorded the highest proportion (80 percent) of GHS 1,000 or more, and an average income of GHS 1,650. Those in Aboabo recorded the lowest proportion recording incomes under GHS 200 (see Table 4.3).



**Table 4.3 – Monthly Income Distribution of Households**

| **Study Communities** | **Household Income (GHS)** | | | | | | |
|---|---|---|---|---|---|---|---|
| | <200 | 200-399 | 400-599 | 600-799 | 800-999 | 1000+ | Median |
| Kodiekrom | - | - | 10.0% | 10.0% | - | 80.0% | 1,200 |
| Ahodwo | 6.7% | 6.7% | 13.3% | 6.7% | - | 66.7% | 1,650 |
| Bohyen | 15.2% | 21.7% | 43.5% | - | 13.0% | 6.6% | 650 |
| Aboabo | 17.4% | 15.2% | 28.3% | 10.9% | 8.7% | 19.5% | 425 |
| Ayigya | 9.4% | 15.1% | 7.5% | 7.5% | 11.3% | 49.1% | 750 |
| Kwadaso Estate | 5.3% | 10.5% | - | 5.3% | 15.8% | 63.2% | 1,400 |
| **Total** | **10.8%** | **13.9%** | **18.1%** | **7.2%** | **9.6%** | **40.4%** | **100.0%** |

*Source: Author's Field Survey, 2012*

### 4.2.4 Household Vehicle Ownership

Regarding household vehicle ownership, the city's average was 0.5 per household. Households in Ahodwo and Kodiekrom reported owning the most vehicles, on average (1.5 and 1.4 per household respectively). Households in Aboabo, Ayigya and Bohyen reported owning the fewest vehicles (0.3, 0.2 and 0.2 per household respectively). These findings support the contention that, households in denser areas tend to have fewer vehicles presumably due to higher auto level of service (because of congestion problems, parking limitations, etc) associated with denser areas (Bhat and Koppelman 1993), and more availability of other modal choices i.e. walking; cycling or public transport (Soltani, 2005). Socio-economic characteristics such as:

households' employment status and household income were also found to be significant in explaining the number of vehicles owned by households in the study communities.

**Table 4.4 –Household Vehicle Ownership in Study Communities**

| Study Communities | Household Vehicles | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | Total | Mean |
| Kodiekrom | 10.0% | 50.0% | 30.0% | 10.0 | 100.0% | 1.4 |
| Ahodwo | 20.0% | 33.3% | 20.0% | 26.7% | 100.0% | 1.5 |
| Bohyen | 86.9 | 13.1 | - | - | 100.0% | 0.2 |
| Aboabo | 82.6% | 13.0% | - | 4.4% | 100.0% | 0.3 |
| Ayigya | 83.0% | 13.2% | 3.8% | - | 100.0% | 0.2 |
| Kwadaso Estate | 26.3% | 47.4% | 15.8% | 10.5% | 100.0% | 1.1 |
| **Total** | **66.9%** | **21.1%** | **6.6%** | **5.4%** | **100.0** | **0.5** |

*Source: Author's Field Survey, 2012*

According to Hanson (1982), trip frequency increases with household size, income and car ownership. This is further supported by Ewing and Cervero (n.d), who argued that, trip frequencies, trip lengths, and mode choice appear to be primarily a function of socio-economic characteristics of travellers. The next section, thus, explores the relationships between the socio-economic characteristics of sampled households presented in this section and their travel behaviour characteristics.

## 4.3 Travel Behaviour Characteristics

While the previous section focused on the characteristics of the sampled households, the purpose of this section is to present the characteristics of the trips themselves. In this section, details of the reported trips are reviewed in order to document the extent to which the travel behaviour varies across the density zones.  Specifically, the section focuses on household trip rates, trip purposes, trip mode and reasons, as well as origins and destination of trips.

4.3.1 Household Trip Rates

The daily average household trip rate was 7.1 trips. However, household trips rates varied across the density zones. Households in the lower residential densities made more trips, on average (8.6 trips, compared to 5.5 trips in the high residential densities). The highest average daily household trip rates were recorded in Kodiekrom (8.9 trips), Ahodwo (8.7 trips), and Kwadaso Estate (8.4 trips). Households in Aboabo, Ayigya and Bohyen, reported the lowest average daily trips of 6.3 trips, 5.5 trips, and 4.6 trips, respectively (see Table 4.5).



**Table 4.5 –Household Trip Rates**

| Study Community | Average Trip Rates |
|---|---|
| Kodiekrom | 8.9 |
| Ahodwo | 8.7 |
| Bohyen | 4.6 |
| Aboabo | 6.3 |
| Ayigya | 5.5 |
| Kwadaso Estate | 8.4 |
| **Average** | **7.1** |

*Source: Author's Field Survey, 2012*

The findings in Table 4.5 confirm the common viewpoint of the role of residential densities, as being the most important built environment element which influences travel choices. A major feature of high residential densities is the mix of land uses, which reduces the demand to travel. Communities with approximate housing-job-shopping balance, see majority of residents working and shopping in their home communities (Cervero, 1989). This could explain the findings in Table 4.5.

A correlation between the average household trips and their socio-economic characteristics also, revealed very significant results. The most significant correlations were: vehicle ownership, employment status, and household income, supported by R-squared values of 0.9351, 0.7597, and 0.6915, respectively. This implies that, vehicle ownership, employment status of household members, and household's income, could explain 93.5 percent, 75.9 percent, and 69.1 percent, respectively, of the variation in household trip rates. Despite the statistically significant relationship between these characteristics and household trip rates, the relationship between household size and household trip rates was not significant, with R-squared value of 0.1769. This is to say that, household size could only explain 17.7 percent variation in household trip rates. The implication is that, increase in household sizes would not necessarily result in an increase in household trip rates, which deviates from the general trend. One significant feature observed, which could partly explain this phenomenon, was the large proportion of household members with age 60 and over, who reported lower level of trips than the active age group (18-60), within households with large sizes.



4.3.2 Trip Purpose

Travel is a derived demand, in that people do not travel for travel's sake. Transportation occurs to facilitate community activities, both socially and economically. Each trip is therefore made for a particular purpose. The survey considered trips based on 6 main trip purposes: work, school, recreation, shopping, church and funeral. The reasons reported for travel were reclassified into 2 modeling trip purpose category based on the following definition: (i) Home-Based Work (HBW) – all trips that start at the home location and terminate at the work location; and (ii) Home-Based Non-Work (HBNW) – all trips that start at the home location and terminate at any location but work – shopping, school, recreation, church, etc.

**Table 4.6 – Trip Purposes of Trip Makers in the Study Areas**

| **Trip purposes** | **Trips** | **Percent (%)** |
|---|---|---|
| Work | 304 | 60.0 |
| School | 160 | 31.5 |
| Recreation | 9 | 1.7 |
| Shopping | 18 | 3.6 |
| Church | 15 | 3.0 |
| Funeral | 1 | 0.2 |
| **Total** | **507** | **100.0** |

*Source: Author's Field Survey, 2012*

From Table 4.6, it can be realised that, movements within the City are generally to work places, accounting for about 60 percent of all trips. These trips usually terminate at the CBD (as can be seen in section 4.3.4), where most jobs in the city are located. This therefore explains the traffic situation on the major arterials leading to the CBD, which are characterized by high level of congestion during the morning and evening peak times.

### 4.3.3 Trip Mode

In addition to trip purposes and their destinations, data were obtained on household's mode of trip. By this, the proportion of households depending on private vehicles, public transport, and non-motorised transport were estimated. The distribution of trips by mode is shown in Table 4.7. As indicated in Table 4.7, mini-bus/trotro and taxi (referred as informal vehicles) were the dominant mode throughout the city, accounting for 54.8 percent of all trips. These were predominantly used in Aboabo, Ayigya and Bohyen. Non-motorized travel occurred in all the study communities, but again was concentrated in Aboabo, Ayigya and Bohyen. This phenomenon is as a result of the proximity of their workplaces to the residences as well as location of schools.

**Table 4.7 – Household Trip Modes in Study Areas**

| **Mode** | **Frequency** | **Percent** |
|---|---|---|
| Walking | 119 | 23.5 |
| Private Car | 100 | 19.6 |
| Mini Bus | 217 | 42.9 |
| Taxi | 60 | 11.9 |
| Cycling | 11 | 2.1 |
| **Total** | **507** | **100.0** |

*Source: Author's Field Survey, 2012*

It can be seen from Table 4.7 that, mini-buses (trotro) is the dominant mode used by trip makers as it accounts for 42.9 percent of all trips made. Walking to trip destinations also contributes to about a quarter (23.5 percent) of all trip modes in the city.

Trip makers usually have different reasons for choosing the various modes of transport ranging from convenience, time or duration of travel, safety, cost and access. Table 4.8 presents the reasons why travel makers in the city prefer one mode of transport over the other. The survey revealed that, as shown in Table 4.8, travelers in study areas put more premium on convenience. However, it was revealed that 72.45 percent and 47.37 percent of travelers who patronize private vehicles and taxis respectively, attributed their choice to the convenience such modes present. Also 42.44 percent of travelers chose "trotro" over other transport modes due to its affordability. This gives the indication that in the attempt of city authorities to plan for sustainable transport, consideration must be given to measures that promote both convenience and affordability. This will satisfy majority of commuters and reduce the ills of road transport - accidents, congestion and vehicular emissions.

**Table 4.8 – Reasons for Choice of Mode**

| **Mode** | **Transport Modes** | | | | | **Total** |
|---|---|---|---|---|---|---|
| | Convenience | Time | Safety | Cost | Access | |
| Walking | 65 | 12 | 5 | 20 | 3 | **105** |
| Private Vehicle | 73 | 10 | 4 | 7 | 11 | **105** |
| Trotro | 46 | 22 | 3 | 89 | 52 | **212** |
| Taxi | 29 | 8 | 8 | 17 | 3 | **65** |
| Cycling | 10 | 2 | - | 4 | 4 | **20** |
| **Total** | **223** | **54** | **20** | **137** | **73** | **507** |

*Source: Author's Field Survey, 2012*

Observations made on the relationship between the type of mode used for a trip and household income was significant and did not deviate from the expected trend, where populations with lower income generally take public transit, while higher-income population take trips with private vehicles (Sperling, 2001). As can be seen in Table 4.9, households with higher average monthly income generally use private vehicles while those who earn lower average monthly income use mini-bus (trotro). Taxis are patronized by households with fairly high income. This could be partly explained by the fact that, households with higher income prefer and are able to pay for higher level of comfort than households with lower incomes.

**Table 4.9 – Average Monthly Income and Mode Type Used**

| Mode Type Used | Average Monthly Household Income (GHS) |
|---|---|
| Private Vehicle (Cars) | 1,822.5 |
| Taxi | 1,012.5 |
| Mini bus (trotro) | 931.5 |
| Walking and Bicycling | 283.5 |
| **Average of Total** | **1,012.5** |

*Source: Author's Field Survey, 2012*



4.3.4 Origin and Destination of Trips

It has been established earlier that trip makers in Kumasi make trips for different purposes dominated mainly by work (60 percent). Table 4.11 indicates that most of these trips end outside the communities in which they originate. About 54.8 percent of all trips in Kumasi are made to the Central Business District (CBD). However, the study revealed that 60.5 percent of all trips made to the CBD are for work purposes. This is explained by the fact that the road network in and around the city is based on a system of radial routes converging on the CBD. This situation results in one-way traffic congestion in the morning and evenings on account of the concentration of activities at the CBD with people making trips into the CBD in the morning and trips out of the CBD during the evening.

This phenomenon contributes to the high volume of traffic on the arterial roads leading to the CBD and consequently congestion during both morning and afternoon peak hours. Notwithstanding, Table 4.11 indicates that 25 percent of home based work trips end in the communities within which they originate. This is encouraging as the mixed use of homes with work reduces the dependence on motorised modes of transport and consequently reduces the level of emissions from vehicles.

**Table 4.10 – Trip Origin and Destination of Study Communities**

| Trip Origins | Trip Destinations | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Within Com. | | Outside Com. | | CBD | | **Total** | |
| | Counts | % | Counts | % | Counts | % | **Counts** | **%** |
| Kodiekrom | 1 | 0.6 | 6 | 8.7 | 25 | 9.1 | **32** | **6.4** |
| Ahodwo | 15 | 9.6 | 7 | 10.1 | 21 | 7.7 | **43** | **8.6** |
| K. Estate | 5 | 3.2 | 2 | 2.9 | 40 | 14.6 | **47** | **9.4** |
| Bohyen | 35 | 22.3 | 5 | 7.3 | 45 | 16.4 | **85** | **17.0** |
| Aboabo | 42 | 26.7 | 17 | 24.6 | 85 | 31.0 | **144** | **28.8** |
| Ayigya | 59 | 37.6 | 32 | 46.4 | 58 | 21.2 | **149** | **29.8** |
| **Total** | **157** | **100.0** | **69** | **100.0** | **274** | **100.0** | **500** | **100.0** |

*Source: Field Survey, 2012*

**Table 4.11 – Destination of HBW Trips of Study Communities**

| **Trip Destinations** | **Counts** | **Percentage (%)** |
|---|---|---|
| Within Community | 76 | 25.0 |
| Outside Community | 62 | 20.4 |
| Central Business District | 166 | 54.6 |
| **Total** | **304** | **100.0** |

*Source: Field Survey, 2012*

From the foregoing discussions, socio-economic characteristics (especially employment, income levels and vehicle ownership) are seen as major reasons for complexities in transport dynamics. They inform trip rates, purpose and choice of mode. People have varied reasons for travelling, choice of mode and trip rates. It is also important to note the influence of, especially, occupation and income, on travel behavior. As indicated earlier, 60 percent of respondents travel for work purposes while 31.5 percent make trip for educational reasons. With an average daily trip rate of 7, and 54.8 percent of all trips ending in the CBD, pertinent issues of congestion are raised. This is made clearer when mode of travel is analysed. While 54.8 percent patronize public transport, 19.6 percent patronize private transport. About 40 percent of respondents patronizing public transport cited affordability as the driving factor for their choice of mode. Interestingly, 72.4

percent and 27.1 percent of those who patronize private and public transport respectively cited convenience as the reason for their choice and this underlines the impact of convenience factor in determining choice of mode, regardless of trip cost (GHS 7.4 for private and GHS 1.46 for mini-bus and taxi).

This section, therefore, has examined the nature of the utilization of the transport system in the city, using the information obtained from the sampled households in the study communities as a surrogate, with a view to establishing factors for the current state of the transport system in terms of the sustainability indicators. It is based on the premised that, individual socio-economic needs for transport, often comes before any concerns about sustainable transport system, and unless these demands are understood, the objectives of transport sustainability may not be achieved.

Using the sustainability indicators developed for this study, the next section, examines the current state of the transport sector in Kumasi.

**4.4 Vehicle Population and Composition in Kumasi**

Road traffic in Ghana has continuously increased during the last decade. The reason for this trend lies mainly in the urban exodus, the increasing population motorization rate especially in Ghanaian capitals, and the high demand for on-road transport. As at December, 2010, the total registered vehicles in Kumasi had cumulatively risen to 91,542 from a figure of 6,425 in 2000. The trend of vehicle registration over the period (2001-2010) is shown in Table 4.12. This increase, however, is not reflective in the year by year vehicle registration in the city, which demonstrates an irregular pattern. This deviates a bit from the Ghana situation, which experienced an increase of about 1.41 percent per annum over the same period (Adarkwa and Poku-Boansi, 2011). This growth in number of vehicles has serious economic, environmental and social implications for the people of Kumasi.

**Table 4.12 – Summary of Total Vehicles Registered in Kumasi and Ghana (2001 – 2010)**

| Year | Kumasi (Cumulative) | % Increase | Ghana (Cumulative) | % Increase |
|---|---|---|---|---|
| 2001 | 6,425 | - | 551,769 | - |
| 2002 | 12,361 | 48.0 | 595,026 | 7.3 |
| 2003 | 18,100 | 31.7 | 643,100 | 9.3 |
| 2004 | 25,945 | 34.5 | 702,648 | 9.2 |
| 2005 | 34,905 | 28.2 | 767,067 | 9.6 |
| 2006 | 44,764 | 25.8 | 841,314 | 10.7 |
| 2007 | 56,301 | 21.5 | 931,642 | 10.9 |
| 2008 | 68,420 | 16.9 | 1,033,140 | 9.2 |
| 2009 | 79,989 | 14.4 | 1,128,138 | 9.1 |
| 2010 | 91,542 | - | 1,230,468 | - |

*Source: DVLA, 2012*

4.4.1 Fleet Stock Distribution (By type, age, and fuel Type)

According to the DVLA (2012), vehicles are registered according to the type, size, fuel type, production year and country of imports; mainly from Europe, Asia and North America. These classifications partly have an impact on congestion and emission levels. Data on year of production of vehicles were extracted from "Vehicular Emissions Inventory in Ghana" (Agyemang-Bonsu, et al., 2007). According to Agyemang-Bonsu et al. (2007), vehicles registered in Kumasi between 2001 and 2010 by their type can be categorised into motor cycles, private motor vehicles, commercial motor vehicles, buses and coaches of all kinds, among others. Data from the DVLA suggest that, mini-buses and private cars occupy long stretches of the roadway in Kumasi, while transporting fewer people due to their low occupancy.

**Table 4.13 – Summary of Vehicles Registered by Type in Kumasi (2006-2010)**

| Year | M/C | | PMV 2000 | | CMV 2000 | | MV 2000+ | | B&C | | Others* | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Freq. | % | Freq. | % | Freq. | % | Freq. | % | Freq. | % | Freq. | % | |
| 2006 | 1,346 | 13.7 | 3,793 | 38.5 | 1,236 | 12.5 | 887 | 9.0 | 1,411 | 14.3 | 1,186 | 12.0 | **9,859** |
| 2007 | 1,275 | 11.1 | 4,275 | 37.0 | 1,594 | 13.8 | 1,079 | 9.4 | 1,959 | 17.0 | 1,355 | 11.7 | **11,537** |
| 2008 | 1,228 | 10.2 | 4,652 | 38.4 | 1,280 | 10.6 | 1,254 | 10.3 | 2,198 | 18.1 | 1,507 | 12.4 | **12,119** |
| 2009 | 1,605 | 13.9 | 3,874 | 33.5 | 1,432 | 12.4 | 1,461 | 12.5 | 1,799 | 15.6 | 1,398 | 12.1 | **11,569** |
| 2010 | 1,923 | 16.6 | 4,065 | 35.2 | 970 | 8.4 | 1,284 | 11.1 | 1,676 | 14.5 | 1,635 | 14.2 | **11,553** |

*Source: Driver and Vehicle Licensing Authority (2011, In Poku-Boansi and Adarkwa, 2011)*

** Include vehicles that do not regularly ply the City's road network. It includes rigid cargo trucks, articulator trucks, agricultural equipment, combine harvesters, construction equipment and mining equipment.*

**Table 4.14 – Summary of Total Registered Vehicles and Proportion of Salon/Private Vehicles in Kumasi (2006 – 2010)**

| Year | Cumulative No. of Registered Vehicles | Cumulative No. of Saloon/Private Vehicle | Proportion of Total (%) |
|---|---|---|---|
| 2006 | 28,286 | 9,363 | 33.10 |
| 2007 | 39,823 | 13,638 | 34.25 |
| 2008 | 51,942 | 18,290 | 35.21 |
| 2009 | 63,511 | 22,164 | 34.90 |
| 2010 | 75,064 | 26,229 | 34.94 |

*Source: Driver and Vehicle Licensing Authority (2011, In Poku-Boansi and Adarkwa, 2011)*

From Table 4.14, although the proportion of private vehicles registered over the period has virtually remained the same (averaging about 32.96 percent per annum), the number of private vehicles cumulatively has increased substantially; from 1,976 in 2004 to 26,229 in 2010. Such a trend implies that private vehicle use is now becoming the unrivalled transportation mode choice in the city. This can pose challenges in the management of traffic within the city considering that the road way and its associated facilities have not experienced any substantial changes or increases in the recent past (Adarkwa and Poku-Boansi, 2011). The preference and use of private cars and saloon cars (up to 2000 cubic capacity) over large buses results in serious traffic congestion, as it is the case on most of the arterial roads in the city.

The distribution of vehicle technologies in a fleet is one of the most important parameters that must be established, especially in estimating the emissions from the on-road vehicle fleet. Data on the vehicles registered by year of production were classified using the EU legislation improvements as a guide. In this regard, vehicles registered over the period were classified by the technology class summarised in Table 4.15.

**Table 4.15 – Guide to the Classification of Vehicles by Year of Production**

| Technology Class | Year of Production |
|---|---|
| Conventional | 1992 |
| Euro I | 1992 – 1996 |
| Euro II | 1996 – 2000 |
| Euro III | 2000 – 2005 |

*Source: Agyemang-Bonsu, et al., 2007*

A study by Agyemang-Bonsu et al., (2007) on 54,810 vehicles in Kumasi revealed that, 51.9 percent of total fleet stock in Kumasi were manufactured before 1993 (Conventional), and 37.9 percent manufactured after 1992 and before 1996 (Euro I) totaling about 89.9 percent (see Table 4.16). This is supported in the study conducted by Poku-Boansi (2008), where he found that about 92 percent of the vehicles used for transport services in Kumasi were over 20 years.

**Table 4.16 – Classification of Fleet Population in Kumasi by Year of Production in Kumasi**

| Technology Class | Fleet Population | Proportion of Total |
|---|---|---|
| Conventional | 292,192 | 51.9 |
| Euro I | 213,422 | 37.9 |
| Euro II | 37,339 | 6.6 |
| Euro III | 19,881 | 3.6 |
| **Total** | **562,834** | **100** |

*Source: Extracted from Agyemang-Bonsu, et al., 2007* ***NB****. The survey included only passenger vehicles, light duty vehicles, heavy duty vehicles, and buses.*



Linder (2006, in Obeng-Odoom, 2009) also contends that only about 8 percent of the vehicles imported into Ghana and by extension Ghanaian cities, including Kumasi, are brand new cars. The remaining 92 percent could be used vehicles. These results become critically imperative in view of government's policy that allows importation of over-aged vehicles with penalty in addition to the fact that it added onto the huge numbers of poorly maintained over-aged vehicles in the country (Agyemang-Bonsu et al., 2010 and Poku-Boansi, 2008). Consequently the age limit beyond which penalties were imposed on vehicles was also waived. This has resulted in most vehicles on the roads providing urban transport services in the City not road worthy; hence resulting in pollution to the environment (see Section 4.7.1 for the discussion on the relationship between age of production of vehicles and their contribution to emissions). A more practical futuristic assessment of this policy dispensation is that importations of conventional over-aged vehicles will perhaps rise and inundate the streets to spur heavy traffic congestion specifically in urban areas.



Data on vehicle classification by fuel type were seldom available from the DVLA. However, estimates by Agyemang-Bonsu et al. (2007) revealed that, vehicles in Kumasi largely run on gasoline, which constitute about 55.1 percent of total vehicle stock. This is followed by diesel and LPG constituting 44.4 percent and 0.5 percent of total vehicle stock, respectively.

**Table 4.17 – Classification of Vehicle Fleet by Fuel Type in Kumasi**

| Fuel Type | Vehicle Population | Percentage of Total |
|---|---|---|
| Gasoline | 309,845 | 55.1 |
| Diesel | 249,666 | 44.4 |
| LPG | 3,323 | 0.5 |
| **Total** | **562,834** | **100** |

*Source: Extracted from Agyemang-Bonsu, et al., 2007*



Table 4.17 indicates that, there is not a large proportion of natural gas vehicles (which is in the form of LPG) on the roads in the city. Natural gas is a clean-burning fuel because it produces up to 90 percent less smog and approximately 40 percent fewer greenhouse gases than gasoline-only and diesel-only vehicles (Rhonda, 2010), which is used in large quantities (99.5 percent) in the city. Comparison of this trend with the data on fuel types of vehicle used by household (obtained from the household survey) revealed consistent results. Data from the field survey revealed that, 60.8 percent of the vehicles used by households run on gasoline, while the 38.5 percent run on diesel. The remaining (0.7 percent) is run on LPG. This has implications on the sustainability of the city's transport system, especially on green house gas emissions.

### 4.5 Accessibility and Mobility in Kumasi

The ultimate goal of most transport activity is the ability to reach desired goods, services and activities, also referred as accessibility. An emphasis on accessibility implies that planners, at a minimum, provide or maintain infrastructure, services, and activities that ensure reliable, all-weather access to markets, employment, and social facilities (World Bank, 1999). But access is difficult to measure so transport planning tends to focus on traffic (vehicle movement) and mobility (the ability to move people and goods) (VTPI, 2002). To achieve this require an understanding of the extent of congestion on roads. Congestion may be described as the existing travel condition of a roadway facility, and it is measured using these parameters: flow, speed, and density (Homburger et al., 1992). Among others, speed based measures have been the most widely used in previous research (Homburger et al., 1992). Congestion in this study, therefore, refers to the situation in which road users cannot drive at their desired speed because they are constrained by the presence of other road users. Consequently, in measuring the congestion levels on the roads in Kumasi, the speed based parameter is used in this study. Adapting to this, speed levels were obtained on 22 key road links in the City, from Adarkwa and Poku-Boansi (2011). These data have been used to develop a congestion index that represents the performance of roads in the City. Congestion indices (CI) for all the identified roads were formulated using the formula:

Congestion Index (CI) =1- (A/M)

Where,

A: Average journey speed observed on the City's roads during peak hours; and

M: Desirable average journey speed on the City's road network during peak hours, which is assumed as 50 Kmph.

The index is formulated such that, the lower the index ($0 \leq CI \leq 0.5$), the lower the congestion, and the better the road's performance. From Table 4.18, it can be seen that, such arterials usually record an average speed of 40 Kmph. However, if the CI value approaches to 1 ($0.5 < CI \leq 1$), that means the road's performance is getting worse (see Table 4.18).

**Table 4.18 – Congestion Index (CI) Categories**

| **Congestion Index (CI)** | **Congestion Categories** |
|---|---|
| 0.0 – 0.25 | Free Flow |
| 0.26 – 0.50 | Moderate Congestion |
| 0.51 – 0.75 | Heavy Congestion |
| 0.76 – 1.00 | Severe Congestion |

*Source: Author's Construct (2012), Based on Homburger et al., 1992.*

The summaries of CI determined for the City's roads are presented in Table 4.19.

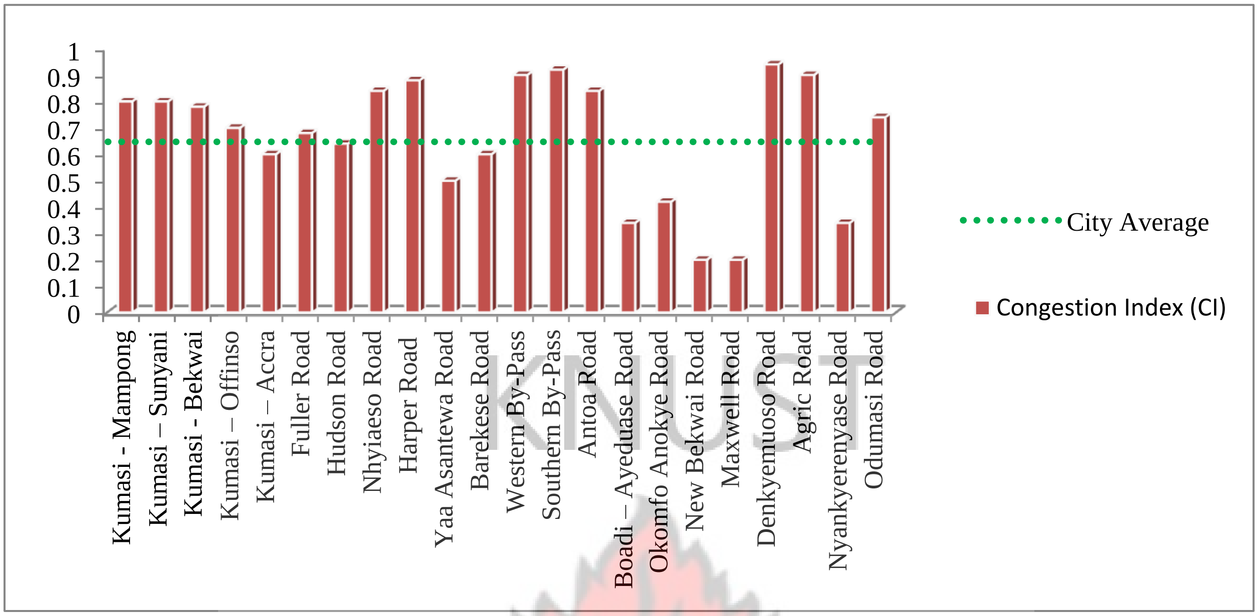
**Table 4.19 - Congestion Analysis of the Urban Road Network in Kumasi**

| Road Name | Design Speed (Km/h) (M) | Observed Speed (Km/h) (A)* | Congestion Index (CI) | Congestion Category |
|---|---|---|---|---|
| ***Major Arterial*** | | | | |
| Kumasi - Mampong | 50 | 10 | 0.80 | Severe |
| Kumasi – Sunyani | 50 | 10 | 0.80 | Severe |
| Kumasi – Lake | 50 | 11 | 0.78 | Severe |
| Kumasi – Offinso | 50 | 15 | 0.70 | Heavy |
| Kumasi – Accra | 50 | 20 | 0.60 | Heavy |
| ***Minor Arterial/Dist*** | | | | |
| Fuller Road | 50 | 16 | 0.68 | Heavy |
| Hudson Road | 50 | 18 | 0.64 | Heavy |
| Nhyiaeso Road | 50 | 8 | 0.84 | Severe |
| Harper Road | 50 | 6 | 0.88 | Severe |
| Yaa Asantewa Road | 50 | 25 | 0.50 | Moderate |
| Barekese Road | 50 | 20 | 0.60 | Heavy |
| Western By-Pass | 50 | 5 | 0.90 | Severe |
| Southern By-Pass | 50 | 4 | 0.92 | Severe |
| Antoa Road | 50 | 8 | 0.84 | Severe |
| Boadi – Ayeduase Road | 50 | 33 | 0.34 | Moderate |
| Okomfo Anokye Road | 50 | 29 | 0.42 | Moderate |
| New Bekwai Road | 50 | 40 | 0.20 | Free Flow |
| Maxwell Road | 50 | 40 | 0.20 | Free Flow |
| Denkyemuoso Road | 50 | 3 | 0.94 | Severe |
| Agric Road | 50 | 5 | 0.90 | Severe |
| Nyankyerenyase Road | 50 | 33 | 0.34 | Moderate |
| Odumasi Road | 50 | 13 | 0.74 | Heavy |
| **City's Average** | **50** | **17** | **0.66** | **Heavy** |

*Source: Author's Construct, 2012*

**Observed Speed Levels Extracted from Adarkwa and Poku-Boansi, 2011*

**Figure 4.1 – Congestion Index Developed for Kumasi's Road Network**




*Source: Author's Construct, 2012*

Table 4.19 and Figure 4.1 show 21 roads ranging from collectors to major arterials status with Congestion Indices (CI) ranging from 0.20 to 0.94, indicating the wide disparities in the general travel conditions or congestion levels on the roads in the city. As indicated earlier, the CI is measured from 0 to 1 indicating the lowest and highest levels of roads performance, respectively. At the same time, the data shows that, speed levels on these roads in the city, which influence the CIs, range from as low as 3 – 40 kmph, which are well below the road design speed of 50kmph.

Closer examination of the data seems to indicate that, generally all major arterials have high CI indicating heavy or severe congestion. This is because all these roads record CI between 0.60 and 0.80 and speed limits of less than 20kmph. In spite of this however, the Kumasi – Mampong and Kumasi Bekwai road corridors recorded heavy congestion when the average daily traffic per lane is used as shown in Table 4.19. The Kumasi – Offinso corridor recorded severe traffic congestion while the Kumasi – Sunyani and Kumasi – Accra road corridors recorded extreme congestion conditions during the peak hours of between 5pm – 6pm. This may partly be due to the increased number of people living along the peripheral areas of the Kumasi – Accra corridor (Kentinkrono, Kwamo, Oduom, Fumesua and Ejisu) and Kumasi – Sunyani corridor (Abuakwa, Akropong, Ntensere, etc) that commute to the city to transact business daily.

Various methods are used to quantify congestion costs. One approach is to determine the price needed to reduce traffic volumes to optimal roadway capacity. Another approach is to calculate the marginal impacts each vehicle entering the traffic stream imposes on other road users, taking into account the speed-flow relationship of each road segment. However, the data needed for such analyses are seldom available so most estimates are based on simplified models that measure incremental delay, vehicle operating costs (fuel and wear), pollution emissions and stress that results from interference among vehicles in the traffic stream, particularly as traffic volumes approach a road's capacity (VTPI, 2011).

Delays on identified roads were determined with variables which include; length of road, ideal travel time and observed travel time. Various sections along the roads recording worst forms of congestion were identified, with their respective lengths taken. The design speed of urban roads (50km/hr) was used in calculating the ideal travel time on the road. Observed travel times derived from Adarkwa and Poku-Boansi (2011) were also used in determining the real travel time and the resulting differences are the experienced delays. The cost of congestion in terms of incremental delays experienced on selected major roads in the Metropolis is presented in Table 4.20.

**Table 4.20 – Estimated Total Delays on Major Roads in the Kumasi Metropolis**

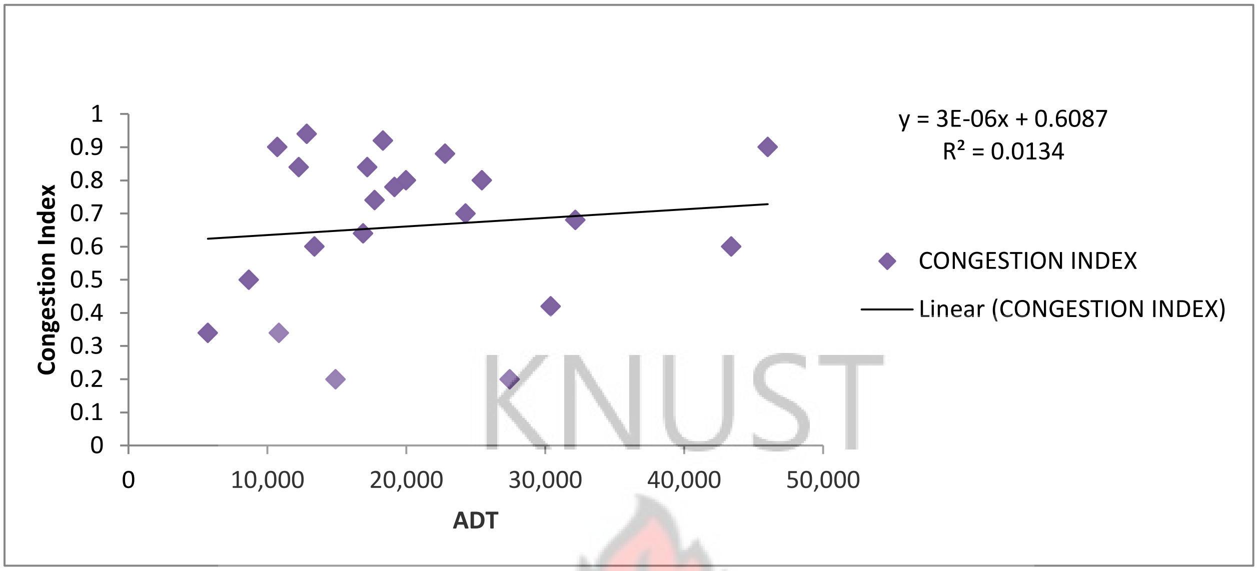
| Road Name | Worst Section (Road Segment) | Length (km) | Free Flow Travel Time (Seconds) | Observed Travel Time (Seconds) | Excess Delays (Seconds) |
|---|---|---|---|---|---|
| Kumasi-Mampong | Tafo Mkt-Suame New Rd. Int. | 1.625 | 117 | 585 | 468 |
| Kumasi-Sunyani | Siloam Hosp. Jn-Agric Rd. Int. | 0.900 | 65 | 324 | 259 |
| Kumasi-Lake | Atonsu Terminal-Gyinyase Rd. Int. | 1.060 | 76 | 347 | 271 |
| Kumasi-Offinso | Breman Jn-Suame New Rd. Int. | 0.700 | 50 | 168 | 118 |
| Antoa Road | Manhyia R/A-Burma Rd. Int | 0.300 | 22 | 135 | 113 |
| Harper Road | Ahodwo R/A- Pine Ave. Int. | 1.425 | 103 | 855 | 752 |
| Yaa Asantewaa Rd | Amakom Int.- Old Ejisu Rd. Int. | 0.200 | 14 | 29 | 15 |
| Odumasi Road | Kotoko Rd Int-Komfo Anokye Rd | 0.325 | 23 | 90 | 67 |
| Barekese Road | Ampabame-Abrepo Int. | 1.150 | 83 | 207 | 124 |
| Southern By-Pass | TUC Jn- Santasi R/A | 0.800 | 58 | 720 | 662 |
| Western By-Pass | Edwenase Rd. Int.-Kwadaso Est. Rd | 1.325 | 95 | 954 | 859 |
| Hudson Road | 6th St Int.- Lake Rd Int. | 1.300 | 94 | 260 | 166 |
| Maxwell Road | Labour R/A- 5th St Int. | 0.425 | 31 | 38 | 7 |
| New Bekwai Road | Gee R/A-Bekwai R/A | 0.750 | 54 | 68 | 14 |
| Okomfo Anokye Road | Airport R/A-Krofrom Tlite | 2.250 | 162 | 279 | 117 |
| **Total** | | **14.535** | **1047** | **5059** | **4012** |

*Source: Author's Estimate, 2012, Based on Adarkwa and Poku-Boansi, 2011.*

From Table 4.20, a total of 4012 seconds (66.9 hours per day) is lost on major roads in the Metropolis, resulting from drops in vehicular flow and speed on these roads. Heavily congested roads in the Kumasi Metropolis include; the Western By-Pass, Harper Road, Southern By-Pass, Kumasi-Mampong Road, Kumasi-Lake Road and Kumasi-Sunyani Road. Congestion along these major roads can be attributed to an imbalance between increased usage of cars in the Metropolis and expansion of road network, and development of settlement on the fringes of the metropolis along these roads, especially the Kumasi-Accra corridor (Kentinkrono, Kwamo, Oduom, Fumesua and Ejisu) and the Kumasi-Sunyani corridor (Abuakwa, Akropong, Ntensere, etc.). A significant contribution of congestion on the roads in the Kumasi Metropolis can also be attributed to the nature of road development, where the road network in and around the city is based on a system of radial routes converging in the CBD. This situation results in one-way traffic in the morning and evenings on account of the concentration of activities at the CBD with people making trips into the CBD in the morning and trips out of the CBD during the evening. An inference from Table 4.10 (Origin and Destination of trips) indicates that 54.8 percent of all trips made, have the CBD as the destination whiles 79.9 percent of all trips having their destination as 'outside the community', end in the CBD. This to a greater extent accounts for congestion on all roads in the Kumasi Metropolis. Although estimates of the economic cost of these delays are not available, clearly, its effects on economical and productivity losses are bound to be substantial, considering the period (8am – 9am) within which this phenomenon occurs – morning peak hours, where most trip purposes to work are made.

As population increases, socioeconomic development becomes apparent. Congestion has been the result of population and demographic dynamics and their resultant impacts on trip rate, destination and purpose (all influencing traffic volume). It was also realized from correlation analysis between ADT volumes and congestion that, the average daily traffic volumes on major roads in the metropolis do not have strong linkage with congestion index. Table 4.19 gives an indication that ADT does not vary directly with congestion index, suggesting that, other factors such as: rising number of low occupancy vehicles, which include individual owned vehicles, taxis as well as mini-buses (trotro), resulting into inefficient use of road capacity; land use structure of the city (resulting into over concentration of activities in the CBD); as well as low investments in high occupancy public transport, impact on congestion in the city.

**Figure 4.2 - Correlation of ADT Volumes and Congestion Index for Kumasi**




*Source: Author's Construct, 2012.*

Traffic congestion and its associated delays influence the city's environment in several ways. These effects generally center on natural resource (fuel) consumption, environmental impacts (emissions) and socio-economic impacts (safety and affordability). As identified earlier in this report, these effects are critical in assessing the sustainability of urban transport systems. The subsequent sections are thus, devoted to a discussion of these effects in the city.

### 4.6 Resource Use (Fuel Consumption)

The amount of fuel consumption by the transport sector is essential to the discussion on natural resource use or consumption. Data on fuel consumption by road transport users have been aggregated at the national level, making city level information scanty. Nonetheless, since there is a proportional relationship between fuel consumption and fleet numbers (Agyemang-Bonsu, et al., 2007), fuel consumption by the transport sector in Kumasi was estimated, using the national vehicle registration and fuel consumption as benchmark (see Table 4.21).

**Table 4.21 – Fuel Consumption by the Transport Sector in Kumasi (2001 – 2010)**

| Year | National Vehicle Fleet | National Fuel Consumed (t) | City Vehicle Fleet | City Fuel Consumed (t) $ |
|---|---|---|---|---|
| 2001 | 551,769 | 1,331,787* | 6,425 | 319,878 |
| 2002 | 595,026 | 1,369,212* | 12,361 | 338,582 |
| 2003 | 643,100 | 1,471,783* | 18,100 | 349,002 |
| 2004 | 702,648 | 1,558,767* | 25,945 | 379,554 |
| 2005 | 767,067 | 1,567599* | 34,905 | 393,446 |
| 2006 | 841,314 | 1,645,979# | 44,764 | 413,118 |
| 2007 | 931,642 | 1,728,278# | 56,301 | 433,774 |
| 2008 | 1,033,140 | 1,814,692# | 68,420 | 455,463 |
| 2009 | 1,128,138 | 1,905,426# | 79,989 | 478,236 |
| 2010 | 1,230,468 | 2,000,698# | 91,542 | 502,148 |

Notes:

*compiled from the "Vehicular Emissions Inventory in Ghana" report, 2007

# Data for these years (2006-2010) were projected using an exponential growth function and a growth rate of 0.05 percent

$ the ratios of the fleet and emissions at the national level were used in estimating for the emissions for Kumasi in 2001-2010

From Table 4.21, over the ten year period (2001 – 2010), fuel consumption by the road transport sector in the city increased steadily from 319,878 tonnes in 2001 to 502,148 tonnes in 2010 (which corresponds to an extent, the amount or levels of emissions to be probably emitted in the natural environment). Considering the fact that, the country has found oil in commercial quantities; the current levels of fuel consumption are likely to increase in the future, which could have effects on the emissions level. According to Agyemang-Bonsu et al (2007), these fuels are used, particularly, in the cold start and hot emission stages of the annual trip distances.

Despite the increasing rate of fuel consumption in the city, it was also realised that, averagely, diesel was consumed the most, followed by gasoline and LPG, with 56.2 percent, 40.8 percent, and 3.0 percent (see Table 4.22).

**Table 4.22 - Average Fuel Consumption (2001 – 2010) in Kumasi by Fuel Type**

| Fuel Type | Fuel Consumed (tonnes) | % |
|---|---|---|
| Diesel | 228,352 | 56.2 |
| Gasoline | 165,778 | 40.8 |
| LPG | 12,190 | 3.0 |
| **Total** | **406,320** | **100.0** |

*Source: Based on Agyemang-Bonsu et al., 2007*



The large proportion of diesel and gasoline fuel (97 percent) consumed by the transport sector in the city, has serious implications on vehicle emissions. Burning fossil fuels such as: diesel and gasoline, releases Carbon Dioxide ($CO_2$) and other greenhouse gases into the atmosphere, contributing to climate change. Unlike other forms of vehicle pollution, Carbon Dioxide ($CO_2$) emissions cannot be reduced by pollution control technologies. They can only be reduced by burning less fuel, which implies less dependence on fuel that contains more carbon – diesel and gasoline.

Fuel use of a vehicle is determined by factors ranging from technical characteristics of the vehicle to divers' behaviour. The technical characteristics, such as: vehicle weight, engine size, and the year of manufacture of the vehicle, are most critical in determining fuel consumption. Agyemang-Bonsu et al. (2007) investigated into the relationship between the ages (technology class) of vehicles and fuel consumption in Kumasi. They found that, conventional and Euro I vehicles respectively account for an estimated 55.8 percent and 32.2 percent of total fuel consumption among all classes of vehicles. The remaining 8.2 percent and 3.8 percent are consumed by Euro II and Euro III vehicles (see Table 4.23).

**Table 4.23 – Average Fuel Consumption (2001 – 2010) in Kumasi by Year of Production of Vehicles**

| Technology Class | Fuel Consumed (tonnes) | % |
|---|---|---|
| Conventional (1992) | 226,727 | 55.8 |
| Euro I (1992 – 1996) | 130,835 | 32.2 |
| Euro II (1996 – 2000) | 33,318 | 8.2 |
| Euro III (2000 – 2005) | 15,440 | 3.8 |
| **Total** | **406,320** | **100.0** |

*Source: Based on Agyemang-Bonsu et al., 2007*

When considering fuel consumption in the city, the need for environmental and economic sustainability become apparent especially with its positive relationship with transport related emissions, and the cost associated with the importation of fuel. Petroleum imports, according to the Bank of Ghana Report (2011), costs the country about $1.72 billion in 2010 (about 22.9 percent of total merchandise imports), and in the first five months of 2012, the country has imported petroleum products, worth $1.5 billion.

### 4.7 Transport Emissions in Kumasi

The state of the environment in general and air quality in particular in the Metropolis has generally improved considering the number of initiatives that have been undertaken. However, a lot more need to be done in the area of air quality mitigation measures, awareness and education, as well as enforcement of regulations, as according to the EPA (2012), the situation is "worrisome". Activities that have contributed to the state of air quality in the Metropolis among others include: fuel combustion from mobile sources; transportation (motorized, rail, domestic aviation), stationery sources; industrial chimneys (feedstock, fuels, processes and flue emissions), and open burning (pneumatic tyres garbage etc).

From Table 4.24, the transport sector exerts the greatest pressure on air quality in the Metropolis, considering its high fuel consumption levels. Emissions from the transport sector results from combustion of fossil fuels, which generate Carbon Monoxide (CO), Carbon Dioxide ($CO_2$), Nitrogen Oxides (NOx), Sulphur Dioxide ($SO_2$), and Ozone ($O_3$) (see Table 4.24 for year by year vehicle emissions in the Metropolis). Carbon Dioxide ($CO_2$) and water vapour ($H_2O$), the major products of combustion, are emitted in vehicle exhaust. These pollutants, among others, have varying degrees of damaging effects on both physical and human environments. These are partly due to the increasing population motorization rates, increasing conventional passenger vehicles (those manufactured in1992 or earlier), and the fact that most vehicles have low fuel-use efficiency, in the Metropolis (refer to earlier section on distribution of fleet population by type, age and fuel type).



Table 4.24 indicates an increasing trend of vehicular emissions in the city. The total estimated pollution load from the transport sector increased from 682.3Gg in 2000 to 819.4Gg in 2005. In 2000, $CO_2$ claimed the largest share (95 percent) of the total, followed by $N_2O$ (2.1 percent), and CO (1.3 percent). The rise is estimated at 14.7 percent per annum depending especially on the commensurate increase in fleet numbers and fuel consumption (refer to Figure 4.3).

**Table 4.24 – Year by Year Vehicle Emissions in Kumasi (2000 – 2005)**

| Year | Greenhouse Gases (Gg) | | | | | | | Acidifying Pollutants and Precursor Gases (Gg) | |
|---|---|---|---|---|---|---|---|---|---|
| | **$CO_2$** | **%** | **$CH_4$** | **%** | **$N_2O$** | **%** | **Total** | **$NO_x$** | **%** |
| 2000 | 648.4 | 97.5 | 2.35 | 0.4 | 14.27 | 2.1 | 665.02 | 5.44 | 32.5 |
| 2001 | 652.6 | 97.5 | 2.37 | 0.4 | 14.27 | 2.1 | 669.24 | 5.44 | 32.2 |
| 2002 | 677.3 | 97.6 | 2.42 | 0.3 | 14.27 | 2.1 | 693.99 | 5.44 | 31.9 |
| 2003 | 704.8 | 97.5 | 2.58 | 0.4 | 15.7 | 2.1 | 723.08 | 5.98 | 32.4 |
| 2004 | 778.4 | 97.5 | 2.84 | 0.4 | 17.28 | 2.1 | 798.52 | 6.58 | 32.5 |
| 2005 | 837.9 | 97.4 | 3.15 | 0.4 | 19.22 | 2.2 | 860.27 | 7.31 | 32.3 |

*Source: Agyemang-Bonsu et al., 2010, Environmental Protection Agency, 2012*

**Table 4.24 Continued**

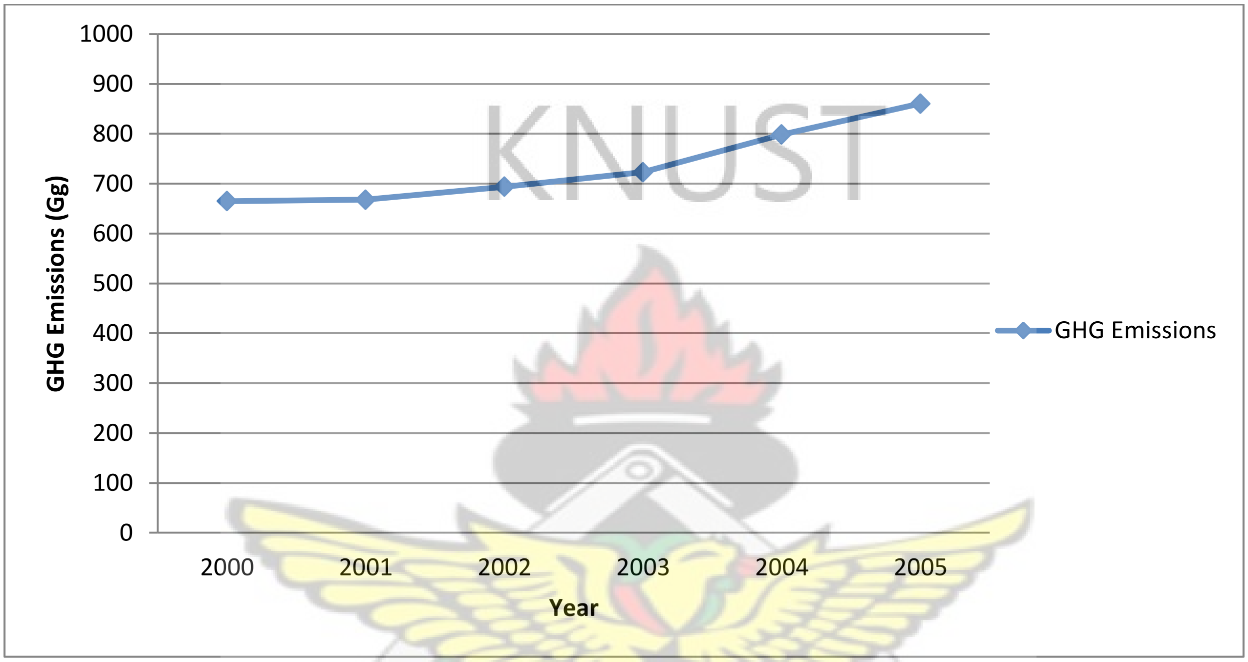
| Year | Acidifying Pollutants and Precursor Gases (Gg) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **CO** | **%** | **PM** | **%** | **VOC** | **%** | **NMVOCU** | **%** | **Total** |
| 2000 | 8.55 | 51.0 | 0.22 | 1.3 | 1.33 | 7.9 | 1.22 | 7.3 | 16.76 |
| 2001 | 8.71 | 51.5 | 0.22 | 1.2 | 1.33 | 7.9 | 1.22 | 7.2 | 19.92 |
| 2002 | 8.82 | 51.8 | 0.22 | 1.3 | 1.33 | 7.8 | 1.22 | 7.2 | 17.03 |
| 2003 | 9.38 | 51.0 | 0.25 | 1.4 | 1.46 | 7.9 | 1.34 | 7.3 | 18.41 |
| 2004 | 10.3 | 50.8 | 0.27 | 1.3 | 1.62 | 8.0 | 1.49 | 7.4 | 20.26 |
| 2005 | 11.5 | 50.9 | 0.35 | 1.5 | 1.8 | 8.0 | 1.65 | 7.3 | 22.61 |

*Source: Agyemang-Bonsu et al., 2010, Environmental Protection Agency, 2012*

Table 4.24 and Figure 4.4 show that total greenhouse gases (a main cause of climate change) from the road transport increased from 665Gg in 2000 to 860.3Gg in 2005. Carbon Dioxide ($CO_2$) component constituted an average of 97.5 percent of the total greenhouse gases between 2000 and 2005. Out of the remaining 2.4 percent, 2.1 percent and 0.3 percent were respectfully accounted for by $CH_4$ and $N_2O$, indicating $CO_2$ as a major component of GHG. The amount of Carbon Dioxide ($CO_2$) emissions largely depends on initial carbon content in the fuel stock and fuel consumption levels (Agyemang-Bonsu et al., 2010). In addition, Carbon Dioxide ($CO_2$) emissions in the city are accounted for by the substantial growth of vehicle population, especially over-aged vehicles in Kumasi over the past years. Even though the data in Table 4.22 seem outdated, it is important to mention that, giving the trend in vehicle registration and fuel consumption within the period, 2001 – 2010, clearly, the current levels of total emissions and greenhouse gases are much higher than these figures.

Apart from the progressive rise in population of vehicles (specifically passenger vehicles including private and commercial) in the city, with its effects on congestion, other reasons for increasing vehicular pollution include significant increment of imports of used vehicles, followed by the increase in mobility stimulated by the economic growth, and the non-existing regulations for fuel and vehicles age of vehicles and outdated automotive technologies. The next section thus explores how these factors (types of vehicles, fuel types used, and the age of vehicles) contribute to the general rise vehicular emissions in the city.

**Figure 4.3 – Trend of Greenhouse Gas Emissions (GHG) by the Transport Sector in Kumasi (2000-2005)**




*Source: Extracted from Agyemang-Bonsu et al., 2007*

4.7.1 Distribution of Total Emissions by Vehicle Types, Fuel and Year of Production of Vehicles

The rate and diversity of emissions varies from vehicles to vehicles. Table 4.23 shows this variance, and which vehicles create which pollutants in Kumasi. An analysis of the relationship between vehicle emissions and the type of vehicles in the city revealed that, emissions from passenger vehicles (private and commercial) accounted for about 70 percent of total emissions between 2000 and 2005, making it a major emission category source among the sub-classes. The remaining 30 percent are from buses and coaches to light duty, heavy duty vehicles and others (see Table 4.25).

**Table 4.25 – Total Emissions by Vehicle Types in Kumasi (2000-2005)**

| Year | Total Emissions (Gg) by Vehicle Type | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Passenger Veh. | | Light Duty Veh. | | Heavy Duty Veh. | | Buses | | **Total** |
| | Freq. | % | Freq. | % | Freq. | % | Freq. | % | |
| 2000 | 477.6 | 72.2 | 122.8 | 18.6 | 13.6 | 2.1 | 47.1 | 7.1 | **661.1** |
| 2001 | 478.7 | 72.2 | 123.1 | 18.6 | 13.7 | 2.1 | 47.2 | 7.1 | **662.7** |
| 2002 | 497.9 | 72.2 | 128.1 | 18.6 | 14.2 | 2.1 | 49.1 | 7.1 | **689.3** |
| 2003 | 519.4 | 72.2 | 133.6 | 18.6 | 14.8 | 2.1 | 51.2 | 7.1 | **719.0** |
| 2004 | 573.6 | 72.2 | 147.5 | 18.6 | 16.4 | 2.1 | 56.5 | 7.1 | **794.0** |
| 2005 | 618.4 | 72.2 | 159.0 | 18.6 | 17.7 | 2.1 | 60.9 | 7.1 | **856.0** |
| **Average %** | **70.0** | - | **18.0** | **-** | **3.0** | - | **6.9** | **-** | **100.0** |

*Source: Extracted from Agyemang-Bonsu, et al., 2007*

*NB. Other vehicle types such as Coaches, Mopeds and Motor Cycles make up the rest (3.2 percent) of total vehicular emissions.*

**Table 4.26 – Average Vehicular Emissions (2000-2005) by Year of Production**

| Year of Production | Emissions by Vehicle Type (Gg) | | | | |
|---|---|---|---|---|---|
| | Passenger Veh. | Light Duty Veh. | Heavy Duty Veh. | Buses | **Total** |
| Conventional | 416.9 | 118.4 | 11.8 | 50.9 | **598** |
| Euro I | 89.7 | 3.6 | 2.3 | 0.5 | **96.1** |
| Euro II | 18.5 | 1.6 | 0.7 | 0.4 | **21.2** |
| Euro III | 2.6 | 0.1 | 0.3 | 0.2 | **3.2** |
| **Average Emissions (2000-2005)** | **527.7** | **123.7** | **15.1** | **52** | **718.5** |

*Source: Extracted from Agyemang-Bonsu et al., 2007*

Estimates by Agyemang-Bonsu et al (2007), and as shown in Table 4.26 indicate that about 79 percent of emission distribution share among passenger vehicles is from vehicles manufactured before 1993 and 17 percent from Euro I vehicles. Emissions from Euro II and Euro III constituted 3.5 percent and 0.5 percent respectively. Similarly, of the total light-duty vehicle emissions (18 percent of total emissions), conventional vehicles account for a total of 95.7 percent whiles Euro I, Euro II and Euro III vehicles form the remaining 2.9 percent, 1.34 percent and 0.06 respectively. Regarding emission from heavy duty vehicles (constituting 2 percent average of the total fleet emissions in the Kumasi), 78.2 percent and 15.4 percent are respectively attributed to conventional and Euro I vehicles whereas 4.6 percent and 1.9 percent are from Euro II and Euro III accordingly. With regards to emissions from urban buses, which accounts for 6.9 percent of total emissions, conventional vehicles accounted for 98 percent. The remaining 2 percent are from fairly newer urban trucks.

An attempt at the contribution of fuel types of vehicles to total vehicular emissions was also made. In view of this, total emissions by vehicle type by year of production by fuel type were examined. This is summarised in Table 4.27.

**Table 4.27 – Summary of Vehicular Emissions by Vehicle Classes in Kumasi**

| Year of Production | Fuel Type | Emissions by Vehicle Type (Gg) | | | | |
|---|---|---|---|---|---|---|
| | | Passenger Veh. | Light Duty Veh. | Heavy Duty Veh. | Buses | **Total** |
| Conventional | Gasoline | 273.1 | 77.6 | 7.7 | 33.3 | **391.7** |
| | Diesel | 142.6 | 40.5 | 4.1 | 17.4 | **204.6** |
| | LPG | 1.3 | 0.4 | - | 0.2 | **1.9** |
| **Sub Total** | | **416.9** | **118.4** | **11.8** | **50.9** | **598** |
| Euro I | Gasoline | 58.8 | 2.4 | 1.5 | 0.3 | **63** |
| | Diesel | 30.7 | 1.2 | 0.8 | 0.2 | **32.9** |
| | LPG | 0.3 | 0.01 | - | - | **0.3** |
| **Sub Total** | | **89.7** | **3.6** | **2.3** | **0.5** | **96.1** |
| Euro II | Gasoline | 12.1 | 1.0 | 0.5 | 0.3 | **13.9** |
| | Diesel | 6.3 | 0.5 | 0.2 | 0.1 | **7.1** |
| | LPG | 0.1 | 0.1 | - | - | **0.2** |
| **Sub Total** | | **18.5** | **1.6** | **0.7** | **0.4** | **21.2** |

**Figure 2.7 Continued**

| | | | | | | |
|---|---|---|---|---|---|---|
| Euro III | Gasoline | 1.7 | 0.1 | 0.2 | 0.1 | **2.1** |
| | Diesel | 0.9 | - | 0.1 | 0.1 | **1.1** |
| | LPG | - | | - | - | |
| Sub Total | | 2.6 | 0.1 | 0.3 | 0.2 | **3.2** |
| **Average Emissions (2000-2005)** | | **527.7** | **123.7** | **15.1** | **52** | **718.5** |

*Source: Extracted from Agyemang-Bonsu et. al., 2007*

The foregoing analysis of the contribution of each vehicle class to emissions in Kumasi indicate that, "conventional-passenger" vehicles running on gasoline dominate fleet stocks in Kumasi and undoubtedly contribute greatly to vehicles emissions in all categories. This is attributable to the increasing importation of over-aged vehicles into the country coupled with the hugely populated older vehicles resident in Kumasi. This position is confirmed by Obeng-Odoom (2009) who argues that, the age profile of vehicles is considered to be the strongest predictor of vehicle emissions in Ghana. This is because the age of vehicles provides some indications of which properties (e.g. engine type, the use of catalytic converters or other emission control devices) the vehicles possess (Kylander *et al.* 2003; Kayoke 2004). The age of a vehicle appears to have an influence on emissions for two principle reasons. Firstly, age is in most cases a surrogate for total usage and accumulated distance and hence a reflection of general state of maintenance. Secondly, age is directly related to both total annual distances driven and the technology of the vehicle in that technology such as catalytic converters has only been mandatory in the past five years. The improved the emissions of carbon monoxide and nitrogen oxides are, the younger the vehicle.

**4.8 Safety of Kumasi's Transport System**

Safety has been assessed to either evaluate and compare the road safety performance of Kumasi or understand the influencing factors. Traditionally safety is assessed using two types of indicators that are classified as traffic safety and personal safety (Tiwari 2012). These are measured as fatalities per miles travel and fatalities per million populations, respectively. In this study, performance indicator measures safety as the share of fatalities of a particular mode user out of the total fatalities. Annual accident statistics were obtained from the records of CSIR-BRRI to establish the trend and nature of accidents in Kumasi. Table 4.26 shows the number of reported cases of road traffic accidents, the number of persons killed (casualties), the number of persons hospitalized, and the number of persons injured but not hospitalized in the city. Over the period 2006 – 2010, there was a general reduction of road traffic accidents, although some years recorded relative increases. In 2006, there were 819 road traffic accident cases in the city, and this dropped to 794 in 2010; a reduction of about 3.1 percent. However, increases were recorded from 2006 – 2007 (3.7 percent), where road traffic accident cases were highest, and between 2008 and 2009 (11.5 percent). A similar pattern can be observed regarding the number of injured victims (hospitalized cases) and the number who died (fatal cases), following a road traffic accident. There was a reduction of hospitalized cases and fatal cases from 2006 to 2010 by 7.2 percent and 2.9 percent respectively.

**Table 4.28 – Trends in Road Traffic Casualties in Kumasi (2006-2010)**

| **Year** | **Fatal** | **Hospitalized** | **Injured Not Hospitalized** | **Damage Only** | **Total** |
|---|---|---|---|---|---|
| 2006 | 68 | 223 | 216 | 312 | 819 |
| 2007 | 87 | 210 | 238 | 314 | 849 |
| 2008 | 87 | 188 | 185 | 246 | 706 |
| 2009 | 86 | 185 | 244 | 272 | 787 |
| 2010 | 66 | 207 | 252 | 269 | 794 |
| **Total** | **394** | **1013** | **1135** | **1413** | **3955** |

*Source: BRRI, 2012*

Although the difference in the period 2006 and 2010 shows a reduction of road accident cases, the relationship in the pattern of occurrence and the types of vehicles is skewed towards lighter vehicles. The accident cases and risk differ between different vehicle categories and even more important, severity of the injury. The lighter vehicle types, such as cars, generate the highest risk to the occupants themselves while the heavy vehicle types, as buses, generate the main risk for non-occupants. Out of the total vehicles involved in road traffic accidents in 2006, 47.9 percent were cars, and this figure increased marginally to 48.6 percent of the total vehicles involved in road accident in 2010; recording an average of 48.1 percent of the total accident cases over the period.

**Table 4.29 – Road Accident Cases by Vehicle Types in Kumasi (2006-2010)**

| Year | Car | HGV | Tract | Bus | Mini-bus | M/C | Pick up | Bicycle | Other | Unknown | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2006 | 649 | 179 | 4 | 150 | 201 | 61 | 71 | 16 | 4 | 20 | 1355 |
| 2007 | 665 | 169 | 5 | 167 | 166 | 66 | 83 | 18 | 3 | 4 | 1346 |
| 2008 | 559 | 148 | 6 | 126 | 169 | 56 | 64 | 10 | 3 | 6 | 1147 |
| 2009 | 596 | 176 | 1 | 105 | 248 | 68 | 82 | 10 | 5 | 4 | 1295 |
| 2010 | 626 | 155 | 3 | 103 | 240 | 71 | 74 | 5 | 1 | 7 | 1288 |

*Source: BRRI, 2012*

Examination of the crash casualty class records in Table 4.30 shows that Cars continue to be the dominant crash vehicle category in all accident severity cases in the city. Between the 2006 and 2010 period, an average of 34.4 percent, 46.4 percent, 47.7 percent and 51.7 percent of fatal cases, hospitalized cases, injured cases and damage only cases respectively involved the car category. Within the same period and for all accident severity cases, mini-buses, HGV and buses followed.

**Table 4.30 – Accident Severity by Vehicle Types (2006-2010)**

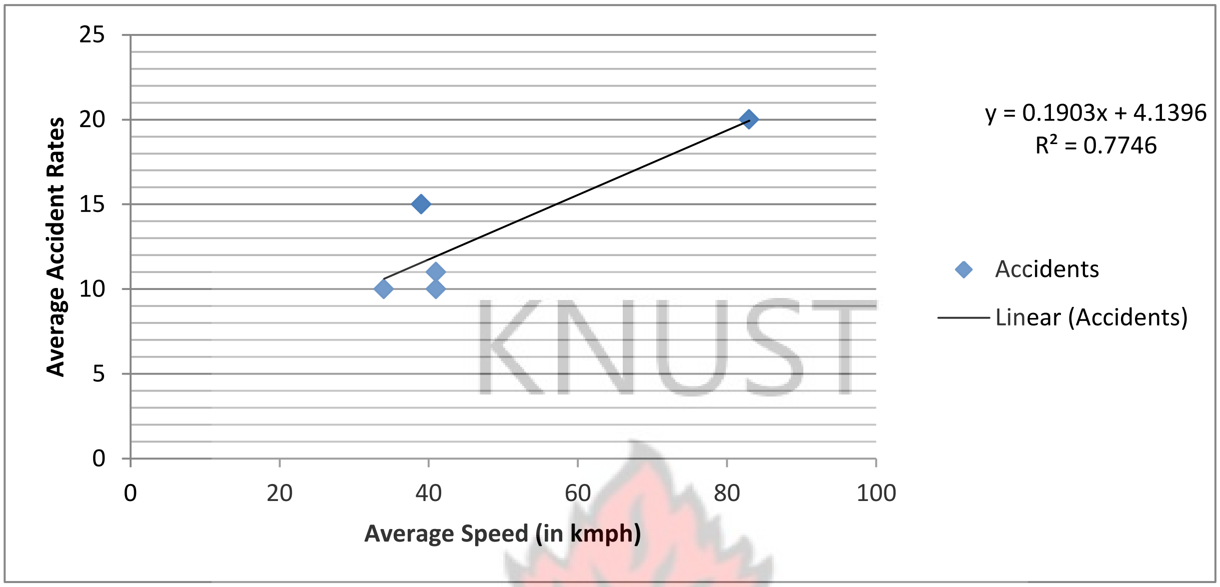
| Accident Severity | Car | HGV | Tract | Bus | Mini-bus | M/C | Pick-up | Bicycle | Other | Unknown | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Fatal | 169 | 85 | 3 | 62 | 86 | 41 | 17 | 7 | 1 | 10 | 491 |
| Hosp. | 628 | 132 | 3 | 131 | 239 | 118 | 71 | 25 | 1 | 6 | 1354 |
| Injured- NH | 839 | 166 | 4 | 155 | 315 | 148 | 96 | 26 | 4 | 6 | 1758 |
| Damage Only | 1462 | 444 | 9 | 303 | 384 | 15 | 190 | 1 | 10 | 32 | 2828 |

*Source: BRRI, 2012*



In order to better understand developments in traffic safety and identify possibilities for its improvement, it is important to gain a clear understanding of how traffic flow processes affect safety on the city's roads. Generally, it has been found that, crash rates increases when vehicles speed reduces. Marchesini and Wiejermars (2010) argue that, once the traffic jam is formed, rear-end crashes may occur at the tail of the queue due to large differences in speed. As traffic starts to become congested, the average speed decreases but the number of interactions increases and flow conditions are unstable. Unstable flow conditions are expected to result in an increase in the frequency of rear-end crashes. Data on five major arterials in the city were employed for this analysis. Vehicle speed was used as a surrogate for congestion, and average accident rates on these roads between 2006 and 2010 were obtained from the BRRI. The statistical analysis shows that, on roads with less speed, more crashes occur.  A look into the relationship between crash severity and congestion, on the other hand, revealed that, crashes that take place on major arterials with less speed, are likely to be less severe.

**Figure 4.4 – Correlation of Accident Rates and Vehicle Speed (kmph)**




*Source: Author's Construct, 2012*

The R-squared value obtained from the correlation analysis, is statistically significant, as vehicle speed could explain 77.5 percent of the variations in the crash data. In a sense, approximately 22.6 percent variations in road crashes remain unexplained by vehicle speed. The percentage unexplained may be attributed to factors other than congestion, such as human behaviour (e.g. drunk driving), which has increasingly been acknowledged as one of the predominant factors in road traffic crashes (Ackaah and Salifu, 2011), weather conditions and factors relating to the vehicle.

**4.9 Summary of Chapter**

The chapter gave detailed description of the current transport situation of Kumasi using the study variables. As reflected in the chapter, travel behavioral patterns in the city are somewhat influenced by the demographic characteristics of persons who undertake these trips. Human travel behavior has had an impact on increase in vehicular ownership in Kumasi. As people make an average of 7 trips per day, with 54.8 percent of such trips ending in the CBD, congestion becomes inevitable. The skewness of trip destination towards the CBD, with "small-sized vehicles" (taxis, "trotos" and private cars) has increased road traffic and hence congestion, especially around the CBD and on other arterial routes (such as Kumasi-Mampong, Kumasi-Accra and Kumasi-Sunyani roads), resulting into increases in fuel consumption, vehicular emissions and occurrence of accidents. This throws the issue of sustainability to the fore, as Kumasi's transport system is examined with other city's transport systems, an issue discussed in detail in the next chapter.

# CHAPTER FIVE

# MEASURING THE SUSTAINABILITY OF KUMASI'S TRANSPORT SYTEM

## 5.1 Introduction

A set of indicators is able to describe a current situation, as presented in Chapter four, and even illustrate trends, if data are collected repeatedly (Bongardt et al., 2011). However, they are not able to determine the sustainability of transport systems, which is the thrust of this study. Therefore, in determining the sustainability of the Kumasi's transport system, a benchmark (for example, a global policy target) against which indicators are compared is important. As Gudmundson (2003, in Bongardt et al., 2011) points out, "with no benchmark, how would we know if systems are sustainable or not?" Notwithstanding the imperativeness of benchmarks, they may not be available or even definable for every aspect, a position reiterated by Bongardt et al. (2011). At what level, for instance, is traffic deaths sustainable, is not possible to define, according to Gudmundson (2003).

Consequently, in this study, the "relative indicator" approach, which according to Toth-Szabo et al. (2011), is the situation where a city evaluates its level of sustainability by comparing its indicators with other cities, is adapted. The Chapter examines the transport systems of four cities including: Mexico City (Mexico), Bogota (Columbia), Istanbul (Turkey), and Lagos (Nigeria), with which Kumasi's is compared. These cities, but for Lagos, for the past three (3) years, have received sustainable transport awards by the Institute for Transportation and Development Policy (ITDP), based on their efforts to improve the sustainability of their transport systems. The inclusion of Lagos, however, is premised on its location (West Africa), which provides a basis for regional comparison. The generalities of each case in terms of the sustainable indicators are presented, with the aim of setting benchmarks, with which Kumasi's transport system is compared.

## 5.2 General Transport Observations of the Four (4) Case Cities

As a starting point to describing the general transport situation of the cities, a number of key urban issues are listed in Table 5.1.

**Table 5.1 – Comparison of Key Urban Parameters of the Case Cities**

| Cities | Urban Parameters | | |
|---|---|---|---|
| | Population | Surface Area ($km^2$) | Population Density (Persons per $km^2$) |
| Mexico City [a] | 8,873,000 | 1,490 | 5,954 |
| Lagos [b] | 17,552,942 | 3,577 | 4,919 |
| Istanbul [c] | 12,600,000 | 5,389 | 2,338 |
| Bogota [d] | 7,259,597 | 1,737 | 3,700 |

*Source: ([a] Rivera et al.,2011, [b] Kumar and Barett, 2008, [c] Kaparias et al., 2010, [d] Leal and Bertini, 2004, [e] Amoako, 2011)*

All the case cities of Mexico City, Lagos, Istanbul and Bogota are the main centers for industrialization, business and foreign trade in their countries. The cities have massive populations and they are so called mega-cities. Notwithstanding these common features, the four cities differ somewhat both in population and in land area. Istanbul had the highest population with some 12.6 million inhabitants and Bogota, the lowest, with 7,259,597 in habitants. The large population of Istanbul also reflects in its land area, with land coverage of 5,389$km^2$.

Whereas it may seem, these cities are not comparable with Kumasi, considering the relatively smaller population (1,989,000) and land area (254 $km^2$), for the dearth of data, they are selected for illustrative reasons. The ensuing sections, thus, provide a glimpse of the transport system characteristics of these cities.

5.2.1 Bogota (Colombia)

Bogotá has about 13,000 lane-km of roadways, of which 10,000 lane-km are paved. Ninety-five percent of the road network was used by 850,000 private vehicles, which transported about 19 percent of the population. Close to 70 percent of trips shorter than 3km were made by car. Buses occupied a low percentage of the roadway network. Seventy-two percent of trips were made by public transit on about 21,000 buses. The average trip by bus was about 1 hour 10 minutes in duration with an average speed of 10kph. The majority of the buses were more than 14 years old with an average of 50 percent occupancy. A total of 48 percent of public transit vehicles were medium sized buses (40-80 passengers), 37 percent small buses (20-40 passengers), and 15 percent were minibuses (Leal and Bertini, 2004). There was no motivation for car owners to switch to public transportation because of the low quality of the system.

Between 1993 and 1997 the demand for bus service increased 27 percent. On the other hand, the bus supply increased 72 percent, which shows the lack of control and planning of the system supply (Leal and Bertini, 2004). This unbalanced growth brought a phenomenon known as “la guerra del centavo,” which can be translated as “the war of the cent.” The war of the cent refers to the aggressive war of the drivers for picking up the maximum number of potential passengers. Because of the excessive number of buses, these private operators had excessive consumption, tires, and other operational requirements. In addition, the lack of maintenance and renovation of vehicles brought excessive operational costs and increased contaminants and noise.

In 1998, Bogotá initiated a mobility strategy in order to overcome its transportation problems. Since 1998 the city has implemented some strategies to reduce congestion such as a reduction of 40 percent of the automobiles used during the peak hours through plate number restrictions, implementation of a bikeway network, pedestrian walkways, and the creation of the Transmilenio (transportation for the third millennium) BRT system, which began operation in 2000. Transmilenio is a high-capacity transportation system that provides the same quality of a Light Rail Transit (LRT) service. LRT is a rail-based transit service that carries a lower volume of passenger than heavy rail. LRT carries more people than BRT, given that, its vehicles are larger and linked. Nonetheless, both BRT and LRT are considered rapid transit modes, because of the following common features: priority at intersections; exclusive lanes in corridors; wide station spacing; high capacity vehicles, frequent service; off-board fare payment, among others. The major difference between BRT and LRT, however, is their financial and transportation demands. LRT is much more expensive than BRT, as measured in construction cost per kilometer, mainly due to its additional infrastructure needs, as well as, operating cost.

The Transmilenio is now one of the world’s premier Bus Rapid Transit (BRT) systems. In January 2006, the system carried over one million passengers per day on a network of high capacity trunk corridors, supported by feeder services that extend system coverage to peripheral areas of the city.

Congestion on major routes in the city has been significantly reduced with less traffic and costs to other commuters. The BRT system has reduced journey times by on average 32 percent, and now has a speed of 26 km/hour (UNFCCC, 2010).

5.2.2 Mexico City (Mexico)



The backbone of Mexico City's transportation system is the Metro, a 200km, rubber tired subway system consisting of 11 separate lines. The system is heavily subsidized by the government, with a flat-rate fare of 2 pesos (about $0.20 USD), and it transports 4.5 million passengers every day, most of whom are working class or the poor (Gilat and Sussman 2003, In Albert et al., 2005).

Mexico City used to have an extensive public bus system, which as late as 1986 provided over 40 percent of the city's trips. During the economic crisis of the 1980s, however, the government greatly reduced its investment in public transit, and the trip share for buses fell to 9 percent by 2000. A new form of transportation emerged to fill the gap as a number of taxi drivers began to carry multiple passengers and operate with fixed routes and fares. Low-capacity sedans were later replaced by 9-seater VW 'combis' and 21-seater 'microbuses'. By contrast, only 16 percent of the region's trips are taken by private automobile, despite the fact that automobile ownership increased by an average of almost 8 percent per year between 1990 and 2000 (Gobierno del Distrito Federal, 2002, In Albert et al., 2005).

The largely unregulated fleet of mini-buses reduced average traffic speeds, lowered road safety (buses competed to get customers and reach their destinations fastest), and increased pollution levels (due to old buses being used and lower average speeds). Today, things have been looking up since the introduction of the metro-buses through a Public Private Partnership (PPP). Travel times have fallen considerably in the BRT routes and average traffic speeds have risen. The BRT system has replaced 1077 micro-buses, which were essentially family-run operations, in certain routes with about 300 metro-buses. The low-floor Metro-buses have their own dedicated lanes, and people pay fares on platforms while waiting so that the buses can move very rapidly. The share of bicycles have also increased (0.7 percent in 1994, 1.5 percent in 2007), and the total of non-polluting modes of transport (bicycle, STC-Subway, tramway, trolleybus and light rail) had only 15.2 percent of the total in 1994 and 17 percent in 2007 (Rivera et.al 2011). The Metro-buses have played an important role in transforming the Mexico City into a more livable, sustainable, and healthy city.

### 5.2.3 Istanbul (Turkey)

Urban transportation has long been formed by a road-based policy focusing on providing more road capacity to accommodate the rapidly increasing number of motor vehicles in Istanbul. As a result, multi-lane roadways, over and underpasses, complex intersections etc. have been built to solve the ever increasing congestion problem. However, additional capacity provided by these road investments facilitated a rapid growth in car use and created additional traffic volumes, as a result of the changes in the land-use and activity patterns.

Almost 90 percent of the private and public passenger trips are made by road vehicles in Istanbul and requires an extensive road network. The total length of the road network of Istanbul is 26,853km (41.3 percent of the total road network of Turkey, which stood at 65,062km in 2009), with 0.9 percent (252km) being urban motorway, 15.9 percent (4257km) making up the urban primary network (A and B Roads) with the rest (22,494km) being the secondary network and the minor roads. In addition to this, the city of Istanbul also has a strategic road network, with Emergency Main Roads which is 2864km long (Kaparias et al, 2010). The modal split for Istanbul is 49.28 percent walking, 0.05 percent cycling, 12.06 percent bus, 0.56 percent light rail, 0.59 percent metro, 1.15 percent commuter rail, 12.95 percent car, 0.16 percent motorcycle/scooter, 1.35 percent taxi and 9.38 percent 'dolmus' minibus (Gercek and Demir, 2008).

The Municipality of Istanbul has successfully introduced an electronic ticketing system (Akbil) that allows for discounted transfers within the public transport network (buses, ferries and rail transit system) and better integration of the system, but additional actions are needed to further improve the efficiency and attractiveness of the public transport system, and stop or at least slow the shift to private vehicles. Buses and minibuses (including "dolmuş" that operate on certain routes) together form the main body of the public transport network. Today, 591 bus routes and 123 minibus routes provide service for over 4.5 million passengers on a network of 6,100km. The existing public transportation infrastructure in the city is mainly operated by the Municipality of Istanbul and largely based on road systems.

The Istanbul Metropolitan Municipality has recognized the need for improving the public transport system and has started some rail transit projects. The rail system is not extensive with a total length of 137km of which most provides a low level of service. Istanbul has a metro (8.5km), a light metro (19.3km), three tramways (32km), two funiculars (1.2km), two nostalgic tramways (4.2km), suburban railways (72km), and two cable cars (0.9km) with a total length of 138km.

### 5.2.4 Lagos (Nigeria)

Lagos has a total of 2,600km of roads which are frequently congested, with over 1 million vehicles on the roads daily. The rapid growth of the private vehicle fleet, combined with reliance on commercial vehicles and motorcycles (locally called molues, danfo, taxis, okada), has resulted in a chaotic, inefficient, expensive and unsafe transport system (Trans Africa Consortium, 2010). Almost 100 agencies at the federal, state, and local levels have a part in the organization and regulation of urban transport in Nigeria. At the federal level, the Ministry of Transport makes national transport policy, but urban transport is one of the functions devolved to the states by the 1999 Constitution. The states make their own laws on traffic and transport, but Lagos state has not yet updated its primary legislation (dating from 1949) to incorporate relevant federal standards (Kumar and Barret, 2008).

Despite the diffusion of authority, Lagos's transportation infrastructure has not kept pace with the city's growth. To address the neglected transport needs of the metropolis and to coordinate the activities of multiple agencies responsible for making and implementing transport policy, the Lagos Metropolitan Area Transport Authority (LAMATA) was created in 2002. LAMATA is a corporate body with an independent board responsible for formulating, coordinating, and implementing urban transport policies and programs in the metropolitan area (Kumar and Barret, 2008).

The introduction of a BRT system in Lagos in 2008 was met with unprecedented success and the system has quickly taken its place as a best practice example because of its high patronage (200,000 daily passengers). The first phase in operational service was a 22km corridor and is mostly segregated from the other traffic and is considered ‘BRT-Lite’ (without some of the attributes of a full BRT system). It took only 15 months from conception to operation and was delivered at a cost of EUR 1.2 million per km, far less than usual (Trans Africa Consortium, 2010).

The indicators used to assess the impact of this new policy demonstrated a significant improvement in mobility along this corridor compared to the previous system, notably: congestion was significantly reduced, as 35 percent fewer buses were needed to carry the same number of passengers; fares were made 30 percent cheaper than previously; travel time was reduced by 35 percent; waiting time at bus stops fell by 55 percent on average; fuel consumption fell by 32 percent for vehicles used along the corridor. This resulted in 25,000 tonnes of $C0_2$ per year being avoided due to the implementation of the BRT services (20 times less $C0_2$ emitted per passenger transported compared to private car) (Trans Africa Consortium, 2010).

As can be gleaned from the foregoing, the use of complementary modes of transport is prominent, in varying degrees, in all the four case cities. In Istanbul for instance, 49.23 percent of all trips are made by walking. It is also clear that, even though these cities still experience some level of congestion, its magnitude has considerably reduced, because of the shift towards these complementary modes. This suggests the importance of multi-modes usage to transport sustainability.

### 5.3 Comparative Analysis

This section offers a comparative analysis of the four (4) cities with Kumasi. The overarching concern is premised on the philosophy of sustainable transport in these cities. A number of key areas for comparison are considered as follows:

i. Modal share;
ii. Accessibility and Mobility;
iii. Emissions; and

iv. Safety

v. Fuel consumption;

This 5-point analysis approach allows for useful comparison in measuring the sustainability of Kumasi's transport system. As mentioned in Chapter two, these indicators have been sourced from a review of key transport sustainability frameworks. Comparing data across cities require a standardized definition of the indicators. This is because; the data have been put together from different sources (Wright, 2004; Montezuma, 2005; Vallouis, 2008; Gercek and Damir, 2008; Parry and Timilsina, 2009; Kouluoglu and Hidalgo, 2010; Luoma et al., 2010; UNFCCC, 2010; UITP, 2010; Aderogba, 2011; and Aderamo, 2012), which have not used the same definitions. For harmonization purposes, performance indicators or targets have been used to define the identified variables, as shown in Table 5.2. Such performance indicators are also useful to evaluate progress towards sustainability. It is important to mention that, ideally, standardized data on safety and fuel consumption are measured in fatalities per 100,000 vehicle km travelled and fuel consumption (tonnes) per 100,000 vehicle km travelled, respectively. However, for the lack of data, the performance indicators in Table 5.3 are used to give a surrogate measure for the indicators in the case cities.

**Table 5.2 – Sustainability and their Performance Indicators**

| **Sustainability Indicators** | **Performance Indicators** |
|---|---|
| Modal Share | The share of private vehicle, public transport, taxis/minibuses and walking/bicycling |
| Accessibility and Mobility | Vehicle speed (kph) |
| Emissions | Carbon dioxide emission (Tonnes) per vehicle population |
| Safety | Number of fatalities per vehicle population |
| Fuel Consumption | Fuel consumption (Tonnes) per vehicle |

*Source: Author's Construct, 2012.*

5.3.1 Modal Share

Transport modal split is an overarching concern to transport sustainability, as they raise issues of congestion, safety and energy insecurity, and damaging to the environment. In addition, the importance of transport modal share to sustainability rest on the carbon intensity (expressed as tonnes of $CO_2$ per passenger-km), which varies widely between these transport modes. The transport modes considered in this analysis are private vehicle, public transport, collective taxis/minibuses, and cycling/walking (non-motorised) patronized by commuters in these cities. Generally, private vehicles/automobiles, taxis and minibuses are considered unsustainable modes of transport. This is because, they have low seating capacities, which induce greater travel volumes, and consequently traffic congestion. The consequences of this are debilitating, as slower vehicles consume more non-renewable energy and emit harmful pollutants into the environment. In contrast, public transport systems, with their large occupancy, optimize road space, thereby reducing traffic congestion and emissions. Even at half or one-third capacity, buses typically use far less fuel and emit fewer pollutants per passenger-km than cars (OECD/IEA, 2009). Non-motorised transport is regarded as the most sustainable; as they do not involve fuel combustion, thus, do not emit any pollutants. To achieve transport sustainability, therefore, there should be a balance between the various transport modes. On this premise, Table 5.3 shows the share of trips that are undertaken by transport modes in these cities.

**Table 5.3 – Transport Modal Share of the Case Cities**

| **Cities** | **Modal Share** | | | |
|---|---|---|---|---|
| | Private Veh. | Public Transport | Taxis/Minibus | Cycling/Walking |
| Bogota (2000) [a] | 12 | 71 | 2 | 15 |
| Mexico City (2007) [b] | 20.7 | 14.8 | 46 | 18.5 |
| Istanbul (2006) [c] | 13.11 | 26.83 | 10.73 | 49.33 |
| Lagos (2008) [d] | 16 | 2 | 37 | 45 |
| **Kumasi (2012) [e]** | 19.6 | - | 54.8 | 25.6 |

*Sources: ([a] Wright, 2004; [b] Rivera et.al, 2011; [c] Gercek and Demir, 2008; [d] UITP, 2010; [e] This Current Study, 2012)*

Table 5.3 clearly shows that, Kumasi's transportation system looks more of a non-supportive nature towards sustainability when compared to the four other countries under review. When Kumasi's private vehicular and taxis/minibuses modal shares are combined (74.2 percent), it gives an indication that, Kumasi's transport system is not sustainable; as comparisons with the other cities (Lagos [53 percent]; Istanbul [23.84 percent]; Mexico City [70.03 percent] and Bogota [14 percent]) shows a relatively low usage of such modes. Again, from the perspective of public transport and walking/cycling, of which Kumasi's share is 23.5 percent, all the other cities' are above 25 percent. The overreliance on these unsustainable modes in Kumasi, could be explained by the lack of alternative modes of transportation, and the absence of some simple and basic amenities, such as walkways, safe bikeways or convenient access to public or mass transit (such as BRT or subways), which are prominent in the other cities.

### 5.3.2 Accessibility and Mobility

Sustainable transport is efficient accessibility. According to Zegras (2006), "sustainable transport is providing more utility, as measured by accessibility, per unit of throughput, as measured by mobility". In this analysis, accessibility refers to the ease with which vehicles move from one point to another in a particular city, measured by vehicle speed (kph). In essence, vehicle speed is an indication of sustainable transportation. The higher the vehicle speed implies less congestion and hence less fuel combustion and fewer emissions. In effect, sustainable transport systems are characterized by high vehicular speeds whereas unsustainable transport systems are characterized by low vehicular speeds. The average speed levels, measured during the peak hours of between 8am – 9am and 5pm – 6pm, for the case cities are shown in Table 5.4.

**Table 5.4 – Vehicle Speed Levels in Case Cities**

| City | Vehicle Speed (kph) |
|---|---|
| Bogota (2006) [a] | 26.0 |
| Mexico City (2006) [b] | 22.4 |
| Istanbul (2008) [c] | 30.0 |
| Lagos (2007) [d] | 23.0 |
| **Kumasi (2012) [e]** | 16.0 |

*Source: ([a] UNFCCC, 2010; [b] Parry and Timilsina, 2009; [c] Kouluoglu and Hidalgo, 2010; [d] UITP 2010; [e] This Current study, 2012)*



With empirical evidence from Table 5.4, vehicle speed in the city of Kumasi is the lowest with vehicles moving at an average of 16 kph as compared to 22.4 kph for Mexico City, 23 kph for Lagos, 26 kph for Bogota and 30 kph for Istanbul. The low vehicular speed recorded by Kumasi is a reflection of the congestion on Kumasi's road network as road capacities are being exceeded (see Table 5.5). This is an indication of the over dependence on low occupancy vehicles (private and taxis/minibuses) in Kumasi, relative to the other cities, as indicated in Table 5.2. Under a business-as-usual scenario, vehicle speed in Kumasi is expected to further reduce, as private vehicle usage is predicted to increase by 1,388.4 percent (669,942) in 2022, if nothing is done now. A pro rata break down of the expected increases in vehicle fleet in Kumasi in 2022 indicates that, vehicle length on roads especially, the major arterials will be very long (see Table 5.5).

**Table 5.5 – Expected Speed Levels on the Major Arterials in Kumasi in 2022**

| Roads | ADT Volume per Lane (2012) | Speed (kph) (2012) | ADT Volume per Lane (2022) | Speed (kph) (2022) |
|---|---|---|---|---|
| Kumasi-Accra | 43,402 | 20 | 157,670 | 5.5 |
| Kumasi-Sunyani | 25,458 | 10 | 71,165 | 3.5 |
| Kumasi-Bekwai | 19,160 | 11 | 54,257 | 3.9 |
| Kumasi-Offinso | 24,269 | 15 | 68,344 | 5.3 |
| Kumasi-Mampong | 19,998 | 10 | 55,911 | 3.5 |

*Source: Projections based on field data using an exponential growth function and a growth rate of 0.2 per cent.*

From Table 5.5, speed levels on all the major arterials in the Kumasi are expected to further reduce in 2022, which are far below the posted speed limit of 50kph in the City. These have serious consequences on fuel consumption and vehicle emissions in the Kumasi.

5.3.3 Transport Emissions

In agreement with literature, a high vehicle emissions per vehicle, is a resounding warning indicating an unsustainable transport system and hence its subsequent effects. As indicated in Table 5.2, in this analysis, $CO_2$ emission is used as a surrogate for transport total emissions in the case cities. This is because of the share of $CO_2$ concentration in the total vehicle emissions in all the cities (above 92 percent), and the contribution of $CO_2$ to greenhouse gas emissions, that contributes to global warming and thereby climate change. Table 5.6 shows the $CO_2$ emissions in the case cities.

The cross city comparison shown in Table 5.6 provides the study a clear opportunity to consider Kumasi's vehicular emissions with respect to other case cities. It is seen that, Kumasi's $CO_2$ emissions appear to be the least when compared to the other case cities; with Istanbul recording the highest $CO_2$ emissions. However, with a rather smaller number of registered vehicles, Kumasi is seen as the highest city emitting $CO_2$ per vehicles with an average of 9.1 tonnes of $CO_2$ per vehicle (2000-2005). Invariably, this presupposes that, the sustainability of Kumasi's transport system is threatened and becomes more unsustainable in nature.

**Table 5.6 – Carbon Dioxide ($CO_2$) Emissions in the Case Cities**

| **City** | **$CO_2$ Emissions (Tonnes)** | **Total Number of Registered Vehicles** | **$CO_2$ Emissions per Vehicles (Tonnes)** |
|---|---|---|---|
| Bogota (2001) [a] | 1,506,000 | 1,000,000 | 1.50 |
| Mexico City (2004) [b] | 1,793,000 | 1,473,208 | 1.02 |
| Istanbul (2007) [c] | 8,900,000 | 2,710,802 | 3.28 |
| Lagos (2010) [d] | 7,467,200 | 1,200,000 | 6.2 |
| **Kumasi (2012) [e]** | 837,000 | 91,542 | 9.1 |

*Source: ([a] Wright, 2004; [b] Rivera et.al, 2011; [c] Vallouis, 2008; [d] Aderogba, 2011; [e] This Study; 2012)*

From this backdrop, it is very necessary to take decisions that are geared towards dealing with this high $CO_2$ emission. However, firstly, the main attributing factors need to be identified and understood to adequately deal with it. Though these have been discussed earlier, it is again worth mentioning here. The main factor that the study identified was the modal share of transport which is largely characterized by large number of private vehicles and taxis/minibuses. Also, the total vehicle fleet in the City is largely old, as 51.9 percent were manufactured before 1993, and most not fettered with catalytic converters which control emissions from vehicles. Unlike other forms of vehicle pollution, Carbon Dioxide ($CO_2$) emissions cannot be reduced by pollution control technologies. They can only be reduced by burning less fuel, which implies less dependence on fuel that contains more carbon – diesel and gasoline.

### 5.3.4 Transport Safety

Although, recently, emissions have been the first well-established health consequence of transport, its effect on road traffic deaths and injuries cannot be over emphasized. As seen in Table 5.7, Kumasi is doing better in terms of the number of traffic fatalities and fatalities per vehicle population. Kumasi is seen as the least city recording traffic fatalities per vehicle population after Istanbul, with 0.0007. Even though the data show this, it is likely not to be the reality, as accidents and injuries related to transport are usually under-reported. In Kumasi, as is the case in most cities of developing countries, the usual sources of data on accidents include police accident report and hospital records, which have their shortcomings that diminish their usefulness. Elsewhere in the other case cities, such as Istanbul and Mexico City, police accident reports are combined in the Fatality Analysis Reporting System (FARS), an ongoing system for deaths related to transport (London et al., 2002). This could account for the relatively large accident figures recorded in these cities. Notwithstanding such shortcomings, the data presented in Table 5.7 is a good indication for the City in achieving social sustainability.

**Table 5.7 – Fatalities per Vehicle Population in Case Cities**

| City | Number of Traffic Fatalities | Number of Registered Vehicle Population | Fatalities per Vehicle Population |
|---|---|---|---|
| Bogota (2003) [a] | 585 | 694,248 | 0.001 ($1x10^{-3}$) |
| Mexico City (2005) [b] | 2218 | 1,473,208 | 0.002 ($2x10^{-3}$) |
| Istanbul (2005) [c] | 265 | 2,710,802 | 0.0001 ($1x10^{-4}$) |
| Lagos (2007) [d] | 1,807 | 527,484 | 0.003 ($3x10^{-3}$) |
| **Kumasi (2012)** [e] | 66 | 91,542 | 0.0007 ($7x10^{-4}$) |

Source: (*[a] Montezuma, 2005; [b] Luoma et al., 2010; [c] Gercek and Demir, 2008; [d] Aderamo, 2012; [e] This Study, 2012)*

Notwithstanding, the relatively low fatalities per vehicle population recorded by Kumasi, as indicated in Table 5.7, the City should not relax on its effort in further reducing accidents and deaths related to transport. Considering the fact that, vehicle population, and particularly, private vehicles in the City are expected to increase by a large margin, with no investments in the transport system, especially, regarding public transport system and non-motorised infrastructure, this current figure is likely to increase.

5.3.5 Vehicle Fuel Consumption

Although data for vehicle fuel consumption for Kumasi is available, that of the other cities was seldom available, hence making comparison difficult. Within this constraint, however, considering the positive relationship between $CO_2$ emissions and the use of fossil fuels (OECD/IEA, 2005), and for the fact that, Kumasi emits more $CO_2$ per vehicle population than the other cities, it can be concluded that, the transport sector in Kumasi consumes more fossil fuel than the other cities. Giving the trend of fuel used by the transport sector in Kumasi, with a growth rate of 0.05 percent per annum, the current figure (502,148 tonnes) is likely to increase. What is disturbing about this is the proportion of diesel (56.2 percent) and gasoline (40.8 percent) consumed in the city by the transport sector, which has serious implications on greenhouse gas and climate change.

The comparative analysis of the case cities' transport systems, as presented in this section, has made known the performance each city in relation to the individual sustainability indicators. There is the therefore the need to ascertain the overall performance of each city's transport system, which will consequently, indicate their overall sustainability. This is the focus of the next section.

### 5.4 Overall Sustainability of the Transport System of Case Cities

The aim of this section is to determine the overall sustainability of the case cities, and most especially, show the relative position of Kumasi, using the issues presented in the previous section as input data. To achieve this, an aggregation method is applied, and the cities are ranked. Aggregation here refers to the method of summing up the scores of the case cities based on their performances in relation to the individual indicators. This requires that, a measuring scale be developed, with which, the performance of the cities are scored. To this end, a rating scale of 1 to 5 is used, where 1 represents the best and 5 represents the worst or the least. By this principle, a city with the best performance with respect to an indicator scores 1 and the worst performing city scores 5. An interpretation of the rating scale is shown in Table 5.8.

**Table 5.8 – Interpretation of the Rating Scale**

| Score | Interpretation of Score |
|---|---|
| 1 | Best |
| 2 | Good |
| 3 | Average |
| 4 | Bad |
| 5 | Worse |

*Source: Author's Construct, 2012.*

It is important to mention that, since the best performance is being assigned a scale of 1 and the worst performance a scale of 5, in aggregating the scores for the purpose of ranking, the smallest aggregated score becomes the best and the largest aggregated score becomes the worst. In view of the fact, each indicator has a unique basis of measurement; the scale of 1 to 5 must be clearly defined with respect to each indicator. This is duly elucidated in subsequent paragraphs.

- Modal Share

The City with the large modal share of public and non-motorized modes of transport scores 1 and the City with the scores 5. This is due to the fact that public transport has high occupancy rate and thus, transports more passengers as compared to private vehicles with low occupancy rates. Also non-motorised mode of transport has no emissions therefore does not contribute to greenhouse gas emissions and air pollution making it sustainable.

- Accessibility

With the unit of measurement being vehicle speed (kph), the city with the highest vehicular speed is deemed sustainable and hence scores 1 whereas the city with the lowest vehicular speed scores 5. This is because low vehicle speeds implies congestion on roads and hence reduces mobility making the transport unsustainable.

- Emissions

Since vehicular emission is a major contributor to greenhouse gases, the least emissions emitted by vehicles the better. Consequently, the city with the least carbon dioxide emission per vehicle scores 1 and the city with the most carbon dioxide emission per vehicle scores 5.

- Safety

Injuries and fatalities caused by road accidents are disadvantages associated with a transport system. The less injuries and fatalities recorded on a transport system the better. In essence, a city scores 1 when it records the lowest injuries and fatalities whiles a city scores 5 when it records the highest number of injuries and fatalities.

- Fuel Consumption

Since there is a direct relationship between fuel consumption and vehicle emissions, the less fuel consumption the better. As a result, a city is considered sustainable (given a score of 1) when there is less fuel consumption per vehicle and unsustainable (given a score of 5) when there is high fuel consumption per vehicle.

Given the parameters, as outlined from the foregoing, the performance of each case city with respect to each indicator, and the consequent aggregation was derived, as indicated in Tables 5.9 and 5.10. Findings from Table 5.9 indicate that, the indicators are not necessarily mutually dependent in achieving sustainability. That is, being rated best in one of the indicators, does not automatically make a city the best in other indicators. For instance, in terms of modal share, which is seen as a predictor of the other indicators, Bogota is rated the best, but trails behind Istanbul in accessibility and safety, and Mexico City in Emissions. This underscores the importance of other factors, other than the principal indicators, in the achievement of the overall sustainability of transport systems. Public transport system and non-motorised transport alone may not be enough in reducing $CO_2$ emissions. Factors such as, the age of vehicles and the efficiency of fuel on which vehicles run, are equally important.

**Table 5.9 – Sustainability Indicator Ratings of Case Cities**

| **City** | **Sustainability Indicator Ratings** | | | |
|---|---|---|---|---|
| | **Modal Share** | **Accessibility** | **Emissions** | **Safety** |
| Bogota | 1 | 2 | 2 | 4 |
| Mexico City | 3 | 4 | 1 | 3 |
| Istanbul | 2 | 1 | 3 | 1 |
| Lagos | 4 | 3 | 4 | 5 |
| Kumasi | 5 | 5 | 5 | 2 |

*Source: Based on Wright, 2004; Montezuma, 2005; Vallouis, 2008; Gercek and Damir, 2008; Parry and Timilsina, 2009; Kouluoglu and Hidalgo, 2010; Luoma et al., 2010; UNFCCC, 2010; UITP, 2010; Aderogba, 2011; and Aderamo, 2012*

Notwithstanding, the relationship between the variables, as shown in Table 5.9, is largely positive. That is, even though cities rated best in modal share are not rated same in the other indicators; their scores are still not below average, indicating the complementary role of the indicators of transport sustainability. The overall sustainability performance of the transport system of the case cities, using inputs from Table 5.9, is presented in Table 5.10.

**Table 5.10 – Overall Sustainability Performance of the Transport System of Case Cities**

| City | Aggregated Score | Rank |
|---|---|---|
| Bogota | 9 | 2nd |
| Mexico City | 11 | 3rd |
| Istanbul | 7 | 1st |
| Lagos | 16 | 4th |
| Kumasi | 17 | 5th |

*Source: Based on Wright, 2004; Montezuma, 2005; Vallouis, 2008; Gercek and Damir, 2008; Parry and Timilsina, 2009; Kouluoglu and Hidalgo, 2010; Luoma et al., 2010; UNFCCC, 2010; UITP, 2010; Aderogba, 2011; and Aderamo, 2012*

From Table 5.10, Kumasi's transport system has the highest overall score, followed by Lagos, Mexico City, Bogota and Istanbul, with scores of 17, 16, 11, 9, and 7, respectively. This implies that, among the five (5) case cities, Istanbul's transport system is the most sustainable, with Kumasi's transport, the most unsustainable. In other words, Kumasi's transport system falls short of being seen as sustainable compared to benchmarks in the other cities. Kumasi's rank in the ladder is an indication of the imbalance between increased usage of cars in the Metropolis and expansion of road network. Carbon Dioxide emissions remain well above the benchmarked cities, resulting from the over dependence on low occupancy vehicles, thereby congestion.

In sum, the comparative analysis has revealed a significant gap between the best-performing cities (and even Lagos) and Kumasi across a number of indicators. Without strenuous efforts to improve performance, this gap will only grow, with serious implications for the City's overall living standards and the transport sector in particular.

### 5.5 Summary of Chapter

The focus of the chapter was to measure the sustainability of Kumasi's transport system. This was achieved by comparing Kumasi's transport system with the transport systems of four other cities, namely: Istanbul; Bogota; Mexico City; and Lagos. The parameters considered in the comparative analysis included modal share, accessibility and mobility, emissions, safety and fuel consumption. Kumasi's performance with the other cities in terms of these parameters is outlined seriatim:

4. The modal split of Kumasi's transport is largely skewed (74.2 percent) towards private cars, taxis, and minibus, all with low occupancy rates and high emissions. On the contrary, Bogota has a public transport modal share of 71 percent, Istanbul 19.36 percent, Mexico City 9 percent, and Lagos 2 percent, which are important for transport sustainability. Kumasi thus, scores 5 on the rating scale, in terms of modal share.

5. Kumasi has the lowest vehicle speed (16kph) and hence the most congested among the five cities, scoring 5 on the accessibility rating scale. This situation is likely to further worsen, given that, private vehicle usage is predicted to increase by 1,388.4 percent (669,942) in 2022;

6. The carbon dioxide emissions per vehicle in the city of Kumasi exceeded that of all other cities indicating an unsustainable transport system. This is as a result of the large share (51.9 percent) of the total vehicle fleet in the City manufactured before 1993, and the fact that most vehicles are not fettered with catalytic converters.

7. In terms of safety, Kumasi performed better as it ranked second among the five cities, following Istanbul. The chapter found that, the traffic accident fatality rate in Kumasi is likely not to be the reality, as accidents and injuries related to transport are usually under-reported.

8. Comparison of the cities in terms of fuel consumption was difficult, as data for the other cities were seldom available. However, considering the positive relationship between $CO_2$ emissions and the use of fossil fuels (OECD/IEA, 2005), and the trend of fuel used

by the transport sector in Kumasi, the current figure of 502,148 tonnes is likely to increase.

In view of the fact that, no single indicator sums up the sustainability of transport systems in an urban context, the scores of each city (which was derived from a rating scale) in terms of the parameters or variables were summed. Overall, Kumasi's transport system scored the highest of 17, implying that, the City's transport system is largely on an unsustainable path. This is because the vehicle population is growing and predicted to even grow much more rapidly than the current infrastructure can accommodate, further reducing speed levels. Air pollution from motor vehicles is also a concern in the City, resulting from large amount of fuel (particularly gases and diesel) consumption. Because roughly 40 percent of all trips in the City are made on foot, exposure of a majority of people to direct emissions from motor vehicles is likely. The unsustainable nature of Kumasi's transport calls for strategies to improve the current performance towards sustainability. Attention will turn to these aspects in the concluding chapter.

# CHAPTER SIX

# SUMMARY OF MAJOR FINDINGS, RECOMMENDATIONS AND CONCLUSION

## 6.1 Introduction

In the previous two chapters (Chapters four and five), a presentation and analyses of the survey data were made. Specific attention was on the present transport situation, with the objective of assessing the sustainability of Kumasi's transport system. This chapter recaps the major findings from the data analysed. In effect it provides a summary of the major findings made from the study. This is done in the light of the concepts identified from the literature reviewed in Chapter two, as it provides an understanding of the situation in Kumasi. Efforts have also been made to offer practical recommendations to help address the problems identified with Kumasi's transport system, within the framework of sustainability, in this Chapter. The Chapter also contains possible areas for further research.

## 6.2 Summary of Major Findings of the Study

The summaries cover the main objectives investigated in the study. The study set out to achieve the following objectives:

1. To develop a framework for measuring transport sustainability;
2. To present the current transport situation of Kumasi; and
3. To determine the sustainability of Kumasi's transport system.

The subsequent sections show how the study objectives were achieved.

### 6.2.1 Objective 1 - Framework for Measuring Transport Sustainability in Kumasi

As has been established in the earlier chapters, transportation provides a myriad of benefits to both local and national economies. However, it presents a number of challenges ranging from congestion, greenhouse gas emissions and pollution. Conventionally, city authorities place more emphasis on the economic benefits derived from the system ignoring its impacts on society and environment. Despite the relevance of maintaining a good balance in these three objectives, in many times precedence is given to the economic objective (aimed at increasing income, wealth, employment, productivity, and social welfare) to the detriment of social (equity, human health, community liveability and cohesion, impacts on historic and cultural resources) and environmental objectives. With the new paradigm of development that shifts its meaning from mere economic indices to include other sectors such as environment and society, various authors and theorists have given sustainable development different, but not too contrasting, definitions.

To really evaluate and assess the performance of transportation system to the goal of sustainability, indicators are required. These are useful for identifying trends, predicting problems, setting targets, evaluating solutions and measuring transport projects. Just as the meaning of the term, there have been different indicators developed to assess the success, or otherwise, of achieving sustainable development. Notwithstanding, all the frameworks propounded, give credence to the interrelated three dimensions of economy, society and environment, referred to as the triple-bottom line.

Criteria for selecting indicators for assessing the sustainability of transport systems may vary relative to geographical or political level. However, it is relevant that irrespective of the level of assessment, indicators or performance measures must be developed to capture a community's broader vision which can be distilled into goals and objectives. Various frameworks have been developed by different authors and institutions for assessing transport sustainability. Five of such frameworks were reviewed, namely: WBCSD Framework for Sustainability Mobility, Victoria Transport Policy Institute's Framework, Sustainable Transportation Performance Indicators, Transport and Environment Reporting Mechanism (TERM) Framework and Sustainable Goals and Performance Measures. Based on the system in Kumasi characterized by congestion, single dominated mode of transport and its attendant high dependence on fossil fuels, seven key variables were selected to assess the sustainability of the system. These indicators are identified as follows: transport costs and prices, modal split, accessibility and mobility, risk and safety, affordability, resource use and transport emissions.

Having critically reviewed the indicators that can be used to assess the sustainability of transportation system and appropriate indicators selected, it becomes important that they are used to benchmark current trends in Kumasi to determine the system's level of performance which is summarized in the next section.

### 6.2.2 Objective 2 – Analysis of the Present Transport Situation in Kumasi

This section provides a glimpse of the present situation of the transport sector in Kumasi; describing its relevance in terms of environmental, economic and human health impacts. On the whole, five main variables out of the seven possible indicators were assessed in the study as demonstrated in Chapter four, the outcome of which as summarized seriatim.



#### 6.2.2.1 Modal split

The study confirmed the generally held assertion that, modes of travel are closely related with residential densities. Mixed use development is often a feature of high density residential areas where places of living are usually interspersed with work places as well as leisure time areas. This implies that there are shorter distances between homes and work places which result in the choice of non-motorized transport modes such as walking and the use of bicycles. This was revealed in the high density areas of Kumasi (Aboabo and Ayigya) where the predominant mode of transport is walking or the use of bicycles. However, the most prominent mode of travel is by taxis and trotros which were patronized by 54.8 percent of those interviewed.

Juxtaposing the modes of transport to the reasons why trip makers use particular modes, it appeared they place high premium on the convenience of the modes as well as cost. This presents an opportunity for reducing the traffic congestion on the streets of Kumasi as public transport vehicles with high capacity could be made more convenient to satisfy majority of commuters and reduce the negative environmental impacts of transportation, accidents, congestion and vehicular emissions. Even though, already, conventional non-motorized modes of transport (walking and cycling) are taking place, their infrastructural facilities are extremely limited throughout the City, and receive little attention. These modes are sustainable given their health benefits as well as limited environmental impacts and hence raise the need for them to be integrated into transportation planning in Kumasi.

### 6.2.2.2 Accessibility and mobility

The ease with which desired goods, services and activities are reached constitutes accessibility. This definition indicates that the free flow of traffic on roads is necessary for an efficient and sustainable transport system. Nonetheless this free flow of traffic is often not achieved due to congestion, which reduces the speed at which vehicles can move. The study revealed that, most of the major roads in Kumasi have very high congestion indices (0.6 – 0.8) and speed limits as low as below 20kph. This heavy nature of traffic congestion was observed to be caused by the rising number of low occupancy vehicles, which include private salon cars, taxis and mini-buses (trotro); resulting in inefficient use of road capacity. The land use structure of the City (resulting into over concentration of activities in the CBD); as well as the dearth of investments in high occupancy public transport also contributes to the heavy traffic congestion.

### 6.2.2.3 Risk and safety

Safety of the population patronizing the transportation system is vital in assessing the sustainability of the system. There has been a general reduction in the rate of accidents recorded in Kumasi over the period of 2006 – 2010. Notwithstanding the general reduction, some years (2007 and 2009) experienced an increase in the number of accidents. This trend does not deviate from the number of injured victims (hospitalized cases) and the number who died (fatal cases) resulting from road traffic accidents in the City. It was also revealed that lighter vehicle types, such as cars, generate the highest risk to the occupants themselves while the heavy vehicle types such as buses, generate the main risk for non-occupants. This shows that both passengers and pedestrians are not spared from these road fatalities implying a worrying trend of high risk on the roads of Kumasi.

Investigating the cause of accident confirmed the assertion held by Marchesini and Wiejermars (2010) that there is a direct relation between congestion and the rate of crashes. The study revealed that most of the accidents recorded occurred on the heavily congested roads. This is basically because unstable flow conditions result in an increase in the frequency of rear-end crashes, partly because of anxiety on the part of vehicle operators. Nonetheless, these accidents are not as more severe like those on lesser congested roads.

#### 6.2.2.4 Resource use (Fuel Consumption)

The rate at which resources are used is essential in discussing the subject of sustainability. Various authors argue that the rate at which renewable resources are used should not exceed its regenerative rates and that non-renewable resources should be used at levels where they can be substituted. Available data indicates that, the rate of fuel consumption has direct relation with vehicle fleet. Fuel consumption by the road transport sector in the City increased steadily from 319,878 tonnes in 2001 to 502,148 tonnes in 2010 (which is predominantly diesel - 56.2 percent and gasoline or petrol - 40.8 percent). This high level of diesel and gasoline (petrol) implies that more vehicle emissions are released in the environment resulting in the negative environmental impacts and attendant health hazards.

#### 6.2.2.5 Transport emissions

A very imperative but often neglected dimension of sustainability is the impact of development on the environment. The environment is often fraught with greenhouse gas emissions without instituting any mitigation measures to ameliorate the impacts on environment. The study revealed that the transport sector exerts the greatest pressure on air quality in the Metropolis, considering its high fuel consumption levels. Emissions such as Carbon Monoxide (CO), Carbon Dioxide ($CO_2$), Nitrogen Oxides (NOx), Sulphur Dioxide ($SO_2$), and Ozone ($O_3$) from the transport sector resulting from combustion of fossil fuels cause damaging effects to both the physical and human environment.  These are partly due to the increasing motorization rates, increasing conventional passenger vehicles (those manufactured in 1992 or earlier), and the fact that most vehicles have low fuel-use efficiency in the Metropolis. Data available from 2000 – 2005 indicates that, unfortunately, carbon dioxides dominate the pollutants constituting more than 97 percent giving an indication of the rate by which the environment in Kumasi is affected.

To this end, the present situation of transportation in Kumasi paints a bleak picture given the high levels of greenhouse gas emissions, the high dependence on fossil fuels, environmental problems like congestion, pollution as well as the high rate of accidents. Since these indicators do not necessarily determine the sustainability of a transport system, a comparative analysis of

Kumasi's system with other cities whose systems are deemed sustainable, was analyzed, the results of which are presented in the next section.

### 6.2.3 Objective 3 - Sustainability of Kumasi's Transport System

This objective was achieved by comparing the present transport situation of Kumasi with four other cities, namely: Mexico City, Bogota, Istanbul and Lagos, using indicators developed for the study as bases. The comparative analysis revealed that Kumasi's transport system is unsustainable. This sub-section elucidates the findings with respect to the five sustainability indicators.

#### 6.2.3.1 Modal Share

A sustainable transport system is considered to have substantial modal share comprising of public transport and non-motorized modes on account of their high occupancy and zero emissions respectively. Kumasi's transport system deviates from this as 74.2 percent of the modal split comprise of private cars, taxis and mini-buses all with low occupancy rates and high emissions. An interesting feature of Kumasi's transport system is the absence of a public transport system. Comparing this to the other four cities, Bogota has a public transport modal share of 71 percent, Istanbul 19.36 percent, Mexico City 9 percent and Lagos 2 percent. Given the predicted rate of growth in private vehicle usage, this situation is likely to get worse in the future if nothing is done about the current situation in terms of transport mode.

#### 6.2.3.2 Accessibility and Mobility

The overarching goal of transport is to efficiently move people and goods from one location to another. Any obstacle that impedes the free movement of people and goods reduces accessibility thereby rendering a transport system unsustainable. In effect, sustainable transport systems are characterized by high vehicular speeds whereas unsustainable transport systems are characterized by low vehicular speeds. The comparative analysis indicated that Kumasi has the lowest vehicle speed and hence the most congested among the five cities. All the cities recorded vehicle speeds above 20 kph with Istanbul recording 30 kph. However, vehicles move at 16 kph on the roads of

Kumasi. Under a business-as-usual scenario, vehicle speed in Kumasi is expected to further reduce, as private vehicle usage is predicted to increase by 1,388.4 percent (669,942) in 2022.

#### 6.2.3.3 Transport Emissions

Transport is a contributor to global warming through the emission of greenhouse gases especially carbon dioxide from vehicles. A sustainable transport in essence must be characterized by low carbon dioxide emission per vehicle. Although the carbon dioxide emission of Kumasi was the least among the five cities, the carbon dioxide emissions per vehicle in the city of Kumasi exceeded that of all other cities. This is primarily due to the large number of private vehicles and taxes/minibuses. Again, about 52 percent of registered vehicles in Kumasi are older than 1993 and most not fettered with catalytic converters which reduce the emissions.

#### 6.2.3.4 Transport Safety

This comprises the social dimension of transport sustainability as it measures road traffic deaths and injuries of a transport system; the lower the fatalities, the more sustainable the transport system. With respect to this indicator, Kumasi out-performed the other cities, thus, showing positive trends towards sustainable transport. Kumasi is seen as the least city recording traffic accidents after Istanbul with fatalities per vehicle population of 0.0007 ($7.0 \times 10^{-4}$).

#### 6.2.3.5 Vehicle Fuel Consumption

In view of the absence of data on fuel consumption for the other four cities but considering the positive relationship between $CO_2$ emissions and the use of fossil fuels and for the fact that, Kumasi emits more $CO_2$ per vehicle population than the other cities, it can be concluded that, the transport sector in Kumasi consumes more fossil fuel than the other cities. This in effect makes Kumasi's transport system unsustainable.

#### 6.2.3.6 Overall Performance of Kumasi's Transport System

From the comparative analysis elucidated, Kumasi falls short of being seen as sustainable compared to benchmarks in the other cities, but along safety dimensions it is showing positive trends. Aggregating the indicators and considering the overall sustainability results, it can be concluded that, Kumasi's transport system is largely on an unsustainable path. Without strenuous efforts to improve performance of the system by moving away from the business-as-usual scenario, the sustainability of Kumasi's transport system will in no doubt deteriorate making the City's overall living standards decline since every sector largely depends on transport. To this end, the study has outlined measures to help improve the performance of Kumasi's transport situation towards achieving sustainable transportation, as presented in the next section.

## 6.3 Recommendations for Sustainable Transport System in Kumasi

The present transport situation in Kumasi as depicted from the analysis in Chapters 4 and 5, is the key factor guiding the study's recommendations. In addition, the transport sector, with its increasing energy demands and resultant global warming, has become a concern inconceivable to the present and future generations. As a result, the recommendations proposed by the study, do not only respond to local needs, but have been cast within the framework of internationally agreed principles of sustainable development and sustainable transport. Based on the review of relevant literature, efforts to improve any transportation system's sustainability should incorporate attributes of system effectiveness and system impacts on economic development, environmental integrity, and the social quality of life. These strategies are recommended bearing in mind the need to balance the ability of the environment to sustain future quality of life, the ability of transport to serve economic development, and ability of society to fulfill its needs of accessibility freely.

### 6.3.1 Promoting Non-motorised Transport Infrastructure

Non-motorised transport, particularly walking and cycling, are generally held as the most sustainable modes of transport (Morchain and Fedrizzi, 2011). Kumasi is likely to realize important improvements in the traffic situation and in the air quality by implementing successful policies that promote a shift from motorized driving to cycling and walking. Better air quality and more active lifestyles will, additionally, translate into improved health of citizens (Morchain and Fedrizzi, 2011). As was revealed from the analysis, a substantial amount of all trips (23.5 percent) to work places and social places in the city were made by walking, with another 11.3 percent by bicycle. In addition, substantial shares of all trips in the city are so short that they can be more efficiently covered by bicycle or walking rather than by motorised transport. Trip characteristics of households in the city as revealed by the study showed that, about 45 percent of all trips by all modes are less than 5km, while about 78 percent are less than 10km. Despite these, there are no pedestrian walkways and bicycle paths in the city, thereby making these modes unattractive and even dangerous for short distances. Efforts should therefore be made by the city authorities to encourage the use of non-motorised transport.

Bicycle and pedestrian travel can be encouraged through investments in infrastructure (i.e., bicycle paths and lanes, sidewalks, crosswalks), supporting amenities (i.e., bicycle parking, benches), and educational and promotional programs. Opportunities for travelers to choose walking and biking increase when growth patterns provide more housing in close proximity to jobs, stores, schools, and recreational destinations (Morchain and Fedrizzi, 2011). In addition, improved pedestrian connections to transit systems have the potential to divert long automobile trips to walking-plus-transit trips.

Bicycling and walking are core elements of a sustainable transportation system. Trips by bicycling and walking produce no emissions and let people work physical activity into their daily routines to improve their health and save money. Commuters who switch to walking and bicycling can reduce their expenditures on fuel and vehicle maintenance while helping to reduce traffic congestion (Morchain and Fedrizzi, 2011). A safe and attractive environment for pedestrians can also help promote economic development by increasing foot traffic near local businesses and attracting tourists and other consumers in Kumasi.

### 6.3.2 Promoting Roadway Bus System and Infrastructure

This measure implies the development of a high quality public transit system for the city of Kumasi. Considering the current state and the projected increases in vehicle population and the share of private motor vehicles (about 1,388.4 percent increase in 2022), average speeds on all types of roads in the city are further expected to fall. To discourage private vehicle usage presently, and in the future, roadway bus system should be developed in the city. Public transport services are important to ensuring transport sustainability because, they offer the most affordable, cost effective, space-efficient and environmentally friendly mode of motorised transport (OECD/IEA, 2002). There are three types of roadway bus system, which can be exploited. These are: (i) buses that operate in general traffic, with no priority; (ii) buses that receive limited priority, such as bus lanes and at traffic signals; and (iii) buses that operate on dedicated infrastructure, such as bus ways, with minimal interaction in general road traffic, which has become known in recent years as "Bus Rapid Transit" (BRT). Each of these types of public transport type has the potential of taking off significant number of taxis (cars) and mini-buses (which have average seating capacity of 5 and 15 seats respectively) from the city's road space, considering that, currently, taxis and mini-buses carry about 54.8 percent of all trips by commuters, according to the study.

In view of its moderate cost of implementation, relatively short implementation time, high quality of service, and capacity to move large number of passengers, BRT system is favoured by the study, as a public transport type for the city. BRT system is a bus route that operates in a dedicated lane, where passengers pay prior to boarding at boarding stations. These two elements of BRT allow buses to travel at higher average speed than traditional bus system, as buses are not affected by traffic and transfer times at stops (OECD/IEA, 2002). This strategy can be piloted on the following routes in Kumasi: Kumasi-Accra road and Kumasi-Sunyani Road, due to their high average daily traffic volumes (43,403 and 25,458 respectively) and their relatively flat terrain, which will maximize the efficiency of the system. The BRT system can thus be further replicated in other areas of Kumasi following its successful implementation on these routes. Implementing BRT system may require the following features: traffic signal prioritization; better bus shelters; fewer stops; special ticketing systems for potential passengers; and better access to BRT stations. These features are important parts of the successful BRT systems in cities such as Curitia (Brazil) and Bogota (Colombia) (OECD/IEA, 2002).

Minimising the inconveniences of passengers choosing public transport, walking distance from departure point to the public transport station, waiting and transfer times between connecting modes of transport, will to a large extent determine the popularity of the public transport mode. Success in this area is attainable, partly, by integrating a package of land use policies, such as high density residential and commercial development within walking distance of BRT station. This would enhance the market appeal of transit system in the city.

A major challenge anticipated in the development of public transport mode is how to cope with the current transport providers, who are likely to lose their jobs. This can be addressed by integrating transport operators in the development of plans, especially at the consultative stage. This has been used by Kampala, Uganda, in the development of a BRT system. It is important to mention that, BRT system is considered and being developed in Accra and it is about time, it is implemented in Kumasi.

### 6.3.3 Promoting Multi-nuclei Centers and Mixed-Use Development

The major cause of congestion in Kumasi, as revealed by the study, is the multiplicity of trips resulting from the over concentration of activities in the CBD. It was found that, 54.8 percent of all trips in Kumasi end in the CBD. Introducing strategies to reduce the number of trips into the CBD, would therefore, go a long way to reducing the level of congestion and its effects of excessive fuel consumption, vehicle emissions, and traffic accidents in Kumasi. Closely associated with this will be the identification and development of secondary centers with substantial investments such that they provide intervening opportunities for those who would have ordinarily made trips to the CBD for some of their daily needs and requirements. This way, the need for trip making to the City's CBD would be reduced considerably. Areas such as Tafo, Atonsu, Breman and Kwadaso can be used to achieve the objective of providing intervening opportunities. These areas, already, have satellite markets which can be further developed into sub-centers to handle some of the activities currently over-concentrated in the CBD.

From a physical planning perspective, it can also be argued that another way of managing travel demand is through the location and distribution of human activities such that there is a dispersal of work places among residential areas. Conventional zoning often results in segregation of residential and commercial land uses. In contrast, mixed-use development locates land uses with complementary functions close together. Complementary uses may include housing, retail, offices, restaurants, and services destinations that people travel to on a regular basis. Locating activities closer together can reduce trip lengths, allowing trips to be made by walking and bicycling rather than by driving and increasing opportunities to combine trips. Individuals can drive to one destination, for example, and then walk to others once they have parked their car. Reducing vehicle trips can bring environmental and quality of life benefits. Furthermore, facilitating access to employment and shopping by walking and bicycling may reduce the need to own a motor vehicle for personal mobility in the city. This way, the need for travel can be better managed and minimized.

### 6.3.4 Improve Energy Efficiency of Travel

Improving vehicle energy efficiency offers an excellent opportunity for GHG mitigation. Strategies such as electric, hybrid, and fuel-cell vehicles are widely accepted, especially in the medium and longer terms, as efforts to improve energy efficiency. In cities of developing countries, such as Kumasi, the feasibility and effectiveness of such options are questionable, as their market penetration in even cities of advanced countries, is currently small. Therefore, in our context, and from a policy perspective, implementation of vehicle emission control standards and emission control devices could be effective in controlling vehicle emissions, especially over the short term.

Emission standards are requirements that set specific limits to the amount of pollutants that can be released into the environment. This standard is set according to the type or category of vehicle. Normally included in emission standard, is fuel economy standard, which also sets up maximum fuel consumption limits according to vehicle weight and by automatic or manual transmission. The setting of fuel economy standards will encourage foreign vehicle firms to introduce more fuel efficient technologies into the Ghanaian market. Already, the EPA with the Assistance of the World Bank, the Global Environmental Facility (GEF), and the Agence Francaise Development (AFD) funded Urban Transport Project, is developing a “road map” to promulgate a nationwide vehicular emission control standard, which would also include fuel economy requirements. Efforts should therefore be aimed at expediting the process.

Emission control devices include: catalytic converters; fuel injection systems; electronic engine control systems; turbo charging systems; and air cooling systems. However, only the first two could be considered in view of the socio-economic and technological conditions pertaining in Ghana, and that matter Kumasi. It should be noted that there are a few vehicles in Ghana already operating on engines fitted with catalytic convertors and fuel injection systems (Kanyoke, 2004). There are also few vehicles using electronic engine control systems and Emission Control

Devices (ECD), especially the new ones. Even though, their penetration into the Ghanaian market is low, it should be ensured that, the effort continues. According to Faiz et al. (1996, in Kanyoke, 2004), the use of emission control devices in vehicles reduces pollutant emissions (including CO, CO2, HC, NOx, and PM) by more than 50 percent. The percentage reduced could be actually higher depending on the emission device or the pollutant in question. This policy can make the air in the city cleaner and residents healthier by cutting emissions.

To achieve this target however, vehicle owners and passengers would have to bear the extra cost of fitting these vehicles with ECD, which Faiz et al., (1996) estimates to be within the range of US$ 130 (GHS 260) per vehicle for catalytic converters. The vehicles that will be affected by such a policy are the ones operating prior to the phase-out of leaded gasoline in late 2003. In 2003, Ghana phased-out leaded gasoline, which means that prior to this period, the effect of catalytic converters as emission control device was ineffective, even though a good number of vehicles have catalytic convertors in them (Kylander et al., 2003). The policy on the other hand is an effective way of internalizing the externalities of vehicle operation, whereby vehicle owners pay for the cost of their emissions through fitting their vehicles with emission control devices, rather than allowing such externalities (emissions) to be borne by the city's residents at large. Notwithstanding the benefits of this policy, it has an effect of increasing travel cost since transport operators would shift that extra cost to their passengers in the form of increased fares.

It is important to mention that, the foregoing recommendations must be supported with the appropriate legal frameworks, training, capacity building, and public awareness campaigns. The initiative however, must stem from the Kumasi Metropolitan Assembly, as according to Act 462 (paragraph [d] of subsection [I] of section 10); the District Assembly "shall initiate programmes for the development of basic infrastructure and provide municipal works and services in the district".

### 6.4 Areas for Further Research

Developmental challenges are multi-faceted in nature and hence demand multi dimensional interventions to address. Sustainable transport development for Kumasi is no exception; consequently this study has identified the following areas for further research, which could be undertaken to gain a better understanding and progress towards the achievement of sustainable transport in the City and other Ghanaian cities in general.

### 6.4.1 Transport Policy and Sustainable Transport Development

Transport policy documents guide the development of transport at the national level. Since the national transport policy, ideally, provides the framework for all city-level transport actions, there is the need to conduct research on the evaluation of this transport policy under the broad categories of sustainable transport principles. This is because sustainability is unlikely to be reached unless transport policy is re-oriented towards explicit sustainability principles or goals.

### 6.4.2 Development of National Sustainable Transport Indicators/Principles

Even though this research has attempted developing a framework to measure the City's progress towards achieving sustainable transport, the best approach will be to develop a national sustainable urban transport framework. This will provide a better measure of the dynamics of the country's transportation systems in relation to sustainability. Although urban transport policies are local in nature and must be tailored to fit the "profile" and context of the particular urban area, the long-term impact and effectiveness of local policies and measures can be compromised, if at national level, the policy framework does not accommodate and support these local policy initiatives. Future research should therefore be conducted in this regard.

## 6.5 General Conclusion

This study was aimed at assessing the sustainability of Kumasi's transport system. This objective of the study has been evolved from global concerns on environmental quality, social equity, economic viability and climate change, all of which are impacted upon by urban transport. Within the limits of the study, Kumasi's transport system is treading an unsustainable path. This was determined by comparing the transport characteristics of Kumasi with other cities whose transport systems are deemed sustainable – Mexico City, Bogota and Istanbul. In addition, and for the purposes of regional comparative analysis, Lagos was included in the evaluation. The comparative analysis revealed that, apart from road fatality per vehicle population, Kumasi lags behind these cities in all the other variables of congestion, fuel consumption and vehicle emissions. This situation is characterized by heavy dependence on informal collective transport (taxis and trotros), high motorization rates, and inadequate facilities for pedestrians and cyclists, in the City.

In the light of these findings, a set of interventions have been proposed, which seek to offer practical and policy guidelines, regarding actions to be implemented making progress towards transport sustainability. The triple-bottom line of economic development, environmental integrity, and social quality of life has been taken into consideration in proposing such interventions to tackle this emerging issue. While each city has a unique character, in terms of their transportation system, it is expected that, this research will have some implications for Ghanaian cities.

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## APPENDICES

### Appendix 1 – Synthesis of Transport Sustainability Indicators from Five Frameworks

| Themes | Indicators | WBCSD | STPI | TERM | VTPI | Jeon et al. |
|---|---|---|---|---|---|---|
| **Economic** | | | | | | |
| Transport costs and prices | Household travel cost | X | X | X | X | X |
| | External cost of congestion | X | | X | X | X |
| | Investment in transport by mode | | | X | | |
| Modal Split | % of transport use by mode | | X | X | X | X |
| **Social** | | | | | | |
| Accessibility and Mobility | Average passenger travel time | | | | X | X |
| | Personal mobility | X | | X | X | X |
| Risk and Safety | Persons killed in traffic accidents | X | X | | X | X |
| | Persons injured in traffic accidents | X | X | | X | X |
| Health Impacts | Population exposed to traffic noise | X | | X | X | X |
| Affordability | Private car ownership | X | | X | | |
| | % of hh income devoted to transport | X | X | X | X | X |
| **Environmental** | | | | | | |
| Resource use | Fuel consumption | X | X | X | X | X |
| | Land take | X | X | X | X | |
| | Preservation of habitat | X | | X | X | |
| Transport Emissions | CO2 emissions | X | X | X | | X |
| | Conventional pollutant emissions | X | X | X | X | X |
| | Noise pollution | X | | | X | X |
| | Water pollution | X | | | X | |

**Appendix 2 - Residential Density for Selected Suburbs in the KMA**

| Suburbs | Population (2000) | Total Houses (2000) | Density (Persons/Hse) |
|---|---|---|---|
| Aboabo | 32,206 | 830 | 38.8 |
| Akorem | 14,025 | 438 | 32.0 |
| Amakom | 39,060 | 1,245 | 31.4 |
| Asafo | 18,457 | 587 | 31.4 |
| Asawasi | 46,243 | 2,525 | 18.3 |
| Ashanti New Town | 20,031 | 618 | 32.4 |
| Manhyia | 24,458 | 634 | 38.6 |
| Atonsu-Agogo | 45,778 | 2,489 | 18.7 |
| Bantama | 22,060 | 1,106 | 19.9 |
| Bremang | 41,956 | 3,316 | 12.7 |
| Dichemso | 21,281 | 934 | 22.8 |
| New Tafo | 47,506 | 1,841 | 25.8 |
| Oforikrom | 38,155 | 1,057 | 36.1 |
| Pankrono | 36,683 | 2,549 | 14.4 |
| Moshie Zongo | 34,980 | 1,320 | 26.5 |
| Asafo | 18,457 | 587 | 31.4 |
| Asokwa | 18,747 | 1,102 | 17.0 |
| Asuoyeboa | 15,226 | 1,358 | 11.2 |
| Bohyen | 10,771 | 440 | 24.5 |
| Bompata | 12,905 | 398 | 32.4 |
| Kwadaso Estate | 8,773 | 837 | 10.5 |
| Buokrom Estates | 11,100 | 1,362 | 8.2 |
| Patase | 9,364 | 721 | 13.0 |
| Fanti New Town | 12,407 | 465 | 26.7 |
| Gyinyase | 10,914 | 939 | 11.6 |
| Kaase | 11,130 | 547 | 20.3 |
| Kronom | 13,988 | 1,148 | 12.2 |
| New Suame | 16,881 | 725 | 23.3 |

**Appendix 2 Continued.**

| Suburbs | Population (2000) | Total Houses (2000) | Density (Persons/Hse) |
|---|---|---|---|
| Tanoso | 13,536 | 975 | 13.9 |
| Ahodwo | 4,265 | 270 | 15.8 |
| Danyame | 5,340 | 628 | 8.5 |
| Kentinkrono | 3,222 | 206 | 15.6 |
| Nhyiaeso | 4,602 | 419 | 11.0 |
| Fankyenebra | 5,895 | 426 | 13.8 |
| (Deduako) Kodiekrom | 3,111 | 322 | 9.6 |
| Odeneho Kwadaso | 4,657 | 457 | 10.2 |
| Apatrapa | 5,028 | 625 | 8.0 |
| Atasomanso | 7,837 | 796 | 9.8 |
| Adiembra | 3,666 | 367 | 9.9 |

**Appendix 3a – Sample Size Determination**

Sample size formula: $n = \frac{N}{1 + N(\alpha)^2}$

where; n is the sample size

N is the sample frame

α is the margin of error defined at 92 percent confidence level (α =0.08).

The sample size was defined from the total number of the six study areas.

$$n = \frac{29146}{1 + 29146\,(0.08)^2}$$

$$n = \frac{29146}{1 + 29146\,(0.0064)}$$

$$n = \frac{29146}{1 + 186.5344}$$

$$n = \frac{29146}{187.5344}$$

$$n = 155$$

Hence a total sample size of 155 households was selected for the purpose of this study.

## Appendix 3b – Determination of the $K^{th}$ Value

Probability sampling, specifically the systematic sampling method, was employed to select household heads for interview. This is giving by the formula: K=N/n, where, "K" - the $K^{th}$ respondent to be interviewed after the first sample unit has selected randomly; "N" – the sample frame; and "n" – the sample size. This is presented as follows:

| Study Community | Sampling Frame | Sample Size | $K^{th}$ Value |
|---|---|---|---|
| Kodiekrom | 322 | 10 | $32^{nd}$ |
| Ahodwo | 270 | 15 | $18^{th}$ |
| Bohyen | 440 | 23 | $19^{th}$ |
| Aboabo | 830 | 46 | $18^{th}$ |
| Ayigya | 1,181 | 53 | $22^{nd}$ |
| Kwadaso Estate | 837 | 19 | $44^{th}$ |
| **Total** | **3,880** | **166** | **$23^{rd}$** |

**Appendix 4 – Research Instruments**

**Appendix 4a – Household Structured Interview**

Name of Community ……………………………………

Name of Respondents …………………………………...

Date of interview ………………………………………..

Start Time of Interview …………………………………. End Time of Interview……………

Contact Number ……………………………………….

**Part 1 - Personal Information (Household Head)**

1. Gender of interviewee:
   - Male……………………………………………………..[ 1 ]
   - Female……………...............................................................[ 2 ]

2. Age of interviewee: ………………………………………

3. Ethnicity: ……………………………………………………

4. Level of Education:
   - Primary…………………………………………………......[ 1 ]
   - Middle/JSS……..…………………………………………[ 2 ]
   - SSS (SHS)……………………………………………….[ 3 ]
   - Technical/Vocational……….……………………….......[ 4 ]
   - Degree Acquired…………….………………………......[ 5 ]
   - HND……………………………………………………..[ 6 ]
   - Diploma……….…………………………………….....[ 7 ]
   - Others (*Specify*) ………………….……………………...[ 8 ]

5. Marital Status of interviewee:
    - Married……………………………………………………[ 1 ]
    - Single (Never married)…………………………………[ 2 ]
    - Widow (er)…………………………………………….....[ 3 ]
    - Divorced……………………………………………......[ 4 ]
    - Separated……………………………………………….[ 5 ]
    - Others (*Specify)*………………………………………....[ 6 ]



6. Employment Status of interviewee:
    - Employed…………………………………………......[ 1 ]
    - Unemployed……………………………………….......[ 2 ]

**Part 2 - Characteristics of Individual Household Members**

1. Type of family
    - Single person…………………………………………...[ 1 ]
    - Nuclear……………………………………………….....[ 2 ]
    - Extended……………………………………………….[ 3 ]

2. What is the size of your household? ………………………..

3. Please supply the information below about the members of your household?

| Hh ID | Name | Gender<br>Male [1]<br>Female [2] | Age | Level of education<br>*Primary [1]*<br>*Middle / JSS [2]*<br>*SSS / SHS [3]*<br>*Technical / Vocational [4]*<br>*Degree acquired [5]*<br>*HND [6]*<br>*Diploma [7]*<br>*Others [8]*<br>*None [9]* | Employment Status<br>*Employed [1]*<br>*Unemployed [2]*<br>*Student (incl. school children)[3]* |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| 4 | | | | | |
| 5 | | | | | |
| 6 | | | | | |
| 7 | | | | | |
| 8 | | | | | |
| 9 | | | | | |
| 10 | | | | | |

**Part 3 - Information on Daily Trips and Activities** (For each person in Household)

1. Please supply the information in the table below about the travel or journey your household make on a regular basis.

| Hh ID | Trip Purpose | Mode (Major) | Mode (Supp.) | Trip Destination | Trip Duration | Trip Length (km) | Cost per Trip (in GHS) | Frequency (per week) |
|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | |
| 2 | | | | | | | | |
| 3 | | | | | | | | |
| 4 | | | | | | | | |
| 5 | | | | | | | | |

2. Please supply the information in the table below about the travel or journey your household make on a less regular basis:

| Hh ID | Trip Purpose | Mode (Major) | Mode (Supp.) | Trip Destination | Trip Duration | Trip Length (km) | Cost per Trip (in GHS) | Frequency (per week) |
|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | |
| 2 | | | | | | | | |
| 3 | | | | | | | | |
| 4 | | | | | | | | |
| 5 | | | | | | | | |

**Key to Questions 1 and 2 of Part 3**

*Trip purpose:*

1. [ ] Work
2. [ ] School
3. [ ] Recreation
4. [ ] Shopping
5. [ ] Church
6. [ ] Funerals…………….............

*Travel Mode:*

1. [ ] Walking
2. [ ] Private car
3. [ ] Public transport (Trotro)
4. [ ] Public transport (Taxis)
5. [ ] Cycling

*Trip Destination:*

1. [ ] Within suburb
2. [ ] Outside suburb
3. [ ] CBD

3. What are the reasons for your choice of mode in questions C1 and C2? (close)

   ……………………………………………………………………………………………………

4. Are any of these characteristics likely to change in the future?
   - Yes……………………………………………………….[ 1 ]
   - No……………………………………………………..[ 2 ]

   If yes kindly complete the table below:



***Anticipated travel characteristics***

| Hh ID | Trip Purpose | Mode (Major) | Mode (Supp.) | Trip Destination |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |

5. If mode of trip is motorised, what roads do you use often? (if possible give the name of roads)

   ……………………………………………………………………………………………………
   ……………………………………………………………………………………………………

6. Please rate your level of satisfaction of the traffic situation on the roads mentioned in Question 5.

| **Road ID** | **Highly Satisfied** | **Satisfied** | **Dissatisfied** | **Highly Dissatisfied** | **Indifferent** |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |

7. What are the reasons for your response in Question 6

   ……………………………………………………………………………………………………
   ……………………………………………………………………………………………………

**Part 4 - Vehicle Ownership and Emissions**

1. What is the make (year of manufacture) and model of vehicle you drive the most?
   - ♦ Make ……………………………………………………..
   - ♦ Model …………………………………………………….

2. Who owns the vehicle
   - ♦ Self……………………………………………………[ 1 ]
   - ♦ Joint…………………………………………………..[ 2 ]
   - ♦ Company……………………………………………...[ 3 ]
   - ♦ Other *(Specify)* …………………………………………..[ 4 ]

3. In what year was the vehicle first registered? ………………..

4. What is the size of the vehicle's engine?…………………………cc's/litres

5. What type of fuel does the vehicle use?
   - ♦ Petrol…………………………………………………..[ 1 ]
   - ♦ Diesel…………………………………………………..[ 2 ]
   - ♦ LPG……………………………………………………[ 3 ]
   - ♦ LPG & Gas…………………………………………….[ 4 ]
   - ♦ Other *(Specify)* ……………………………………………...[ 5 ]

6. How many km per gallon does the vehicle do on average daily?

   ……………………………………………………………………………………

7. How much petrol/diesel do you personally put in the vehicle you drive the most in an average week? ……………………………………………………………………

8. How much money do you spend on petrol/diesel in an average week (in GHS)?

   ……………………………………………………………………………………

9. Do you drive any other vehicles owned by the household?

- If yes what are they?

  ………………………………………………………………………………………

  ………………………………………………………………………………………

  Roughly how many km do you drive in these other vehicles in a month / week?

  ………………………………………………………………………………………

  ………………………………………………………………………………………

10. Please supply the information in the table below on other vehicles you drive:

| **Vehicle ID** | **Vehicle Type** *Private [1]* *Commercial [2]* | **Vehicle Model** | **Year of Manufacture** | **Fuel Type** *Petrol [1]* *Diesel [2]* *Gas [3]* | **Average Fuel Consumption /per Wk (in Litres)** |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |

11. How many thousand km do you think you drove in the last twelve months? (for private vehicle owners only)

    …………………………………………………………………………………………

12. How many of the total miles you drive are on major arterials in the City?

- Very few (0-10%)………………………………………[ 1 ]
- Less than half of miles (10-40%)………………………..[ 2 ]
- About half of miles (40-60%)……………………………[ 3 ]
- More than half of miles (60-90%)………………………[ 4 ]
- Almost all of miles (90-100%)…………………………..[ 5 ]
- None……………………………………………………..[ 6 ]

13. How many of the total miles you drive are on minor arterials in the City?

- Very few (0-10%)………………………………………[ 1 ]
- Less than half of miles (10-40%)………………………..[ 2 ]

- About half of miles (40-60%)…………………………...[ 3 ]
- More than half of miles (60-90%)……………………….[ 4 ]
- Almost all of miles (90-100%)…………………………..[ 5 ]
- None……………………………………………………..[ 6 ]

14. How many of the vehicles you owned are used in a day?

..........................................................................................................................



15. Are they used for the same purposes?
- Yes……………………………………………………..[ 1 ]
- No……………………………………………………...[ 2 ]

16. Does the whole household use different vehicles when you are attending functions (Eg. Church, Funerals) together?
- If yes why?

………………………………………………………………………………………
………………………………………………………………………………………

17. Is this situation likely to change in the near future?
- If yes, why and how?

………………………………………………………………………………………
………………………………………………………………………………………
- If no, why?

………………………………………………………………………………………
………………………………………………………………………………………



**Part 5 - General Accessibility**

1. How do you move about in this town (internal trips)?
- By Foot…………………………………………………...[ 1 ]
- By Bicycle……………………………………………….[ 2 ]
- By Private vehicle………………………………………...[ 3 ]

- By Public vehicle (mini-bus/Trotro)…………………….[ 4 ]
- By Public vehicle (taxi)…………………………………[ 5 ]
- Others (Specify) ……………………………………...[ 6 ]

2. If by vehicle (private/public), which roads in the town do you use often?

………………………………………………………………………………………………

………………………………………………………………………………………………

3. What are the reasons for your answer to question 2?

| Road ID | Reasons for Road Usage |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |

4. Please rate your level of satisfaction of the conditions of the roads mentioned in Question 3.

| Road ID | Highly Satisfied | Satisfied | Dissatisfied | Highly Dissatisfied | Indifferent |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |

5. What are the reasons for your response in Question 4?

………………………………………………………………………………………………

………………………………………………………………………………………………

**<u>Part 6 - How you feel about your Travel / Journey</u>**

1. How do you feel in general about the amount you travel in a week?
   - Much too much…………………………………………..[ 1 ]
   - Rather too much……………………………………......[ 2 ]
   - About right……………………………………………..[ 3 ]

- Rather too little…………………………………………..[ 4 ]
- Much too little…………………………………………....[ 5 ]

2. Are there any changes you would like to be able to make in the amount and mode of your travel?
   1. [ ] yes
   2. [ ] no

If yes:

- What?

  ……………………………………………………………………………………………

  ……………………………………………………………………………………………

  And

- Why?

  ……………………………………………………………………………………………

  ……………………………………………………………………………………………

3. For each of the following sustainability measures please provide in the table whether you would consider doing it or normally already doing it:

| **Sustainability Measure** | **Already do it** | **Would Consider it** | **Would not consider it** |
|---|---|---|---|
| Buy a car with a small engine | | | |
| Combine journeys for different purposes to reduce the number of trips | | | |
| Use public transport | | | |
| Walk or cycle for short journeys | | | |
| Other measures, please describe | ……………………………………………………………… ……………………………………………………………… | | |

**Part 7 - Economic Profile of Household**

1. What is your occupation *(Household Head)*?

   - Primary occupation ……………………………………………..
   - Secondary occupation ………………………………………….

2. What is/are your main sources of income?

   - Primary occupation ……………………………………………..
   - Secondary occupation ………………………………………….
   - Others (specify) …………………………………………………

3. What are the main sources of income for the members of your household who are working?

| Hh ID | Name | **Type of employment**<br>*Professionals* [1]*<br>*Self-employed [2]*<br>*Unskilled labourers [3]* | Average income per month (in GHS) |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |
| 6 | | | |
| 7 | | | |
| 8 | | | |
| 9 | | | |
| 10 | | | |

* *Professionals refer to Teachers, Nurses, Doctors, Accountants, etc.*

4. In your estimation, what is the total monthly income of your household (in GHS)?

   ………………………………………………………………………………………

***Household Expenditure***

5. Please supply in the table below how much your household spends in total per week or per month on each of the following items:

| Household Item | Weekly Expenses (in GHS) | Monthly Expenses (in GHS) |
|---|---|---|
| a. Food and groceries | | |
| b. Clothing | | |
| c. House rent (if renting) | | |
| d. Personal transport: fuel, maintenance, etc. | | |
| e. Public transport (mini-bus, taxi, etc) | | |
| f. Utilities (water, electricity, etc) | | |
| g. Medical expenses | | |
| h. Education | | |
| i. Others | | |

6. In your estimation, what is the total monthly expenditure of your household (in GHS)?

   ……………………………………………………………………………………………

7. Any general comment on the current transport situation in the Metropolis?

   ……………………………………………………………………………………………

**Appendix 4b – Institutional Survey**

**Structured Interview for Urban Passenger Transport Unit (UPTU)**

1. Is there a local transport policy for Kumasi?
   - ♦ If yes, what is/are its main objective(s)?

     …………………………………………………………………………………………

     …………………………………………………………………………………………

2. To what extent is the policy enforced in the City?

   ………………………………………………………………………………………………

   ………………………………………………………………………………………………

3. What are the levels of patronage (%) of the following modes of transport in the City?
   1. [ ] Road transport………………………..
   2. [ ] Rail transport………………………….
   3. [ ] Air transport …………………………
   4. [ ] Others (*Specify)* ………………………

4. What are the current and future key issues and challenges with transportation in Kumasi?

   ………………………………………………………………………………………………

   ………………………………………………………………………………………………

5. Is there attention for **sustainable transportation** in Kumasi, in terms of:
   - ♦ Reducing the over-dependence on road transport? 1. [ ] yes 2. [ ] no

     If yes, how is it been done, and what are the main indicators

     …………………………………………………………………………………………

     ……………………………………………………………

   - ♦ Promoting non-motorized forms of transportation 1. [ ] yes 2. [ ] no

If yes, how is it been done, and what are the main indicators

………………………………………………………………………………………………

………………………………………………………………………………………………

- Promoting public transport? 1. [ ] yes 2. [ ] no

  If yes, how is it been done, and what are the main indicators

  ………………………………………………………………………………………………

  ………………………………………………………………………………………………

- Reducing transport related emissions? 1. [ ] yes 2. [ ] no

  If yes, how is it been done, and what are the main indicators

  ………………………………………………………………………………………………

  ………………………………………………………………………………………………

6. Which aspects of the sustainable issues in question 5 lack consideration at the moment, and why?

   ………………………………………………………………………………………………

   ………………………………………………………………………………………………

7. How well does the Assembly satisfy transportation needs of the City in terms of investment in:

- Roadway construction and maintenance

  ………………………………………………………………………………………………

  ………………………………………………………………………………………………

- Public transport services

  ………………………………………………………………………………………………

  ………………………………………………………………………………………………

- Pedestrian facilities

  ………………………………………………………………………………………………

  ………………………………………………………………………………………………

- Safety improvements

  …………………………………………………………………………………………

  …………………………………………………………………………………………

- Others

  …………………………………………………………………………………………

  …………………………………………………………………………………………

8. What are the current traffic management strategies practiced in the Metropolis by the KMA?

   …………………………………………………………………………………………

   …………………………………………………………………………………………

9. Is there generally enough revenue to cover all transport expenses in the Metropolis?

   1. [ ] yes 2. [ ] no

10. If no, why?

    …………………………………………………………………………………………

    …………………………………………………………………………………………

11. What are the sources of revenue for financing transport projects in the Metropolis?

    1. [ ] development partners
    2. [ ] the State
    3. [ ] the City

12. Is the revenue stream stable and predictable?

    1. [ ] yes 2. [ ] no

13. Kindly give reasons for your response to question 12:

    …………………………………………………………………………………………

    …………………………………………………………………………………………

14. What proportion (%) of your inflows are invested in:

    - Roads ………………………………………………

- ♦ Public transport …………………………………..
- ♦ Non-motorised transport ……………………….

15. What innovative strategies would you recommend to reduce travel demand and improve traffic conditions in the Metropolis?

………………………………………………………………………………………………
………………………………………………………………………………………………

16. Any comments on the transport situation in the Metropolis?

………………………………………………………………………………………………
………………………………………………………………………………………………

***Thank you once again.***

**Structured Interview for the Environmental Protection Agency (EPA)**

1. What is the state of air quality in the Metropolis?

   ……………………………………………………………………………………………
   ……………………………………………………………………………………………

2. What activities contribute to the state of air quality in the Metropolis?

   ……………………………………………………………………………………………
   ……………………………………………………………………………………………

3. Please supply in the table information on emission levels by sector in the Metropolis

| **Sector** | **Emissions Level (%)** |
|---|---|
| Industry | |
| Commercial | |
| Domestic | |
| Road Transport | |
| Other Transport | |
| Others (*Specify)* …………………………………… | |

4. What are the impacts of road transport /traffic on the City's environment, in terms of:

   ♦ Greenhouse Gases

     ……………………………………………………………………………………………
     ……………………………………………………………………………………………

   ♦ Acidifying Pollutants and Precursor Gases

     ……………………………………………………………………………………………
     ……………………………………………………………………………………………

5. Please supply in the table information the levels of emissions components from the road transport by year in the Metropolis

| **Year** | **$CO_2$** | **$CH_4$** | **$N_2O$** | **$NO_x$** | **CO** | **Pb** | **VOC** | **NMBOC** | **PM** |
|---|---|---|---|---|---|---|---|---|---|
| 2005 | | | | | | | | | |
| 2006 | | | | | | | | | |
| 2007 | | | | | | | | | |
| 2008 | | | | | | | | | |
| 2009 | | | | | | | | | |
| 2010 | | | | | | | | | |
| 2011 | | | | | | | | | |

***Key to Chemical Symbols in Question 5***

| | |
|---|---|
| $CO_2$ | Carbon Dioxide |
| $CH_4$ | Methane |
| $N_2O$ | Nitrous Oxide |
| $NO_x$ | Nitrogen Oxides |
| CO | Carbon Monoxide |
| Pb | Lead |
| VOC | Volatile Organic Compounds |
| NMVOC | Non-Methane Volatile Organic Compounds |
| PM | Particulate Matter |

6. What factors are the most important determinants of pollution levels from the road transport sector?

   ……………………………………………………………………………………………

   ……………………………………………………………………………………………

7. Is there a relationship between the age of vehicles used and the emission levels from the road transport sector in the City?

   ♦ If yes, how?

   ……………………………………………………………………………………………

   ……………………………………………………………………………………………

   (*Any data to support this?)*

8. Is there a relationship between the types of vehicles (*by fuel)* used in the City and the emission levels from the road transport sector?

   - If yes, how?

     ………………………………………………………………………………………

     ………………………………………………………………………………………

   (*Any data to support this?)*

9. At what level would you consider emissions from the transport sector harmful?

   ……………………………………………………………………………………………

   ……………………………………………………………………………………………

10. Are there regulations to guide emissions in the City, especially with regards to the road transport sector?

    - If yes, to what extent are these regulations enforced and observed in the City?

      ………………………………………………………………………………………

      ………………………………………………………………………………………

11. Are there any alternative technologies that might be less harmful to the environment you would want to recommend?

    - If yes, what?

      ………………………………………………………………………………………

      ………………………………………………………………………………………

12. Any general comment on the road transport and emission levels in the City?

    ……………………………………………………………………………………………

    ……………………………………………………………………………………………

***Thank you once again.***

**SEMI-STRUCTURED INTERVIEW FOR THE DRIVER AND VEHICLE LICENCING AUTHORITY (DVLA)**

1. Data on the total number of registered vehicles in Kumasi (2006 – 2011)

2. Data on the classification of registered vehicles (2006 – 2011) in Kumasi by vehicle type (private, commercial, buses/coaches, trucks, etc.)



3. Please supply in the table information the classification of registered vehicles in Kumasi by year of manufacture

| Year of Manufacture | Year of Registration | | | | | |
|---|---|---|---|---|---|---|
| | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
| 1991 | | | | | | |
| 1992 | | | | | | |
| 1993 | | | | | | |
| 1994 | | | | | | |
| 1995 | | | | | | |
| 1996 | | | | | | |
| 1997 | | | | | | |
| 1998 | | | | | | |
| 1999 | | | | | | |
| 2000 | | | | | | |
| 2001 | | | | | | |
| 2002 | | | | | | |
| 2003 | | | | | | |
| 2004 | | | | | | |
| 2005 | | | | | | |
| 2006 | | | | | | |
| 2007 | | | | | | |
| 2008 | | | | | | |
| 2009 | | | | | | |
| 2010 | | | | | | |

4. Please supply in the table information on the classification of registered vehicle in Kumasi by fuel type:

| Fuel Type | Year of Registration | | | | | |
|---|---|---|---|---|---|---|
| | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
| Petrol-engined | | | | | | |
| Diesel-engined | | | | | | |

## SEMI-STRUCTURED INTERVIEW FOR BUILDING AND ROAD RESEARCH INSTITUTE (BRRI)

1. Accident trends in the Metropolis (2006 - 2011)
2. Number of vehicles involved in accidents (2006 – 2011)
3. Number of accidents by different vehicle types (2006 – 2011)
4. Nature of accidents
5. Severity of accidents & degree of injury
6. Persons killed in accidents (2006 – 2011)
7. Persons injures in accidents (2006 – 2011)