ASSESSMENT OF THE STATE OF DEVELOPMENT OF AUTOMOBILE DESIGN AND MANUFACTURING IN GHANA

BY

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DECLARATION

I hereby declare that this submission is the result of my own work towards an MSc. in Mechanical Engineering, and that, to the best of my knowledge, this report contains no material, neither previously published by another person nor submitted for the award of any other degree of a university, except where acknowledgement has been duly made in the text. Any opinion or view expressed and any errors found in this work, however, are exclusively my responsibility and do not necessarily represent the organizations or individuals who have been cited in this work.

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DEDICATION

This work is dedicated to my family and friends, especially my late father Mr.Akayeti John, my mother Mrs. Akayeti Paulina Atompoka and my children; Kibuka and Antonia who have in many ways enriched my life, God bless you.

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ABSTRACT

Vibrant automobile design and manufacturing industries have played significant roles in the industrial growth of many countries. Ghana however, has yet to develop an automobile design and manufacturing industry comparable to that of the developed countries. There is therefore the need to take a closer look at the automobile design and manufacturing industry in the country. To this end, a combination of research methods comprising interviews, questionnaire and observation are employed in collecting data, targeting auto-manufacturing firms in both the formal and informal sectors of the economy. The study focuses on several relevant issues including the caliber of personnel engaged in the industry, types of machine tools employed, engineering materials and processes used in the design and production of parts. Key findings from the study are that qualified automobile design and manufacturing engineers are in short supply, resulting in the production of low quality parts and components. The sector is characterised by the use of conventional machine tools, rudimentary welding and forming processes to produce parts in small quantities. Computer Numerical Control (CNC) machine tools are virtually non-existent in the sector. The government could play a key role by supporting the domestic auto-parts manufacturing centres in the informal sector, particularly those at the Suame Magazine to promote their growth and development in the industry.

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LIST OF ACRONYMS

ACRONYMS	MEANING
AISI	American Iron and steel Institute
ASEAM	Association of South East Automobile Manufacturers
ASTM	American Society for Testing and Materials
CIA	Central Intelligence Agency
CKD	Complete knock down
CVT	Transport Comfort Voyageur
GDP	Gross Domestic Products
GM	General Motors
HICOM	Heavy Industry Corporation of Malaysia
JGC	Jospong Group of Companies
KNUST	Kwame Nkrumah University of Science and Technology
MC	Mitsubishi Corporation
MIDP	Motor Industry Development Programme
MIG/TIG	Metal Inert Gas / Tungsten Inert Gas
MMC	Mitsubishi Motor Corporation
MMT	Metro Mass transit
MOTI	Ministry of Trade and Industry
NCP	National Car Project
NICs	Newly Industrialized Countries
NTC	Transnational Corporation
OEMs	Original Equipment Manufacturers
R&D	Research and Development
RSW	Resistance Spot Welding

SAE	Society of Automotive Engineers
SMAW	Shielded Metal Arc Welding
SOE	State Owned Enterprise
SUVs	Sports and Utility Vehicles
TMC	Toyota Motor Corporation
UNESCAP	United Nation Economic and Social Commission for Asia and the Pacific
VIP	Very Important People
WTO	World Trade Organization

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

An automobile may be defined as a motorized vehicle powered by an internal combustion engine that is used to transport people and items from one location to another. Automobiles include motorcycles, tricycle, trucks, buses, coaches, vans among others.

The automobile manufacturing industry has played a major role in the socio-economic development of many countries, and can be considered an important measure of the industrial level of a country, as it generates huge added value to the economy in a country (Lee, 2011). For instance, the motor vehicle industry is an important part of the U.S. economy, accounting in 2010, for over 674,000 jobs, or 5.8% of all U.S. manufacturing employment (Canis, 2011).

A vehicle typically consists of over 20,000 parts, each one of which plays a vital role in developing an economy and creating jobs in a country (Lee, 2011). Apart from job creation, the automobile industry is also a technology-intensive industry; lots of different technologies developed in other industries can be widely employed in this industry.

It is estimated that as at 2002, there were 590 million passenger cars worldwide; (Perkins, 2009). In 2007, 806 million cars and light trucks were on the road. These numbers are increasing rapidly, especially in China and India (Laudou et al., 2008).

Ghana has no well developed automobile manufacturing industry and thus imports most of her vehicles. Used vehicles (5-10 years old) constitute about 70 percent of vehicles imported into the country (FY 2000 Country Commercial Guides: Ghana).

The country has long - established large and medium-size manufacturing enterprises such as textiles, drinks, food, plastics, vehicle assembly and aluminium processing. There are also multinational companies such as Valco and Unilever that also run factories. A number of various state - owned enterprises also used to be involved in manufacturing, but since liberalization opened up the market for foreign competitions in the 1980s, many factories have been closed down leading to substantial job losses.

Ghana's current industrial policy has resolved to provide an enabling environment for the private sector to effectively perform its role as the engine of growth (Ministry of Trade and Industry, 2011). This has encouraged companies such as the Jospong Group of Companies (JGC), a mother company under which Zoomlion Ghana is a subsidiary, to establish a Vehicle Assembly Plant in Accra. This plant imports engines, and builds other parts locally to assemble DONGFENG vehicles and trucks suitable for transportation, waste management and other construction sector activities of the country.

1.2 Problem Statement

Well-developed indigenous automobile manufacturing industries have played significant roles in the industrial growth of many countries, particularly the Newly Industrialised Countries (NICs) such as South Korea, Malaysia and China. However, Ghana has yet to develop an automobile design and manufacturing industry comparable to that of the developed countries.

In view of this, the overall aim of the study is to assess the current state of automobile design and manufacturing in Ghana in order to bring out the constraints hampering the realisation of the full potential of the sector.

1.3 Research Objectives

The main objective of the study is to assess, investigate and report the practices, prospects and challenges facing the automobile design and manufacturing in Ghana.

The specific objectives are:

1. To investigate the soundness of the engineering processes and methods employed in the Design and manufacturing of automobiles in Ghana
2. To determine the factors militating against the development of world-class automobile design and manufacturing in Ghana
3. To access the caliber of Technical personnel engaged in the industry

1.4 Significance of the Study

Automobile design and manufacturing can have an enormous impact on the social and economic activities of Ghana. To this end, the results of this research would be of great significance in various ways to policy makers, business practitioners' and other stake holders.

The findings and results of this study will provide reliable scientific measure in assessing the level of performance of the assembly plants and/or 'magazines' in the country.

It will also give government agencies such as the Ministry of Trade and Industry, an insight and guidance in monitoring the impact of automobile assembly plants in Ghana. In addition it will also create awareness about the large direct employment and job multiplier in the supply chain as well as the industry's economic contribution to exports and technology development in general.

Finally, the study will provide stakeholders such as investors, pressure groups, consumer associations information to enable them offer useful suggestions toward improving the performance of the automobile manufacturing industry.

1.5 Scope of the Study

The study focuses on the manufacture of trailers for heavy duty trucks, articulated truck buckets, tipping buckets and body building of buses, coaches as well as cars. A few vehicle parts are also considered. The processes (materials selection, types of welding and finishing) and machine tools involved in accomplishing these works formed part of the study.

1.6 Organization of Study

The thesis is organized into five chapters. Chapter one, is the introduction; it describes the background of the study, highlights the problem statement for the research, states the objectives of the study, comments on the significance of the study and lastly, discusses the organization of the thesis. Chapter two includes review of relevant literature, emphasizing definitions and global historical development of the automobile. Chapter three focuses on the methodology used to conduct the study whilst chapter four deals with analysis of results and discussions. Finally, chapter five presents the key findings, conclusions and recommendations arising from the study.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 Introduction

This chapter presents the relevant literature pertaining to this study: It comprises of definitions of various concepts associated with the study, engineering materials used in manufacturing, reviews of Global and African historical development of the automobile industry; with special cases in the United State of America, South Korea, Malaysia, South Africa and Egypt. The chapter also provides a historical development of automobile industry in Ghana. Finally, this chapter will equally capture some challenges faced by the automobile industry in Ghana.

2.2 The Automobile/ Motor Vehicle

The Automobile is a wheeled vehicle used for land-transport of people and goods and powered by a fossil fuel based internal combustion engine (Wad, 2010). It is also defined as any power-driven vehicle which is moved by its own means, having at least four wheels, with a maximum design speed exceeding 25km/h (European Commission, 2012).

2.3 The Automobile Design and Manufacturing Process.

The design and manufacturing process of an automobile involves various divisions within the Original Equipment Manufacturer (OEM), scores of first-tier suppliers, a number of second-tier and sub-tier suppliers, and tooling suppliers (Brunnermeier et al, 1999). This exchange of data amongst the OEMs supports the process of concurrent engineering and design, allowing these organizations to work together to improve the performance and manufacturability of the product. In this light, the number of people, organizations, and functions involved in producing an automobile increases the complexity of the data exchange process. Digital representations of products and parts have replaced physical drawings as a convenient form in which product data are stored, analyzed, and communicated among the people contributing to the design of an automobile, adding that there are many different software and hardware systems used throughout the automotive supply chain.

2.4 The Structure of an Automobile

The composition of an automobile is very complex and a typical motor vehicle consists of about 15,000 parts and accessories that must be designed to be well-suited to the given specifications (Brunnermeier, et al., 1999). An automobile comprises several major systems, each of which contains many subsystems, components, and interfacing parts. Designers must bring together these systems to enable the successful final assembly of the vehicle. Figure 1 shows the complex structure of an automobile.

2.5 Definitions of Design and Manufacturing

Manufacturing is an organized activity that converts raw materials and purchased items into marketable products (Adejuyigbe, 2003). Manufacturing integrates many disciplines in engineering and management. To this end, - Manufacturing can be said to be critical to a country's economic welfare and thus determine its standard of living.

Manufacturing involves the use of physical and chemical processes of varying the geometry, property and appearance of a given state of material to make parts or products (Groover, 2007). It includes assembling of multiple parts to make products and that its accomplishment involves a combination of machinery, tools, power and labour. Figure 2.2 (a) shows that manufacturing is carried out as chain of operations and each operation draws the material closer to the required state. Manufacturing alters materials into items of greater value by means of one or more processing and assembling operations (Groover, 2007). Fig.2.2 (b) illustrates that manufacturing adds value to the material by altering its shape or property.

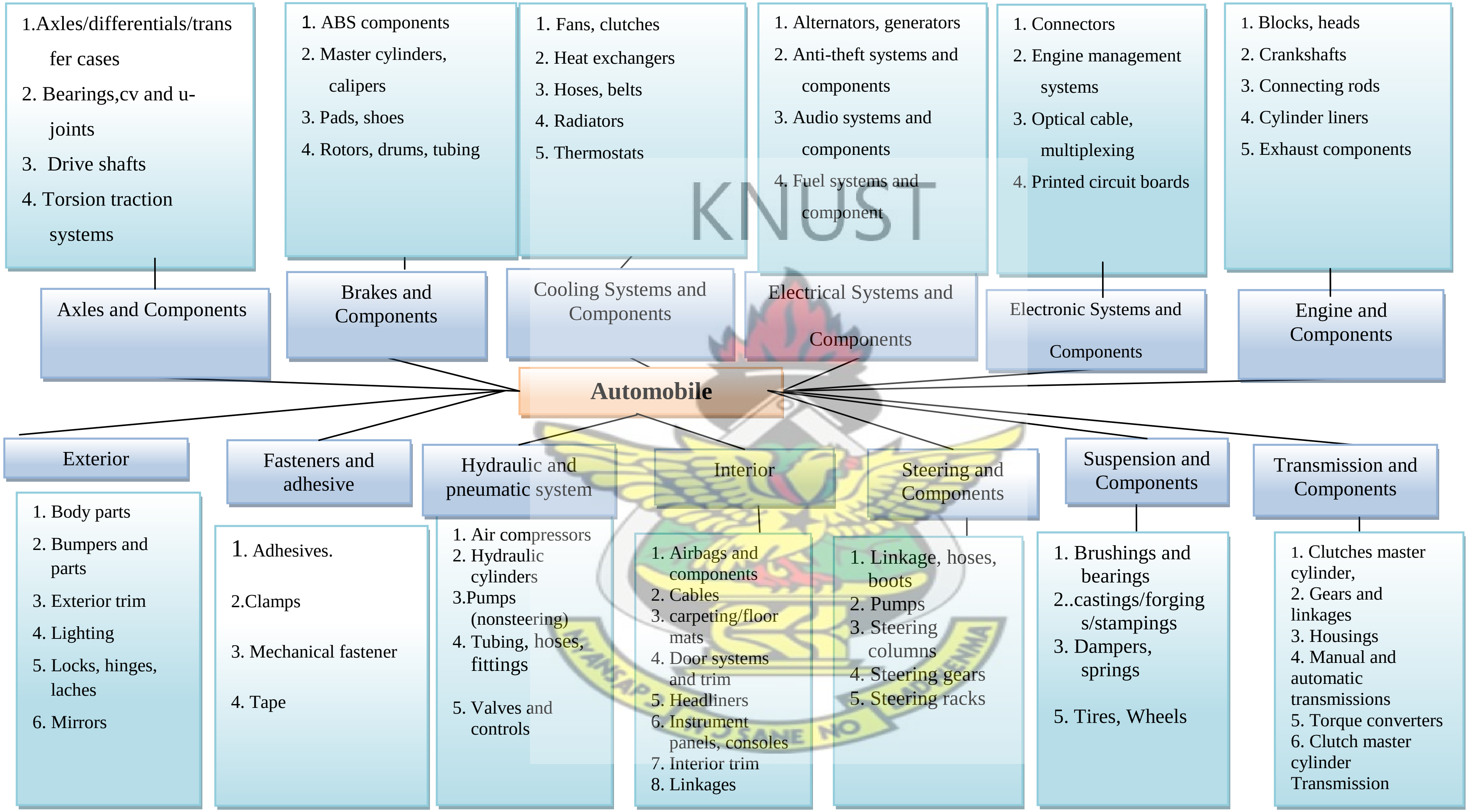

Figure 2.1: Complex Structure of Automobile parts

Source: Brunnermeier et al (1999)

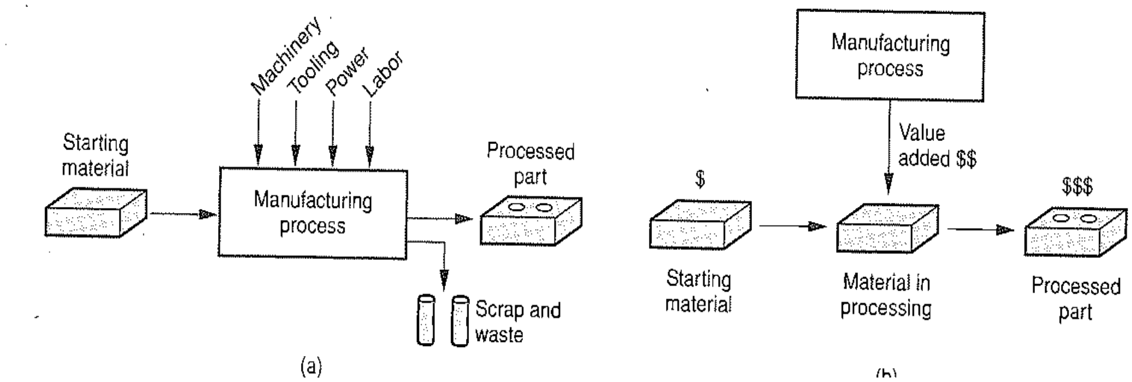

Figure 2.2: Two ways to define Manufacturing (a) as a technical process and (b) as an economic process (Source: Fundamental of Modern Manufacturing).

2.6 Motor Vehicle Assembly

The techniques used to assemble motor vehicles differ from manufacturer to manufacturer; the main step in assembly is the body shop where the vehicle begins to take shape as sides are welded together and then attached to the underbody of the vehicle (NPI, 1999). The underbody is made up of three key pieces of galvanized steel that contain the floor pan, components for the engine and chassis. After welding together the underbody, it is tested for dimensional and structural accuracy. It is then joined together in a tab-slot fashion with the side frame and various other side-assemblies. Taps tabs into slots, and clamped mostly by robots. Roof supporting members are provided, and the roof then installation. Final welding is done and chassis lids and bonnets are then installed.

2. 7 Engineering Materials Used in Manufacturing

A material is that out of which something is or may be made. Engineering materials cover a wide range of metals and non-metals which must be worked upon to form the finished product (Shigley et al, 1986).

Generally engineering materials may be classified into one of these basic types:

- Metals – (i) Ferrous–steels, cast iron, etc

(ii) Non-ferrous–Cu, Al, Zn, Si etc., and their alloys

- ❖ Ceramics
- ❖ Composite materials
- ❖ Polymers

Metals:- Metals play important role in the automobile design and manufacturing industry and everyday life of human beings. Examples of commonly employed metals used largely in components and parts manufacturing include:

(1) Steel – these are made up of low, medium, high and Alloy steels example stainless steels.

(2) Cast Iron

(3) Non-Ferrous Metals including copper, aluminium, zinc, tin etc. and their alloys.

(1) Steel Products

Carbon Steel is the most widely used type of steel. Its properties depend primarily on the amount of carbon content it contains. Carbon steels are used in a wide range of products such as structural beams, car bodies, kitchen appliances and many others.

The carbon composition in weight percent (wt %) of the various carbon steel products used commonly in machinery manufacturing are shown in Table 2.1.

Table 2.1: Various Carbon Steels and Their Compositions

Type of Steel	Composition
(i) Low carbon steel	0.05 - 0.15wt% C
(ii) Medium carbon steel	0.45 - 0.55wt% C
(iii) High carbon steel	0.7 - 1.5wt% C
(iv) Alloy steels	Contains various amounts of carbon in addition to other alloying elements such as chromium, titanium, vanadium, nickel, molybdenum etc. Example Stainless steel

Source: (Dowling, 1993)

Low carbon steels - have relatively low tensile strength and are often selected for cool work formability in the basic requirement.

Medium carbon steels - are used where higher strength properties are needed. They are further hardened and strengthened by heat treatment or cool working. Components made of these materials can be forged and machined easily.

High carbon steels - are used mainly where wear is a major consideration. For example cutting tools and springs (Cullum, 1989).

Alloy steels –Examples includes stainless steels, tungsten steels, high speed tool steels etc. (Cullum, 1988).

Among the reasons for using steel in the body structure of automotive is its intrinsic capacity to absorb impact in a crash situation. Also it has good formability with joining capability that makes these materials often first choice for designers of body structure (Ghassemieh, 2011).

(2) Cast Iron: This is essentially an engineering material containing between 2.14 and 6.70 wt%C (Callister, 2000). The types of cast irons and their compositions available are shown in Table 2.2.

Table 2.2: Types of Cast Iron, their Compositions and Applications

Cast Iron	**Composition**	**Application**
(i) Gray cast iron	(a). 2 .3 – 3.8 wt% C (b). contain flakes of graphite in a matrix of ferrite	Engine blocks, brake drums, engine cylinders, pistons etc
(ii) Malleable Cast Iron	(a). 2-3 wt% C (b). Contains ferrite or pearlite matrix	Power train parts of vehicle, steering knuckles, universal joint yokes, wheel hubs, bearing caps, etc
(iii) Nodular Cast Iron	(a). 3.2-4.2 wt% C (b). Contains nodules, or spheroids, or rounded graphite particles	Valves and pumps bodies, high strength gears, automobile crank shafts, etc
(iv) White Cast Iron	(a). 1.8-3.6 wt% C (b). Contains free carbon in a combined form as cementite	Mill liners, grinding balls, etc

Source: (Smith, 1997)

(4) **Non-Ferrous Metals:** A wide range of non-ferrous metals and their alloys are also available for automobile design and manufacturing. However, pure non-ferrous metals such as copper, aluminium, tin etc. have limited engineering applications. Non-ferrous metal alloys including magnesium alloys, aluminium alloys titanium alloys and many others are widely used in varied areas in engineering.

i). Magnesium alloy

Magnesium alloys are known to have been used in the manufacture of engines and other automobile parts but not for cylinder blocks. Fleming underscored the use of the material in the manufacture of many other vehicular parts such as steering wheels and columns, seat frames, transmissions cases, and crankcases, among others (Fleming, 2012). The biggest attraction for manufacturers is that the material is not only lighter, but has other useful characteristics such as high shock and dent resistance and a greater ability than aluminum alloys in terms of dampen noise and vibrations (Material world, 2003). Again, it has the same strength as cast iron and aluminum alloys. Material Scientists and engineers were determined to exploit these characteristics of magnesium alloy and use it to fabricate engine blocks.

There were a number of magnesium alloys available that met or even exceeded the requirements demanded by manufacturers for an engine block, but insufficient material stability at high temperatures slowed down their actual use.

In 2003 however, Materials Scientists and Engineers made a discovery of sand-cast AMS-SC1 magnesium alloy. This grade of alloy contains two rare earth elements, lanthanum and cerium and was heat-treated. The material has the potential of stabilizing the strength of the alloy at high engine operating temperatures which is inevitable for the effective functioning of an engine block. Bettles et. al (2003) undertook an experimental study and came out with results that demonstrate that the yield and creep strength of AMS-SC1 shown in Table 2.3 essentially stays at 177^{o}C as it is room temperature. This implied that the material is able to tolerate wide range of temperature without loss in strength. Other properties of magnesium alloy include good thermal conductivity, excellent machining and casting qualities.

Table 2.3: Yield and creep strengths of magnesium AMC-SC1 at room Temperature 150ºC and 177ºC

	Room temperature (24)	**150^{o}C**	**177^{o}C**
Yield strength, MPa	120	116	117
Creep strength, Mpa	-	120	98

ii). Aluminium alloys: These are alloys in which aluminium (Al) is the predominant metal. The main alloying elements are copper, magnesium, manganese, silicon and zinc. There are two major classifications, namely casting alloys and wrought alloys. About 85% of aluminium is used for wrought products such as rolled plate, foils and extrusions. Cast aluminium alloys offers cost-effective products due to the low melting point; however they generally have lower tensile strengths than wrought alloys. The most important cast aluminium alloy system is Al–Si, where the high levels of silicon (4.0–13%) contribute to give good casting characteristics. Aluminium alloys are widely used in engineering structures, automobile engine block and components where light weight or corrosion resistance is required.

(b) Ceramic materials: These are produced by baking naturally occurring clays at high temperatures after moulding to shape. Ceramics typically consist of oxides, nitrides, carbides, silicates or borides of various metals. They are used for high – voltage insulators and high – temperature – resistant cutting tool tips. Examples of ceramic materials are silicon carbide, boron nitride, abrasives and tungsten carbide (Dowling, 1993).

(c) Composite Materials: These are materials made up from, or composed of a combination of different materials to take overall advantage of their different properties. Common examples of composite materials used include-

i. Carbon-carbon composites: this material has both reinforcement and matrix as carbon. The carbon-carbon composites are used in rocket motors, as friction materials in air crafts, high-performance automobiles and advanced turbine engines

ii. Polymer-matrix composites: this consists of a polymer resin as the matrix, and fibres as the reinforcement medium. Example is fibre glass which is mostly used for making automotive and marine bodies, plastic pipes, storage containers etc

iii. Ceramic-matrix composites: this basically consists of ceramic materials which are used for making components in automobile and aircraft gas turbine engines

iv. Metal-matrix composites: this essentially consists of a ductile metal matrix. Examples include super alloys, copper and aluminium alloys which are largely used to manufacture machine parts required to operate in high temperature environments (Callister, 2000).

(d) Organic and inorganic Materials: Examples of organic materials available include Thermoplastic Polymers, Thermosetting Polymers, Laminated Polymer Structures, Foam and Cellular Polymers, Elastomers, Wood, Adhesives, Lubricants and Fuels (Lehman, 1999). These are useful materials in automobile industry.

2.8 Use of Computer Aided Designed (CAD)/Computer Aided Manufacturing (CAM)

Computer Aided Product development has become one of the most important techniques in the automobile industry and that concurrent engineering concept has integrated Computer Aided Design (CAD)/ Computer Aided Engineering (CAE)/ Computer Aided Manufacturing (CAM) systems (Lin, et al, 2008). The use of the CAD/CAM software has improved drawing, reduces product development time and cost, enhances product quality and coerces products into the market within a short time (Eritas et al, 1993).

2.9 Use of Robots in the Automobile Industry

The emergence of industrial robots has led to a speed up of the process of manufacturing in the automobile industry through automation (Adejuyigbe, 2010). Within this concept, automation has to do with a system of manufacturing that is designed to extend the capacity of machines to perform certain tasks formerly done by humans and to control sequences of operations without human intervention.

2.10 Global Historical Development of the Automobile Industry

The pioneers of automobile were more concerned with producing a basic self-propelled vehicle than anything else. As practical mechanics and engineers, they were concerned with the mechanical problems of adapting an engine to a personal means of transportation (Arslan, 2006). Actually, a good number of the early inventors paid little attention to vehicle design; they were satisfied with mounting a motor on a light carriage or a bicycle. A Frenchman, created the first steam car in 1770 (Bellis, 2012).The steam car produced had limited potential - heavy, slow and took a long time to preheat the water.

The first cars to be powered by internal combustion engine running on fuel gas started in 1806, and by the late 19th century, the modern gasoline or petrol-fuelled internal combustion engine appeared (Eckermann, 2001).

In 1885, Gottlieb Daimler and Carl Benz created the petrol internal combustion motorcycle and 3-wheeler respectively (Mark Wan, 2000).

Figure 2.3: The First Car with an Internal Combustion Engine.

2.11 The Case of U.S.A. Automobile Industry

General Motors was formed in 1908 as a merger of a number of firms, with its most prominent components being Buick, Cadillac, and Olds Motor Works, dating back respectively to 1903, 1902, and 1901. Ford Motor Company entered the industry in 1903 while Chrysler Corporation emerged in 1924 through the efforts of Walter Chrysler, ex-president of Buick, who reorganized the two leading firms that had emerged, after they had suffered some setbacks, into a single vibrant firm (Klepper, 2001). In 1911, Ford and General Motors became the two top firms contributing about thirty-eight percent (38%) of the industry's output and after 1930 General Motors, Ford, and Chrysler combined, accounted for over eighty percent (80%) of the industry's output in the U.S (FTC, 1939).

By 1908 the automotive industry was well established in the United States with Henry Ford manufacturing the T-model and General Motor Corporation being founded (Gillespie, 1992).

2.12 The Case of South Korea Automotive Industry

Domestic automobile industry began in Korea in1962, following the first five-year economic development plan which the South Korean government enacted: the imports of completed cars were prohibited, assemblers were given tax exemptions, and parts and components were exempted from import tariffs. The government encouraged a total production of cars in the country (Green, 1992).

The process of technological development in the Korea automobile industry identified four developmental stages namely: Initial accumulation of knowledge about making automobiles, Assembling, Manufacturing and Creation using own technology (Mo-Joon et al, 2006). The first stage of technology development was before 1961, where several assemblers and parts suppliers, assembled cars with used engines and manufactured parts such as pistons, brake linings and fan belts.

The second stage started with Shinjin Motor Company' which entered into a technology alliance with Toyota to produce Coronas in 1966. Backing this development were auto mechanics who had their training in the military service in 1966, and together with another 3,303 trained Motor vehicle mechanics. These steps contributed significantly to the development of the automobile industry in Korea.

The major car makers in Korea also spent a lot of resources on Research and Development (R&D) (Mo-Joon et al., 2006). - It is worth noting that, as of 1993, ten percent (10%) of Hyundai Motor Company's total employees were researchers. Kia recruited 7.9% in 1990, and Daewoo hired ten-point-one percent (10.1%) in 1993 (Mo-Joon et al., 2006).

The number of Doctor of Philosophy (PhD) certificate holders among the researchers also, kept on growing in the establishment of these three car makers (Mo-Joon et al., 2006). Table 2.4 indicates the number of researchers in the three aforementioned establishments (Hyundai, Kia and Daewoo) from 1990 to 2000. It demonstrates the importance the three carmakers attached to improvement in technological capacity. The ratio of PhD's among researchers in the table is a manifestation that technological development in 1990s was still high on process technology.

Table 2.4: Researchers in Korea Automobile Industry

Company	**Hyundai**			**Kia**			**Daewoo**		
Year	1990	1993	2000	1990	1993	2000	1990	1993	2000
Researchers	3418	4100	8000	15000	1700	5000	916	1373	3185
share in total employees (%)	-	10.0	-	7.6	6.7	-	5.1	10.1	16.1
PhD holders	14	16	80	11	20	-	12	25	64
Master's Degree holders	256	313	1000	105	135	-	61	255	704
Share of PhD's in the total researchers (%)	0.4	0.4	1.0	0.7	1.2	-	1.3	1.8	20

Source: Kim et al (1999)

The South Korea automobile industry is noted to be one of the largest in the world and is becoming the fastest in the global market (Lee, 2011). In terms of production volume in 2010 it was the fifth largest in the world but in export volume it scored the sixth position. The three major companies- Hyundai Motors Company, Kia Motors Corporation and Daewoo Motor Corporation accounted for about ninety percent (90%) of the South Korea market. The merged Hyundai-Kia ranks fifth in terms of production volume after Toyota, General Motors (GM), Volkswagen, and Ford in the world (Lee, 2011). Korea is now considered one of the most advanced and sophisticated automobile producing countries in the world along with the other super powers like United States, Japan and Germany.

2.13 The Case of Malaysia's Automobile Industry

The government of Malaysia took a very long term strategic view to build an automobile industry. Even though the establishment of Proton came to light in the 1980s, the national automotive industry had begun in 1962 (Simpson et al, 1998). By 1967, the Government of Malaysia had approved six assembly plants for operation within Malaysia and these assembly plants were all joint venture projects between Malaysian companies and European vehicle manufacturers (Bin - Yahaya, 2010). The growth in the Malaysian automotive industry, especially with regards to components manufacturing was not very successful at that time (UNESCAP report, 2000). Before the early 1980s, there was only overseas transplant car assembly within Malaysia, with very small local automotive product suppliers (Abdulsomad, 2000).

2.13.1 The National Car Project

To promote large economic scale of the automobile industry, the Government of Malaysia in 1983 inaugurated the first National Car Project (NCP), known as the " Proton," this was a joint venture between the Heavy Industry Corporation of Malaysia (HICOM), Mitsubishi Motor Corporation (MMC) and Mitsubishi Corporation (MC) of Japan (Abdulsomad, 1999). The NCP was expected to develop the automotive industry, and thus promote the Malaysian people's participation in the industry. Additionally, it also aimed at shifting the focus in the Malaysian automotive industry from assembling foreign cars to manufacturing cars and automotive parts.

The original components of the car were entirely manufactured by Mitsubishi but gradually local parts being used as technologies were transferred and skills gained (Abdul-Hamid et al, 2008). By 2008 Proton had recorded production of more than 3 million cars (Proton Annual Report, 2008).

2.14 Historical Development of Automobile Industry in Africa

2.14.1 The Case of Automobile Industry in South Africa

The automotive industry in South African dates back to the 1920s and has since grown from an import and assembly industry to an import-substitute industry (Ishaq, 2009).

After the Second World War in 1945, the South African automotive industry grew further and even faster. Motor Assemblers and Car Distributors Assembly plants were established in Durban and East London respectively (Onyango, 1999).

As at 1999 there were eight producers of light vehicles in South Africa and they assembled 317,000 units, out of which eighteen-point-five percent (18.5%) were exported. Most of these manufacturers were able to build a variety of models (Black, 2001). These assemblers are now wholly or partly owned by their parent company in Japan, the US or Europe.

2.14.2 The Case of the Egyptian Automotive Industry

The Automotive Industry in Egypt started in the early 1960's as part of the National Industrialization Policy which later on was established as part of the public owned assembly companies for the production of passenger cars, trucks and buses (Askar et al, 2005). These companies assembled cars under license agreements with Fiat, an Italian manufacturer and the German truck and bus producer, Magirus Deutz.

The main objective of the industry was to produce cars for the domestic market, with no plans for expanding the industry's focus towards exports. Therefore the locally assembled cars were mainly economic cars based on simple technology, cheap to maintain and repair given the unskilled aftermarket automobile repair industry.

General Motors began producing automobiles in Egypt in 1985, establishing Egypt's first privately owned automotive manufacturing company, the General Motors (GM) Egypt (IMC report, 2005). The company assembled passenger cars, sports utility vehicles (SUVs) and light and medium-duty trucks for the Opel-Chevrolet and Isuzu. Table 2.5 provides a general idea of the major motor vehicle assemblers and importers in Egypt, including a list of the brands they assemble or import by vehicle type.

Many foreign companies entered the Egypt car industry in the 1980s. With the flows of the foreign capital and the continued protection of the automotive sector, these foreign companies made lucrative profits. Al-Nasr Automotive has persistently been a key player in the sector as it assembled vehicles under several acquired license from international brands as Chrysler, KIA, Peugeot and others. The Auto industry in Egypt also possesses a highly professional caliber of engineers and skilled labour (Hamza et al, 2012).

Table 2.5: Shows the Major Motor Vehicle Assemblers and Importers in Egypt.

Company	Passenger cars	LCVs	Trucks	Buses
	Brand			
	DOMESTIC ASSEMBLY			
Bavarian Auto Group	BMW			
Daewoo Motors Egypt	Daewoo			
Egyptian Automotive Manufacturing			Eamco	Eamco
Egyptian German Automotive Company	Mercedes			
Manufacturing Commercial Vehicles		Mercedes	Mercedes	Mercedes
General Motors Egypt	Opel	Chevrolet	Chevrolet	Hashim, Wahab
Hyundai Motors Egypt	Hyundai			Hyundai
El Nasr Automotive Manufacturing	Tofas			
KIA Motors Egypt	KIA			
Peugeot Egypt	Peugeot			
Suzuki Egypt	Suzuki LADA		Suzuki	
Gorica Egypt for Industry S.A.E			MAN	Gorica
Arab American Vehicles	Jeep			
Ghabbour Group of Companies		Mitsubishi	Mitsubishi, Volvo	Mitsubishi, Volvo
Nissan Motor Egypt	Nissan			
IMPORTS				
Abou Ghaly Motors	Subaru			
Bavarian Auto Group	BMW			
Daimler Chrysler Egypt	Chrysler,Dodge			
Egyptian Automotive Co.	VW	VW		
Egyptian German Automotive Co.	Mercedes			
Manufacturing Commercial Vehicles		Mercedes	Mercedes	Mercedes
Egyptian International Motors	Renault			
Engineering Automotive Co.	Seat	Seat		
Futaimisr Trading Co.	Honda			
Hyundai Motors Egypt	Hyundai	Hyundai	Hyundai	Hyundai
IVECO		IVECO	IVECO	
KIA Motors Egypt	KIA	KIA	KIA	KIA
Peugeot Egypt	Peugeot	Peugeot		
Ragab Import & Export	Daihatsu,Ford	Daihatsu,Ford		
Suzuki Egypt		Suzuki,LADA		Suzuki
Gorica Egypt for Industry S.A.E			MAN	
Arab American Vehicles	Jeep			

Source: Egyptian Automobile Manufacturers Association (EAMA).

2.14.3 Development of Automobile Industry in Ghana

A number of vehicle assembly plants such as Gharmot, National Investment Corporation (NIC) vehicle assembly plant and workshop and Neoplan assembly plant were established when Ghana gained independence in 1957. These were part of government's industrialization drive that increased manufacturing's share of GDP from 10 percent in 1960 to 14 percent in 1970 (www.Mongnabay.com). However, this period of growth was followed by over a decade of de-industrialization and most of these enterprises did not survive in the era of restrictive trade regimes that led to scarcity of foreign exchange (Dinye and Nyaba 2001).The vehicle assembly plants were among the State Owned Enterprise (SOE) that were subsequently privatized due to poor management and dependence on state funds for survival (Kwakye, 2011).

2.14.4 Some Challenges of the Automobile Industry In Ghana

There are a number of challenges facing the automobile industry in Ghana. Some of which include:

- There is rapid increase in the size of the informal sector in Ghana and gradual decline in average size of industrial firms (Sandefur, 2010). The informal sector which is made up of small enterprises such as vehicle repairs and maintenance shops, automobile spare parts dealers and many others are not able to source huge financial assistance from the financial institutions to enhance their operation due to inadequate collateral security.
- The automobile parts sector in the Suame magazine in Kumasi and Kokompe in Accra are areas of homegrown manufacturing centres in the country which have not gained the necessary attention to achieve their full potentials in contributing to the industrial growth in Ghana. (Agyeman-Duah 2008).

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter presents the methodology of the study. The main topics included here, are; research design, study population, sampling procedures, sample size, sources of data, methods of primary data collection, pre-testing of questionnaire, field observation, interviews and finally, method of data analysis.

3.2 Research Design

The descriptive survey design was deemed appropriate for the study because it is versatile and practical, in that, it identifies present conditions and points to recent needs. Again attempts were made to determine the incidence, distribution and interrelationship among sociological and psychological variables. Moreover, it would make it much easier to survey, interpret, synthesize, and integrate data in a bid to examine the implications and interrelationships identified in the study.

The choice of this design was further motivated by the fact that descriptive research or survey aims mainly at describing, observing and documenting aspects of a situation that naturally occurs (Polit and Hungler (1995). The study therefore used a non-experimental design, the design of the survey being descriptive and cross-sectional in nature.

3.3 Study Population

The target Automobile Industries/firms for the study included Neoplan Automobile Assembly Plant, Kumasi, Jospong Group of Companies (JGC) Vehicle Assembly Plant, Accra, and the Apostle Safo Kantanka “Suaye” Technology Centre, Gomoa-

Mpota, Central Region. Others included vehicle body builders, hydraulics mechanics, chassis builders, and machine tool shops at Suame Magazine, Kumasi.

3.3.1 Rationale for Selection of Study Population

The Neoplan Ghana Ltd. Assembly plant was selected because of its experience spanning forty years in automotive activities such as assembling of buses, and coach body building. JGC vehicle assembly plant Ltd., was also included because it assembles vehicles from Complete Knock Down (CKD) kits and builds tipping buckets for tipper trucks. JGC operates as a medium scale industry in Ghana. Apostle Safo Kantanka "Suaye" Technology Centre was chosen because it is one of the indigenous technology centres that are into design and manufacturing of vehicles and engine components and parts on trial basis. Similarly, Suame Magazine is prominent industrial cluster noted mainly for its automotive activities such as vehicle body building, chassis building, auto hydraulics, machine tools operations, among others.

3.4 Sampling Procedure

The survey employed simple random, stratified and purposive sampling techniques in selecting the sample for the study. Respondents were stratified into Engineers, Technicians and Mechanics/Artisans.

3.5 Sample Size

A table for determining the random sample size for populations was used to determine the sample size for this study. This suggested minimum sample sizes were 48, 10, 3 and 86 for Neoplan, JGC, Suaye and vehicle body builders, hydraulic mechanics, chassis builders as well as machine tools shops (Krejcie & Morgan., 1970).

Table 3.1: Sample Size

S/No	Selected Areas	Population of Employees	Sample Size
1	Neoplan Automobile Assembly Plant-Kumasi	55	48
2	JGC Vehicle Assembly Plant - Accra	13	10
3	Apostle Safo Kantanka "Suaye" Technology Centre Gomoa- Mpota, Central Region	3	3
4	Vehicle body builders, Hydraulic mechanics, Chassis builders and Machine tool shops at Suame Magazine –Kumasi	110	86
	Total	**181**	**147**

The aggregate sample size for the survey is one hundred and forty seven (147). In total, one hundred and thirty four (134) questionnaires were returned by respondents and this formed the basis of the analysis.

3.6 Types, Sources and Methods of Data Collection

This section presents the types and sources of data used for the study as well as the various methods of their collection.

3.6.1 Primary data

Primary data was obtained by direct observation, informal discussions and responses from Engineers, Technicians, and Artisans of the selected automobile establishments in both the formal and informal sectors in the industry.

3.6.2 Secondary data

Secondary data were obtained from published and unpublished sources including theses and books from the libraries of Kwame Nkrumah University of Science and Technology (KNUST), Polytechnics, Ministry of Trade and Industry (MoTI), Research Institutions and internet websites.

3.6.3 Methods of Data Collection

A combination of data collection tools were employed to gather data from respondents in the selected automobile industry for the survey. These include the administration of structured and semi-structured questionnaire for the collection of primary data. The questionnaire for the survey featured a mixture of questions that were common in terms of issues relating to automobile design and manufacturing in Ghana. The questionnaire for the interviews was divided into three sections:

(i) Personal data of technical personnel engaged or respondents

(ii) Factors militating against automobile design and manufacturing in Ghana a

(iii) Soundness of various methods employed in the manufacturing of automobiles in Ghana.

Observation check lists made up of various automobile parts categorized under engine parts, transmission systems, steering and suspension systems, body and chassis systems and vehicle electrical systems were used to record observations by ticking in order to establish observable items, for example, engine block, gasket, push rods, gears, shafts, cross rod, hubs and other machine tools used to produce items in the workshops and production centres.

3.7 Pre-Testing of Questionnaire

Pre-testing of questionnaire provides not only a measure of the correctness and interpretation of the questionnaires but also an opportunity for discovering new aspects of the problem to be studied. Before finalizing the questionnaire, a design trial of 25 questionnaires was administered at a selected area within the Suame Magazine in Kumasi. On the basis of this some modifications and additions were made. The pre-testing led to the removal of some errors and ambiguities before the final administration was performed. The final form of the questionnaire is shown in appendix A.

3.8 Field Observations and Interviews

A total of 53 firms were visited during the survey. Table 3.2 shows a breakdown of these firms.

Table 3.2: Breakdown of the Number of Firms Visited

No.	Firms	Number of firms visited
1	Vehicle body builders at Suame Magazine Kumasi	25
2	Hydraulic Mechanics - Suame Magazine Kumasi	8
3	Machine Tool shops - Suame Magazine Kumasi	10
4	Chassis builders - Suame Magazine Kumasi	7
5	JGC Vehicle Assembly Plant- Accra	1
6	Neoplan Ghana. Ltd-Kumasi	1
7	Apostle Safo Kantanka Auto workshop, Gomoa – Mpota	1
	TOTAL	**53**

Also, observation of methods used to fabricate tipper truck buckets, articulated truck trailer buckets, fuel tankers, cargo truck buckets and buses was done to complement the information obtained from the respondents.

Through further observation, additional and vital information which was not covered by the questionnaire and interview was obtained. Such information include: state of machine tools and production methods.

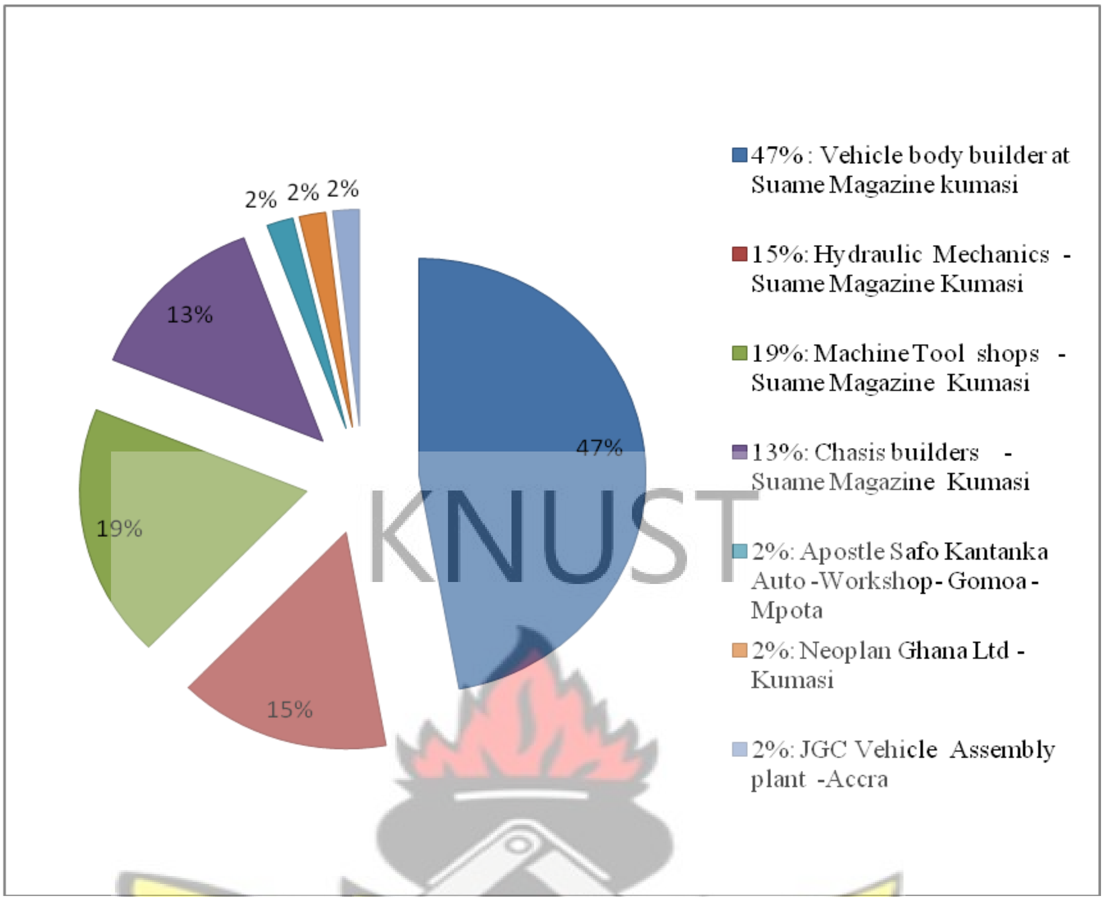

Figure 3.1: Breakdown of Automobile Workshops Visited

3.9 Method of Data Analysis

SPSS and STATA were the primary analysis tools used in analyzing the data collected. The responses provided in the questionnaire were displayed for easy analyses in the form of tables, pie charts and cross tabulations. Each objective of the research was analyzed by using appropriate statistical measures. Descriptive statistics were employed in the analysis of the set objectives of the study.

To address the first objective of this study, observatory and a checklist of questions, in addition to the questionnaire were employed in establishing the engineering methods and procedures that are to be used in carrying out design/production activities. The responses were then described qualitatively and quantitatively.

There are a number of factors that militate against automobile design and manufacturing, and these factors serve as major obstacles to the second objective of this study, stated above. This objective was analyzed by first establishing the constraints faced by Technicians, Engineers, and Mechanics/Artisans and the type of machine tools and equipment used in the automobile establishment.

The third objective was analyzed by taken into consideration the profession and level of education as well as work experience of personnel's engaged in the field of automobile activities in the industry.

CHAPTER FOUR

ANALYSIS OF RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the analysis and interpretation of both primary and secondary data. This discussion touches on:

(1) Demographic parameters of personnel engaged in the industry

(2) Factors militating against automobile design and manufacturing and

(3) Soundness of various methods employed in the design and manufacturing of automobiles.

4.2 Level of Education of Workers in the Industry

The figures in Table 4.1 show that of the 134 workers in the Industry, 44.78% are Senior High School (SHS) and Technical school graduates. Those with Middle School Certificate /Junior High School accounted for 40.30%, more than those with Diploma certificate 13.43%, followed by those with degrees 1.49%.

Table 4.1: Level of Education of Workers in the Industry

Level of Education	Frequency	Percentage
Middle/JHS	54	40.30
SHS/Technical	60	44.78
Diploma	18	13.43
Degree	3	1.49
Total	**134**	**100.00**

4.2.1 Professions of Respondents

Figure 4.1 reveals that 56.72% of the respondents are Mechanics/Artisans. Automobile/Mechanical Technicians (41.04%) far outnumber Automobile/ Mechanical Engineers (2.24%). These percentages suggest that the automobile industry does not have enough high caliber professional engineers to drive the industry. This is in contrast to the Egyptian automobile industry which Hamza (2011), notes possesses high caliber professional engineers and skilled labour.

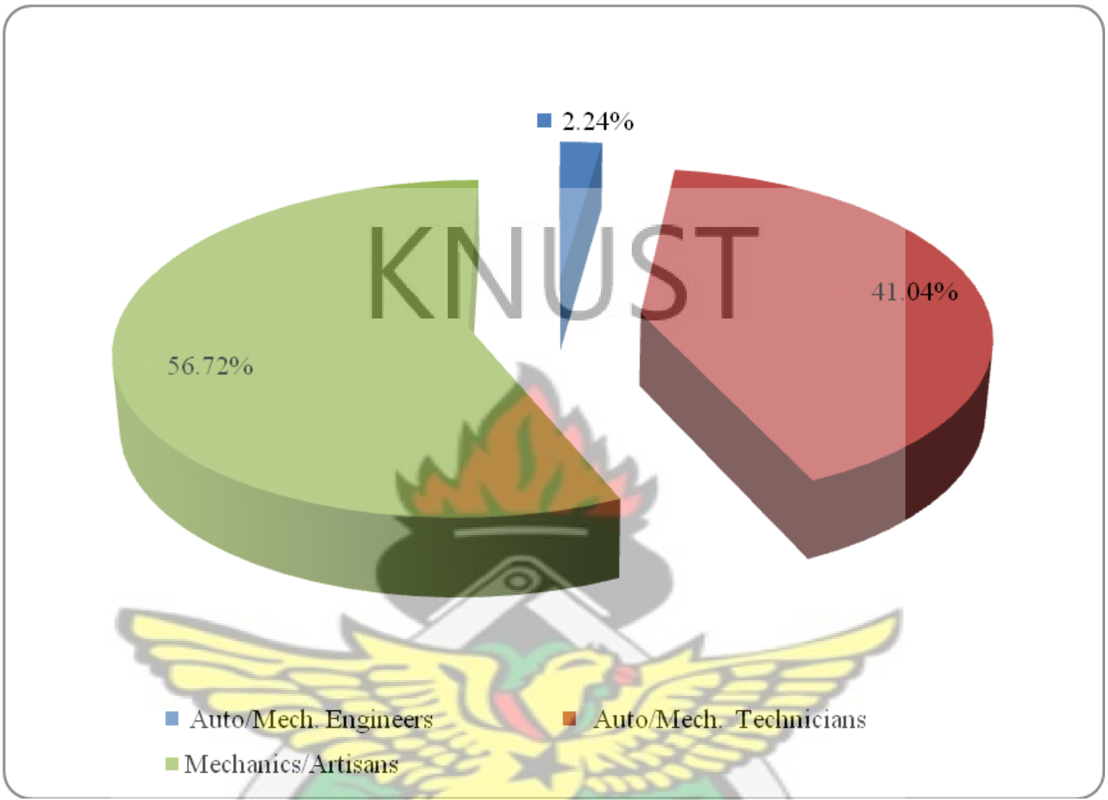

Figure 4.1: Profession of Respondents

4.2.2 Respondent's Number of Years of Work Experience

Table 4.2 indicates that 44.03% of respondents have 6-10 years of work experience. Those with 15 years experience or above 35.07% are more than those with 1-5 years work experience 16.42%, followed by those with 11-14 years work experience 4.48%.

Table 4.2: Respondents Number of Years of Work Experience

Years of worked	Frequency	Percentage
1-5 years	22	16.42
6-10 years	59	44.03
11-14 years	6	4.48
15 years and above	47	35.07
Total	**134**	**100.00**

4.3 Factors Militating against Automobile Design and Manufacturing in Ghana

4.3.1 Number of Automobile /Mechanical Engineers Engaged

Table B2 in Appendix B shows that 112 respondents representing 96.55%, admit that their firms do not engage the services of automobile designers. Only 3 respondents representing 3.45% do this. This represents a major adverse factor affecting the development of automobile design and manufacturing in Ghana. This situation is further explained in Table 4.3.

The table shows that 109 representing 94.80%, out of 115 respondents, further disclosed that there are no engineers in their firms. Only 2 respondents each, representing 1.70%, indicated their firms engage between 1 to 3 engineers. The said firms include JGC vehicle Assembly plant located at Accra with a work force of 13 has three engineers, Neoplan Ghana Ltd, Kumasi has three while Apostle Safo Kantanka at Gomoa in the Central Region has two. This revelation has adverse implications on the quality and growth of the automobile industry in Ghana.

Table 4.3: Number of Automobile /Mechanical Engineers Engaged

No. of Auto/ Mech. Engineers Engaged.	Frequency	Percentage
None(0)	109	94.80
One Engineer	2	1.70
Two Engineers	2	1.70
Three Engineers	2	1.70
Total	115	100.00

4.4 Number of Mechanical/Automobile Technicians Engaged

Table 4.4: Number of Mechanical/Automobile Technicians Engaged

No. of Auto/Mech. Technicians Engaged	Frequency	Percentage
None(0)	90	76.30
1	2	1.70
2	11	9.30
3	6	5.10
4	2	1.70
5	2	1.70
10	4	3.40
20	1	0.80
Total	**118**	**100.00**

The need to assess the level at which firms engage technicians also becomes evident, considering the nature of engineering activities that are going on in most of the firms visited. Table 4.4 indicate that 76.30% of the 118 respondents pointed out that technicians are not engaged in their firms. Eleven respondents representing 9.30% indicated that their firms engaged six technicians whilst four, representing 3.40%, said they engaged ten technicians in the production of automobile components. The above figures show that technician capacity is not being adequately built in the automobile industry.

4.4.1 Use of Drawings and Diagrams in Designs and Manufacturing of Automobiles

Regarding engineering drawings, Table 4.5 suggests that a significant percentage of respondents' firms 62.69% do not use engineering drawing at all. Manual drawing scored 29.85% while the use of Computer Aided Design (CAD) registered 7.49%. These figures confirm that drawing is not adequately used in the development of automobile components or products in most workshops. This finding contrasts sharply with the observation of Lin. (2008) that competition in the automobile industry and concurrent engineering concepts have resulted in integration of CAD/CAE/CAM systems with the main rationale for use being to reduce product development time, cost and improve product quality.

Table 4.5: Use of Drawings and Diagrams in Design and Manufacturing of Automobiles

Kinds of Drawings/Diagrams used	Frequency	Percentage
Manual Drawing	40	29.85
Computer Aided Design (CAD)	10	7.46
None (neither CAD nor manual drawing)	84	62.69
Total	**134**	**100.00**

4.4.2 Types of Automobile Components and Systems Produced

Table B12a and B12b in Appendix B show that of the 134 respondents, 22.4% said their firms produce exhaust systems, 14.9% produce bumpers and 6.7% produce cylinder head covers while 37.3% produce gears, shafts, bushes and, pulleys.

However, components such as steering systems and crankshafts did not score any mark. The scenarios presented above suggest that development of the local automotive components industry in the country is facing several challenges in technology and in the design and manufacturing of parts.

4.4.3 Types of Machine Tools Used

Table B10a and B10b of Appendix B again reveal that the machine tools used the most by automobile workshops are grinding machines 93.3%, followed by drilling machines 87.3%, welding machines 80.6%, then lathe machines 55.9%. 20.9% of these workshops have band saw machines, whereas few automobile workshops 8.2% have milling machines and air impact machines 3.7%. All these machine tools are of the conventional type. Thus the benefits of Computer Numerical Control (CNC) machine tools are missed including high quality and repeatability.

4.4.4 Other Challenges in Using Machines Tools

Most of the respondents 84.3% indicate infrequent power supply as one of the challenges they face in their use of machine tools to produce automobile parts. This is followed by frequent machine breakdown 20.9% with 5.2% arguing that obsolete machines are a major challenge they face in the use of machine tools. (See Table B11 in Appendix B).

4.4.5 Automobile Components or Parts Produced by Casting

Table 4.6 below indicates that few respondents in the informal sector use the casting methods in the production of automobile parts. Only 2.26 % produce components or parts using the casting method while a great majority 97.74% do not. These figures reveal that, limited foundries in the country produce automobile components or parts using casting method. This stands in sharp contrast to the findings of Panchal (2010) in India, where the foundry industry produces almost 7 million mega tonnes of castings and contributes significantly to the economy and the growth of the engineering sector.

Table 4.6: Automobile Components / Parts Produced by Casting

Auto-components produced by casting	Frequency	Percentage
Yes	3	2.26
No.	130	97.74
Total	**133**	**100.00**

4.5 Soundness of Various Methods Employed in the Manufacturing of Automobiles

4.5.1 Building of Motor Vehicle Bodies

In respect of the soundness of the methods employed, 72 respondents, representing 54.96% build vehicle bodies exclusively using welding without much regard to quality (Table B1 of Appendix B). Further information on this is given in Table 4.7.

4.5.2 Types of Vehicle Bodies Built

From Table 4.7, 38.7% of respondents' firms are involved in building cargo truck buckets, 26.67% in articulated truck bucket building and 17.33% in fabrication of tipper truck buckets. Also, 6.67% and 10.67% of respondents said their firms are into the building of fuel tankers, buses and coaches respectively. A closer look at the types of vehicles listed in the table shows that heavy duty vehicle body building is common. The reason accounting for this may be that the designs and accompanying manufacturing processes of heavy duty vehicle bodies are much simpler as compared to that of smaller vehicles like saloon cars.

Table 4.7: Type of Vehicle Bodies Built

Type of vehicle bodies built	Frequency	Percentage
Articulated truck buckets	20	26.67
Cargo truck buckets	29	38.67
Tipper truck buckets	13	17.33
Fuel tankers	5	6.67
Buses & Coaches	8	10.67
Total	**75**	**100.00**

4.5.3 Materials Used in Building Vehicle Bodies

Table B3 in Appendix B again demonstrate that the most common material used in vehicle body building in Ghana is steel. The type of steels mostly used in Ghana include ASTM A1008 cold rolled sheet metals, hot rolled sheet metals, galvanized steel sheets, and U-channel metals. Assessment of these steel metals shows that, apart from chemistry data for commercial quality, and mechanical data tests of these materials done at their country of origin, there are no any laboratory tests conducted on these materials to ascertain the composition, before putting them to use at the various workshops and firms. Specifications of these steels conform to international standards such as AISI, AISE, SAE of their countries of origin. A number of reasons account for the preference for steel in vehicle body construction from the point of view of the engineers. Whereas some are of the view that vehicles built of steel are more robust on the road and also more resistant to pressure and impact, others maintain that steel-built vehicles are generally more durable and comfortable. A number of expert views agree with an assertion by Ghassemieh (2011) in his observation of steel built vehicles. He explains that the major reason for using steel in building vehicle body is its inherent capability to absorb energy in a crash situation, in combination with good formability and joining capability. In a similar observation, Akpakpavi (2010), noted in his investigation that engineering materials available in the country for machinery design and manufacturing essentially comprise low and medium carbon steels which are supplied in the various forms. According to him, the use of this kind of material is common because other engineering materials containing the requisite materials for the purpose of building vehicle bodies are hard to come by. It is obvious from the above that automobile designers and manufacturers in Ghana have limited scope of materials to work with as compared to their counterparts in the developed countries where the use of special steels and sound alloys dominates due to weight saving factor. It is important to add that the over reliance on limited steels for the manufacture of vehicles limits the soundness, aesthetics and durability of automobile components and parts produced in Ghana.

4.5.4 Methods of Fabrication Used

Figures shown in Table B4 of Appendix B indicate that welding is predominantly a joining process used in vehicles' body building.

4.5.5 Types of Welding Methods Used

Figures in Table B5, in Appendix B indicate that 84.93% of firms use shielded metal arc welding (SMAW) exclusively. The study revealed that 13.67% of respondents, mainly from the JGC Vehicle Assembly Plant and Neoplan Ghana Ltd use either Tungsten Inert Gas (TIG) welding or Metal Inert Gas (MIG) welding in addition to (SMAW). Respondents from Neoplan Ghana Ltd representing 1.4% said the company uses Resistance Spot Welding (RSW) in combination with (SMAW). The figures point to the fact that within the arc welding group, shielded arc welding process is the most widely adopted form of welding used in vehicle body fabrication in Ghana, with RSW being the least used. This is contrary to what pertains in the developed countries where RSW is predominantly used in the auto- industry due to its low cost, high speed and its applicability to automation (Meranda, 2011).

Respondents maintain that the choice of SMAW by most local vehicle body fabricators was influenced by the user–friendly nature of the equipment. They maintain that it is inexpensive with a simple set up–time. This is very much in line with the assertion by Gourd (1995) that any process chosen should provide the required quality at the lowest cost: and that in making a choice between processes, quality must be considered in terms of the skill and ability of the welders available to do the job.

This is an ample demonstration that as a country, we need to equip these vehicle body fabricators with the necessary welding skills and equipment to handle more sophisticated welding techniques that are capable of manufacturing technologically advanced products in order to engender a productivity that can compete favourably with those in the developed nations.

4.5.6 Methods Used to Test Welded Joints

Welded joints are normally tested to ensure that they can accomplish their intended function. In actual fact the basis of a specification for weld quality is often an assessment of the number and size of the defects that can be present in a weld before it is declared defective and therefore rejectable. There are a number of destructive and non-destructive tests used in the assessment of welds in automobile body building. Table B6 of Appendix B indicates that 85.4% of firms use visual inspections to ascertain the quality of welded joints. This is usually the first step in assessing quality. By this method the inspector visually examines the weldment for:

(a) Conformance to dimensional specifications on the part of drawing

(b) Incomplete fusion, cracks, cavities, and other defects and

(c) Warpage

The welding inspector again determines whether additional tests are necessary within the non destructive group. The disadvantages with the visually inspection is that only surface defects can be detected. 14.52% of respondents said that they use chipping harmer to take out carbon deposits on the surface of welded area to expose cracks, cavities and others forms of defects. This form of assessment alone does not give the true quality of the weldment. This, therefore, means that both destructive non-destructive methods of testing welds should be considered when fabricating vehicle bodies in Ghana.

4.5.7 Welding to International Standards

Tables B7 and B8 of Appendix B show that 61% of respondents do not weld to international standards. Another 38.10% said that they weld to GS ISO 156141 of the Ghana Standards Authority.

4.5.8 Use of Robots and Automation in Automobile Manufacturing

Robots are used extensively in advanced countries in the automobile industry. These machines are ideal for use in the assembly of vehicles bodies, welding, mounting of motors and gear boxes, painting and coating and many others. This Observation is supported by the opinion of Adejuyigbe (2010) who also observe that robots bring efficiencies and quality to manufacturing and extends the capacity of machines to perform certain tasks not done well by humans. Yee and Jim (2011) further note that using robots has the power to democratize manufacturing industries, especially firms that specialize in mass production of technology products and product components.

The findings of the study however suggest that robots are not used in any automobile manufacturing company in Ghana (Appendix, table B9). This could be due to the low level of technology in the production and use of robots in the country.

4.5.9 Local Workshops Producing Automobile parts

As indicated in Table 4.8 below, a few engineering firms (15%) manufacture the exhaust systems of vehicles locally using the welding method. Again, 23% of these firms produce vehicle seats locally, while 45% produce body frames using the welding method. Some engineering firms use the machining method to produce shafts (26%). It is further found that engineering firms produce gears (17%) using the milling method whereas 25% of them use forming method to manufacture gaskets for vehicle engine blocks. However, majority of parts used are imported into the country. With this, most firms are in agreement.

Table 4.8: Automotive Parts and Manufacturing processes used in manufacturing them

PROCESS	AUTOMOTIVE PARTS (%)						
	Exhaust System	**Gasket**	**Gears**	**Shafts**	**Engine Blocks, Crankshafts, Pistons**	**Seats**	**Body Frame**
Machining	-	-	17	26	13	-	-
Welding	15	-	-	-	-	23	45
Forming	-	25	-	-	-	-	-
Casting	-	-	-	-	1.9		
Total	**15**	**25**	**17**	**26**	**14.9**	**23**	**45**

4.6. Profile of some Automobile Assembly and Parts Manufacturing Firms in Ghana

Suame Magazine is a well-known industrial cluster in Ghana, located at the Suame district of Ashanti region. The cluster is noted for its focus on automotive activities such as vehicle body building, spare part sales, electronics component dealers, scrap dealers, tools dealers, blacksmiths, vehicles and vehicle accessories sales, to machine tool shop operators and casting experts among others.

Various activities such as building of articulated trailers, truck buckets (cargo trucks), Tipper truck buckets, Fuel tankers and the production of automobile parts - gears, shafts, bushes, among other things, using various types of machine tools and welding is done at the Magazine by mechanics, majority of whom have very weak foundation in formal engineering.

The operations at Suame Magazine are informal. All operations are carried out according to what practitioners have learnt from their predecessors. Documentation of jobs and other administrative procedures for future reference purposes are non-existent. As a result, it is very difficult to obtain any statistical data on the operations of the artisans within Magazine.

The survey and interview at the Suame magazine reveals that it takes a maximum of 8 years to become a 'master mechanic' in the trade before one can establish his/her own shop. Depending on their specialization, the mechanics can be grouped into the following:

(1) Body builders

(2) Hydraulics mechanics

(3) Chassis builders

(4) Vehicle mechanics and

(5) Machinists

Body Builders: These are mainly welders of heavy vehicles and, who are responsible for the fabrication and construction of tipper truck buckets, trailer buckets, fuel tankers and cargo truck buckets.

Hydraulic Mechanics: They specialize in both pneumatic and hydraulic systems of vehicles; particularly the hydraulic systems of the tipping mechanisms of tipper trucks.

Chassis Builders: These are responsible for the construction of heavy vehicle chassis of various ranges.

Vehicle Mechanics: The work of vehicle mechanics is general in scope and mainly concerned with the smooth running of the vehicle. They do repairs and maintenance on vehicle engines, gearboxes, fuel injectors, and electrical systems.

Machinists: These are mechanics that use the machine tools to produce automobile parts such as gears, shafts, bushings, cylinder linings among others.

Example of both the finished and unfinished works of mechanics/artisans at the Suame Magazine are captured below:

Figure 4.2: (a) Fabrication of articulator trailer bucket at Suame Magazine

Figure 4.3: Fabrication of Cargo truck bucket at Suame Magazine

Figure 4.4: Construction of fuel tankers at the Suame Magazine

4.7. Neoplan Ghana Ltd Assembly Plant-Kumasi

The plant was the first bus manufacturing assembly plant in West Africa to produce Neoplan tropical buses and coaches locally for Ghana and the West Africa market (www.neoplan.de). It has been operating for the past forty years. Its integrated service centre in Kumasi builds a number of buses such as Tata Marcopolo, DVL Neoplan, Yaxing, DVL Jonckheere, Daf and Fiat Iris bus/iveco model for Metro Mass Transit Company Limited (MMT), VIP buses and coaches, Transport Comfort Voyageur (CVT) buses in Burkina Faso.

The production section of the plant, which deals with the fabrication of the body of buses and coaches, uses mainly manual welding methods**.** Welding of the skeletal body frame, skeletal covers, vehicle floor mounts as well as the seats of the buses and coaches are done by metal inert gas (MIG) and tungsten inert gas (TIG) methods; Spot welding is applied to the body panel where galvanized sheet metal is mostly used. In all of these instances, engineering drawings and diagrams are used. Inspections of the buses bodies and welded joints are done by quality inspectors using visual methods only. The buses and coaches are painted using an in-house spraying booth.

Most components and parts used in assembling the buses such as shock absorbers, coil springs, seals, control arms, boot clamps, headlamps, starter brushes and many others are all imported.

The Plant builds a maximum of three (3) buses in a week and approximately between One hundred (100) to one hundred and fifty (150) buses in a year.

Figure 4.5: A bus being prepared for spraying at the Neoplan assembly plant in Kumasi

4.8. JGC Vehicle Assembly Plant

This plant is a subsidiary of Jospong Group of Companies (JGC) in Ghana; it is located in Accra, off the Tema motorway. This ultra-modern plant was commissioned in 2010. It assembles ranges of vehicles and trucks from complete knock down (CKD) imported kits.

Assembly and welding activities carried out in the plant are not automated. Light duty trucks are assembled from CKD kits manually. Electrical wiring of the vehicles is done locally. Fabrication of tipping buckets of trucks and other parts of the truck bodies are done locally at the plant using MIG and TIG welding methods. Painting of the vehicles is done in a spraying booth located within the plant.

The plant assembles between five to six vehicles in a week, considering the minimum of five vehicle in a day, this translates to 240 vehicle in a year.

Figure 4.6: Light duty truck bucket under construction at the JGC Vehicles Assembly plant

Figure 4.7: A Truck With a Tipping Bucket Fabricated at the JGC Vehicle Assembly Plant

4.9. Apostle Safo Kantanka's "Suaye" Technology Centre

The activities in the automobile workshop of 'Suaye' form part of the ongoing research trials of their Technology Centre. The shop is divided into five sections namely: design, foundry, machining, Chassis/body building and a spray booth.

Design section: This section is responsible for the design and specification of the interior and exterior parts of the saloon and the four wheels drive (FWD) vehicles produced at the centre. They also design some automobile components as well as patterns for casting these components.

Foundry section: This section uses sand casting methods to produce components such as engine blocks as shown in Figures 4.8 and other engine parts. Materials mostly used are aluminium alloys, magnesium alloys and cast iron.

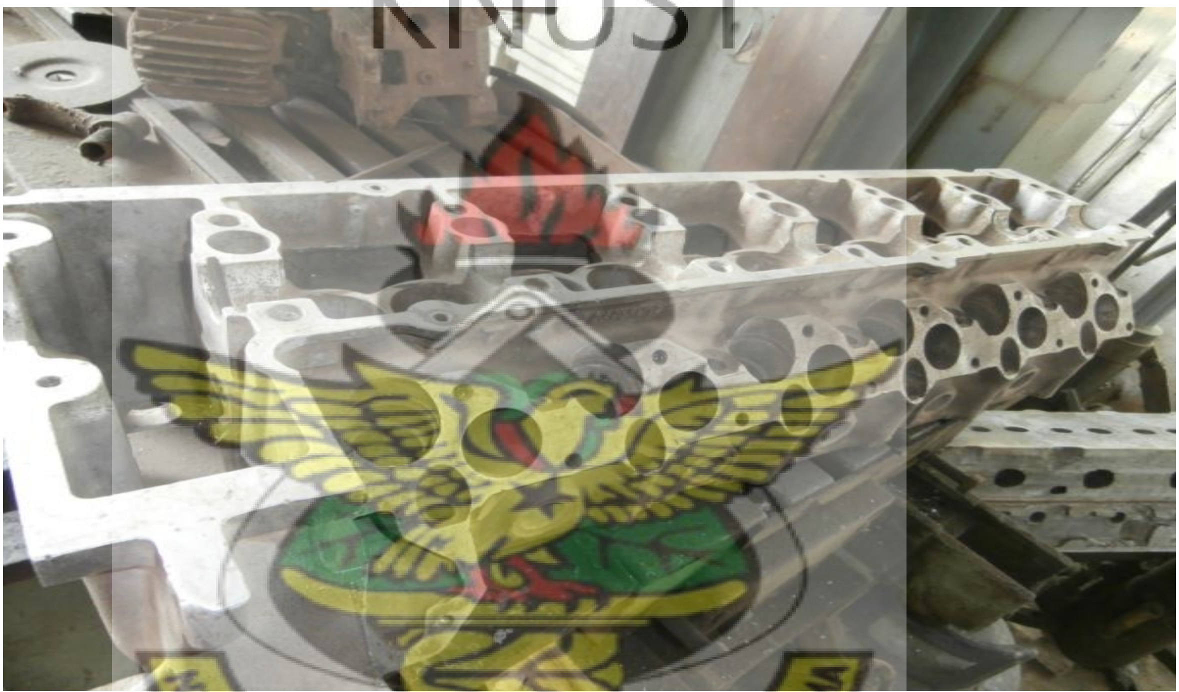

Figure 4.8: Cast Magnesium Alloy Engine Block at Apostle Safo Kantanka's "Suaye" Technology Centre Foundry

After casting the engine block conventional lathes, milling and drilling machines are used machined cylinder bores, drill oil holes, ream and tapped. These manual operations are subsequently followed up by series of finishing operations to obtain the required surface finish and coolant passages before heat treatment is carried out. These processes are rudimentary, time consuming in terms of set-up time and uneconomical as compared with the use of computer numerical control (CNC) machines which are adoptable to multi-step machining system, parallel processes, processes optimization and reconfigurable flexibility.

Vehicle Chassis and Body Building Section: Figure 4.9 shows the chassis of a vehicle under construction. The chassis is fabricated using rectangular hollow sections of carbon steel. This is then painted using oil paint to brighten it and to provide it with a corrosive protection. Gales, et al after a study discovered that in most advanced countries hollow section of stainless steels or galvanized steels are used for the fabrication of chassis (Gales, et al (2007). They again noted that chromium content of stainless steel ensures adequate corrosion protection and therefore removes the need to paint. This gives the materials an added advantage in terms of durability.

Figure 4.9 : Chassis of a vehicle fabricated at Apostle Safo Kantanka's "Suaye" Technology Centre' Workshop

Machining section: Conventional lathes, universal milling machines and drilling machines as well as grinding machines are used for finishing operations on components to ensure the required dimensions and surface smoothness are met before heat treatment is carried out, if needed.

Spraying booth: A modern spraying booth is used to paint the vehicle produced at the centre.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

The objective of this thesis study was to assess the current state of automobile design and manufacturing in Ghana, investigate the soundness of various methods employed in the manufacturing of automobiles and to determine the factors militating against automobile design and manufacturing.

5.1 Summary of Key Findings

The following are the key findings of the study:

- Qualified automobile designers and engineers are woefully in short supply in the automobile manufacturing industry.
- The use of engineering drawings; both manual and computer generated is very low among most players in the automobile industry.
- The use of conventional machine tools dominates all automobile workshops investigated. CNC machine tools are non-existent.
- Very few foundries produce automobile parts using sand casting methods
- Fabrication of heavy duty truck buckets, articulated truck buckets, tipping buckets and, the bodies of buses and coaches are fast advancing and are more common than manufacture of saloons cars in the country.
- Engineering firms use welding, forming and sand casting methods to produce parts locally albeit, in small quantities. These include vehicle seats, gears, and exhaust systems among others.
- Irregular power supply coupled with the use of obsolete machine tool is also a major problem confronting the automobile industry.

5.2 Conclusions

The investigation has brought to the fore a number of key revelations regarding the kind of engineering work that goes on in Ghana with regards to automobile design and manufacturing. The findings enable one to draw some valid conclusions that hinge upon the durability, market acceptability, suitability or user-friendliness of the products. Results from the study as illustrated in the foregone analysis provides sufficient grounds for one to draw a number of conclusions:

- Poor technical know-how, coupled with the lack of financial resources has compelled many of the engineers and technicians to adopt rudimentary engineering methods and techniques of producing automobile parts.
- Most engineering components and vehicle body fabrications, particularly in the informal sector is done by artisan /mechanics who have weak foundation in formal engineering and also lack specialized welding techniques as well as equipments.
- The design and manufacturing of components and parts in the industry does not appear to follow any proper standards system.

5.3 Recommendations

In light of the findings and conclusions deduced from the study there is need for some form of intervention measures in the design and fabrication of vehicle parts locally in Ghana. The conclusions drawn expose a yawning gap between production and efficiency of the products manufactured in the Ghanaian setting. The following recommendations will go a long way to improve upon the state of production and serviceability of the locally manufactured products.

- The use of engineering drawing should be encouraged strongly amongst practitioners in the automobile design and manufacturing industry, this will lead to sound engineering practices in the country.
- The Automobile industry and other relevant institutions should collaborate with higher engineering educational institutions in Ghana for funding to develop programmes and train technicians, mechanics and artisans to acquire the requisite competences to enhance their performance in the automobile industry.
- Relevant stakeholders including the government should facilitate the provision of domestic automobile parts manufacturing centres with modern machines and tools so as to enable them contribute effectively to the development of the automobile industry.
- Government should provide an enabling environment in the form of positive tax exemption and subsidies to attract world-class automobile companies into the country to stimulate the establishment, growth and technological advancement of the local automobile industry. This is what happens in South-East Asia, for example, South Korea, where in the formative stages of the automobile industry the Government banned importation of assembled vehicles and encouraged the importation of parts for assembly to promote domestic development of the industry (Lee, 2011).

5.4 Recommendation for Further Study

- Future studies could look into the possibility of upgrading selected automobile parts workshops and assembly plants into factories for full scale design and production of standardized automobile parts and components.

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APPENDIX A 1

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

MECHANICAL ENGINEERING DEPARTMENT

QUESTIONNAIRE ON STATUS OF AUTOMOBILE DEVELOPMENT

This questionnaire aims to collect data to assess the state of development of automobile design and manufacturing in Ghana.

I am a student researcher of KNUST undertaking a study on automobile design and manufacturing in Ghana. This questionnaire solicits your input to that survey. You are assured that data collected is for academic purpose only and will be treated with the utmost confidentially.

SECTION A. PERSONAL DATA OF TECHNICAL PERSONNEL ENGAGED OR RESPONDENTS

Please tick [√] in the box or provide an answer where applicable.

1. Name of industry/establishment………………………………………………………

2. Highest level of education. (a) Primary [ ] (b) Middle/JHS [ ]

(c) Secondary/Technical School [ ] (d) Diploma [ ] (e) First degree [ ] (f) Masters Degree [ ] (g) Non-formal education [ ] (h) Other(s), specify…………

3. What is your Profession?

(a) Engineer [ ] (b) Automobile Technician [ ] (c) Mechanic /Artisan [ ]

(d) Other(s) (please specify)…………………………………………

4. Number of years you have worked in the automobile industry?

(a) 1-5 years [ ] (b) 6 -10 years [ ] (c) 15 years or above [ ]

SECTION B. FACTORS MILITATING AGAINST AUTOMOBILE DESIGN AND MANUFACTURING IN GHANA

(Please tick or provide answers where applicable)

5. Number of mechanical /automobile engineers engaged in the company?.............

6. Number of mechanical /automobile technicians engaged in the company? ....

7. Are there automobile designers in the company? Yes [ ] No. [ ]

8. If yes provide number of trained designers in the company? …………

9. What kinds of drawings and diagrams do you use in the design and manufacture of automobiles in the department?

a. Manual drawing [ ]

b. Computer aided designed (CAD) [ ]

c. None [ ]

d. Other(s) specify ………………………………………..

10. What type of automobile components and system are produced in the company? (Tick as many as you know)

a. Exhaust system [ ]

b. Bumpers [ ]

c .Steering system [ ]

d.Cylinder head covers [ ]

e. Crankshaft design [ ]

Other(s) specify …………………………………….

11. Select the type and indicate the number of machine tools used in the manufacturing of automobile parts /components in the company in the table below.

Machine	Conventional Machine (tick)	Number	CNC Machine (Tick)	Number
Boring machine				
Turret lathe machine				
Threading machine				
Lapping machine				
Grinding machine				
Band saw machine				
Lathe				
Milling				
Drilling machine				
Polishing				
Welding Machine				
Other machines				

12. Challenges you encounter in the use of the above machines in manufacturing?

a. Irregular power supply [ ]

b. Frequent breakdowns [ ]

d. Other(s) specify…………………………………..

13 (a). Do you produce cast automobile components/parts in your company?

Yes [ ] No. [ ]

(b). If yes, indicate the method of casting, components produced, raw materials used and sources of supply of raw material in the table shown below.

No. item	Method of casting	Auto-components /parts produced	Materials used	Source of raw material

14. Challenges regarding the acquisition of various materials for the production of automobile parts.

a. accessibility to materials……………………………………………….…………………

b. Acquisition in terms of cost……………………………..…………………………..

c. Obtain locally or imported……………………………………...……………………

SECTION C: SOUNDNESS OF VARIOUS METHODS EMPLOYED IN THE MANUFACTURING OF AUTOMOBILES

15. Do you build motor vehicle bodies in the company? Yes [ ] No [ ]

If yes, provide the appropriate answers to the following question/statements in the table below by listing as many as possible where applicable.

16	Types of vehicle body produced	
17	Type of materials used in building the vehicle bodies	
18	Method of fabrication employed	
19	what type of welding method do you used	
20	what method is used to test welded joints of auto parts produced	
21	Do the welds conform to any international standard?	
22	Name the welding standard employed	
23	Do you use robots in the company?	
24	If yes what work are they engaged in	
25	How many robot do you engaged	

APPENDIX A2

CHECKLIST OF AUTOMOBILE PARTS									
		MANUFACTURED LOCALLY							IMPORTED PARTS
		Casting	Welding	Machining	Forming	Milling	Blanking	Casting	
ENGINE PARTS									
1	Engine Block								
2	Cylinder Head								
3	Cylinder Lining								
4	Crankshaft								
5	Camshafts								
6	Connecting Rods								
7	Piston								
8	Piston Rings								
9	Gudgeon Pin								
10	Intake, Exhaust Valves								
11	Intake, Exhaust Valve Springs								
12	Air Cleaner And Filter								
13	Exhaust System								
14	Catalytic Converters								
15	Exhaust Silencers								
16	Fuel Filter								
17	Crankshaft pulley								
18	Carburetor								
19	Gasket								
20	Rocket arms								
21	Push rod								

TRANSMISSION SYSTEM									
22	Gear box								
23	Clutch								
24	Propeller shaft								
25	Rear axle								
26	Front axle								
27	Four wheel drive gear box								
28	Drive shaft								
29	Universal joint								
30	Final drive and differential								
31	Constant velocity -joint								
32	Pilot bearing								
33	First Gears								
34	Thrust washer								
35	Front bearing retainer								
36	Shift fork								
37	Rear bearing								
38	synchronizer								
39	Snap ring								
40	Seal								
41	Pressure plate								
STEERING AND SUSPENSION SYSTEM									
42	Shock absorber								
43	Coil spring								
44	Control arms								
45	Leaf spring								
46	Center bolt								
47	Spring shackle bushing								
48	Tie plate								
49	Wheel								
50	Hub								
51	Steering shackle								
52	Cross rod								

53	Steering Knuckle								
54	Steering wheel								
55	Steering gear box								
56	Tie rods								
57	Steering shaft								
58	Steering damper								
59	Steering rack								
60	Boot								
61	Boot clamp								
BODY AND CHASIS SYSTEM									
62	Chassis Frame								
63	Seat belt								
64	Heat exchanger								
65	airbags								
66	seat								
67	Body frame								
VEHICLE ELECTRICAL SYSTEM									
68	Oxygen Sensor								
69	Headlamp								
70	Starter solenoid								
71	Starter brush								
72	Felt seal								
73	Armature bearing								
74	Starter drive yoke								
75	Sleeve								
76	Insulator								
77	Spark plug								
78	Temperature sensor								
79	Electronic Petro Injector								
80	Spark plug wire								

APPENDIX A3

Oral Interview Guide at Suame Magazine

1. How long does it take to learn as an apprentice?

2. What is the nature of the training?

3. What is your area of specialization?

4. How do you measure your work?

5. Are there any regulatory bodies that check what you do?

7. Who are they?

8. Do you need any permit to work?

9. What is your level of education?

APPENDIX B

Table B1. Motor Vehicle Bodies Built

Do you build motor vehicle bodies?	Frequency	Percentage	Cum. Percentage
Yes	72	54.96	54.96
No	59	45.04	100.00
Total	**131**	**100.00**	

Table B2. Automobile Designers

Automobile Designers.	Frequency	Percentage	Cum. Percentage
No	12	96.55	96.55
Yes	3	3.45	100.00
Total	**115**	**100.00**	

Table B3. Material used in building vehicle body

Material used in building vehicle body.	Frequency	Percentage	Cum. Percentage
Metals-steel	75	100.00	100.00
Total	**75**	**100.00**	

Table B4. Methods of fabrication used

Method of fabrication used.	Frequency	Percentage	Cum. Percentage
Welding	75	100.00	100.00
Total	**75**	**100.00**	

Table B5. Type of welding method used

Type of welding method used.	Frequency	Percentage	Cum. Percentage
Arc welding	62	84.93	84.93
MIG &TIG welding	10	13.67	98.60
RSW	1	1.40	100.00
Total	**73**	**100.00**	

Table B6. Methods used to test welded joints

Methods used to test welded joints.	Frequency	Percentage	Cum. Percentage
Visual inspection	53	85.48	85.48
Chipping hammer (Sound test)	9	14.52	100.00
Total	**62**	**100.00**	

Table B7.welding to International Standards

Do the welds conform to any international standard?	Frequency	Percentage	Cum. Percentage
Yes	8	38.10	38.10
No	13	61.90	100.00
Total	**21**	**100.00**	

Table B8. Welding Standard used

Name the welding standard employed.	Frequency	Percent	Cum. Percentage
GS ISO	8	38.10	38.10
None	13	61.90	100.00
Total	**21**	**100.00**	

Table B9. Use of Robots

Do you use robots?.	Frequency	Percentage	Cum. Percentage
No	67	100.00	100.00
Total	67	**100.00**	

Table B10a: Type of machine tools (Summary)

Type of machine tools	Frequency	Percentage	Cum. Percentage
Grinding			
Yes	125	93.28	93.28
No	9	6.73	100.00
Total	134	100	
Band saw			
Yes	28	20.90	20.90
No	106	79.10	100.00
Total	134	100	
Lathe			
Yes	75	55.97	55.97
No	59	44.63	100.00
Total	134	100	
Milling			
Yes	11	8.21	8.21
No	123	91.97	100.00
Total	134	100.00	

Table B10b: Type of machine tools

Summary

Type of machine tools	Frequency	Percentage	Cum. Percentage
Welding			
Yes	108	80.60	80.60
No	26	19.40	100.00
Total	134	100	
Drilling			
Yes	115	87.3	87.3
No	19	12.7	100.00
Total	134	100	
Air impact			
Yes	5	3.73	3.73
No	125	96.27	100.00
Total	130	100	

Table B11. Challenges Encounter

Challenges encounter in the use of machine tools in manufacturing	Frequency	Percentage	Cum. Percentage
Irregular (Infrequent) Power supply			
Yes	113	84.33	84.33
No	21	15.67	100.00
Total	134	100	
Frequent Machine Breakdown			
Yes	28	20.90	20.90
No	106	79.10	100.00
Total	134	100	
Ageing Machines			
Yes	7	5.22	5.22
No	127	94.78	100.00
Total	134	100	

Table B12a: Type of Components and systems produced

Type of Components and systems produced	Frequency	Percentage	Cum. Percentage
Exhaust System			
Yes	30	22.39	22.39
No	104	77.61	100.00
Total	134	100	
Bumpers			
Yes	20	14.93	14.93
No	114	85.07	100.00
Total	134	100	
Steering Systems			
Yes	0		
No	134	100.00	100.00
Total	134	100	

Table B12b: Type of Components and systems produced

Type of Components and systems produced	Frequency	Percentage	Cum. Percentage
Cylinder Head Cover			
Yes	9	6.72	6.72
No	125	93.28	100.00
Total	134	100	
Crankshaft			
Yes	0		
No	134	100.00	100.00
Total	134	100	
Gears, Shafts, Bushes and Pulleys			
Yes	50	37.31	37.31
No	84	62.69	100.00
Total	134	100	

APPENDIX C

a.

Finished cars

Figure A1: a. and b. Photos Taken from Sarfo Kantanka Automobile Technology Centre

Figure A2. JGC Assembly Plant