

**KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,
KUMASI, GHANA**

**TRADITIONAL PRACTICES IN AUTOMOBILE MAINTENANCE IN
GHANA: AN ANALYSIS OF AUTOMATIC TRANSMISSION DRIVES**

BY

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(BSc Mechanical Engineering)

**A Thesis submitted to the Department of Mechanical Engineering,
College of Engineering,**

in Partial Fulfillment of the Requirements for the Award of the Degree

**MASTER OF SCIENCE IN
MECHANICAL ENGINEERING**

NOVEMBER, 2019

DECLARATION

I hereby declare that this submission is my own work towards the award of an MSc degree in Mechanical Engineering and that, to the best of my knowledge, it contains no material previously submitted by another person, nor material which has been accepted for the award of any other degree of this or any other university, except where due acknowledgement has been made in the text.

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ABSTRACT

This study assesses the competence of automobile maintenance practitioners in the diagnosis and repair of automatic transmission vehicles. The study focuses on several relevant issues including the knowledge of personnel engaged in the servicing of automatic transmission vehicles, frequency of use of automatic transmission drives, and peculiar challenges associated with the use of automatic transmission vehicles. A combination of research methods comprising interviews, questionnaire and face-to-face dialogue were employed in collecting data, aiming at automatic transmission garages in both the formal and informal sectors. A total of 983 questionnaires were administered to four automobile stakeholders namely vehicle operators (536), wayside mechanics (202), used vehicle importers (232) and dealers (13) in four cities in Ghana specifically, Takoradi, Kumasi, Tema and Accra. The respondents were purposively sampled from the general population in the four cities. Analysis of variance, Chi-Square and basic charts were used to display and interpret trends in the data. The study revealed that 17.7 % of wayside mechanics were classified as poor by vehicle operators, 27.6% as average, 38.4% as good, 14.4 % as very good and 1.9 % as excellent. 0.9% of dealers were rated as poor by vehicle operators, 1.9%, as average, 1.5% as good, 36.2% as very good and 59.5% as excellent. 66% of respondents indicated that they patronize wayside mechanics because they are affordable in their services while only 3% of respondents indicated that the dealers were affordable to patronize. A cost effective automobile maintenance database has been designed and hosted on <http://automatictransmissionhelpcentre.com>. This will complement the effort of the wayside mechanic in solving automatic transmission drive problems and also enhance the knowledge of vehicle operators and dealers in servicing automatic transmission drives.

DEDICATION

This work is entirely dedicated to God Almighty.

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ACKNOWLEDGEMENT

My gratitude goes to the Almighty God for granting me good health, guidance, and helping me this far in my education. I wish to express my sincere thanks to my supervisor Dr. Francis Davis, a lecturer at Kwame Nkrumah University of Science and Technology, School of Engineering and Dr. Adam Larbie of CFAO for their immense support, direction, encouragement and guidance which enabled me to complete this work. A special thanks also goes to Dr. Anthony Adjei Agyemang a lecturer at Kwame Nkrumah University of Science and Technology, School of Engineering for his immense support. I am also grateful to Dr. Charles Emmanuel Oppon, of Mechanical Engineering Department-CCTU for his guidance and direction. Finally, I wish to express my deepest appreciation to my beloved wife, Rita Boafo and children for their patience and support during the course of this program.

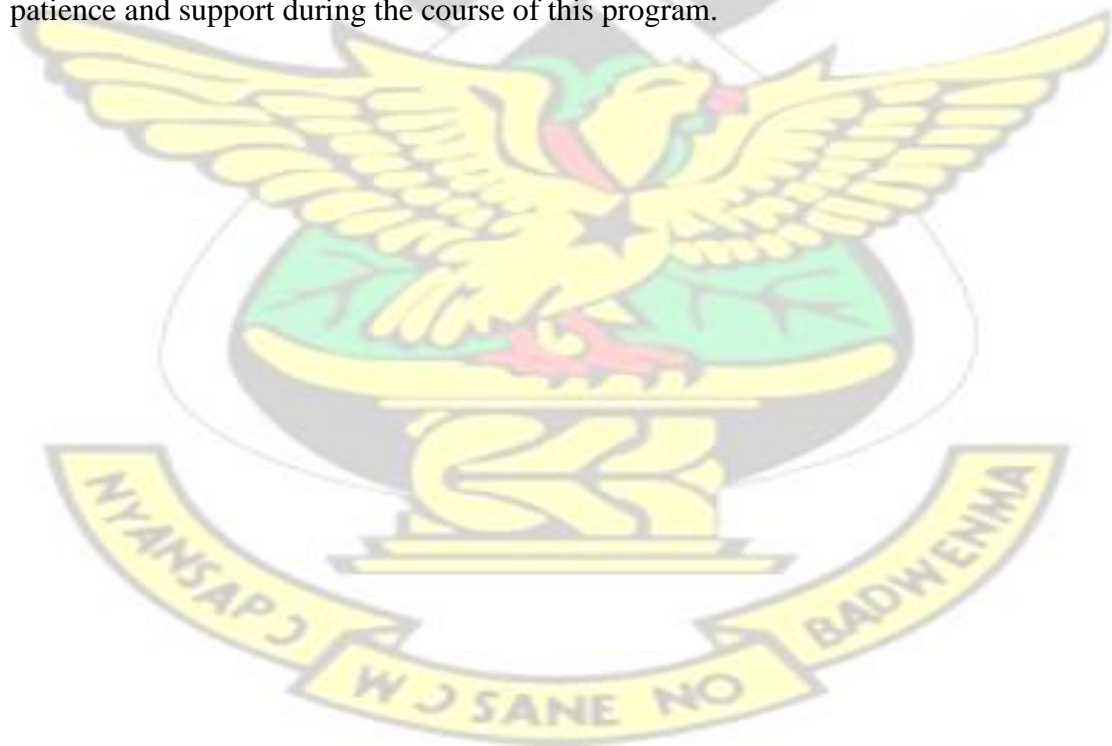


TABLE OF CONTENTS

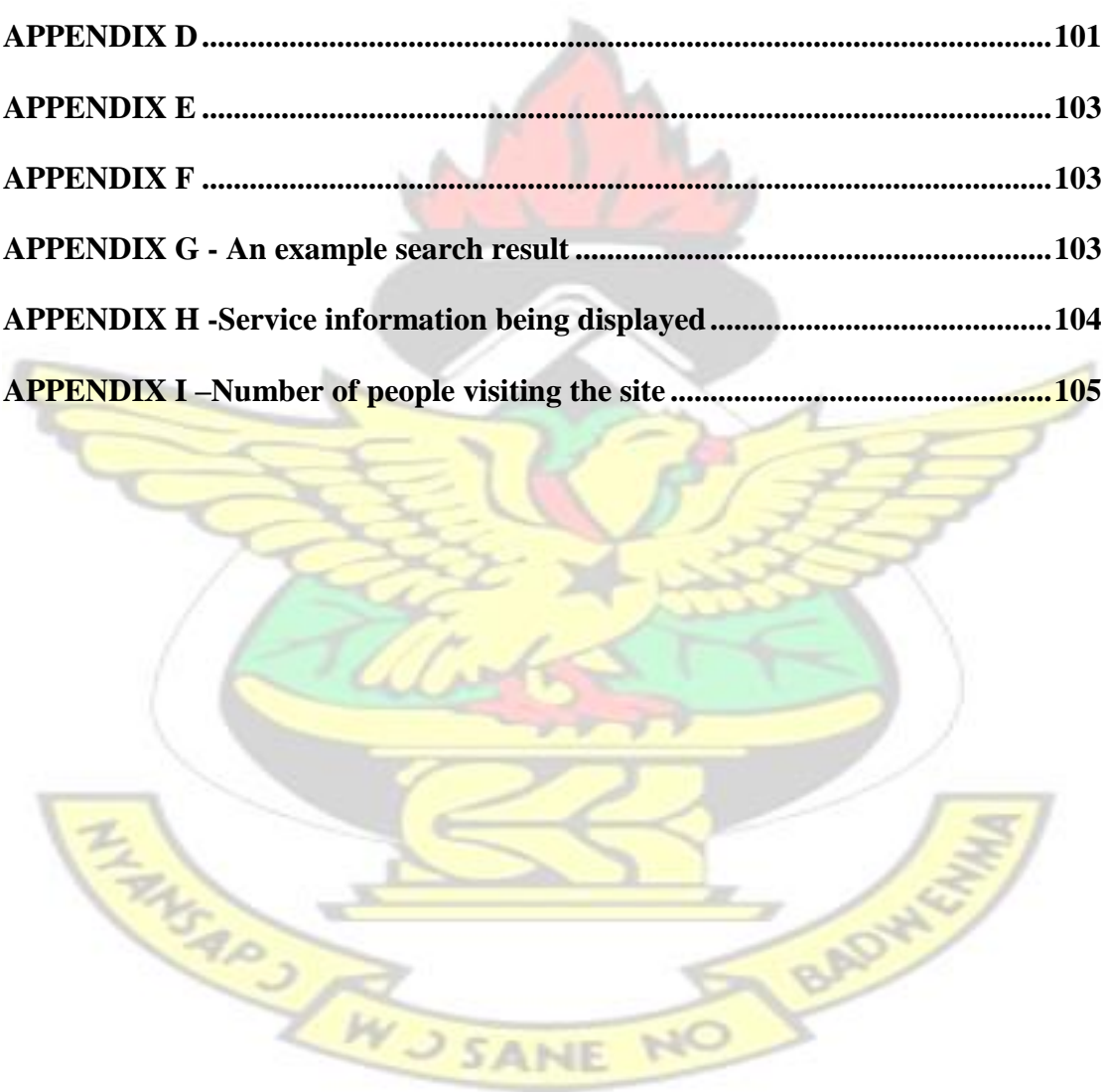
DECLARATION	ii
ABSTRACT	iii
DEDICATION	iv
ACKNOWLEDGEMENT	v
TABLE OF CONTENTS	vi
LIST OF TABLES	xi
LIST OF FIGURES	xiii
LIST OF ACRONYMS	xv
CHAPTER ONE	1
INTRODUCTION	1
1.1 Background of the Study	1
1.2 Problem Statement	3
1.3 Research Objective	4
1.4 Significance of the Study	4
1.5 Scope of the Study	5
1.6 Organization of the Study	5
CHAPTER TWO	7
LITERATURE REVIEW	7
2.1 Global Historical Development of Automatic Transmissions	7
2.2 Automatic Transmissions in Vehicles	11
2.3 Trends in Vehicle Maintenance	12
2.4 Types of transmissions.....	13
2.4.1 Manual transmissions.....	13
2.4.1.1 Sliding-gear type.....	14
2.4.1.2 Constant-mesh type (Synchro – Mesh).....	16

2.4.2 Automatic transmission	17
2.4.2.1 Automatic Transmission Arrangement	23
2.4.3 Parts of an Automatic Transmission	26
2.4.3.1 Torque Converter	26
2.4.3.1.1 Pump	28
2.4.1.2 Turbine	29
2.4.1.3 Stator	30
2.4.4. Lockup Torque Converter	31
2.4.5 Planetary Gear Set	31
2.4.6 Band	34
2.4.7 Clutches	35
2.5 Servicing of Automatic Transmission	36
2.5.1 Visual Inspection	38
2.5.2 Transmission Dipstick	39
2.6 Types of Automatic Transmission	39
2.6.1 Hydraulic Automatic Transmission	39
2.6.2 Continuously Variable Transmission	40
2.6.3 Manumatic (Tiptronic)	42
2.6.4 Semi-automatic Transmission (Paddle Shift Transmission)	42
2.7. Automatic Transmission Drive Problems	43
2.7.1 Transmission slipping	43
2.7.2 Fluid Burning Smell	43
2.7.3 Delayed engagement	44
2.7.4. Transmission warning light	44
2.7.5. Fluid leak	45
2.8 Tools used in servicing Automatic transmission drives	45

2.9 Electronic control of transmission	47
2.10 Electronically Controlled Transmission Components	48
2.11 Practices of Auto Technicians	49
2.12 Automatic Transmission Fluid (ATF)	50
CHAPTER THREE	52
METHODOLOGY	52
3.1 Study Area	52
3.1.1 Rationale for selecting the study Area	52
3.2 Study design.....	52
3.3. Sample Size.....	53
3.4 Sample Size Determination.....	53
3.4.1 Sampling Technique	54
3.5 Sampling Procedures	54
3.6 Data and Sources.....	54
3.6.1 Pre-test of Instrument.....	55
3.6.2 Fieldwork and Data Collection	56
3.6.3 Data Analysis	56
3.7 Ethical Considerations	57
CHAPTER FOUR.....	58
RESULTS, FINDINGS AND DISCUSSION.....	58
4.1 Profile of Respondents	58
4.2 Demographic Characteristics	59
4.2.1 Gender.....	59
4.2.2 Educational background.....	59
4.2.2.1 Vehicle Operators	59
4.2.2.2 Dealers	61

4.2.2.3 Used Vehicle Sales	61
4.2.2.4 Mechanics	61
4.2.3 Age of Vehicle Operators	62
4.3 Sale of ATDs.....	62
4.3.1 Years of Operation of Business	62
4.3.2 Record keeping of Sales of ATDs by Dealers	63
4.3.3 Extent of patronage of ATDs.....	63
4.3.3.1 Frequency of New Cars Sold by Dealers.....	63
4.3.3.2 Frequency of Used Cars Sold by Used Vehicle Importers	64
4.3.3.3 Reasons for Choice of Transmission Type	66
4.4 Expertise in Servicing of ATDs.....	67
4.4.1 Automatic Drive Problems Brought to the Garages	67
4.4.2 Faults Repaired Easily and Tools Used	68
4.4.3 Faulty Components	69
4.4.4 Characteristics of Wayside Mechanics	70
4.4.5 Knowledge and Competence	70
4.5 Challenges Associated with the Use of ATDs.....	73
4.5.1 Choice of Garage for Servicing	73
4.5.2 Challenges associated with the use of ATDs.....	75
4.5.3 Rating of Garages	76
4.5.4 Rate of Revisit to Mechanics	77
4.6 Design of a Maintenance System Database.....	78
4.6.1 Brief Description.....	78
4.6.2 Principle of Operation.....	79
CHAPTER FIVE	83
CONCLUSION AND RECOMMENDATION.....	83

5.1 Summary of Key Findings	83
5.2 Conclusion	84
5.3 Recommendations.....	85
REFERENCES.....	86
APPENDIX A	91
APPENDIX B	94
APPENDIX C	99
APPENDIX D	101
APPENDIX E	103
APPENDIX F	103
APPENDIX G - An example search result	103
APPENDIX H -Service information being displayed.....	104
APPENDIX I –Number of people visiting the site	105



LIST OF TABLES

Table 2.1 Some Tools used in servicing Automatic transmission drives	47
Table 2.2 A few samples of automatic transmission fluid and some applications.	51
Table 3.1 Sampling Population.....	54
Table 4.1 Gender distribution of respondents.....	59
Table 4.2 Level of Education of Respondents	60
Table 4.3 Age Distribution	62
Table 4.4 Sale of Automatic Transmission Drives	63
Table 4.5 Average Number of New Cars Sold from 2007 to 2016	64
Table 4.6 Average Number of Used cars Sold from 2007 to 2016.....	64
Table 4.7 Total Number of cars Sold from 2007 to 2016.....	65
Table 4.8 Reasons for Choosing a Type of Transmission	67
Table 4.9 Automatic Drive Problems	68
Table 4.10 Faults Repaired Easily	68
Table 4.11 Special Service Tools Available to the Shop.....	69
Table 4.12 Faulty Components	70
Table 4.13 Characteristics of Wayside Mechanics	70
Table 4.14 Knowledge and Competence by Specialization.....	71
Table 4.15 Competence of Mechanics in Solving ATD Problems	72
Table 4.16 Correlation	72
Table 4.17 Challenges Associated with the use of ATD	76

Table 4.18 Rating of Garages77

Table 4.19 Rate of Revisit to Mechanics77

KNUST



LIST OF FIGURES

Figure 2.1: The First Car with an Internal Combustion Engine.	7
Figure 2.2 Transmission system for a rear wheel drive vehicle (Source: Howstuffworks, 2002)	11
Figure 2.3 Manual Transmission Assembly	14
Figure 2.4 Sliding Mesh	15
Figure 2.5 Constant mesh,	17
Figure 2.6 Basic automatic transmission Source –	18
Figure 2.8 Epicyclic Gear – External Type Overdrive	23
Figure 2.10 Automatic Transmission Arrangement.....	25
Figure 2.11 Torque converter parts.....	26
Figure 2.12 Stator Turbine Rotates.....	27
Figure 2.13 Torque converter	28
Figure 2.14 Torque Converter components	30
Figure 2.16 Planetary gear (Courtesy of General Motors Corporation)	32
Figure 2.17b Holding Planet Carrier.....	33
Figure 2.17a Holding the Ring Gear.....	33
Figure 2.17c Holding the Sun Gear	34
Figure 2.18 (A) Typical single wrap and (B) double wrap transmission band designs	35
Figure 2.19 Wear material in the bottom of an automatic transmission pan,	37

Figure 2.20 the magnet in the oil pan37

Figure 2.21 Metal V-belt CVT drive: (a) basic Layout; (b) belt structure41

Figure. 2.22. Chain CVT drive: (a) basic Layout; (b) chain structure.....42

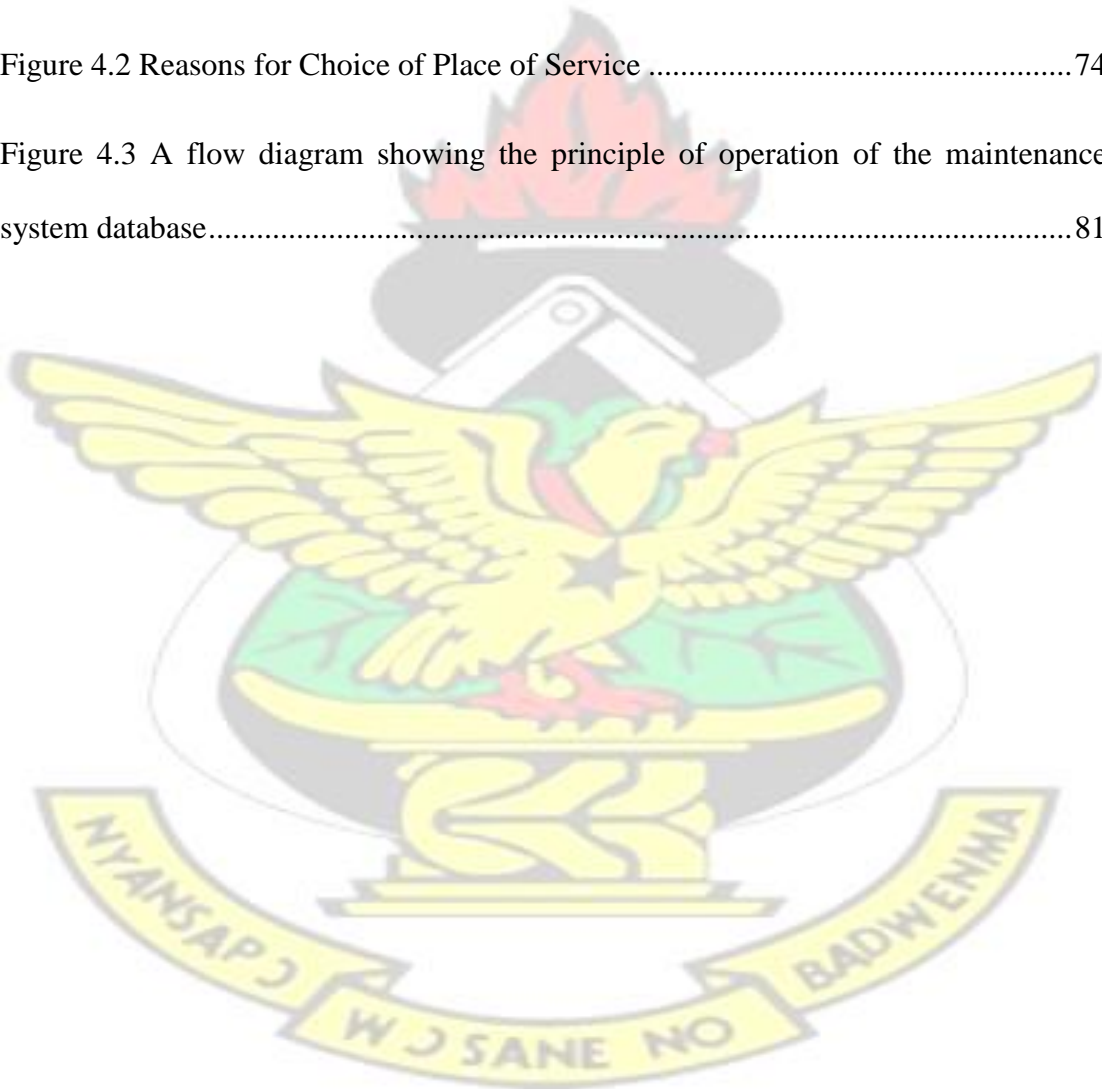
Figure 2.23 Transmission output shaft seal after removing output flange45

Figure 2.24 ECAT block diagram.....48

Figure 4. 1 Trend of ATD Cars Sold from 2007 to 201665

Figure 4.2 Reasons for Choice of Place of Service74

Figure 4.3 A flow diagram showing the principle of operation of the maintenance system database.....81



LIST OF ACRONYMS

Acronyms	Meaning
ATD	Automatic Transmission drive
ATF	Automatic Transmission Fluid
ASE	Automotive Service Excellence
MSD	Maintenance System Database
MTD	Manual Transmission Drive
MySQL	Structured Query Language (SQL)
GM	General Motors
KNUST	Kwame Nkrumah University of Science and Technology
SAE	Society of Automotive Engineers
SUV	Sports Utility Vehicles
PCM	Power Control Modules
PHP	Hypertext Preprocessor
TCM	Transmission Control Modules
ECAT	Electronic Controlled Automatic Transmissions
ECU	Engine Control Unit
CVT	Continuously Variable Transmission
TCC	Torque Converter Clutch

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

An automobile may be defined as a driven vehicle predominantly powered by an internal combustion engine that is used in carrying persons and items from one destination to another. Automobile includes motorcycles, tricycles, trucks, buses, vans, coaches, among others (Akayeti, 2014). When a mechanical device is said to be maintained, the notion is to keep it in a good and efficient state. Vehicle maintenance consists of a practice where an automobile is serviced on a consistent basis to avert a major breakdown. It implies that an automobile vehicle will last longer and function very well if the user follows the vehicle maintenance schedule recommended by the manufacturer (Akinola, 2005). The indigenous automobile repair and maintenance garages in Ghana have played a major role in the socio-economic development of the country, and they can become an important contributor to the development of the country by adding value to the economy (Lee, 2011). According to Santini and Van Gelder (2017), modern vehicles are equipped with complex, computer-controlled electrical systems while older vehicles function with simple wiring and no electric components. The improved complexity and expanded variety of makes and models have created a need for timely access to relevant, complete, and accurate information in order to carry out maintenance, diagnosis and repair activities.

Maintenance management is gradually moving away from the traditional skill-based management discipline which depended on experience, guts and luck, to a more modernized form and the use of sophisticated and complex machine and equipment (Mahesh and Ram, 2010). Technology keeps advancing and changes to technological

equipment of which automobiles are no exemption occur from one stage to another. Technological developments in the automobile industry have led to modification of vehicles systems, thus making its use very easy; such vehicle system is the transmission system which drives these vehicles today (Amjad, et al., 2010).

Motor vehicle transmission fundamentally transfers the power from an engine to road wheels through the drive shaft. In simple terms, the transmission uses different gear sizes to give the engine a mechanical advantage over the driving wheels. The transmission must multiply engine torque to get the vehicle moving. It does this by reducing speed to increase torque (Crolla and Mashadi, 2011). Power transmission in an automobile could be of the manual type, automatic type, semi-automatic type, or continually variable type. A very common norm for categorizing vehicles is the transmission system they employ, hence the reference to manual or automatic transmission vehicles (Mashadi, 2012).

An automatic transmission, also called automatic gear box is a type of motor vehicle transmission that can automatically change gear ratios as the vehicle moves, thereby freeing the driver from having to move a lever to select gears manually when driving the vehicle (Halderman, 2014). An automatic transmission is easy to drive because of the automatic shifting of gear ratios by electronic and hydraulic sensory systems hence making driving easier since there is no clutch pedal as compared to the manual which requires the driver's attention on the clutch pedal and gear selection when driving. According to an online automotive research company (Edmunds.com), only seven percent (7%) manual transmission of new cars were sold at the beginning of 2012. As of August 2013, only 3.9 percent of new cars sold for the year had manual transmissions, a show of a decline in the sale of manual transmission vehicles, reasons for which could be attributed to customer preferences over the years (Lachnit, 2013).

Using an automatic transmission car in Ghana goes with a lot of challenges, in terms of maintenance and other services that will keep the vehicle moving. Ghanaian technicians fall short of the requisite knowledge, skills and tools needed to carry out the manufacturer recommended maintenance work on automatic transmission drive. This situation can be attributed to the fact that a high number of technicians have little knowledge on the repair and maintenance of these vehicles (Gopalakrishnam & Banerji, 2013). As a result, maintaining such vehicles and their associated costs is often higher as compared to manual vehicles. Ghana has no comprehensive automobile manufacturing industry and thus imports almost of her vehicles. Used vehicles constitute almost 70 percent of the vehicles imported into the country with a high number of them being automatic transmission drives (Akayeti, 2014). Although automatic transmission vehicles come with a numerous treaty of user convenience, their proliferation in a country hitherto dominated by manual transmission cars needs careful assessment. Potential issues regarding the availability of skilled mechanics, energy efficiency, capital cost, maintenance and repair of automatic vehicles need to be addressed.

1.2 Problem Statement

The automobile industry in Ghana in recent years is progressively experiencing an apparent increase in the number of automatic transmission vehicles. In spite of the number of automatic cars imported into the country, only few standard auto service workshops (dealers) such as Toyota Ghana Company Limited, Japan Motors Company Limited, Rana Motors and Mechanical Lloyd, among few others are capable of offering quality maintenance and repairs for these cars. The increase in automatic transmission vehicle population calls for an increase in the number of service garages which provide maintenance services to these cars. Vehicular repairs have become increasingly

sophisticated; new equipment, software and techniques are needed to determine the root causes of failure for many components in modern vehicles. Automobile maintenance practitioners in developing countries like Ghana are not well equipped with the skill and knowledge in repairing faults associated with automatic transmission drives and do have limited means of enhancing their servicing capabilities. It is prudent to investigate the challenges associated with the maintenance of automatic transmission drives in Ghana to help local mechanics as well as the users of these vehicles in servicing them.

1.3 Research Objective

The main objective of this work is to investigate the level of expertise of traditional automobile maintenance practitioners in servicing automatic transmission drives.

The Specific Objectives

1. To ascertain the extent of patronage of automatic transmission drives and the challenges associated with them.
2. To establish the level of expertise of the wayside mechanics in servicing of automatic transmission drives.
3. To design automatic transmission drive maintenance system database in order to enhance the servicing capabilities of the wayside mechanics.

1.4 Significance of the Study

This study could be significant in helping to reduce the “trial and error” system that has been adopted by many wayside mechanics with the help of the maintenance system database. This study could benefit users of automatic transmission drives so as to prevent frequent breakdowns. Data gathered from this research will reveal evidence to

support the suspicion that the number of automatic transmission vehicles are growing steadily since Ghana depends on vehicles manufactured by developed countries. The results would provide reliable scientific measure in assessing the level of performance of wayside mechanics as well as peculiar challenges associated with the use of automatic transmission vehicles. The study will also design a maintenance system database for possible causes and remedies to compliment the knowledge and expertise of mechanics servicing automatic transmission drives.

This research will provide information to stakeholders such as investors, pressure groups, and consumer associations to enable them offer useful suggestions towards improving the performance of the automobile servicing industry in the country.

1.5 Scope of the Study

The study focuses on automatic transmission cars in Ghana. The research focused on the extent of patronage of automatic transmission cars, the expertise and equipment required in servicing, and the peculiar challenges associated with the use of automatic transmission cars in Ghana. Data collection was limited to the Accra, Tema, Takoradi and Kumasi metropolitan areas of Ghana.

1.6 Organization of the Study

The thesis is organized into five Chapters. Chapter one comprises the background of the study, the problem statement, research objectives, significance of the study, the scope, and organization of the study. Chapter two is the literature review that provides the theoretical background support for the study. Thus, it reviews pertinent literature covering important aspects of the study. Chapter three focuses on the research methodology used to conduct the study. This comprises the research design, approaches adopted, sampling selection procedure, preparation and distribution of questionnaires.

Chapter four presents the results and discussion of findings and the design of a database. Finally, Chapter five summarizes the key findings of the study, draws conclusions from the findings and offers recommendations for further improvement and study.

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CHAPTER TWO

LITERATURE REVIEW

This chapter provides overview information about transmissions as well as detailed introduction to operating principles of transmission systems in automobiles. It comprises a brief history of manual and automatic transmissions in vehicles, trends in vehicle maintenance, information on the types and components of automatic transmission systems as well as peculiar challenges associated with the use of automatic transmission. A review of works done by other researchers on the same or similar topics are also discussed.

2.1 Global Historical Development of Automatic Transmissions

The history of automobile begins with the technological revolutions that happened in Europe throughout the early 1800's and continued a century later with the groundbreaking efforts of American auto-makers who started mass-production of cars (Hounshel, 1984).

The first cars to be power-driven by internal combustion engine running on fuel gas started in 1806, see figure 2.1 and by the late 19th century, the modern petrol-fueled or gasoline internal combustion engine emerged (Eckermann, 2001).



Figure 2.1: The First Car with an Internal Combustion Engine.

The origin of automatic transmission dates back to 1894, when the contemporary automatic transmission was introduced by two French engineers, “Louis-Rene Panhard and Emile Levassor”. Ten years down the line, the idea was improved by Massachusetts the Sturtevant brothers, in Boston. It delivered two forward speeds automatic transmission that were engaged and disengaged by the achievement of centrifugal weights devoid of a foot-operated clutch. With increasing engine speed, the weights swung out to engage the bands-first, the low-speed band and then the high-speed band. The device often failed without warning due to the stress of changing gear ratios (Motorera.com, 2010).

The concern of the inventors of automobile was more of producing a basic self-propelled vehicle than anything else. As practical mechanics and engineers, their concern was on the mechanical problems of adapting an engine to a personal means of transportation. (Motorera.com, 2010).

The most important development in automatic transmission occurred in 1908 with the introduction of Henry Ford's outstanding Model T. Aside being cheap and reliable by the standards of the day, the Model T was built-in a simple, two speed plus reverse planetary transmission whose operation was manually controlled by the driver using pedals. This type of transmission did not require more of the driver's skills like the modern, unsynchronized manual transmission, but still important that the driver realizes when to make a shift, and be able to take-off smoothly (Madison, 2014).

The first semi-automatic transmission was introduced in 1937 by General Motors (GM), which they named and promoted as the “Automatic Safety Transmission” (AST). The AST had four forward speeds and used a planetary gear set and a friction clutch. Oldsmobile also came out with a four-speed semi-automatic transmission also called the "Automatic Safety Transmission" (AST) that same year, (Soto & Sweat, 2016). In

1939, a newly designed version of the AST developed by both General Motors' Cadillac and Oldsmobile divisions called the Hydramatic (Hydra-Matic) became famous. The Hydramatic automatic transmission was introduced in the 1940 model year vehicles, the Hydramatic was the first fully automatic mass produced transmission developed for passenger automobile use. The Hydra-Matic consisted of three planetary gear sets that were operated hydraulically to produce four forward speeds plus reverse. A fluid coupling was used to connect the engine and transmission. These two companies claimed that the Hydra-Matic transmission increased fuel economy by 10 – 15% over a standard transmission. The Hydramatic transmission established the foundation from which future automatic transmissions would be designed and built (Soto & Sweat, 2016).

In 1948, the automatic transmission had advanced into the hydraulic torque converter that is known today, coupled to a planetary gear train. The first vehicle manufacturers to use the converter was Buick. Other companies soon followed suit with similar design like Chevrolet Powerglide, Fordomatic and Merc-O-Matic in 1950 and the Chrysler M-6 Torque Converter Automatic in 1951.

General Motors introduced the "Jetaway" Hydra-Matic, in 1956, which was different in design compared to the older model. This model addressed the issue of shift quality, which was an ongoing problem with the older versions of the Hydra-Matic, the new transmission utilized two fluid couplings, the primary one that linked the transmission to the engine, and a secondary one that replaced the clutch assembly that controlled the forward gear set in the older model. In the early 1980s, the three-speed units with torque converters were being supported and gradually replaced by overdrive-equipped transmissions providing four or more forward speeds. Many automakers also adopted the lock-up torque converter to improve fuel economy (Soto & Sweat, 2016).

As technology advanced, Engine Control Units (ECUs) became more capable, much of the logic built into the transmission valve body was offloaded to the ECU. In addition to the ECU'S, manufacturers used a different computer controlled transmission called Transmission Control Unit (TCU), also known as the Transmission Controlled Module (TCM), which shares information with the engine management computer. In this case, solenoids in the transmission are turned on and off by the computer controlled shift patterns and gear ratios, rather than the spring-loaded valves in the valve body. The use of solenoids allows for more accurate control of shift points, shift quality, lower shift times (Tenberge, 2015)

Current developments in the automatic transmission system led to the development of the first six-speed (the ZF 6HP26 in the 2002 BMW E65 7-Series) by both ZF Friedrichshafen and BMW. Mercedes-Benz also introduced the first seven-speed in 2003 called 7G-Tronic. Toyota was the first to introduce an eight-speed in 2007 on the Lexus LS 460 (Soto & Sweat, 2016). Mercedes-Benz later developed the 7G-Tronic and released a semi-automatic transmission with the torque converter replaced with a wet multi clutch called the AMG SPEEDSHIFT MCT.

In 2014, Jeep released the world's first nine-speed automatic transmission for passenger vehicles in its 2014 model Jeep Cherokee (Soto & Sweat, 2016).

It is projected that over 100,000 charters created the modern automobile (Dietlin, 2011). Earlier vehicles were predominantly equipped with manual transmissions. However, automatic transmission started to be used on a large scale in the early 1950s, and now about 85% of North American vehicles are also equipped with this transmission (Halderman, 2014).

2.2 Automatic Transmissions in Vehicles

According to Ben-Ari (2008), a transmission is any mechanism connected to the back of an engine that transfers the power developed by the engine of an automobile to the driving wheels or provides an appropriate variation of the engine torque at the road wheels, whenever required.

The transmission permits the vehicle to travel forward and reverse while the engine only rotates in one direction. It also allows the vehicle to travel at widely different speeds even though the engine has a narrow range of rotational speeds, (Sobey, 2009), In this process, a number of gears that are fixed at the back of the engine play essential part (Jha, et al., 2013). In addition to providing a collection of gear ratios to meet different driving conditions, the gearbox must provide a stable neutral and a reverse gear (Bonnick & Newbold, 2011).

The main function of the transmission is to provide the necessary variation to the torque applied by the engine to the wheels. This is achieved by changing the gearing ratio between the engine output shaft and the drive shaft (Jain & Asthana, 2002). The transmission is connected to the engine through the clutch. The input shaft of the transmission therefore turns at the same rpm as the engine. The transmission is connected to the engine through the clutch as shown in figure 2.2

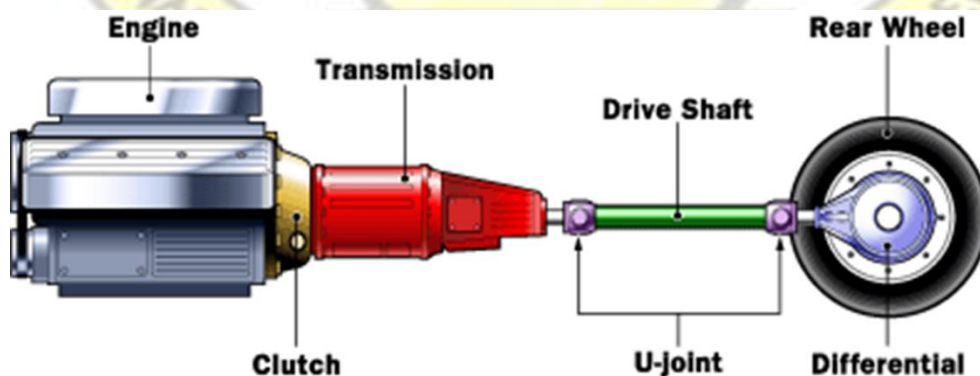


Figure 2.2 Transmission system for a rear wheel drive vehicle (Source: Howstuffworks, 2002)

2.3 Trends in Vehicle Maintenance

As with all mechanical systems, vehicles cannot remain new forever. A constant use of vehicles results in their general wear, tear and breakdowns; and as the parts breakdown and wear out, so must they be maintained. When a vehicle is maintained, the notion is to keep it in a good and useful state. Vehicle maintenance denotes a practice where an automobile is tuned-up on a set time interval or when the vehicle has travelled a certain distance to prevent a major breakdown or the need for major repair (Micheal, 2014).

According to Santini & Van Gelder (2017), vehicle and customer information from different sources provide the basic knowledge required to conduct repair and servicing. The skill to properly service a vehicle is dependent on the mechanic's ability to study and apply technical information. The current development of vehicle services consequently call for the use of more complex and highly technological specialty diagnostic equipment to examine vehicle faults for repair and service. To ensure this for efficiency, safety, comfort, reliability and so on, skilled professional hands are required. As technology keeps advancing and changes to technological equipment of which automobile are no exception take place, the problems facing automobile garages in Ghana have rather compounded. At present, a large percentage of the auto mechanics, both the skilled and trainees, of the local garages in the country find it very difficult to diagnose and maintain up-to-date cars (Micheal, 2014).

According to studies done by automobile manufacturers, about 30% of vehicles can be repaired following the information, suggestions, or guidelines concerning replacement parts found in a technical service bulletin (TSB), (Halderman, 2014). Before a specific search of a TSB can be done, the technician must know the following information about the vehicle under service:

- Make, model, and year of the vehicle
- Engine size and VIN
- Transmission type
- Federal, high-altitude, or California emissions
- Current hard codes
- History or soft codes
- CM/TCM part number for applicable module flash, (Halderman, 2014)

Without these input information, the technician cannot access the information that will help with the repairs. Unfortunately most technicians in Ghana fall in this category – thus vehicles with problems cannot be professionally and efficiently repaired

2.4 Types of transmissions

Transmission systems can be divided into three different types which are manual transmission, automatic transmission and continuously variable transmission (Hedman, 2011).

2.4.1 Manual transmissions

According to Akple et al. (2013), the simplest and oldest type of transmission still in use is the predictable manual transmission system which consists of a set of gears which are in mesh when transmitting power (figure 2.3). Manual transmission requires frequent shifts between gears. It also requires engaging and disengaging a clutch while shifting gears. Manual transmission mechanism is important since it is used in various vehicles. The mechanism varies a little between various types of vehicles, but all follow the same ideas. Manual transmissions have a total mechanical efficiency of 96.2%, which is the utmost efficiency value for any type of transmission (Kulkarni, et al., 2006).

Manual transmissions feature a movable gear selector and clutch. A driver changes gears by depressing a clutch (to uncouple the engine from the transmission) and then shifting gears with a gear shift lever, most often mounted in the floor to the right of the driver. Each location of the gear shift lever engages a pair of gears that provide a different gear ratio. Each ratio drives the wheels at a different speed for the same engine speed. The clutch is a connection device that is used to connect the engine and the gear box (Sobey, 2009). The clutch allows the engine to continue working when one is waiting in traffic. The clutch helps in changing the gear while the engine is running with the crank spinning uninterrupted (Haridas, 2007). The two basic types of manual gear change are sliding-gear type and the constant-mesh

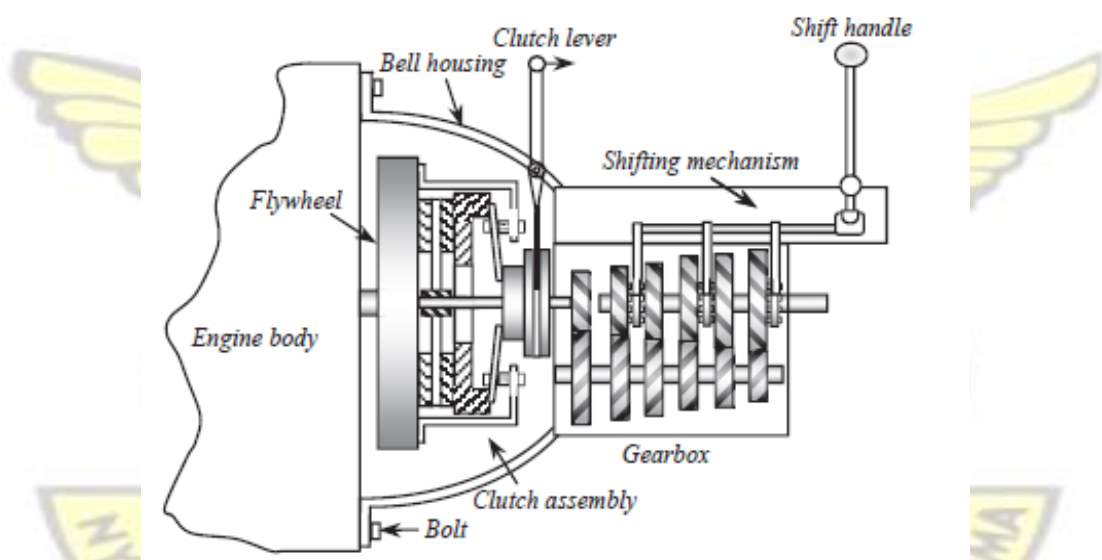


Figure 2.3 Manual Transmission Assembly

Source: (Crolla & Mashadi, 2011)

2.4.1.1 Sliding-gear type

These types of transmissions are normally found on old model cars. With the sliding-gear type, only the main drive gear and cluster gear move, nothing else is moving inside

the transmission once the transmission is in neutral (Brain, 2016). Gear meshing takes place by the sliding of gears on each other, i.e. axially along the splined main shaft to mesh with the corresponding gears on the lay-shaft with in-line input and output shafts as shown in figure 2.4 (Jain & Asthana, 2006).

To power the wheels, the driver must press the clutch pedal and change the gear lever in order to mesh the gears and apply engine power to move the vehicle. The movement of the gear lever moves the shift linkage and forks to slide a gear along the main shaft, which is mounted directly above the cluster. The clutch pedal is free and the engine's power is directed to the drive wheels, after the two gears are meshed. Since gear shifting is realized by sliding the gears on the main shaft, the transmission shift linkage is intended to unmesh one gear before being able to mesh another due to the numerous gears on the main shaft of different diameters and tooth number. Gear clash may occur because the gears are all rotating at different speeds with these transmissions. Due to gear grinding or clashing during engagement, this type of transmission is no longer in use (Cook, 2009).

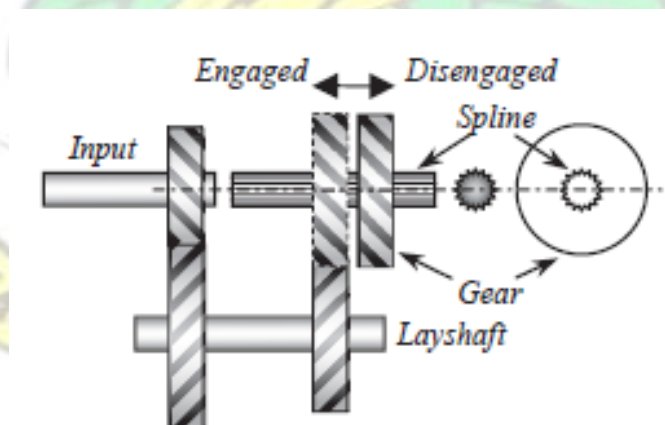


Figure 2.4 SLiding Mesh

Source: (Crolla & Mashadi, 2011)

2.4.1.2 Constant-mesh type (Synchro – Mesh)

In modern transmissions and transaxles, all forward gears are synchronized.

The constant mesh, known as synchronized transmissions, overcomes the difficulty of gear clashing in the sliding mesh manual transmission (Bonnick & Newbold, 2011).

It is a fully "synchronized" manual transmission equipped with synchronizers. It brings components that are rotating at different speeds to one synchronized speed and ensures that the pinion shaft and the speed gear are rotating at the same speed by locking these components together to prevent clashing (i.e. the drive gear, cluster gear and mainshaft gears) or grinding while shifting. Reverse gear is not usually fitted with a synchronizer and wear on the teeth of the reduction gears are reduced, (Erjavec, 2010).

Figure 2.5 shows a schematic diagram of a constant mesh manual transmission. The two opposing gears are in constant mesh with this type but the gear on the output shaft has a hole in the centre and is not connected to the shaft and no torque is delivered between the two. The power transfer is done through a sliding collar with a spline in its core and dog teeth over its sides. The collar is always turning with the output shaft through the splines and when it is shifted to the side, its dog teeth fit into the matching teeth on the side of the gear and the shaft, collar and gear connect to each other and power is transferred, (Crolla & Mashadi, 2011).

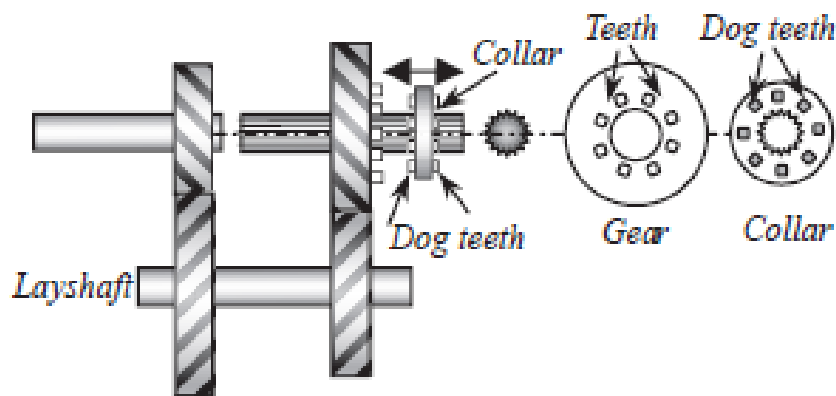


Figure 2.5 Constant mesh,
Source: (Crolla & Mashadi, 2011)

2.4.2 Automatic transmission

In order to enhance driving performance, lessen emissions, and improve fuel economy, the automotive manufacturers for power train systems introduced the automatic transmission system knowing that transmission plays an important role in performance. The basic function of any type of automotive transmission is to transfer the engine torque to the vehicle with the desired ratio smoothly and efficiently (Sun & Hebbale, 2005).

The basic automatic transmission (as shown in Figure 2.6) consists of a stylish hydraulic–mechanical system integrating a torque converter in place of the clutch. A system of planetary (epicyclic) gears delivers the various forward and reverse ratios (Gilles, 2012).

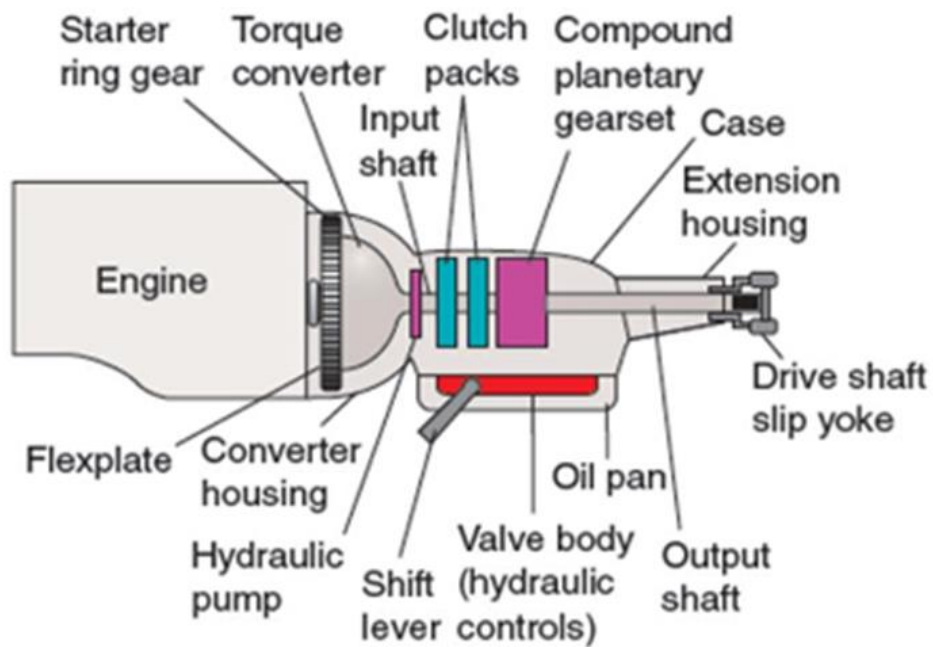
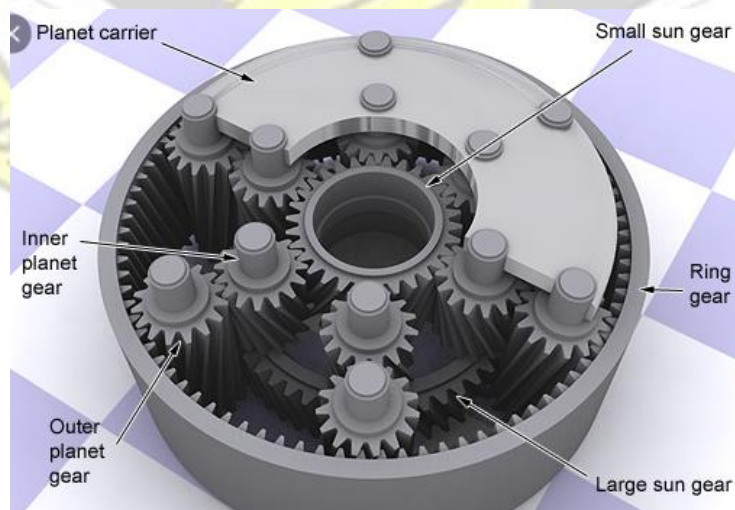


Figure 2.6 Basic automatic transmission Source –
Source: (Gilles, 2012)

In the automatic transmission, the gear set is the same as those in a manual transmission box, however, a vacuum cylinder or a hydraulic cylinder is used to perform automatic gear shifting. The automatic transmission system for current automobiles uses a planetary gearset as shown in the figure 2.7 instead of the traditional manual transmission gear set.



The whole system is controlled by means of an advanced mechanism of valves supplying pressurized oil to brake bands and clutches for engagement of the right gears. Such systems worked well and were fully accepted by motor manufacturers before the revolution in microelectronics which brought in sophisticated engine management systems. The additional degrees of freedom provided by electronic control have permitted the shift processes to be optimized and have given rise to improvements in the operation and efficiency of automatic gearboxes (Gilles, 2012). The planetary gear set spin centrifugally and can generate different gear ratios including, the ratio of the angular velocity of the input gear to that of the output gear including reverse gear without engaging or disengaging the gear set.

Automatic transmission cars do not have clutch pedals, a driver does not need to operate a clutch to change gears and the car can be brought to a halt without changing to a neutral gear. Automatic gearboxes are commonly built-in with a torque converter as a replacement for a clutch. The simple fluid flywheel is not normally used now but the new refined torque converter offers a way for separating the engine from the gearbox which does not need driver operation. The torque converter re-engages the engine to the gearbox, permitting the vehicle to take off or come to rest in a manner devoid of the driver doing anything except pressing the accelerator or brakes (Hillier & Coombes, 2004).

Early automatic gearboxes developed have three or four forward speed units and reverse but current vehicles vary from four to eight gears with the five and six-speed units being the most common (Erjavec, 2010). As a substitute for a gearstick, the driver moves a lever called a selector. Some automatic gearboxes have selector positions for “park”, “neutral”, “reverse”, “drive”, “2” and “1” (or “3”, “2” and “1” in some cases) as shown in figure 2.9. Others just have drive, park and reverse. The engine will only

start if the selector is in either the “park” or “neutral” position due to an incorporated inhibitor switch for safety reasons.



Figure 2.9 Automatic Gearstick

Source: (carsut.com)



The pre-defined gear ratios are as follows:

In park, the output shaft is locked to the case of the transmission so that the drive wheels cannot move. To avert sudden movement of the vehicle, the selector cannot be moved from park to drive with the engine running unless the brake pedal has been pressed with most vehicles (Denton, 2012). The reverse gear selector position is used to move the vehicle in reverse. Reverse usually uses a lower gear ratio than any of the forward gears. In the **neutral** position no torque is being transmitted through the automatic transmission. In this position the engine can be started by the driver.

The **Drive (D)** position involves the overdrive ratios in automatic transmission vehicles. If there is an overdrive shift mode, however, then D is used to provide all forward gears except overdrive. This position is used when driving in hilly areas or when towing a vehicle equipped with an overdrive selection. In **third (3) position**, the transmission will upshift normally to third gear but will not upshift to the fourth gear, which means no matter how hard one presses the pedal; the transmission will not change to fourth gear. When the third (3) position is selected while driving in a higher gear, the transmission will downshift into third if the vehicle speed is low enough to prevent the engine from being over-revved. This gear selection is used for the gentle grades at a moderate vehicle speed.

With **second (2) or D2 or S**, the car will start to run in first gear but will simply confine up to the second gear. It is very convenient when driving up hill or driving in hostile situations. It is also useful to increase the engine braking effect while descending a hill. In this case, the vehicle speed is controlled and the engine speed is increased to provide engine compression braking. This gear selection is used for the gentle grades at a moderate vehicle speed.

The **first (or low) or D1 or L** position specifies that the car will only run in first gear. In this gear selection, the vehicle speed is controlled and the engine speed is increased to provide engine compression braking. This gear selection is used for the sharpest hill at the lowest possible speed (Halderman, 2012). The **Overdrive (OD)** is only available in some cars. The overdrive gear is normally the highest gear, this gear causes the output shaft to run faster than the input shaft which would make the engine run at a low speed to achieve a better fuel economy, lower emission levels and reduce fuel consumption.

The overdrive can be fixed to the outside of the gearbox or, as is the case in the current automatic gearboxes developed, it can be combined as a fifth gear in the standard four-speed gearbox.

The epicyclic type of overdrive is operated by hydraulic pressure in the control of a solenoid, which is triggered by a switch near the control column. This type of overdrive typically operates in the higher gears at speeds above 30 mph, an inhibitor switch is set to prevent engagement of lower speeds. The input shaft to the overdrive operates an oil pump that generates the oil pressure required to move the cone clutch to the overdrive, or direct drive position. In the internal type of overdrive the fifth gear and its synchromesh are housed at the end of the mainshaft, as shown in Figure 2.8 (Bonnick & Newbold, 2011)

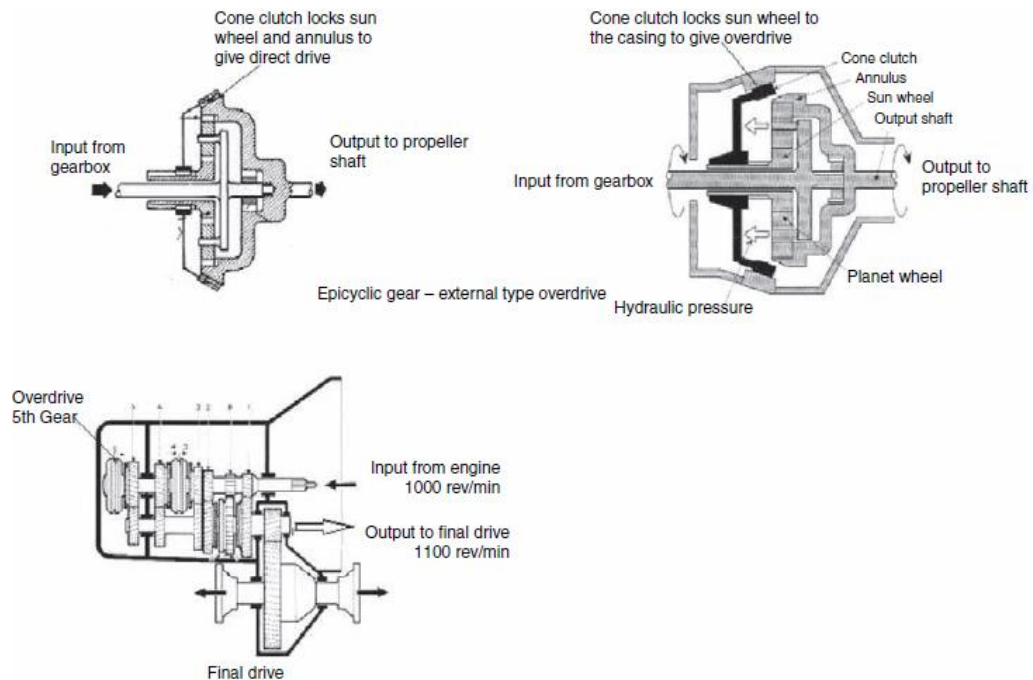


Figure 2.8 Epicyclic Gear – External Type Overdrive

Source: (Bonnick & Newbold, 2011)

The modern automatic transmission is one of the most complicated mechanical components in today's automobile. Automatic transmissions contain mechanical systems, hydraulic systems, electrical systems and computer controls, all working together in harmony. Its complexity is virtually unnoticed until there is a problem (Xiangyang, et al., 2018).

2.4.2.1 Automatic Transmission Arrangement

The output from the gearbox is at the end transferred to the final drive and differential gear before passing to the road wheels and the type of drive has an important consequence on control, comfort, economy, safety and space available as well as influencing the design of the transmission, both with front-wheel and rear-wheel and with four-wheel drives.

The prevailing technology for road cars is currently driving the front wheels or a standard drive. Rear-wheel drive used to be common but is now used mainly in sports cars. Four-wheel drive instead is decisively incorporated in new designs. Nearly every single model series now comprises a four-wheel drive model

(Naunheimer, et al., 2010).

There are fundamentally two arrangements of automatic transmission systems. These are rear and front wheel drive arrangements. On the front wheel drive, the transmission (gear box) may be joined with the differential unit to form one component called the transaxle. The engine is connected to the torque converter and then to the transaxle. This is shown in Figure 2.10A. In the rear wheel drive the engine is mounted on the front part of the vehicle and connected to the torque converter and then to the transmission box. Power is transmitted to the rear wheel via a shaft mounted on the transmission. This is also illustrated in Figure 2.10B. Also, these two options can be combined to produce a four wheel drive. In the four wheel drive, the engine is in the front part of the vehicle and power is then transmitted to both rear and front wheels through shafts mounted on the transmission. The transfer case placed after the transmission box sends power to the front wheel. This is also illustrated in Figure 2.10C

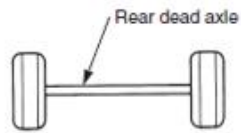
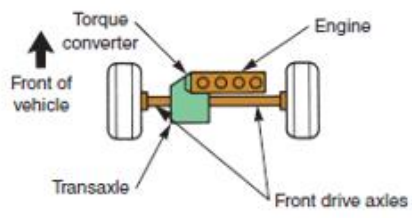


Figure 2.10A

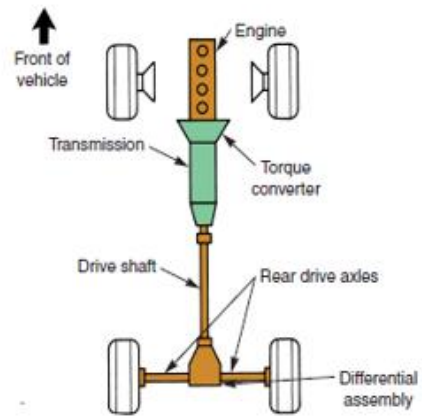


Figure 2.10B

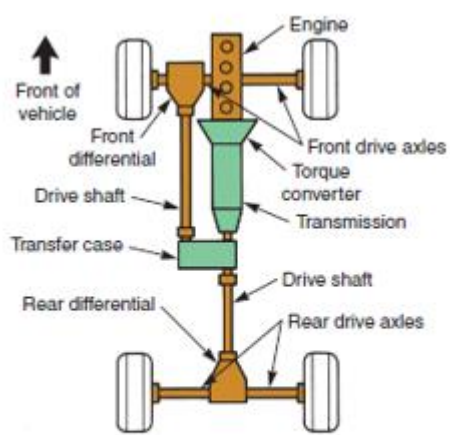


Figure 2.10C

Figure 2.10 Automatic Transmission Arrangement

2.4.3 Parts of an Automatic Transmission

The major parts of an automatic transmission system are the torque converter, planetary gear system, the wet clutches and the brake bands

2.4.3.1 Torque Converter

According to Hillier et al, (2004), a torque converter is standard in automatic transmissions of all types and basically replaces the clutch. It changes a high speed or low torque input from the engine into high torque or low speed output to drive the transmission and as a result allows the smooth take-up of the vehicle from rest. In addition, due to the ‘slip’ influence, it substantially multiplies the number of gear ratios accessible by efficiently interpolating amongst each fixed gear ratio.

A torque converter is mostly a divergent pump turbine unit, confined in a casing in some measure filled with hydraulic oil (Gilles, 2012). The torque converter provides an automatic means of connecting the engine torque to the input shaft of the transmission. It comprises a rotary pump or impeller, stators, and an energetic circular turbine (figure 2.11) (Erjavec, 2010).

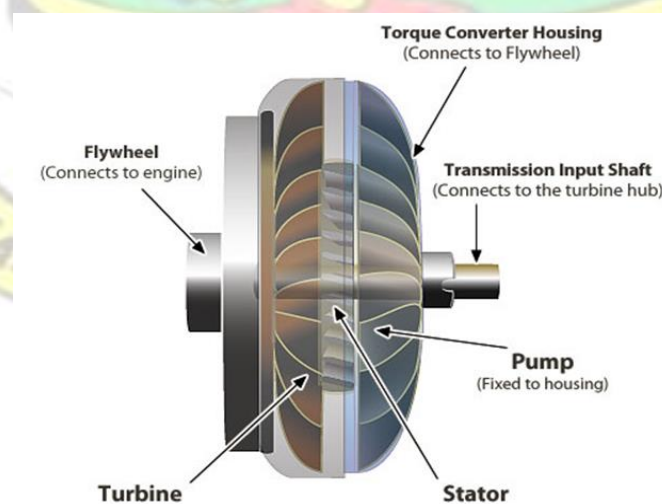


Figure 2.11 Torque converter parts

Source: (Erjavec, 2010)

The torque converter looks like a large doughnut sliced in half. One half, called the pump impeller, is bolted to the drive plate or flywheel. The other half, called the turbine, is connected to the gearbox input shaft. Each half is lined with vanes or blades. The pump and the turbine face each other in a case filled with oil (Denton, 2012).

The stator is located in-between the pump and the turbine (figure 2.12), facing each other in a casing filled with oil. In short, the torque converter is a kind of fluid coupling, which permits the engine to spin to some extent independently of the transmission. It is liable for pressurizing automatic transmission fluid, a pressurization that supplies the force necessary to shift transmission gears. Hence a faulty torque converter can prevent transmission fluid from being accurately pressurized, which in turn negatively impacts transmission gear function and operation (Mister, 2017).

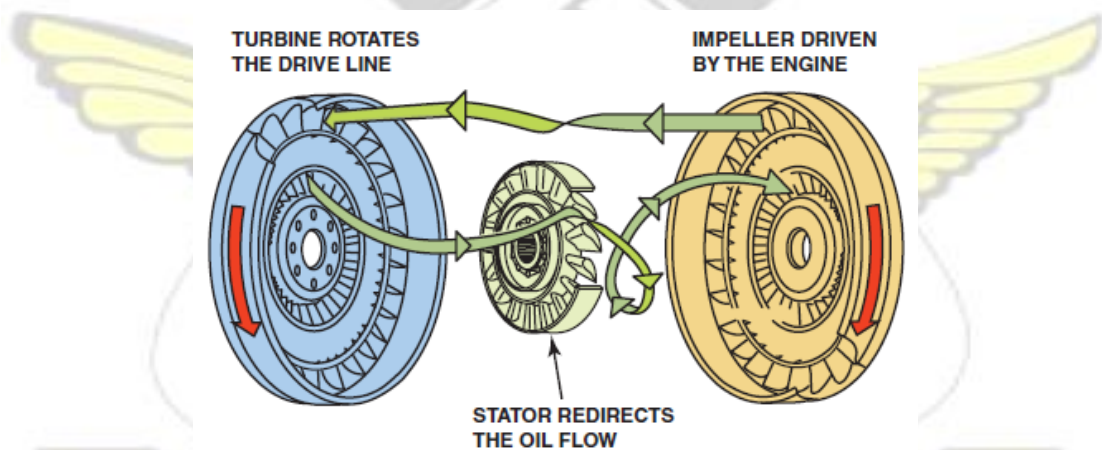


Figure 2.12 Stator Turbine Rotates

Source: (Halderman, 2012)

Torque converters are one-unit, welded and balanced assemblies that cannot be taken apart or simply refurbished (Figure 2.13). Though they can be restored using specialized equipment, most shops merely replace converters as a component if they fail (Halderman, 2012).

The faster the engine revolves, the higher the torque applied to the turbine. When the engine speed is low, the turbine can be held static as the force of the transmission fluids kinetic energy is too small to overcome the holding force of the brake system application (Fischer, et al., 2015)



Figure 2.13 Torque converter

Source: (Erjavec, 2010)

With an automatic transmission, a torque converter usually takes the place of a mechanical clutch in a vehicle, disconnecting the transmission from the engine. It is typically positioned between the engine's flex or drive plate and the transmission. With a manual transmission the drive plate replaces the flywheel, since the function of the flywheel is to reduce vibration and level out engine pulsation. The weight of the torque convertor provides sufficient mass to reduce engine vibration, hence automatic transmissions do not require flywheels as with manual transmission (Halderman, 2012).

2.4.3.1.1 Pump

The pump inside a torque converter is a type of centrifugal pump. It is also known as the impeller. It is the input drive member connected to the crankshaft powered by the

engine. As the impeller spins, fluid is flung to the outside. As fluid is flung to the outside, a vacuum is created that pulls more fluid in at the center. The fluid then goes into the blades of the turbine, which is connected to the transmission (Fijalkowski, 2011).

The impeller forms one core unit of the torque converter shell and has several curved blades that rotate as a unit with the shell. It drives at engine speed, acting similar to a pump to start the transmission oil circulating inside the torque converter shell.

The impeller is sited with its back facing the transmission housing, while the turbine is sited with its back to the engine. The curved blades of the turbine face the impeller assembly.

To help reduce oil turbulence between the turbine and impeller blades that would slow impeller speed, the turbine blades are designed to have a greater curve than the impeller blades and reduce the converter's efficiency (Erjavec, 2010).

2.4.1.2 Turbine

The **turbine** is the output (driven) member. It is splined to the transmission's turbine shaft. The **turbine** is placed on the engine side of the converter. The turbine looks like the impeller in construction, but has more blades and greater curvature. The direction of curvature of the turbine blades is opposite to that of the impeller blades. It is free to rotate in the housing, and the center hub has splines that mates with splines on the input shaft of the transmission (Santini & VanGelder, 2017). The impeller blades pick up fluid in the converter housing and sends it in the direction of the turbine, as shown in Figure 2.14. Fluid flow energises the turbine, and when the flow between the impeller and the turbine is sufficient, the turbine rotates and causes the transmission input shaft to spin which primarily causes the vehicle to move (Halderman, 2012).

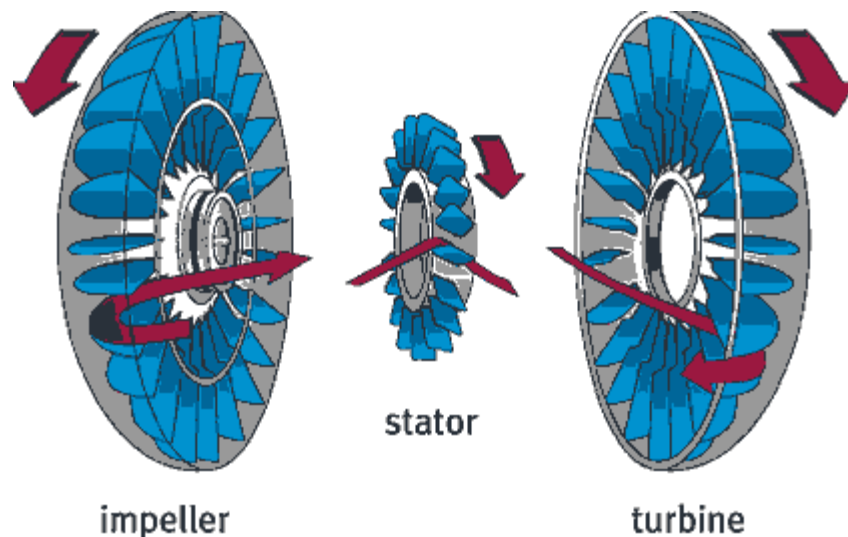


Figure 2.14 Torque Converter components

2.4.1.3 Stator

The **stator** is located at the center of the torque converter. To avoid power wasting by slowing down the engine, the stator redirects the transmission fluid returning from the turbine before it hits the impeller again as shown in figure 2.14. The side of the stator blade with the inward curve is the concave side while the side with an outward curve is the convex side.

The stator vanes changes the direction of oil flow after it has gone through the turbine and sends it back to the impeller. The stator has a very aggressive blade design that almost completely reverses the direction of the fluid. This enables the impeller to increase the twisting force (Erjavec, 2010).

To further aid in redirecting the oil flow, the stator rotates on a one-way roller clutch so that it is free to rotate in the engine direction but not in the opposite direction. This allows the stator to stay efficient when the turbine is turning, and not just when it is standing still. The re-direction of oil flow results in a real multiplication of the torque developed by the engine in the course of acceleration, particularly from a stop (Godfrey & Haynes, 1996).

2.4.4. Lockup Torque Converter

A lockup torque converter reduces the 10% slip that takes place between the impeller and turbine at the connection point. The engagement of a clutch between the impeller and the turbine assembly significantly improves fuel economy and reduces operational heat and the engine speed. The assembly of a lockup torque converter is typically called a *torque converter clutch (TCC)* which is shown in the figure 2.15 below.



Figure 2.15 Torque converter clutch (TCC).

(Source: freeasestudyguides.com)

Through the years, many different types of TCC systems have been used. The most common design is the electronically controlled lockup piston clutch. Clutch lockup systems can also be fully mechanical, centrifugally controlled, or dependent on a viscous coupling (Benford & Fodale, 1991).

2.4.5 Planetary Gear Set

The popularity of planetary gears is due to their advantages such as high power density, compactness, multiple and large compact gear ratios and load sharing among planets (Gawande, et al., 2014).

Almost all automatic transmissions depend on planetary gear sets to transfer power and multiply engine torque to the drive axle. Compound gear sets combine two simple planetary gear sets so load can be spread over a greater number of teeth for strength and also to obtain the largest number of gear ratios possible in a compact area.

A simple planetary gear set consists of three primary components.

1. Sun gear
2. Planet carrier (including planet pinion gears)
3. Ring (annulus) gear

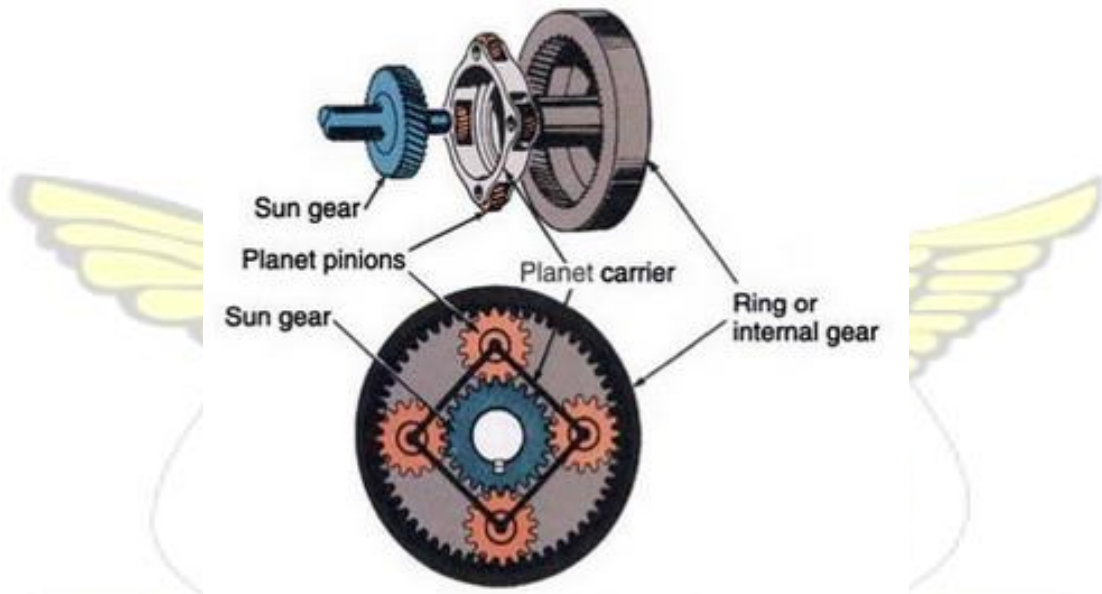


Figure 2.16 Planetary gear (Courtesy of General Motors Corporation)

The **sun gear** is located in the center of the assembly as shown in figure 2.16. It is either a spur or helical gear design. It meshes with the teeth of the planetary pinion gears. Planetary pinion gears are small gears fitted into a framework called the **planetary carrier**. For simplicity, planetary pinion gears are called **planetary pinions**,

Each member of a planetary gear set can rotate or be held at rest. Transmitting torque through a planetary gear set is only possible when a drive member is held at rest, or when two of the members are locked together.

Any one of the three members can be used as the driving or input member (Figure 2.15a,b&c). Simultaneously, another member might be kept from rotating and accordingly becomes the reaction, held, or stationary member.

The third member then becomes the driven or output member. Subject to which member is the driver, which is held, and which is driven, either a torque increase (underdrive) or a speed increase (overdrive) is produced by the planetary gear set. An example is with **figure 2.17a**. The maximum reduction can be achieved by using the sun gear as the input, holding the ring gear and using the planet Carrier as the output, with **figure 2.17b**. The reverse can also be achieved using the sun gear as the input, holding the planet Carrier and using the ring gear as the output with the diagram shown in **figure 2.17c**. Minimum reduction can be achieved using the ring gear as the input, holding the sun gear and using the planet Carrier as the output. Output direction can also be reversed through various combinations (Erjavec, 2010).

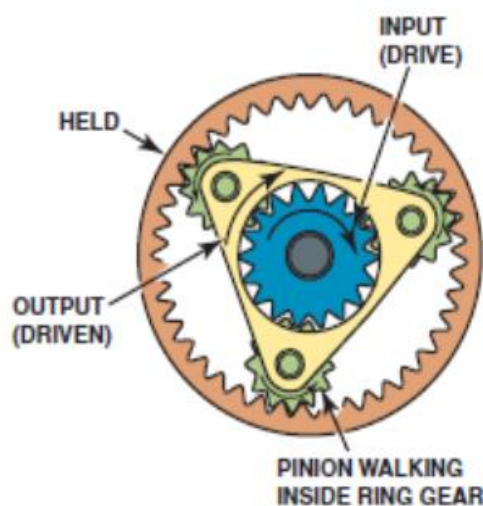


Figure 2.17a Holding the Ring Gear

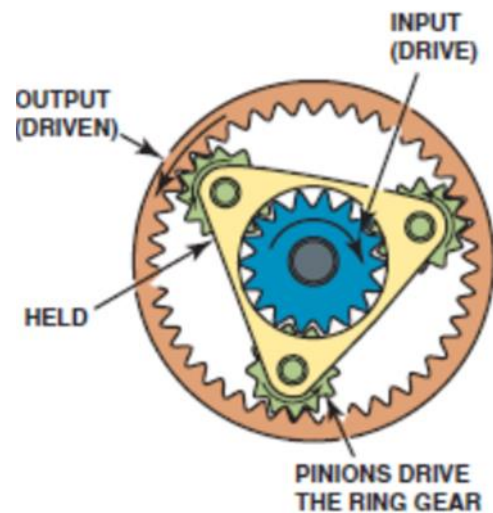


Figure 2.17b Holding Planet Carrier

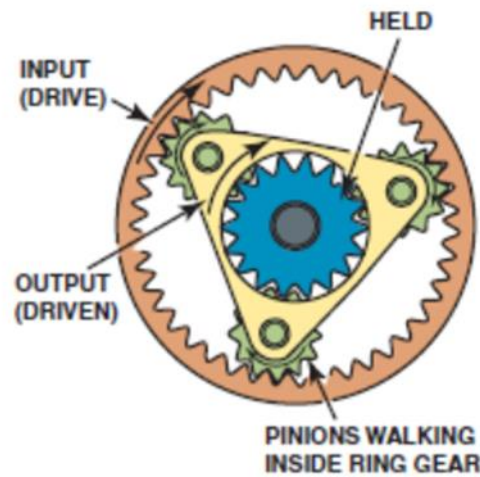


Figure 2.17c Holding the Sun Gear

Source: (Erjavec, 2010)

2.4.6 Band

A band is a braking assembly positioned around a stationary or rotating drum or carrier. The band brings a drum to a stop by wrapping itself around the drum and holding it. The band is hydraulically applied by a servo assembly. An element of the planetary gear train is connected to the drum. The purpose of a band is to hold an element of the planetary gear set by holding the drum and stationarily connecting the planetary gear element. The held planetary gear set element is known as a reaction element. Bands offer excellent retention properties and require a minimum of space within the gearbox housing. When a band closes around a rotating drum, wedging takes place. The wedge effect is known as a self-triggering action (Erjavec, 2010).

The bands used in automatic transmissions are rigid, flexible, single or double-wrapped. Single steel wrap bands (Figure 2.18) are used to hold gear trains driven by high-performance motors.

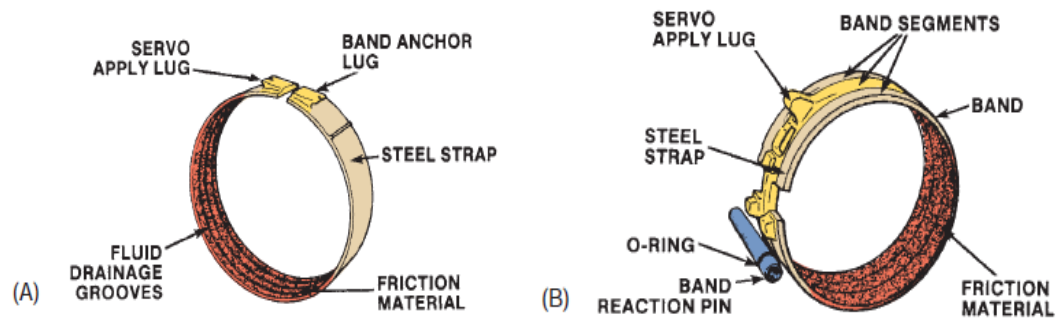


Figure 2.18 (A) Typical single wrap and (B) double wrap transmission band designs

The double wrap band is a circular exterior contracting band typically designed with two or three segments (**Figure 2.18B**). As the tape closes, the segments align around the drum to form a cushion. Bands may also be categorized as either flexible or fixed, depending on how well they hold their shape when they are off the drum.

State-of-the-art automatic transmissions use thin single or double wrap bands for increased efficiency. For high output engines double wrap bands made with heavy thick steel strapping are required (Erjavec & Pickerill, 2015).

2.4.7 Clutches

Power flow through a planetary gear set rests completely on what gear set members are the input or output and which member is held stationary. These actions are controlled by the driving and reaction members or devices (Erjavec & Pickerill, 2015).

Automatic transmissions change gears by applying clutches to hold or drive different elements of two or more planetary gear sets that provide different gear ratios, unlike manual transmissions. Transmission clutches are also capable of both holding and driving members, unlike a band, which can only hold a planetary gear member (Halderman, 2012).

In an automatic transmission operation, both sprag and roller overrunning clutches are used to hold or drive members of the planetary gear set. These clutches operate mechanically. An overrunning clutch allows rotation in only one direction and operates at all times. One-way overrunning clutches can be either roller-type or sprag-type clutches (Crolla & Mashadi, 2011).

2.5 Servicing of Automatic Transmission

Transmission maintenance is very significant to retain a vehicle running smoothly and effectively. It is made up of hundreds of multiparts that enable a vehicle to move.

The condition of an automatic transmission is less dependent on users driving style. Heat is an opponent of an automatic transmission. The transmission is cooled by the engines radiator also, so when the engine overheats, so does the transmission (Dahl, 2017). The customer's concern or complaint should be properly understood before diagnosing a transmission problem. The conditions that exist when the problem occurs must be known (Erjavec, 2010).

According to Hillier (2012), before carrying out any diagnosis with the automatic gearbox, it is recommended that the oil level and condition should be visually assessed, as this can give some good clues to various faults. For example, if the gearbox oil is dirty and the car is not changing gear smoothly or is slipping when changing gear, it is more likely that the oil contains particles of the clutch or brake bands due to wear of these frictional surfaces.

All automatic transmissions have a means of filtering the transmission fluid. Debris is continually produced during typical driving conditions (figure 2.19) and needs to be removed on a consistent basis.



Figure 2.19 Wear material in the bottom of an automatic transmission pan,

Source: (Halderman, 2014)

Removing the transmission's oil pan aids the mechanic to clean the inside of the pan where debris can settle as well as access filters. Beside with the filter, most modern transmissions have an additional method of trapping debris, a strong magnet in the bottom of the pan, as shown in figure 2.20 that can catch fine particles of metal, the magnet has to be cleaned by the mechanic when the transmission pan is removed (All State Transmission and Auto Repair, 2018).

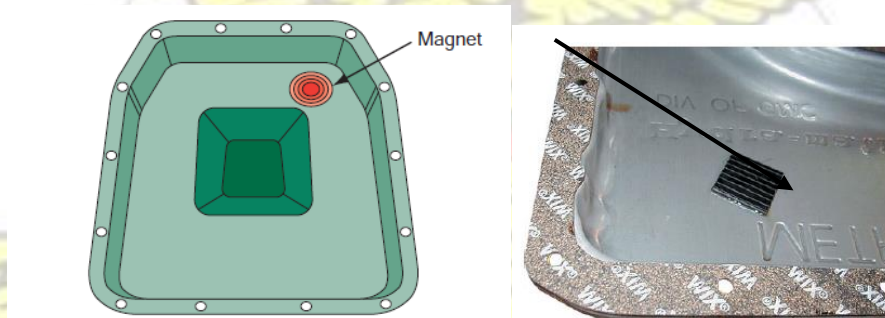


Figure 2.20 the magnet in the oil pan

Source: (Halderman, 2014)

Automatic transmissions require a fluid check and topping-up, if required, every 5000 km, and ought to be drained and refilled at some 40,000 km intervals. Cleanliness is essential with all hydraulic systems, any particle of cloth or deposit will block valve operation.

Owing to overheating complications the car must not be operated at full power beyond a few seconds with the converter turbine stalled. Strict safety measures are essential when power testing a car with automatic transmission in the workshop to prevent the possibility of an accidental gear engagement setting it in motion (Sully, 1988).

Preventative maintenance such as changing of transmission fluid and the transmission filter (when appropriate), replacement of pan gasket and a lift inspection, helps keep the transmission fluid clean and the transmission running smoothly. If the vehicle has an engine performance problem, the cause should be found and corrected before any conclusions on the transmission are made (Erjavec, 2010).

2.5.1 Visual Inspection

Diagnosis of transmission problems must begin with checking the level of the transmission fluid and condition, conducting a thorough visual inspection, checking the different linkage adjustments, repossessing all DTCs, and checking basic engine operation (Erjavec, 2010).

The visual inspection starts underneath the hood with a prompt check of the fluid level and condition. The check can be done with the engine running and the transmission in Park depending on the model, some can be checked in Neutral. Some are checked with the engine off, and a number of current model makes are not even fitted with a conventional dipstick, demanding special tooling and techniques to properly check fluid level. Usually, all models are checked with the transmission warmed up to operational temperature with some requiring a precise temperature range for perfect fluid measurement. Very low or high fluid level both can have a bearing on transmission performance. In both cases, the fluid can aerate in the pan, sending tiny bubbles throughout the hydraulic circuits (Meier, 2010).

2.5.2 Transmission Dipstick

According to Erjavec, (2010), a transmission dipstick is normally used to check the level of the fluid and to add ATF to the transmission. Other transmissions have a side plug on the pan or the transmission to check and replenish fluid level.

Checking an automatic transmission's fluid level requires four resources: access to the proper service information, up-to-date training, adequate time to perform the fluid level check and access to special tooling if required. Transmissions with dipsticks need to be checked under the proper operating conditions. Transmission fluid temperature has always been critical for proper level checking along with the vehicle being on a level surface. Transmissions without dipsticks normally need to have their fluid levels checked at a cold or warm temperature (between 68 and 130° F) (Kelly, 2013).

2.6 Types of Automatic Transmission

The Main Types of Automatic Transmission available are:

- Hydraulic
- Continuously variable transmissions.
- Manumatic (Tiptronic)
- Semi-automatic Transmission (Paddle Shift Transmission).

2.6.1 Hydraulic Automatic Transmission

The hydraulic automatic transmission switches to the best gear without driver involvement except for starting and going into reverse. The type of automatic transmission used on current American cars usually consists of a fluid device called a torque converter and a set of planetary gears. The torque converter transmits the engine's power to the transmission using hydraulic fluid to make the connection. For more efficient operation at high speeds, a clutch plate is applied to create a direct

mechanical connection between the transmission and the engine. (Santini & VanGelder, 2017).

2.6.2 Continuously Variable Transmission

The vast majority of transmissions in road going vehicles is either manual or conventional automatic in design. These transmissions use meshing gears that offer different ratio steps between engine and the vehicle speed. Nevertheless, other designs exist that can transmit power and at the same time give a stepless change of ratio; in other words a continuously variable transmission (CVT).

According to Crolla (2009), a CVT is a transmission that will allow an input to output ratio to change continuously without any steps in a range between two finite limits.

A CVT is typically found on some front-wheel-drive vehicles that use a transaxle. As an alternative of using three or more gears, a continuously variable transmission uses two variable width pulleys, sometimes called *variators*, to change the gear ratio from about 2.5:1 to an overdrive ratio of 0.5:1.

A CVT permits the engine to operate in a speed range where it is most effective. As a result, instead of causing the vehicle speed to fluctuate as the transmission shifts gears, the vehicle speed is more constant as the pulleys change to increase the speed of the vehicle. The outcome of using a CVT is improved fuel economy and reduced exhaust emissions (Halderman, 2012).

According to Srivastava & Imtiaz (2008), a CVT is an emerging automotive transmission mechanism that offers a range of gear ratios between high and low limits with fewer moving parts. This as a result improves the fuel economy and acceleration performance of a vehicle by permitting better corresponding of the engine operating conditions to the variable driving scenarios.

As a different advanced transmission design, the CVT is a transmission with no fixed forward speeds. The gear ratio varies with engine speed and temperature. These transmissions are, on the other hand, fitted with a one-speed reverse gear. Some CVT transaxles do not have a torque converter; rather, they use a manual-transmission type flywheel (Erjavec & Pickerill, 2015).

A simple structure of a power- CVT consist of two variable diameter pulleys kept at a fixed distance apart and coupled by a transmitting device like belt or chain. One of the sheaves on each pulley is movable. The belt can undergo both tangential and radial motions subject to the torque loading the axial forces on the pulleys. This, as a result, causes uninterrupted variations in the transmission ratio. Fig. 2.21 and Fig. 2.22 give a picture of the basic layout of a metal V-belt CVT and a chain CVT. In a metal V-belt CVT, torque is transmitted from the driver to the driven pulley by the pushing action of belt elements (Srivastava & Imtiaz , 2008)

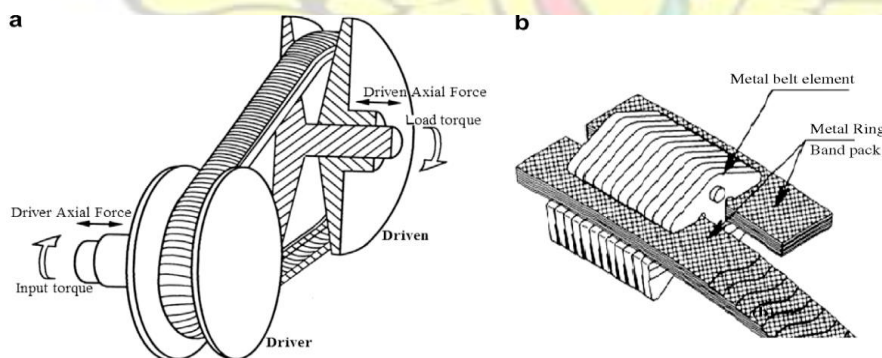


Figure 2.21 Metal V-belt CVT drive: (a) basic Layout; (b) belt structure

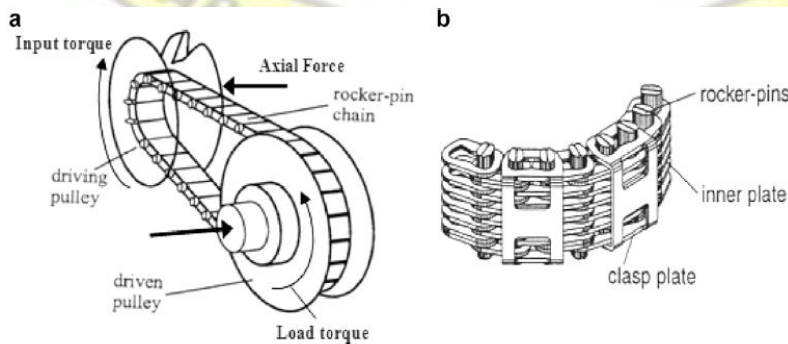


Figure. 2.22. Chain CVT drive: (a) basic Layout; (b) chain structure

2.6.3 Manumatic (Tiptronic)

Like a manual transmission, an automated manual also employs a mechanical clutch; however, the action of the clutch is not controlled by the driver via the clutch pedal but rather is automated using electronic, pneumatic or hydraulic controls. Sometimes referred to as a "Direct Shift Gearbox" ("DSG") or a "Sequential Manual Gearbox" ("SMG"), this transmission allows for either fully automatic forward gear shifts or manual shifts through the gear selector or through buttons or paddles on the steering wheel.

2.6.4 Semi-automatic Transmission (Paddle Shift Transmission).

A semi-automatic transmission (SAT) (also known as a clutch less manual transmission, automated manual transmission, flappy-paddle gearbox, or paddle-shift gearbox) is an automobile transmission that does not change gears automatically, but rather facilitates manual gear changes by dispensing with the need to press a clutch pedal at the same time as changing gears (Yao, 2008).

It uses electronic sensors, pneumatics, processors and actuators to execute gear shifts on input from the driver or by a computer. This removes the need for a clutch pedal, which the driver otherwise needs to depress before making a gear change, since the clutch itself is actuated by electronic equipment which can synchronize the timing and torque required to make quick, smooth gear shifts (Tahmasebi, 2014). The system was designed by automobile manufacturers to provide a better driving experience through fast overtaking manoeuvres on highways (Naranjo, 2007).

2.7. Automatic Transmission Drive Problems

Automatic transmission problems are normally triggered by poor engine performance. These problems include, abuse resulting in overheating, harsh driving conditions, mechanical malfunctions, electronic failures, and improper adjustments. There are a number of transmission problems that can occur regularly. These problems do not have the same causes. There is no one cause of transmission problems except wear and tear which is due to the friction and heat created by their various moving and interacting components.

Identifying and learning about what these common transmission problems are, why they happen, and what one should do about them is the most pre-emptive way one can find minor problems before they advance into major ones, and keep ones wheels on the road (Mister, 2017). Here are some of the signs of automatic transmission (AT) problems which should not be ignored:

2.7.1 Transmission slipping

When experiencing automatic transmission slipping and driving in a particular gear, your car changes gears suddenly without any reason or action on your part. The engine sound may change in pitch or start to sound like grumbling, the car may also seem like it is struggling and is suddenly underpowered (Shilling, 2015)

2.7.2 Fluid Burning Smell

In an automatic vehicle, a burning smell of transmission fluid suggests there is a problem that is causing the transmission fluid to overheat. The transmission fluid becomes less effective over time when it oxidizes, thus combines with oxygen, begins to coagulate as a result of debris, and breaks down. If one smells something burning in

the car, immediate action should be taken to ensure the car doesn't catch fire (Mister, 2017)

2.7.3 Delayed engagement

One of the most common warning signs of problems with any automatic transmission is delayed engagement. A delayed engagement is a kind of slip that happens when the clutches or bands, which help the vehicle to move, do not operate promptly. This arises when the internal seals wear or become hard due to irregular fluid replacement.

Delayed engagement is described by a long delay of approximately 1.5 to 2 seconds from the moment one selects a gear to drive or reverse, this will be noticed on the first drive in the morning, if the car was parked overnight (Mister, 2017)

2.7.4. Transmission warning light

If the car's computer perceives any unusual readings from the sensors, a code will be stored and the automatic transmission indicator light will turn on to alert the driver of possible issues. Malfunctioning sensors will also give false readings causing the light to come on so always have the sensors tested again. One of the most common issues that causes this indicator light to illuminate is when the transmission fluid temperature is higher than normal (Cates, 2016).

A warning light alone, like "check engine" light, usually does not mean one has a transmission problem, but if any of the above signs are happening in conjunction with an illuminated warning, the problem should be diagnosed by a professional (Shilling, 2015).

2.7.5. Fluid leak

Transmissions are normally sealed components that should by no means leak fluid. Having observed any leak spots on the driveway or garage floor, start by checking the fluid level, then perform a comprehensive visual inspection. A typical leaking transmission fluid sometimes appeared in an intense red or dark red. When this happens there is the need to visit an auto service shop immediately (Halderman, 2014).

A transmission has the probability of leaking in areas like Axles seals, Front seal of the transmission, Vent (if transmission overheats), Pan Gaskets and Shifter seals or any seals, as in figure 2.23 (Mister, 2017)



Figure 2.23 Transmission output shaft seal after removing output flange

Source: (audipage.com)

2.8 Tools used in servicing Automatic transmission drives

For some wayside mechanics, the idea of using the correct tool is totally foreign. They will happily tackle the most complex overhaul procedures with only a set of cheap open-end wrenches of the wrong type, a single screwdriver with a worn tip, a large hammer and an adjustable wrench (Halderman, 2014). Though they often get away with it, this

cavalier approach is unwise and hazardous. It can result in relatively minor annoyances like stripped fasteners, or cause catastrophic consequences. It can also result in serious injury. Table 2.1 shows some tools used in servicing automatic transmission drives

KNUST



Table 2.1 Some Tools used in servicing Automatic transmission drives

DIAGNOSTIC TOOL	USAGE
Automatic transmission pressure gauge	It is built to indicate high and low pressure ranges of automatic transmission vehicles
Automatic diagnostic scanner tool	Used to read trouble codes and erase them if possible
Pressure manometer	A device which is used in measuring the pressure of a fluid, it consists of a tube filled with a liquid where the level of liquid being determined by the fluid pressure and the height of the liquid being indicated on a scale
High pressure fuel pump dismantle tool	It uses high pressure in helping to dismantle the fuel pump injection system
Automatic diagnostic injection measuring tool	Used to test different kinds of injector and high-pressure pumps with complete experimental data
Automatic transmission fluid changer	It is used to change Automatic Transmission Fluid (ATF)
Wishbone lever	It is used on suspension arm and hub work maintenance

2.9 Electronic control of transmission

The key aim of electronically-controlled automatic transmission (ECAT) is to improve on conventional automatic transmission in the following ways: gear changes should be smoother and quieter, improved performance, reduced fuel consumption, reduction of characteristic changes over system life, increased reliability.

The important points to remember are that gear changes and lock-up of the torque converter are controlled by hydraulic pressure. In an ECAT system, electrically controlled solenoid valves can influence this hydraulic pressure. Most ECAT systems now have a transmission ECU that is in communication with the engine control ECU as shown in Figure 2.24 (Denton, 2012).

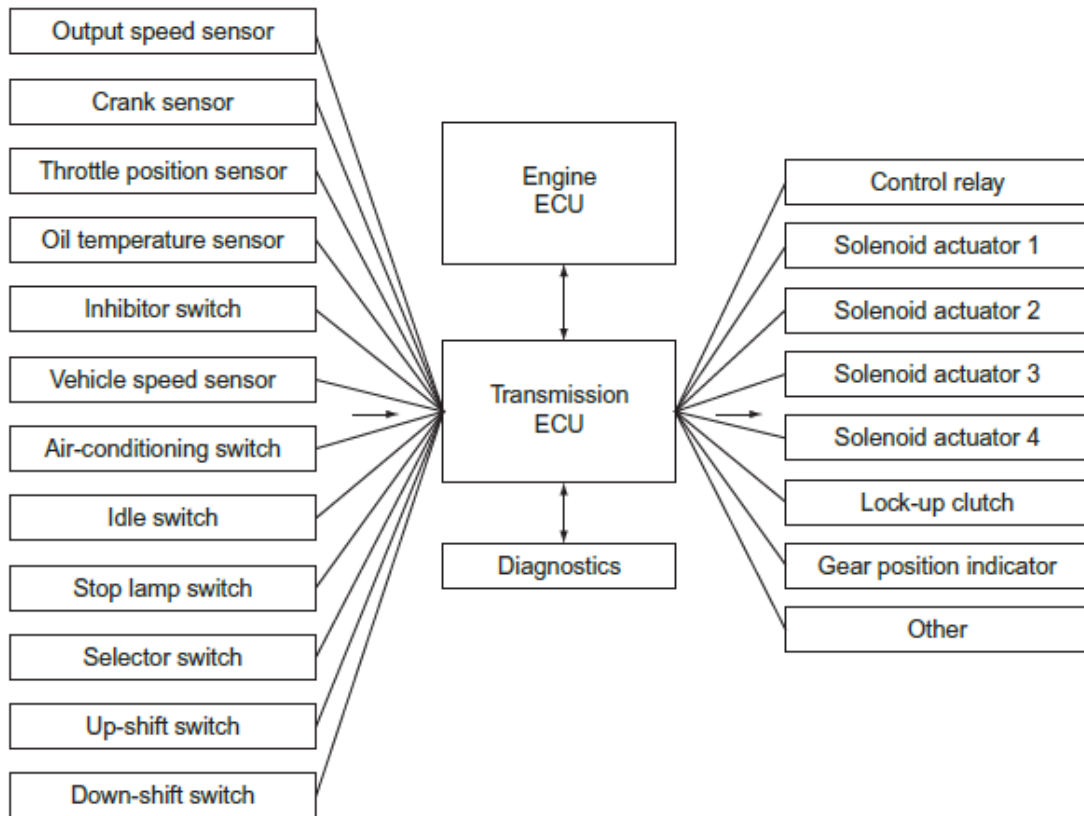


Figure 2.24 ECAT block diagram.

Source: (Denton, 2012)

2.10 Electronically Controlled Transmission Components

In the fully electronically controlled transmission, the shift points are controlled by the vehicle's powertrain control module (PCM) or a transmission control module (TCM). Most vehicle manufacturers have integrated the TCM into the construction of the PCM. The PCM receives various inputs from the engine and transmission to determine the shift timing and the firmness of the shift (Santini & VanGelder, 2017).

A PCM will have a detailed transmission fault codes stored, whereas the ECM may only give you a P0700 (transmission fault identified) as a clue to an electronic problem to solve (Meier, 2010).

2.11 Practices of Auto Technicians

Upon receiving a vehicle with a transmission problem the auto-technician is to:

1. Listen to driver's concerns and road test the vehicle to verify Mechanical and Hydraulic System problems. Before starting to repair or rebuild a transmission, it has to be a fact that the vehicle has a problem. The diagnosis begins with checking fluid levels, by checking components that require fluid to operate, complications due to low fluid levels can be sighted and hence make the job easier.

2. Diagnose Noise and Vibration problems.

Noise from transmission is usually caused not by the gearbox, but other components. Noise problems are best diagnosed by paying a great deal of attention to the speed and condition at which the noise occurs. In some instances, noisy transmission is caused by the oil pump or other components that rotate like drive chain or input shaft. These are areas which are checked first with noise complaints.

3. Diagnose unusual fluid usage, type, level and condition problems

When checking the Transmission, it is worthwhile to know that Automatic Transmission Fluid is normally pink or red, if the fluid has a dark brownish or blackish colour and a burned odour then the fluid is overheated and has to be replaced.

4. Perform Pressure Tests

These tests are performed when the transmission or when the shift timing is wrong. This is usually done by observing the changes in pressure within the Transmission at different operating conditions.

5. Perform Stall Tests

The stall test is to start the engine, putting the car in drive, applying the brakes and pressing down on the Accelerator. The Engine will revolve to a certain point where it can't go any further, that is the stall point. This test is to check if the stall speed is below the preset value then the problem is most likely a restricted exhaust or slipping stator clutch. With a higher stall speed, then the problem may be slipping bands or clutches in the Transmission (Delmar, 2001).

2.12 Automatic Transmission Fluid (ATF)

Automatic transmission fluid is a specifically formulated oil having various additives to resist grueling working conditions. The ATF's are distinct fluid dyed red so that it is not easily confused with engine oil. There are different types of automatic transmission fluids and they should be used according to the recommendation in the car's owner's manual.

According to Erjavec (2010), the specific fluid that ought to be used in an automatic transmission depends on the transmission design and the year the transmission was built. It is important that the correct type of ATF be used and should be checked regularly. Constant reference to the service or owner's manual for the right type of fluid to use is important. Some transmission dipsticks are also marked with the type of ATF required. Even though there are many types of ATF available, the most common ones are DEXRON® III/MERCON® - Recommended for all automatic transmissions requiring. DEXRON® III, DEXRON® IIE, DEXRON® II, DEXRON® or MERCON® transmission fluids. Table 2.2 shows examples of the types and applications of selected vehicles and fluids.

Table 2.2 A few samples of automatic transmission fluid and some applications.

GENERAL MOTORS	DESCRIPTION	MAZDA/NISSAN/SUBARU	DESCRIPTION
Type A	1949	Mazda ATF-III	Specific vehicles and years
Type A, Suffice A	1957 (friction modified)	Mazda ATF-MV	Specific vehicles and years
Dexron	1967 (lower viscosity)	Nissan Matic D	Specific vehicles and years
Dexron II	1978 (lower viscosity)	Nissan Matic J	Specific vehicles and years
Dexron II-E	1990 (improved low temperature fluidity)	Nissan Matic K	Specific vehicles and years
Dexron III	1993–2005 (improved low temperature fluidity)	Subaru ATF	Specific vehicles and years
Dexron VI	2005 (improved viscosity stability)	Subaru ATF-HP	Specific vehicles and years
FORD/JAGUAR	DESCRIPTION	AUDI/BMW/MERCEDES/VOLVO	DESCRIPTION
Type F	1967 (non-friction modified; designed for older band-type automatic transmissions)	Audi G-052-025-A2	Specific vehicles and years
Mercon	1987 (friction modified)	Audi G-052-162-A1	Specific vehicles and years
Mercon V	1997 (highly friction modified)	BMW LA2634	Specific vehicles and years
Mercon SP	Used in the Ford six speeds such as the 6R60 6HP 26 and also the 2003 and up Torque Shift	BMW LT1141	Lifetime fill (BMW warns to not use any other type of fluid)
Idemitsu K-17	Jaguar X-type	Mercedes 236.1	Specific vehicles and years
CHRYSLER	DESCRIPTION	Mercedes 236.2	Specific vehicles and years
Chrysler 7176	Designed for front-wheel-drive transaxles	Mercedes 236.5	Specific vehicles and years
ATF + 2	1997 (improved cold temperature flow)	Mercedes 236.6	Specific vehicles and years
ATF + 3	1997 (designed for four-speed automatics)	Mercedes 236.7	Specific vehicles and years
ATF + 4	Used in most 20000 and newer Chrysler vehicles	Mercedes 236.9	Specific vehicles and years
HONDA/TOYOTA	DESCRIPTION	Mercedes 236.10	Specific vehicles and years
Honda Z-1	For use in all Honda automatic transaxles	Volvo 97340	Specific vehicles and years
Toyota Type III	Specific vehicles and years	Volvo JWS 3309	Specific vehicles and years
Toyota Type IV	Specific vehicles and years	MITSUBISHI/HYUNDAI/KIA	DESCRIPTION
Toyota WS	Lower viscosity than Type IV; used in specific vehicles and years	Diamond SP II	Specific vehicles and years
		Diamond SP III	Specific vehicles and years



CHAPTER THREE

METHODOLOGY

The study seeks to assess, investigate and report on the current state of servicing of automatic transmission drives in Ghana. Issues covered in this chapter include the study area, study design, sources of data, study population, sample and sampling procedure. The research instruments, pre-test of instrument, data analysis and ethical issues were also considered.

3.1 Study Area

The study area comprised four cities in Ghana namely Accra, Tema, Kumasi and Takoradi. These cities are the main business centers of the nation where there are a lot of transport activities. There are also many transport business organizations and mechanics in these cities with new vehicles being imported often.

3.1.1 Rationale for selecting the study Area

The total registered vehicle population in Ghana as of 2010 is approximately one million with concentration in the four biggest cities, namely Accra, Kumasi, Tema, and Takoradi (Hesse & Ofosu, 2014). The four centers mentioned are all urban areas and the research sampled views from these cities which is a rational representation of the urban geographical locations in Ghana. These cities are among the top ten cities with high population and are major centers of economic activities in Ghana (Ghana Statistical Service 2015). Hence, it is thought that the views of the respondents from these centers would suitably represent the whole population.

3.2 Study design

A cross sectional study design was used to ascertain the propositions made in this study. Cross sectional design was used to capture information on a wide variety of variables

such as age, gender, and education at a single point in time. In a cross sectional study, the researcher's aim is to obtain a representative sample by taking a cross section of the population. This design was adopted mainly because the prevalence of a particular phenomenon can be estimated across the population.

3.3. Sample Size

The target population for the study was vehicle operators (drivers), wayside mechanics, used vehicle importers and dealers above 18 years who were within the study area at the time of the study. This category of people was used for the study because they possess the information sought for the study. The researcher adopted the stratified random sampling method to randomly collect data from each of the identified group of respondents.

3.4 Sample Size Determination

The selection of a sample size depends on a number of factors such as: (1) Transportation Costs (2) Coverage of the target population, (3) Flexibility of asking follow-up questions, (4) Respondents' readiness to participate, (5) Response trustworthiness.

The categories of people recognized to work directly on vehicle gearboxes were auto mechanics, vehicles operators, used vehicle importers and garages. Due to the unavailability of a comprehensive sampling frame, the researcher chose a sample size of 1000 respondents for the study. At the end of the survey, a total of 536 vehicle operators, 232 used vehicle importers, 13 new car dealers and 202 garages were involved in the study.

3.4.1 Sampling Technique

In terms of probability sampling, the stratified and simple random sampling techniques were used to select the respondents due to their heterogeneous nature (vehicle operators (536), wayside mechanics (202), used vehicle importers (232) and dealers).

Table 3.1 Sampling Population

Category	Sample	Total number Respondent	Percentage
Vehicle operators	551	536	55.1%
Dealers	15	13	1.3%
Used vehicle Importers	232	232	23.2%
Wayside Mechanics	202	202	20.2%
Total	1000	983	99.8%

3.5 Sampling Procedures

The study used a multistage sampling technique to select a sample size of 1000. In the first place, the stratified sampling technique was used to divide the areas into different strata to ensure homogeneity of the population. These strata included Tema, Accra, Kumasi and Takoradi. The researcher then sampled the participants within each stratum using the purposive sampling technique to select participants for the study.

3.6 Data and Sources

The study made use of primary data. Primary data was derived from a fieldwork with the help of questionnaires (Appendices A-D). Four (4) sets of questionnaires were designed accordingly for each identified source of information on automatic transmission drives (wayside mechanics, used vehicle importers, vehicle operators, and dealers). The questionnaire was mainly made up of closed ended questions because they are easier and quicker for respondents to answer, with only few open ended questions which implored additional explanations from respondents. The questionnaire was organized under the following themes: Sales of automatic

transmission drives, Servicing of automatic transmission drives (cars), Challenges associated with the use of automatic transmission.

The questionnaires were formed using the Delmar's automotive test as a guide. The Delmar's automotive test is a sub-section of the Automotive Service Excellence (ASE) standard. ASE is a non-profit, independent entity formed in 1972 and dedicated to improving the quality of automotive servicing and repair through the voluntary testing and certification of automotive technicians. Upon passing at least one exam and providing a proof of two years of related work experience, the technician becomes ASE certified. A technician who passes a series of exams attains ASE master technician status (Delmar, 2001).

In ASE tests, Technician A, Technician B type of questions is used (Appendix B). These types of questions present two different technicians who try to solve problems on vehicles, but with different approaches – one right and the other wrong. The ability of candidates to pick the right answers and pass the tests is a proof of their qualification as automotive technicians (Delmar, 2001).

3.6.1 Pre-test of Instrument

To ensure feasibility and validity of data collection instrument, it is essential to pre-test it (Brink & Wood, 1998). Pre-testing was done to ensure that the instrument measured quality and concise information. The pre-testing was conducted in Tema. The instrument was administered to ten (10) importers and ten (10) mechanics. Questionnaire were interpreted into the local dialect and administered by researchers because of the perceived low level of education among respondents. The essence of the pre-test was to pinpoint any ambiguities in the research instrument and make the required corrections before the actual survey. It also helped the researcher to know how

the interrogation should be done to get the right responses from respondents. As a result, the researcher modified the wording of these questions to enable respondents to easily understand the information being sought from them. The final form of the questionnaire is shown in appendices A - D.

3.6.2 Fieldwork and Data Collection

The actual fieldwork lasted for about eight months. The researcher employed the services of four male field agents who were third year students reading mechanical engineering as a programme of study in the Cape Coast Technical University. The researcher had to orient them to ensure that they collect the desired information from the field. The researcher simultaneously accompanied the field agents to each study area to introduce them and to help them acquaint themselves with the respondents.

The field agents translated the various items on the questionnaire into a local dialect and administered the questionnaire to respondents because of the perceived low level of formal education among some respondents. At the end of each day, the questionnaires were collected and scrutinized for any missing entries.

On few occasions, the researcher had to make a follow up to some respondents to seek further clarification on responses that were provided to the open-ended questions. Only three days in a week (Tuesdays, Wednesdays and Saturdays) were used for the data collection. This was done to enable the researcher and the field agents use the days in between data collection days to prepare for the field activity.

3.6.3 Data Analysis

After the questionnaires were collected and cleaned, the researcher generated a coding manual that was used for the data entry. The Statistical Package for Social Sciences (SPSS) Version 21 was used to analyse the data. Descriptive and inferential statistics

as well as charts were used to illustrate the findings of the study. In addition, the transport department of Kwame Nkrumah University of Science and Technology (KNUST) was also purposively sampled to get their views on the subject matter. The transport department have a wealth of experience and knowledge in automobile engineering, and due to its close proximity to the research, the researcher decided to use their input to integrate into results.

3.7 Ethical Considerations

It is essential to keep information taken from respondents in confidence (Fraenkel & Wallen, 2000). Respondents were adequately informed in order to seek their consent before being engaged in the study. The objectives and nature of the research, possible outcomes of the research and how results were circulated were made known to the respondents. An introductory letter from the Department of Mechanical Engineering KNUST was given whenever a potential respondent wanted to be sure of the purpose of the work. This convinced the respondents that the study was purely for academic purposes thereby encouraging them to give their responses. The researcher went ahead to explain to the participants the questions and gave an assurance of anonymity and confidentiality that their names would not be written on any part of the questionnaire. These motivated respondents to bring out true issues with respect to the study objectives. All sources of literature that were used for the study were accurately acknowledged in agreement with the creeds of academic copyright, honesty and fair use.

CHAPTER FOUR

RESULTS, FINDINGS AND DISCUSSION

This chapter analyses the data collected from the survey of respondents. It presents the results according to the objectives set for the study. Analysis of demographic characteristics of respondents was presented first, followed by the extent of patronage of Automatic Transmission Drives (ATD) in Ghana. The level of expertise in servicing of automatic transmission drives, and the peculiar challenges associated with the use of automatic transmission drives are also presented.

4.1 Profile of Respondents

Dealers: They are known for providing high quality service. Technicians at these shops are usually manufacturer-trained and they specialize in performing repairs on special vehicle makes. They also import new vehicles and vehicle components that are required for the repairs and are more likely to be on hand at a dealership. They adhere strictly to the manual instructions of their parent companies. These automobile companies include, Toyota Ghana Company Limited, Japan Motors, CFAO, Stallion Motors Ghana Limited, Mantrac Ghana Limited, Mechanical Lloyd, Joe Auto company, Rana Motors Delta Equipment Limited (Africa Motors Division) and Alliance Motors Limited.

Wayside (local) Mechanics: They are known to have low technical educational levels of auto mechanics, lack of appropriate maintenance practices, lack of diagnostic machines. Many vehicle owners choose to acquire the service of local garages because of the relatively cheaper price and instant services some of them render depending on the repair.

Vehicle Operators: Vehicle operators refer to drivers of private cars who most of the time have little or no knowledge concerning problems associated with automatic transmission vehicles though a majority of them drive these vehicles. They mostly rely on dealers or wayside mechanics in addressing the problems they have with their vehicles.

Used Vehicle Sales Persons: They import and sell all kinds of models of vehicles which have been slightly used in other countries and in Ghana. They are mostly sole proprietors.

4.2 Demographic Characteristics

4.2.1 Gender

Table 4.1 depicts the gender distribution of all participating respondents in the study. Majority of respondents (81.7%) were male, with the remaining being female (18.3%). All responding importers, mechanics and dealers were males.

Table 4.1 Gender distribution of respondents

Category	Male n (%)	Female n (%)	Total n (%)
Vehicle operators	356 (66.4)	180 (33.6)	536 (54.5)
Used vehicle Sales Person	232 (100)	0 (0.0)	232 (23.6)
Wayside Mechanic	202 (100)	0 (0.0)	202 (20.5)
Dealer	13 (100)	0 (0.0)	13 (1.3)
Total	803 (81.7)	180 (18.3)	983 (100)

Source: Field data, 2018

4.2.2 Educational background

4.2.2.1 Vehicle Operators

443 vehicle operators (drivers) who took part in the survey (representing 82.6%) had tertiary education. Table 4.2 shows the level of education of the vehicle operators. This gives an indication that a huge representation of the respondents are educated enough

to have fair opinion about the subject matter under discussion. Fifty-seven, 57(10.6%), respondents had either a basic or secondary level education. Nineteen vehicle operators who took part in the survey had no formal education. Seventeen, 17(3.2%) vehicle operators reported to have had other forms of education.

Table 4.2 Level of Education of Respondents

Category	n	%
<i>Vehicle Operators</i>		
Non-Formal Education	19	3.5
Middle/JHS	6	1.1
Secondary/Technical School	51	9.5
Diploma/First Degree	139	25.9
Master's Degree	231	43.1
PhD/Professor	73	13.6
Other	17	3.2
<i>Used Vehicle Sales</i>		
Non-Formal Education	1	0.4
Middle/JHS	0	0.0
Secondary/Technical School	140	60.3
Diploma/First Degree	91	39.2
Master's Degree	0	0.0
PhD/Professor	0	0.0
<i>Dealers</i>		
Non-Formal Education	0	0.0
Basic Level	1	8.3
Middle/JHS	0	0.0
Secondary/Technical School	1	8.3
Diploma/First Degree	4	33.3
Master's Degree	6	50.0
<i>Mechanics in dealer shops</i>		
Basic Level	1	8.3
Middle/JHS	0	0.0
Sec/Technical School	9	75.0
Diploma/First Degree	2	16.7
<i>Wayside Mechanics</i>		
Basic Level	97	18.1
Middle/JHS	102	19.0
Secondary/Technical School	209	39.0
Diploma/First Degree	122	22.8
Master's Degree	6	1.1

Source: Field data, 2018

4.2.2.2 Dealers

Half (50%) of the surveyed dealers had master's degree, while four (33.3%) had a diploma or degree. One respondent had basic level education, and another had secondary or technical education.

4.2.2.3 Used Vehicle Sales

A total of 140 respondents who took part in the survey as sales persons had secondary level education, and 91(39.2%) had tertiary level education. This gave the indication that respondents had an adequate understanding for the questions posed to them.

4.2.2.4 Mechanics

For the wayside mechanics, majority i.e. 209 (39%) reported having had secondary/technical level education, while 199 (37.1%) had basic level education. Some 128(23.9%) had tertiary level education. It is evident from the study that majority of mechanics at the various wayside garages in Ghana have low levels of education or lack adequate training and re-training and are most likely unable to use computers and internet facilities for vehicles repairs. This finding is supported in a study by Akpakpavi (2015) who discussed that this creates an inability of mechanics to identify parts of modern vehicles engines by their correct technical names and functions. Baidoo and Odum-Awuakye (2015) in their research on the influence of service quality delivery in the SMEs of Motor Vehicle Repair Service industry in Ghana, concluded that practices of the SMEs could be improved by giving their personnel the needed professional training or retraining. The full demographic data on the level of education of respondents is presented in Table 4.2.

4.2.3 Age of Vehicle Operators

The distribution for the vehicle operators' age shows that majority of respondents were in the age group of 36 to 40 years (39.9%) followed by those between the ages of 46 and 50 years (22.2%). Additionally, 16.8% of respondents were reported to be between the ages of 31 and 35 years. Cumulatively over 65% of the respondents were at most 45 years old. Table 4.3 shows the age distribution of vehicle operators.

Table 4.3 Age Distribution

	n (%)
<i>Age of respondents (mean (sd))</i>	28 (<i>sd</i> = 5.09)
<i>Age at first drive (mean (sd))</i>	42 (<i>sd</i> = 7.95)
<i>Years of driving (mean (sd))</i>	14 (<i>sd</i> = 7.50)
<i>Age of Respondents</i>	
25 - 30	16 (3.0)
31 - 35	90 (16.8)
36 - 40	214 (39.9)
41 - 45	36 (6.7)
46 - 50	119 (22.2)
51 - 55	34 (6.3)
56 - 60	6 (1.1)
61+	21 (3.9)

Source: Field data, 2018

4.3 Sale of ATDs

4.3.1 Years of Operation of Business

53.3% of the dealer companies have operated in the industry for over 16 years, and 30.8% have operated between 13 – 16 years, while 7.7% have operated in the industry between 9 to 12 years. Cumulatively, dealer companies which were surveyed ran their businesses for at least nine years. This gives the indication that through experience in the industry, they have first-hand knowledge on the type of transmissions that have high demand. Table 4.4 gives the information on the sale of ATDs.

Table 4.4 Sale of Automatic Transmission Drives

Characteristics	n	%
Years of Operation of Business (<i>years</i>)		
5 – 8	1	7.7
9 – 12	1	7.7
13 – 16	4	30.8
16 >	7	53.8
Records on the Number of Automatic Drives Sold		
Yes	9	69.2
No	4	30.8

Source: Field data, 2018

4.3.2 Record keeping of Sales of ATDs by Dealers

Table 4.4 reports that 9 out of 13 of the dealerships have kept records on the number of automatic drives sold, whereas four (4) did not keep these records.

4.3.3 Extent of patronage of ATDs

Importation of cars into the country is mostly done by dealers and used vehicle operators. They are responsible for the sale of most cars in the country. The frequency of sales of ATDs can be directly related to the extent of patronage of ATDs by vehicle operators.

4.3.3.1 Frequency of New Cars Sold by Dealers

The results of analysis of frequency of sales from dealers is shown in Table 4.5. An average total of 563 cars were sold in 2014, recording the highest number of car sales between 2007 and 2016. Out of this number, 57.90% representing 326 cars were ATDs. In addition, the lowest average number of sales was recorded to be 104 in 2007 of which 40.05% were ATDs. From the table again, it can be observed that the percentage of ATDs has been increasing over the years (2007 – 2016). This shows that most of the cars sold were ATDs indicating an increase in patronage of ATDs.

Table 4.5 Average Number of New Cars Sold from 2007 to 2016

Year	Number of Dealers	Mean for Total Sales/Garage	Mean for ATDs	% of ATDs
2007	8	104	42	41
2008	8	198	60	30
2009	8	292	164	56
2010	8	203	114	56
2011	8	310	203	66
2012	8	373	267	72
2013	8	420	230	55
2014	9	564	326	58
2015	9	400	240	60
2016	9	561	472	84

Source: Field data, 2018

4.3.3.2 Frequency of Used Cars Sold by Used Vehicle Importers

The results of evaluation of frequency of sales of used cars is as shown in Table 4.6.

An average total of 104 cars were sold in 2016, recording the highest number of cars sold from 2007 to 2016. Out of this number, 82.02% representing 85 cars were ATDs.

The lowest average of cars sold was recorded in 2010 to be 39 of which 18 (46.73%) cars were ATDs. From the table again, it can be observed that the percentage of ATDs has been increasing over the years (2007 – 2016). This shows that more of the used cars sold are ATDs indicating an increase in patronage of ATDs.

Table 4.6 Average Number of Used cars Sold from 2007 to 2016

Year	Number of Garages	Mean for Total sales/Garage	Mean for ATDs	% of ATDs
2007	126	41	15	37
2008	126	50	24	48
2009	126	40	22	54
2010	135	39	18	47
2011	135	71	40	57
2012	140	78	50	63
2013	140	88	57	65
2014	140	98	65	66
2015	140	99	72	74
2016	140	104	85	82

Source: Field data, 2018

The results of evaluation of frequency of sales of cars from both dealers and used vehicle importers is shown in Table 4.7. A total of 19616 cars were sold in 2016, recording the highest number of cars sold over the period. Out of this number, 82.53% representing 16190 cars were ATDs. The lowest number of cars sold over the period was recorded in 2007 to be 5975 of which 2228 (37.29%) cars were ATDs. From the table, it can be observed that the percentage of ATDs has been increasing over the period (2007 – 2016) indicating an increase in patronage of ATDs over the period.

Table 4.7 Total Number of cars Sold from 2007 to 2016

Year	Number of Garages	Total Sale of cars	Total for ATDs	mean of ATDs	% of Total ATDs
2007	134	5974	2228	17	37
2008	134	7919	3504	26	44
2009	134	7434	4089	31	55
2010	143	6918	3384	24	49
2011	143	12059	7072	49	59
2012	148	13957	9105	62	65
2013	148	15679	9858	67	63
2014	149	18742	12017	81	64
2015	149	17400	12310	83	71
2016	149	19616	16190	109	83

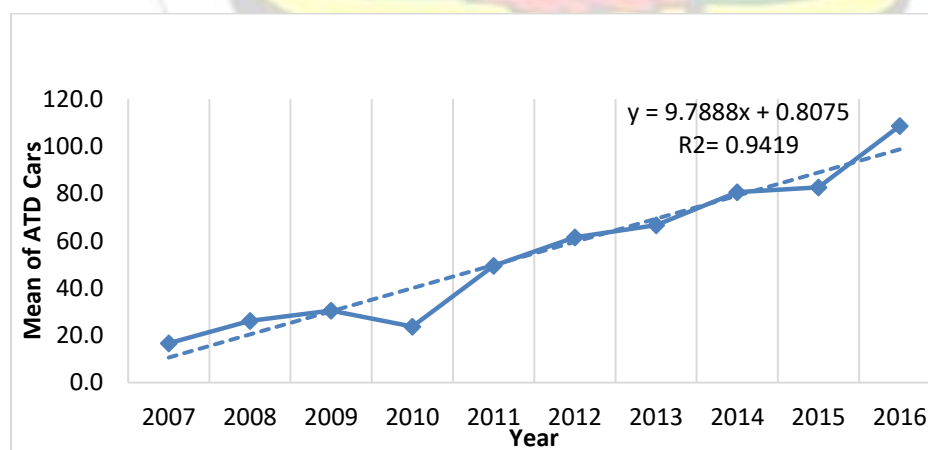


Figure 4. 1 Trend of ATD Cars Sold from 2007 to 2016

A time plot of the average number of ATDs sold from both dealers and used vehicle importers from 2007 to 2016 is shown in Figure 4.1. This is an indication of the extent of patronage of ATDs over this period. From the figure, an upsurge in popularity of ATDs from 2007 to 2016 can be observed which is in agreement with Akple et al. (2013). However, the plot shows a drop in sales of ATDs between 2009 and 2010 before picking up again after 2010. The extent of patronage of ATDs revealed a linear relation of $y = 9.7888x + 0.8072$. Since the y intercept is close to zero, the slope can be taken as the rate of patronage of ATDs showing a uniform sale of ATDs at an annual increasing rate of 10 ATD cars per garage

Source: Field data, 2018

4.3.3.3 Reasons for Choice of Transmission Type

Several reasons for choice of transmission type as enumerated by the sales persons are shown in Table 4.8. Approximately 92 % of the vehicle operators cited driving comfort as the main reason for purchasing an ATD car, whereas ease of maintenance was the reason for 49 (100%) vehicle operators who purchased MTDs. The cost of a car was a very important factor for the choice of ATDs. From table 4.8, it is clear that where two cars of the same price were on display, the respondents would prefer the one with ATD. This is very much in line with the assertion by Mogre (2013) that, 'if you are a back-seat driver and prefer luxury when on the move or you have a busy schedule, you should look no further than an ATD'. However, if you love to enjoy each bit of drive and do not want much maintenance cost, support the idea of saving fuel, then MTD is best'. In support of choice of MTDs over ATDs, Akple et al. (2013), in their study on driver preference for automatic or manual transmission systems for vehicles in Ghana, concluded that individuals prefer ATD based on three factors that include repairability, reliability and better fuel economy.

Other reasons included the brand of car which was divided among vehicle operators who preferred either ATDs (44.8%) or MTDs (55.2%). There was a very significant association between their reasons and the choice of transmission [χ^2 (4, n = 536) = 275.885, p =0.000].

Table 4.8 Reasons for Choosing a Type of Transmission

Reason for Purchasing Car	Automatic		Manual	
	n	%	n	%
Driving Comfort	378	92.4	31	7.6
Ease of Maintenance	0	0.0	49	100
Cost of Vehicle	12	100	0	0.0
Brand of Car	26	44.8	32	55.2
Other	8	100	0	0.0

Source: Field data (2018)

4.4 Expertise in Servicing of ATDs

4.4.1 Automatic Drive Problems Brought to the Garages

Automatic drive problems that were mostly reported to the garages are as shown in Table 4.9. Information collected from the mechanics showed that there were four major automatic drive problems mostly attended to at their garages: Burnt transmission fluid (95.1%), Leaking transmission fluid (89.7%), Noisy transmission (86.2%) and Slips between shifts (80.3%). Other problems that were mostly reported to the garages were Faulty Torque converter (69.0%) and Inconsistent Hydraulic Pressure (54.7%).

Table 4.9 Automatic Drive Problems

Automatic Drive Problems	n	%
Burnt Transmission Fluid	193	95.1
Leaking Transmission Fluid	182	89.7
Noisy Transmission	175	86.2
Slips Between Shifts	163	80.3
Faulty Torque Converter	140	69.0
Inconsistent Hydraulic Pressure	111	54.7

Source: Field data, 2018

4.4.2 Faults Repaired Easily and Tools Used

This section sets out to do two major things: the first is to verify the faults mechanics of the various garages usually repaired with ease; second is to check the list of tools mostly used in fixing these faults. Table 4.10 indicates the various faults as mentioned by mechanics to have been solved easily, whilst Table 4.10 shows whether the tools needed to solve them were immediately available at the shop. Faults mostly repaired with ease were: Leaking transmission fluid (89.7%), Burnt transmission fluid (88.7%), Noisy transmission (87.2%) and Slips between shifts (35.5%). Other problems that respondents were able to repair were the Faulty Torque converter (11.8%) and Inconsistent Hydraulic Pressure (10.3%).

Table 4.10 Faults Repaired Easily

Able to Repair	n	%
Leaking Transmission Fluid	182	89.7
Burnt Transmission Fluid	180	88.7
Noisy Transmission	177	87.2
Slips Between Shifts	72	35.5
Faulty Torque Converter	24	11.8
Inconsistent Hydraulic Pressure	21	10.3

Source: Field data, 2018

The available tools in table 4.11 for mechanics was the Automatic diagnostics scanner (72.9%) followed by the ATF changer (30.0%). Other tools available were Automatic

Transmission Pressure Gauge (29.6%), Pressure Manometer (29.6%), Anti-Lock Brake system diagnostic tool (18.2%), Automatic diagnostic injection measuring tool (15.3%), High pressure fuel pump dismantle tool (11.8%) and Wishbone lever tube (7.9%).

From the study, it is revealed that, the wauside mechanics lacked the modern tools and equipment for service delivery. The lack of modern equipment and logistics was mentioned by Baidoo and Odum-Awuakye (2015), and Akpakpavi (2015), as they emphasized on the provision of electronic vehicle diagnostic equipment's to aid in the provision of quality service at the garages.

Table 4.11 Special Service Tools Available to the Shop

Tools	n	%
Automatic Diagnostics Scanner Tool	148	72.9
Automatic Transmission Fluid (ATF) Changer	61	30.0
Automatic Transmission Pressure Gauge	60	29.6
Pressure Manometer	60	29.6
Anti-Lock Brake System (ABS) Diagnostic Tool	37	18.2
Automatic Diagnostic Injection Measuring Tool	31	15.3
High Pressure Fuel Pump Dismantle Tool	24	11.8
Wishbone Lever Tube	16	7.9

Source: Field data, 2018

4.4.3 Faulty Components

Table 4.12 illustrates the faulty components respondents encounter during repair of ATD. Common faulty components are Seals and Gaskets (79.3%), closely followed by Hydraulic System (78.3%). Torque Converter (46.8%), Planetary Gear Sets (23.2%) and Governor, and the Modulator (21.2%) were also recorded.

Table 4.12 Faulty Components

Component	n	%
Seals and Gaskets	161	79.3
Hydraulic System	159	78.3
Torque Converter	95	46.8
Planetary Gear Sets	47	23.2
Governor and the Modulator	43	21.2

Source: Field data, 2018

4.4.4 Characteristics of Wayside Mechanics

Table 4.13 depicts the various characteristics wayside mechanics had. On average 17 (SD = 11.74) vehicles were serviced in the last month of which 15 (SD = 9.17) were automatic vehicles. The number of vehicles serviced in a month ranged from 15 to 29. The average number of auto mechanics for a garage was 5 (SD = 6.87). The mean score for knowledge of ATD problems was 4.39 out of 9 (SD = 1.52) presenting a percentage score of 48.77%. The mean score for Competence in ATD was 4.43 out of 9 (SD = 2.13) presenting a percentage score of 49.22%.

Table 4.13 Characteristics of Wayside Mechanics

Variables	Mean	SD
Number of Vehicles Serviced in the Last Month	17	11.74
Maximum Number vehicles Serviced in a Month	29	10.17
Minimum Number vehicles Serviced in a Month	18	9.61
Number of Automatic Vehicles Serviced in the Last Month	15	9.17
Number of Auto Mechanics	5	6.87
Knowledge of ATD problems	4.39	1.52
Competence in ATD	4.43	2.13

Source: Field data, 2018

4.4.5 Knowledge and Competence

ANOVA test showed in Table 4.14, reveals that knowledge levels of mechanics on ATDs varied significantly for Transmission types normally serviced by the mechanics ($p = 0.000$). Evidently, mechanics who serviced both types of drives had more knowledge than those in either manual or automatic group.

An ASE test conducted for the mechanics on specialized transmission revealed that there were significant differences between the knowledge levels of Mechanics for three types of vehicles ($p = 0.000$). In this instance, mechanics who serviced automatic specialized transmissions had more knowledge scores than mechanics who did both or manual. Table 4.14 shows the trend.

In terms of competence, no significant differences were recorded for competence in servicing automatic, manual drive cars or both ($p = 0.245$). Meanwhile, there were significant differences in the competence in repairing specialized transmission drives as mechanics who dealt with both types of cars had more competence ($p = 0.000$).

Table 4.14 Knowledge and Competence by Specialization

	Knowledge			Competence		
	Mean	S.D	<i>p</i> -value	Mean	S.D	<i>p</i> -value
Transmission Normally Service						
Automatic	2.00	2.09	0.00	4.33	2.61	0.245
Manual	0.58	0.51				
Both	2.45	1.05				
Specialized Transmission						
Automatic	2.37	1.60	0.00	4.21	1.77	0.000
Manual	0.41	0.51				
Both	1.96	1.48				

Source: Field data, 2018

In assessing the competence of mechanics, the researcher used an aggregated data from only respondents who were able to fix the different ATD problems as and when they were confronted with them. Table 4.15 reveals that, mechanics were highly competent fixing issues with Leaking Transmission Fluid (21.5%). This was followed by 19.5% for Noisy Transmission (19.5%), Burnt Transmission Fluid (16.9%), Slips Between Shifts (15.3%). Other ATD problems showed relatively less competences: Faulty Torque converter (7.8%) and Inconsistent Hydraulic Pressure (4.2%).

Table 4.15 Competence of Mechanics in Solving ATD Problems

ATD Problems	n	%
Slips Between Shifts	47	15.3
Noisy Transmission	60	19.5
Burnt Transmission Fluid	52	16.9
Leaking Transmission Fluid	66	21.5
Broken or Damaged Universal Joint	45	14.7
Inconsistent Hydraulic Pressure	13	4.2
Faulty Torque Converter	24	7.8
Total	307	100.0

Source: Field data, 2018

A correlation analysis performed showed that the association between the competence of mechanics in repairing ATD problems and Knowledge of ATD was not statistically significant ($r = 0.045$, $p = 0.527$). This shows that knowledge of ATD did not enhance competence of mechanics in solving ATD problems. Table 4.16 shows the correlations analysis.

Table 4.16 Correlation

		Competence	Knowledge
Competence	Pearson Correlation	1	
	Sig. (2-tailed)		
	n	198	
Knowledge	Pearson Correlation	0.045	1
	Sig. (2-tailed)	0.527	
	n	198	203

From the results, it is revealed that mechanic's knowledge of ATD problems on a scale of 1 to 10 was below the average mark of 4. Though performance of mechanics on the knowledge scale was abysmal, this form of assessment alone does not portray the competence of the mechanics since the competence of mechanics in ATD also revealed an average performance, as mechanics could only fix a few different ATD problems and when they were confronted with them. Mechanics participating in the study were only able to fix issues that were easy and visible like Leaking Transmission fluid and Burnt Transmission fluid. The lack of association of knowledge with competence gives

credence to the fact that most of the mechanics knowing ATD problems does not mean they can solve the problems.

In addition to this, mechanics knowledge on ATDs varied significantly for the transmission types normally serviced, with mechanics who serviced both types of drives having further knowledge than those who serviced either manual or automatic drives. Mechanics specialized in ATDs had higher levels of knowledge scores than mechanics who specialized in MTDs. No differences were revealed for competence in servicing automatic, manual drive cars or both.

Automatic diagnostic scanners, ATF changer, Automatic transmission pressure gauge, Pressure manometer and Anti-lock brake systems diagnostic tool were the few available tools reported in the garages. The unavailability of most of the ATD tools to the garages is corroborated by observations of Baidoo and Odum-Awuakye (2015) that SMEs of automobile service garages lacked several modern equipment needed to provide quality services. Similarly, Akpakpavi (2015) concluded in his study on modern automobile vehicle repair practices that the inability to acquire modern vehicle diagnostic equipment and tools by garages hinders their full capacity to operate.

4.5 Challenges Associated with the Use of ATDs

4.5.1 Choice of Garage for Servicing

Results of analysis of the choice of garage in figure 4.2 shows that majority 259, (48%) of the vehicle operators preferred wayside garages, while 195 (36%) normally would choose private garages. Eighty-two which represents 15% of vehicle operators would choose dealers. Meanwhile, vehicle operators mentioned that “cost” (68%); “quality of work” (21%); “time of delivery” (3%) were the reason for their choice.

Chi-square test performed showed an association between the choice of garage for service and reasons $\chi^2 (6, n = 536) = 221.27, p = .000$. This indicated that respondents, for instance, attributed their choice of wayside garage to the cost of servicing, which Meier (2010) said, the main complaint from consumers is the cost of a professional fluid service, while others who chose private garages did so for the timely delivery of service. Other vehicle operators chose dealerships for the quality of service they offer, which according to Baidoo and Odum-Awuakye (2015) is due to the high educational level of mechanics at dealerships. Figure 4.2 shows a cluster bar chart that depicts the vehicle operators' choices and reasons.

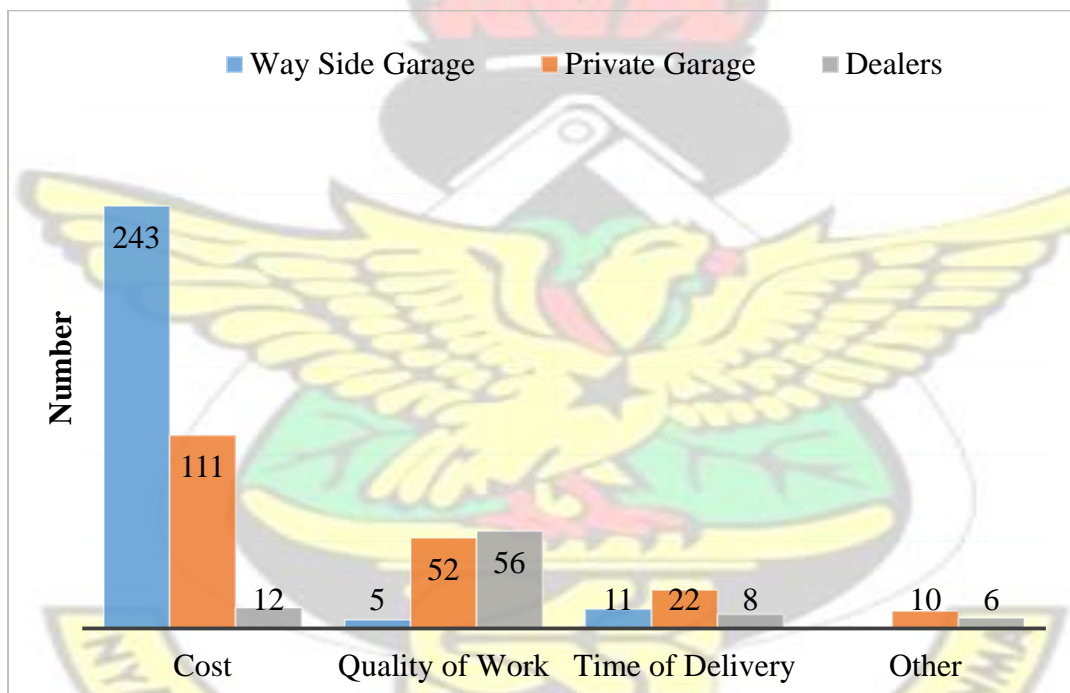


Figure 4.2 Reasons for Choice of Place of Service

Source: Field data, 2018

4.5.2 Challenges associated with the use of ATDs

Mechanics reported automatic cars as the type with highest rate of breakdown 196 times (96.6%) and manual cars only reported 7 times (3.4%).

67% of vehicle operators will only visit the workshop when there is a breakdown. Whereas, 18.8% visit once every six months, and 5.8% once every year, twenty-six percent of vehicle operators visit the mechanic workshop once a month. Table 4.17 shows the list of challenges associated with the use of ATDs.

Of the vehicle operators who took part in the survey, 52.6% never check their ATF level. Some other vehicle operators (11.4%) make it a habit of checking once a week, while 9.7% will check once a month. Only 37 (6.9%) of vehicle operators make daily checks of their ATF level. Only 37.5% of participating vehicle operators change their ATF, while 62.5% never do.

From the results of the study, 360 (67.2%) would only change their ATF when the car develops a problem. However, 59 (11%) of the respondents do not know that they must use the mileage instead. 79.7% of vehicle operators do not know the right transmission fluid for their cars

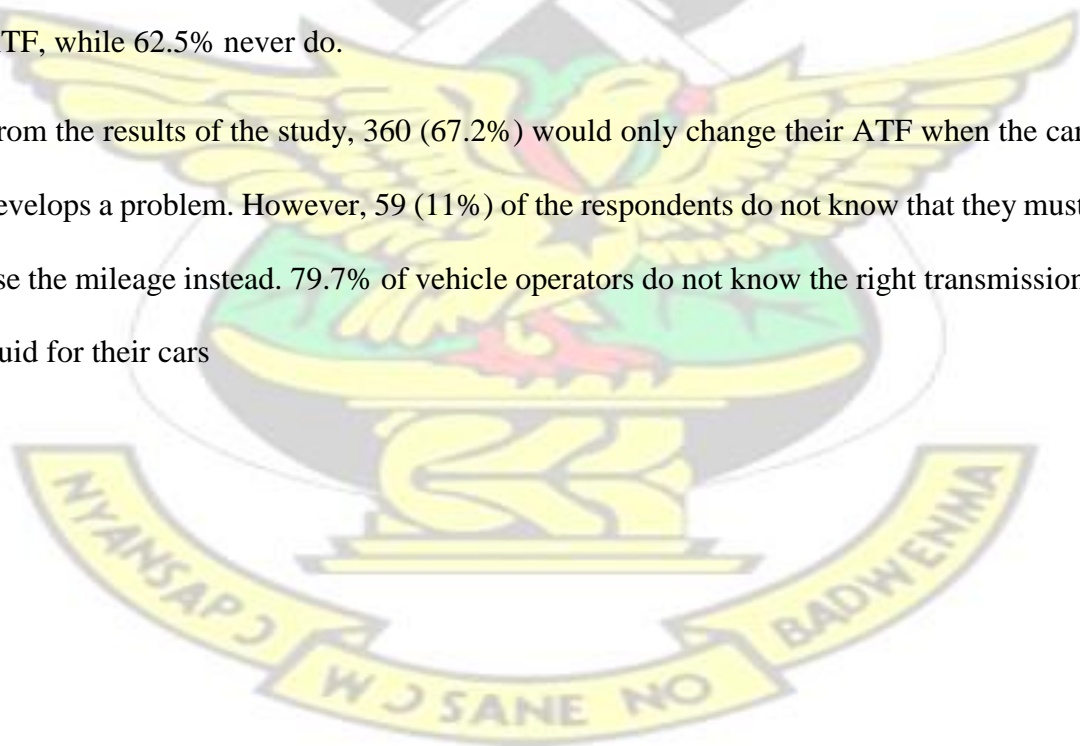


Table 4.17 Challenges Associated with the use of ATD

Challenges	n	%
Frequency of breakdown (Mechanics)		
Automatic	196	96.6
Manual	7	3.4
Period of Visit to Mechanic Workshop to Service Vehicle		
Once a Month	26	4.9
Once every six months	101	18.8
Once every year	31	5.8
Unless Faulty	359	67.0
Other	19	3.5
Frequency for Checking ATF Level		
Everyday	37	6.9
Once a week	61	11.4
Once a month	52	9.7
Do Not Know	104	19.4
Never	282	52.6
Ever Changed ATF		
Yes	201	37.5
No	335	62.5
How Often Respondents Change ATF		
Every Six Months	49	9.1
Every Year	68	12.7
Unless there is Problem	360	67.2
Between every 30-50,000 Miles	59	11.0
Know the Right ATF for Vehicle		
Yes	109	20.3
No	427	79.7

Source: Field data, 2018

4.5.3 Rating of Garages

Vehicle operators were requested to rate the knowledge of mechanics of the three garages in servicing of automatic transmission drives using a five-point Likert scale (1 – Poor to 5 – Excellent). The results showed that for the knowledge of garages, dealers had a mean score of 3.51 ($sd = 0.710$) and Private garages scored 2.49 ($sd = 0.689$). Wayside garage scored the least with 1.55 ($sd = 1.002$). This implies that Dealers' garage scored higher ratings among the three categories, an indication of higher preference of dealers garage to the Private or wayside garages. This trend is illustrated in Table 4.18.

Table 4.18 Rating of Garages

Category	Poor	Average	Good	Very Good	Excellent	Mean (s.d)
	n (%)	n (%)	n (%)	n (%)	n (%)	
Dealers	5 (0.9)	10 (1.9)	8 (1.5)	194 (36.2)	319 (59.5)	3.51 (0.710)
Private	5 (0.9)	10 (1.9)	272 (50.7)	214 (39.9)	35 (6.5)	2.49 (0.689)
Wayside Mechanics	95 (17.7)	148 (27.6)	206 (38.4)	77 (14.4)	10 (1.9)	1.55 (1.002)

Source: Field data, 2018

4.5.4 Rate of Revisit to Mechanics

Vehicle operators were also asked to indicate whether there is a reoccurrence of the transmission problem after it has been fixed by the mechanic. Majority (93.7) of the respondents indicated that there is a reoccurrence of transmission problem while 6.3% of respondents indicated that the transmission problem does not occur after it has been fixed by a mechanic. Among respondents who had a reoccurrence of transmission problem, 71.5% indicated that it takes between a month to six months for the transmission problem to reoccur. 6.0% of respondents also indicated that the transmission problem reoccurs between a week to a month while 15.3% indicated that it takes them between six months to a year before a reoccurrence of the transmission problem. About 7 (7.2%) of respondents, however, indicated that the transmission problem does not reoccur until after a year and beyond. Table 4.19 presents the rate of revisit to mechanics.

Table 4.19 Rate of Revisit to Mechanics

	n	%
<i>Reoccurrence of Transmission Problem</i>		
Yes	502	93.7
No	34	6.3
<i>Rate of reoccurrence of transmission Problem</i>		
Between a week to a month	30	6.0
Between a month to Six months	359	71.5
Between Six months to a year	77	15.3
A year and beyond	36	7.2

Source: Field data, 2018

The findings in this section indicate two main challenges faced in the use of ATDs.

Firstly, forty-nine (49%) of vehicle operators preferred wayside mechanics due to cost of service of the transmissions hence the increase in breakdown. The participating vehicle operators maintain that it is expensive to service with the dealers or private garages, and that in making a choice for a garage they would prefer the affordable wayside garages. Secondly, bad attitude toward maintenance by vehicle operators was shown to be challenge to the use of ATDs. It was obvious from the above analysis that most users of ATDs have bad maintenance habit, a cause of their inability to regularly check and service the transmissions until it breakdown.

4.6 Design of a Maintenance System Database

The research findings and analysis have revealed a low level of knowledge on proper schedule maintenance procedures, persistent incorrect fault diagnosis, high demand from clients of ATDs and far too frequent relapse of fixed failures. The above mentioned problems are largely attributable to the lack of service manual referencing by technicians and the unavailability of such relevant service manuals. An example is where technicians reported no knowledge on transmission fluid change based on recommended mileage that the fluid has run. Based on the above challenges a cost effective and user friendly maintenance system database was designed to enhance the servicing capabilities of the wayside mechanics as well as the “Fix it yourself” users of automatic transmissions drives

4.6.1 Brief Description

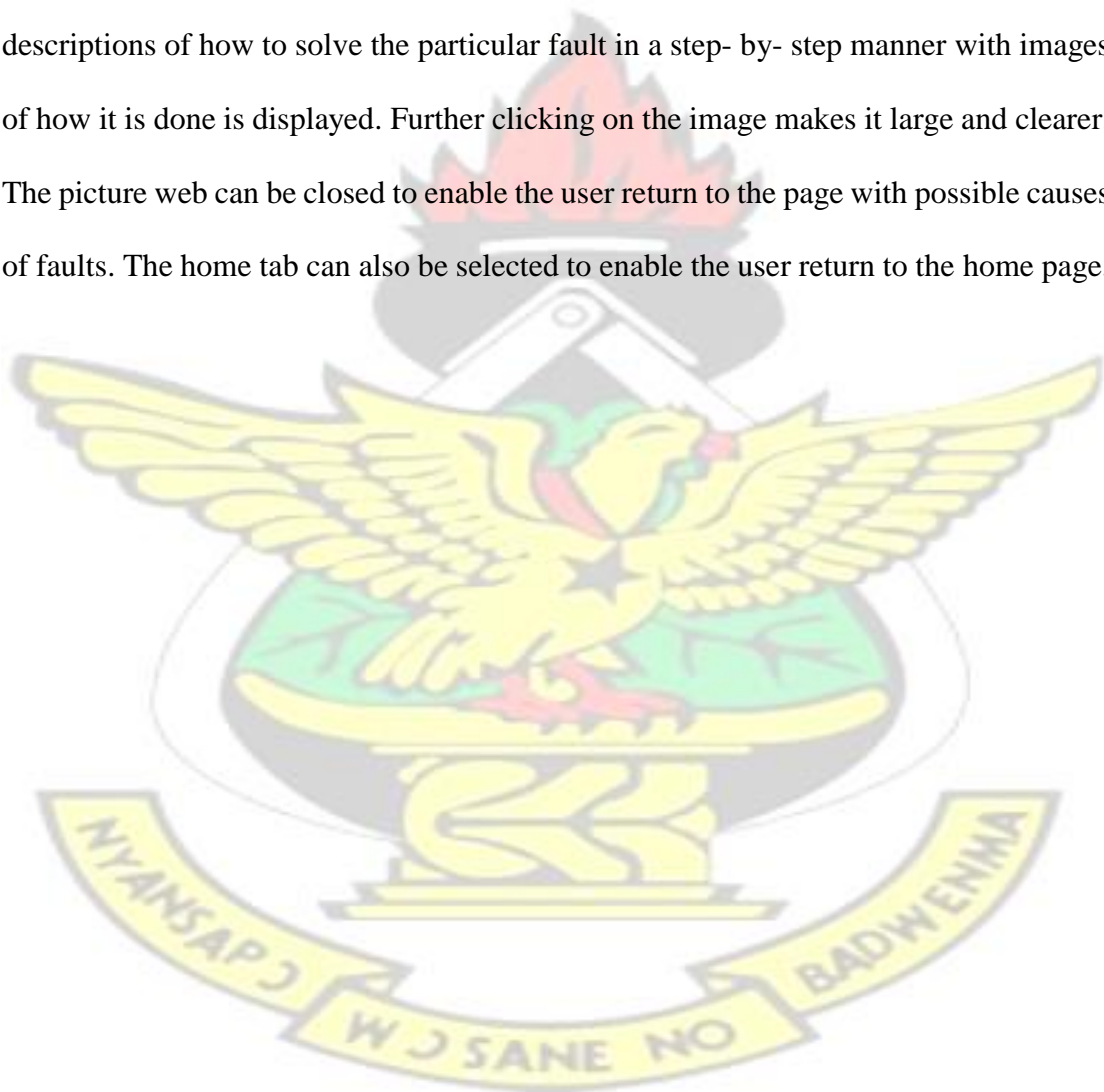
The maintenance system database design comprises automatic transmission drive faults, causes and recommended solutions. The system design was created using MySQL (Structured Query Language). To access and display information from the

MySQL database, a PhP (Hypertext Pre-processor) application was created for the query and displayed in webpage format. Since the database used is a local host, a WampServer was used to test the database application. A WampServer is a Platform where one can easily develop and test Web applications locally on a PC. The WampServer contains stacks of Apache web server, MySQL database and PHP compiler. Performance, reliability and ease of use makes MySQL an ideal choice for development of this database. The main interface of the database system shows a cut view of a modern automatic transmission gear box showing the gear system. This page has the inscription “welcome to George’s transmission help center.” There is a fault list displayed at the top left corner of the home page and a search inbox to enter queries having a “submit” button below it. The maintenance system database lists fifteen (15) problems related to ATDs with images of the problems displayed adjacent to the stated problem. These are displayed on clicking the “fault list” displayed on the welcome page. The maintenance system database also lists a number of possible causes to each problem stated on the website and gives a step- by- step description of solutions to the problem with images of how to address the problem.

4.6.2 Principle of Operation

To utilize this service information database software, a WampServer was launched using the site <http://automatictransmissionhelpcentre.com>, that could either be accessed using a mobile phone or a computer and the user gets logged on the database and the interface shown in Appendix E pops up. From the page, the user can either enter and submit a search phrase or proceed to a list of faults as illustrated in appendix F. Appendix G and H display a typical search result and its content respectively. Pictures of the service procedures are shown in order to illustrate this clearly. Figure 4.3 shows a flow diagram of the principle of operation of the maintenance system database. The

flow diagram is a multi-stage cycle which starts by entering the web address which leads to the “welcome to George’s transmission help centre.” On the home page, the user has an option to either click on ‘fault list’ or to enter a fault in a search inbox. By clicking on ‘fault list’ the user is shown all the 15 faults on the website for the user to make a choice. If the user enters a fault in the search inbox, a number of faults related to what the user entered are displayed for the user to make a choice. Having made a choice of a fault, a pop- up window which displays the possible causes of the fault and descriptions of how to solve the particular fault in a step- by- step manner with images of how it is done is displayed. Further clicking on the image makes it large and clearer. The picture web can be closed to enable the user return to the page with possible causes of faults. The home tab can also be selected to enable the user return to the home page.



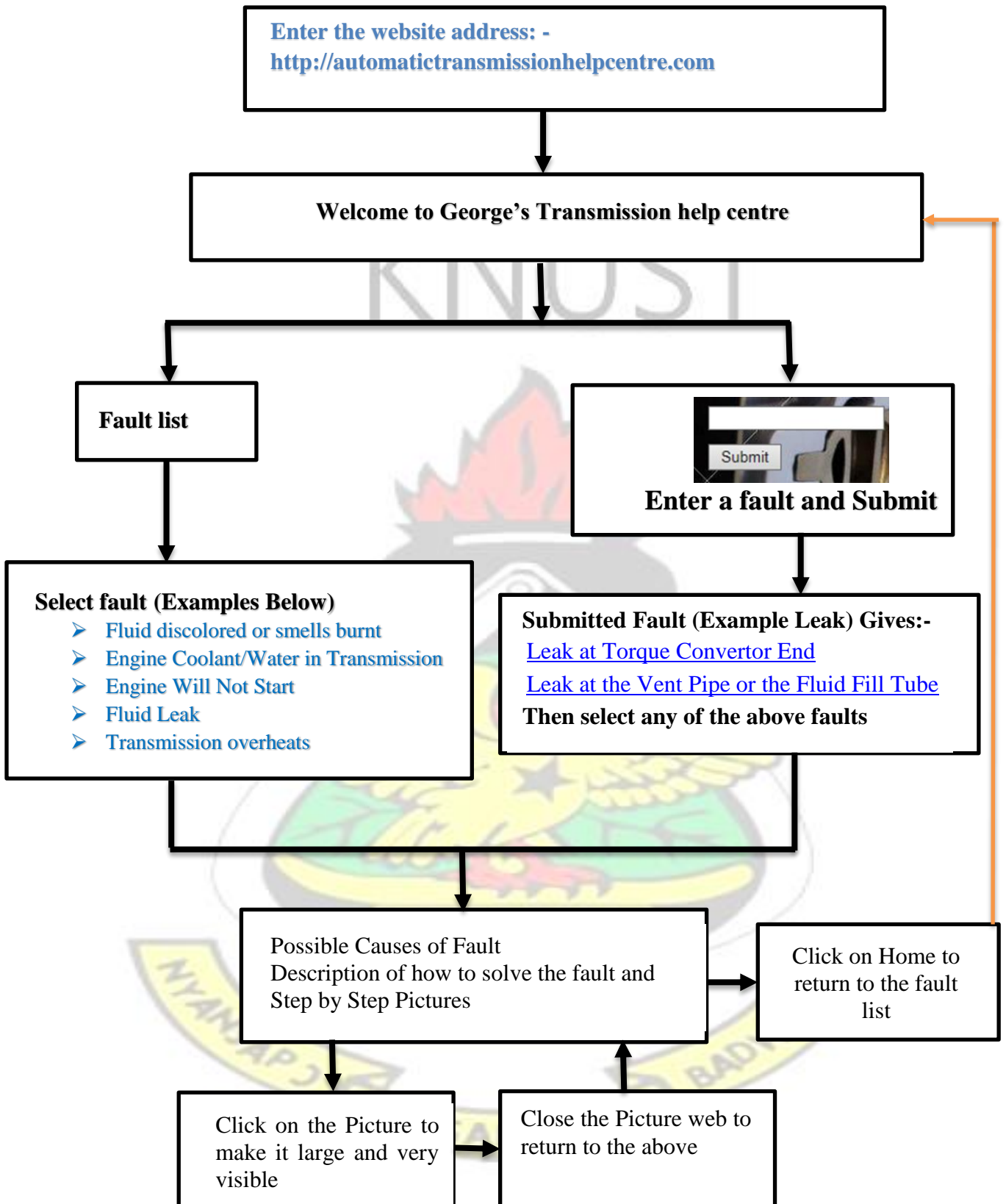


Figure 4.3 A flow diagram showing the principle of operation of the maintenance system database

4.7.3 Testing

The testing of the maintenance system database (MSD) sought to sample the views of wayside mechanics on the performance of the MSD and its impact on servicing automatic transmission drives. It also aimed at assessing the perception of vehicle operators on the usage of the MSD. Two focus group discussions for mechanics and vehicle operators was conducted in Tema to get feedback on the MSD. The criteria for selecting the wayside mechanics was based on ownership of garages servicing only automatic transmission drives while that of the vehicle operators was based on operation of automatic transmission drive and educational level (a minimum of first degree). A sample size of between 12 and 14 participants per group was chosen because existing literature recommends ranges from 6-14 participants per group (Kitzinger, 1995; Stewart and Shamdasani, 2014; Manoranjitham and Jacob, 2007). The groups were taken through a demonstration of how the MSD works. They were then assisted to visit the website using their mobile phones in order to have a first-hand feel of the website. Eleven (11) out of the 14 wayside mechanics opined that the MSD was flexible and easy to use since it required only mobile data. Besides, its usage was said to be less time consuming in the diagnosis of ATD faults. Three (3) of the mechanics were unable to access the website due to issues with phones. The 12 vehicle operators were able to access the website and admitted that the database could help in identifying some faults before visiting a mechanic.

As of the time of putting this thesis together, 43 days after the installation of the website, a total of 154 people had visited the website. See Appendix I for details. Out of this number, 126 of them had been to the site once while 28 had visited the website more than once. This shows that the MSD could be useful to both vehicle operators and wayside mechanics.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

The main objective of the study is to investigate the level of expertise of traditional automobile maintenance practitioners in servicing automatic transmission drives. The specific objectives include (1). To ascertain the extent of patronage of automatic transmission drives and the challenges associated with them. (2). To establish the level of expertise of traditional automobile practitioners in servicing of automatic transmission drives. (3). To design automatic transmission drive maintenance system database in order to enhance the servicing capabilities of the wayside mechanics. The following findings, conclusions and recommendations are drawn based on the outcome of the study.

5.1 Summary of Key Findings

The following are the key findings of the study:

- i. There was uniform increase in patronage of ATDs at average of 10 cars per garage within 2007 to 2016. This can be attributed to the customers' preference for drive comfort, lower stress rate in traffic-prone areas and better fuel economy.
- ii. Burnt Transmission fluid, Leaking Transmission Fluid, Noisy Transmission, Slips between Shifts, Broken, Inconsistent Hydraulic Pressure and Faulty Torque converters are the ATD problems brought to the garages on different days. Out of these problems, only Burnt Transmission Fluid, Leaking Transmission Fluid and Noisy Transmission are faults the mechanics repair easily.

- iii. 148 (95%) of the wayside garages did not have modern tools and equipment for proper diagnosis and repair.
- iv. Competence of wayside mechanics in solving ATD problems was poor due to electronic nature of modern ATDs, they therefore result to trial and errors to solve these problems.
- v. Forty-nine percent (49%) of vehicle operators prefer wayside mechanic servicing or attending to their transmissions due to the affordable cost even though they know most of the mechanics are incompetent.
- vi. Bad maintenance attitude of vehicle operators is a major challenge towards the use of ATDs as they do not make regular checks or servicing on the transmissions until there is a breakdown.

5.2 Conclusion

The investigation has brought to the fore a number of key revelations regarding the facts as claimed by traditional maintenance practitioners with regard to maintaining ATDs in Ghana. The findings of the study enable one to draw some valid conclusions about the patronage of ATDs, challenges associated with their use, level of expertise of mechanics and availability of modern tools and equipment. Results from the study as illustrated in the foregone analysis provides sufficient grounds to draw the following conclusions:

- a. The extent of patronage revealed a linear relation of $y=9.7888x + 0.8072$. This shows a uniform increase in sales of ATDs at an annual increasing rate of 10 cars per garage.

- b. The level of expertise of the wayside mechanics is below average. This is demonstrated in their trial – and – error approach in fixing ATD problems. The level of expertise of the dealers is higher compared to the private garages.
- c. A cost effective automobile maintenance database has been designed and hosted on <http://automatictransmissionhelpcentre.com>. This will complement the effort of the wayside mechanic in solving automatic transmission drive problems and also enhance the knowledge of vehicle operators and dealers in servicing automatic transmission drives.

5.3 Recommendations

The research has revealed that 49% of users of ATDs depend on wayside mechanics for fixing of their ATDs. In view of this, stakeholders in the automobile industry should inspire, equip and empower wayside mechanics in order to deal with this responsibility.

The following other recommendations are made:

- i. Automobile Laboratories of Technical Universities should be well resourced to focus on the training of students and mechanics in ATD related issues.
- ii. Workshops of Technical Institutions in the country should be equipped to provide hands – on training of engineering trainees in maintaining ATDs.
- iii. Policy makers and government should consider reducing taxes on the importation of tools and equipment used for fixing automatic transmission drives.
- iv. Organise inservice training for way side mechanics

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APPENDIX A

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

DEPARTMENT OF MECHANICAL ENGINEERING

QUESTIONNAIRE ON THE SERVICING OF AUTOMATIC TRANSMISSION VEHICLES IN GHANA – DEALERS

This questionnaire aims to collect data on automatic transmission vehicles and their use in Ghana. I am a student researcher of KNUST undertaking a study on automatic transmission vehicles in Ghana. This questionnaire solicits your input to this study. You are assured that data collected is for academic purpose only and will be treated with the utmost confidentiality. Thank you for your kind consideration.

SECTION A.

Please tick [✓] in the bracket or provide an answer where applicable.

1. Name of industry/establishment.....
2. Years of active employment.....
3. Highest level of formal education.
 - a) Basic level [] (b) Middle/JHS [] (c) Sec/Technical School [] (d) Diploma /First Degree [] (e) Master’s Degree [] (f) PhD /Professor [] (g) Non-formal education []
 - (h) Other(s), Please specify.....
4. What is your profession?
 - (a) Engineer [] (b) Technician [] (c) Mechanic /Artisan []
 - (d) Other (s) Please specify
5. What is your rank?

Technician [] Supervisor [] Superintendent [] Engineer []

1. How long has the company been in operation?

1 - 4yrs [] 5 – 8yrs [] 9 – 12yrs [] 13 – 16yrs [] 17yrs and above []
2. Do you have records on the number of automatic drives you sold?

YES [] NO []
3. If yes, please help us with this data by helping us complete the table below. The first entry is just a guide.

Year	Number of automatic vehicle	Number of manual vehicle
e.g. 2005	e.g. 2000	e.g. 500
2007		
2008		
2009		
2010		
2011		
2012		
2013		
2014		
2015		
2016		

4. Do you service automatic transmission drives?
Yes [] No []
5. If yes, how long have you been servicing automatic transmission drives?
1-5years [] 6-10 years [] 11-15 years [] 16-20 years [] 20 years and above []
6. Apart from the automatic transmission drives, what other servicing to you do?
.....
7. What type of services do you render on automatic drives?
.....
8. Have there been an increase in the number of automatic transmission drives you service?
Yes [] No []
9. If yes, how much in terms of numbers do you think automatic transmission drives have increased compared to the manual in the last 5years?
(a) 1 – 50% (b) 51 – 100% (c) 101 – 150% (d) 151 – 200% (e) 201% and above
10. Do you have the records on the number of vehicles you service in a month?
Yes [] No []
11. Please how many cars/vehicles did service last month?
.....
12. How many of these vehicle are automatic drives.....
13. In terms of months, provide the average maximum and minimum number of vehicles you service
A. Maximum.....
B. Minimum
14. How many auto mechanics work in these garage?
.....
15. Are they all trained to service automatic transmission drives?
Yes [] No []
16. If No, then please provide the number of auto mechanic who are trained to service automatic transmission drives?
.....
17. Do you think graduates from technical institutions in Ghana have the requisite knowledge to service automatic transmission drives?

Yes [] No [] Don't know []
18. What is the level of education of the technicians/mechanics you employ?
a) Basic level [] (b) Middle/JHS [] (c) Sec/Technical School []
(d) Diploma /First Degree []

19. With your experience, what is/are some main challenges associated with servicing of automatic transmission drives in Ghana?

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

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APPENDIX B

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

DEPARTMENT OF MECHANICAL ENGINEERING

QUESTIONNAIRE ON THE SERVICING OF AUTOMATIC TRANSMISSION VEHICLES IN GHANA

PERCEPTIONS AND FACTORS MILITATING AGAINST SERVICING OF AUTOMATIC VEHICLES TRANSMISSION [WAYSIDE MECHANICS]

This questionnaire aims to collect data on automatic transmission vehicles and their use in Ghana.

I am a student researcher of KNUST undertaking a study on automatic transmission vehicles in Ghana. This questionnaire solicits your input to this study. You are assured that data collected is for academic purpose only and will be treated with the utmost confidentiality. Thank you for your kind consideration.

(Please tick [✓] or provide answers where applicable)

1. Name of Shop
2. Which of the following vehicular transmission systems do you normally service in your workshop
Automatic [] Manual [] Both []
3. Which of these are you specialized in?
Automatic [] Manual [] Both []
4. What type of vehicles in your opinion experiences more frequent breakdowns with its transmission system?
Automatic [] Manual []
5. Which of them are you able to repair easily
Automatic [] Manual []
6. In terms of service charge in relation to vehicle transmissions, which is more expensive?
Automatic transmission [] Manual Transmission [] equal charges []
7. Please how many cars/vehicles did service last month?.....
8. Please provide the maximum and minimum number of vehicles you service in a month
C. Maximum.....
D. Minimum
9. How many of these vehicle are automatic drives.....
10. How many auto mechanics work in these garage?
.....
11. Are they all trained to service automatic transmission drives?

Yes [] No []

12. If No, then please provide the number of auto mechanic who are trained to service automatic transmission drives?

13. Which of the following automatic transmission drive problems are usually reported to your shop.
 (tick [√] all that apply)

Problems	Tick [√]
A. Slips between Shifts	
B. Noisy Transmission	
C. Burnt Transmission Fluid	
D. Leaking Transmission Fluid	
E. Inconsistent Hydraulic Pressure	
F. Faulty Torque Converter	

14. Which of these problems are you able to repair /solve easily (completely)
 (Please tick [√] all that apply)

Problems	Tick[√]
1. Slips between Shifts	
2. Noisy Transmission	
3. Burnt Transmission Fluid	
4. Leaking Transmission Fluid	
5. Inconsistent Hydraulic Pressure	
6. Faulty Torque Converter	

15. Which of the following automatic transmission drive components often develop faults (tick [√] all that apply)

Component	Please Tick[√]
1. Planetary Gear Sets	
2. The Hydraulic System	
3. Seals and Gaskets	
4. The Torque Converter	
5. The Governor and the Modulator	

16. Would you say that the rate at which automatic vehicles are entering the country calls for special training of mechanics

Yes [] No []

17. Give reason for your answer?

18. Which of the following tools are available at your shop (Please tick [✓] all that apply)

	Tools / Equipment	[✓]
A	Automatic Transmission Pressure Gauge	
B	Automatic Diagnostics Scanner tool	
C	Pressure Manometer	
D	High pressure fuel pump dismantle tool	
E	Anti-lock Brake System (ABS) diagnostic tool	
F	Automatic diagnostic injection measuring tool	
G	Automatic transmission fluid (ATF) changer	
H	Wishbone Lever Tube	

Others(specify).....



Knowledge and skill (please select the correct answer)

1. When diagnosing a transmission problem, which of these will do first
 - A. Use pressure gauge
 - B. Change the transmission fluid (ATF)
 - C. Checking fluid level (ATF)
 - D. Add more fluid (ATF) and test run
2. The turbine, stator and pump are components of a
 - A. Planetary gears
 - B. Torque converter
 - C. Clutch
3. Which of the following tool is a handy for locating transmission leaks?
 - A. Air test
 - B. Blacklight and dye
 - C. Foot power
 - D. All of the above
4. In examining the pan contents
 - A. a small amount of metal particles is considered normal
 - B. a golden-brown coating is a sign of a needed fluid change
 - C. metal or melted plastic debris indicate a need for a transmission overhaul
 - D. All of the above
5. Which of the following is/are necessary to diagnose torque converter clutch problem?
 - A. Wishbone lever tube
 - B. Automatic transmission fluid (ATF) changer
 - C. Tachometer and an oil pressure gauge
 - D. Pressure manometer
6. Which of these do you need to pay a particular attention to when making road test?
 - A. Upshifts and downshifts timing
 - B. Garage shifts quality
 - C. Infrequent noise that might arise
 - D. All of the above
7. In case a transmission is stuck in a lower gear and the engine speed increases to 6000rpm and stays there, what will be the maximum possible vehicle speed?
 - A. Approximately 50km/h
 - B. Approximately 80km/h
 - C. Approximately 100km/h
 - D. Approximately 150km/h
8. In case a transmission is stuck in a higher gear and the engine speed increases round 2000 to 2250rpm, what will be the maximum possible vehicle speed?
 - A. Approximately 50km/h

- B. Approximately 80km/h
 - C. Approximately 100km/h
 - D. Approximately 150km/h
9. When diagnosing transmission noise problems, it is important to note
- A. The frequency or pitch of the noise
 - B. When the noise occurs
 - C. If the noise changes with load on the car
 - D. All of the above

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APPENDIX C

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

DEPARTMENT OF MECHANICAL ENGINEERING

QUESTIONNAIRE ON THE SERVICING OF AUTOMATIC TRANSMISSION VEHICLES IN GHANA – VEHICLE OPERATORS QUESTIONNAIRES

This questionnaire aims to collect data on automatic transmission vehicles and their use in Ghana.

I am a student researcher of KNUST undertaking a study on automatic transmission vehicles in Ghana. This questionnaire solicits your input to this study. You are assured that data collected is for academic purpose only and will be treated with the utmost confidentiality. Thank you for your kind consideration.

SECTION C.

(Please tick [✓] or provide answers where applicable)

1. Highest level of formal education.
 a) Basic level [] (b) Middle/JHS [] (c) Sec/Technical School [] (d) Diploma/First Degree [] (e) Master’s Degree [] (f) PhD/Professors []
 (g) Non-formal education []
 (h) Other(s), Please specify.....
2. Gender Male [] Female []
3. Please which year were you born?

4. At what age did you start driving?

5. What type of vehicle are you driving? (years)
 Car [] SUV [] Mini Bus [] heavy duty []
6. What transmission system is your vehicle made of?
 Automatic [] Manual []
7. Are you using or ever used automatic transmission drive (car) before?
 Yes [] No []
8. What mainly informed your decision to acquire the above transmission?
 Driving comfort [] Ease of Maintenance [] Cost of vehicle []
 Brand of Car []
 Others (specify).....
9. Which of these garages would you prefer to service your vehicle?
 Way side garage [] Private garages [] Dealers []
10. How would you rate the skill/knowledge of the following garages on the servicing of automatic transmission drives

Garages	Excellent	Very good	Good	Average	Poor	Don’t know
Dealers garage						
Private garages						
Way side garages						

Continue from Q11 if you answered yes to Q 7

11. Do you think we have enough mechanic shops with requisite expertise to service automatic transmission vehicles? Yes [] No []
Don't Know []
12. Where do you normally service your automatic transmission (drive) vehicle?
Way side garage [] Private garages [] Dealers []
13. What informs your decision to choose the answer in 11 above
Cost [] quality of work [] Time of delivery []
Others (specify).....
14. What is the level of education of the mechanic who service your vehicle
(a) Basic level [] (b) Middle/JHS [] (c) Sec/Technical School []
(d) Diploma/First Degree [] (e) Master's Degree [] (f) don't know
15. How often do you visit the mechanic workshop to service your transmission
Once a month [] once every six months [] once every year []
unless faulty []
Others (specify).....
16. How often do you check your automatic transmission fluid (ATF) level?
Everyday [] once a week [] once a month [] don't know []
never []
17. Have you ever changed the fluid (ATF) before?
Yes [] No []
18. How often do you change the fluid (ATF)?
Every six months [] Every year [] Unless there is a problem []
Between every 30-50,000 miles []
19. Do you know the right transmission fluid (ATF) for your vehicle?
Yes [] No []
20. Having fixed a transmission problem with your mechanic, does the problem reoccur?
Yes [] No []
21. If yes, how long does it take for the same problem to reoccur?
A. Between a week and to a month
B. Between a month to six months
C. Between six months to two years
D. A year and beyond

APPENDIX D

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

DEPARTMENT OF MECHANICAL ENGINEERING

QUESTIONNAIRE ON THE SERVICING OF AUTOMATIC TRANSMISSION VEHICLES IN GHANA - USED VEHICLES IMPORTERS

This questionnaire aims to collect data on automatic transmission vehicles and their use in Ghana.

I am a student researcher of KNUST undertaking a study on automatic transmission vehicles in Ghana. This questionnaire solicits your input to this study. You are assured that data collected is for academic purpose only and will be treated with the utmost confidentiality. Thank you for your kind consideration. SECTION D

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

1. Name of industry/establishment.....
2. Years of active employment.....
3. Highest level of formal education.
a) Basic level [] (b) Middle/JHS [] (c) Sec/Technical School [] (d) Diploma /First Degree [] (e) Master's Degree [] (f) PhD /Professor [] (g) Non-formal education []
(h) Other(s), Please specify.....
4. How long has the company been in operation?
1 - 4yrs [] 5 – 8yrs [] 9 – 12yrs [] 13 – 16yrs [] 17yrs and above []
5. Do you have records on the number of cars you sold?
YES [] NO [] N/A []
6. If yes, please help us with this data by helping us complete the table below.
The first entry is just a guide.

Year	Number of automatic vehicle	Number of manual vehicle
e.g 2005	e.g. 2000	e.g. 500
2007		
2008		
2009		
2010		
2011		
2012		
2013		
2014		
2015		
2016		

7. Please what informs your decision on the type of transmission of vehicles you import?

	[√]
Cost of vehicle	
Country of origin	
Year model	
Type of vehicle	
Customer demand	

8. Out of the number of cars you import into the country, which of the two vehicles sales fast

Automatic transmission [] Manual transmission []

9. Which of the two cars/vehicles sales less

Automatic transmission vehicles [] Manual transmission vehicles []

10. What are some of the challenges associated with selling the cars you import?

Automatic drives

.....

.....

.....

.....

Manual drives

.....

.....

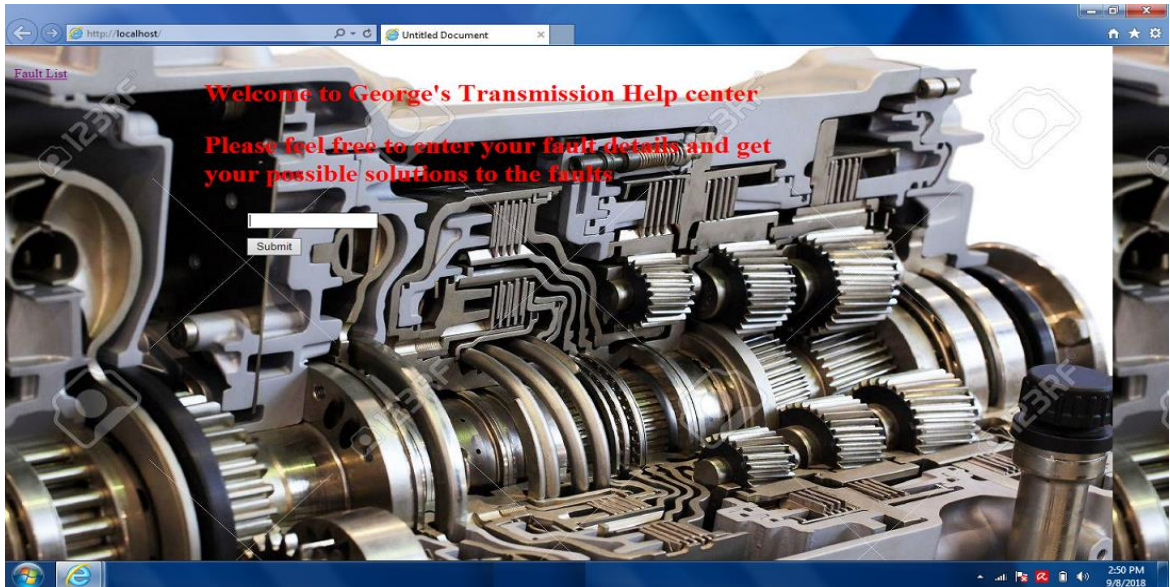
.....

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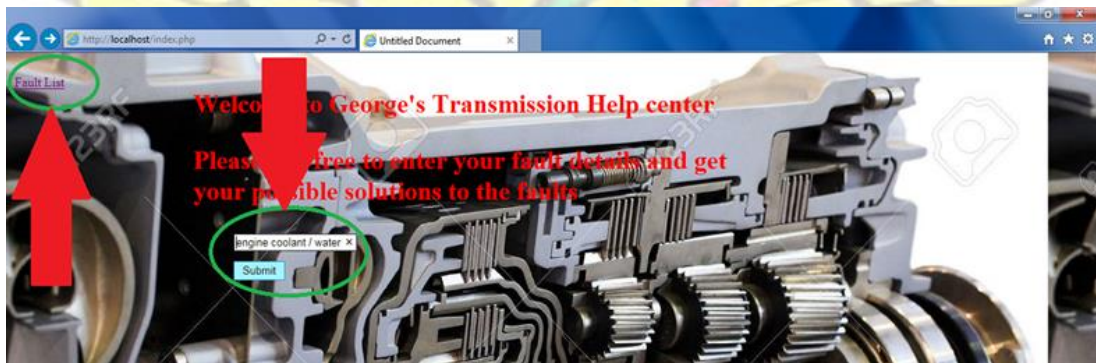
APPENDIX E

Welcome page from where user can access the service information database

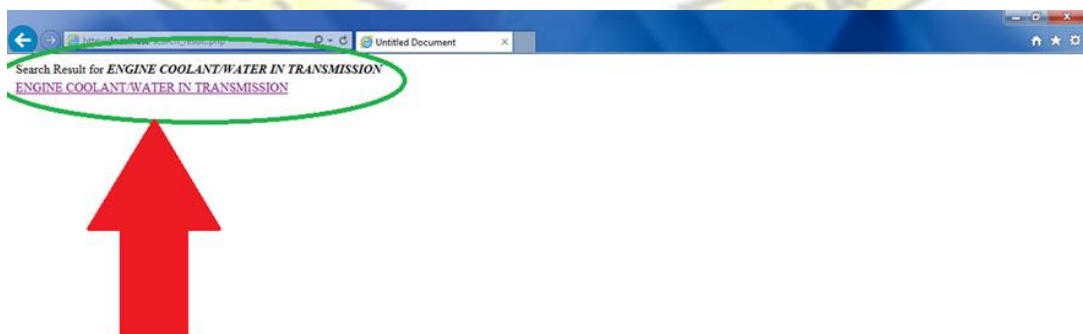


APPENDIX F

Fault list and a phrase search illustrations



APPENDIX G - An example search result




APPENDIX H -Service information being displayed








ENGINE COOLANT/WATER IN TRANSMISSION

Home Causes +

Fault List

Causes of Fault	
The antifreeze or water will deteriorate the seals, gaskets and the glue that bonds the clutch material to the pressure plate. Both conditions may cause damage to the transmission	

Solutions +

Cause	Description	Image						
The antifreeze or water will deteriorate the seals, gaskets and the glue that bonds the clutch material to the pressure plate. Both conditions may cause damage to the transmission	If antifreeze or water has entered the transmission, perform the following: 1. Disassemble the transmission. 2. Replace all of the rubber type seals (the coolant will attack the seal material which will cause leakage). 3. Replace the composition-faced clutch plate assemblies and the 2-4 band assembly (the facing material may separate from the steel center portion). 4. Replace all of the nylon parts (washers). 5. Replace the torque converter. 6. Thoroughly clean and rebuild the transmission, using new gaskets (bonded and non bonded) and oil filter. 7. Flush the cooler lines after the transmission cooler has been properly repaired or replaced.							

Windows Taskbar: 3:00 PM 9/8/2018

APPENDIX I –Number of people visiting the site

