DEVELOPMENT OF ELECTRONIC BRAKING SYSTEMS TROUBLESHOOTING AND MAINTENANCE MANUAL FOR AUTOMOBILE CRAFTSMEN IN NIGERIA

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ABSTRACT

The study developed electronic braking systems troubleshooting and maintenance manual for automobile craftsmen in Nigeria. Seven research questions were raised and answered as well as five null hypotheses were formulated and tested at 0.05 level of significant. Sequential Exploratory Research Design was adopted for this study. The study was conducted in Federal Capital Territory (FCT), Abuja, Kaduna, Kano, Lagos and Plateau States, Nigeria. The targeted population for the study was 174 consisting of 56 teaching and 43 non-teaching Subject Matter Experts (SMEs) and 75 automobile craftsmen (48 males and 27 females). The study utilized the whole population of the study. The instruments used for data collection includes: Electronic Braking System Troubleshooting and Maintenance Objectives Interview Protocol (EBSTMOIP), Electronic Braking Systems Troubleshooting and Maintenance Questionnaire (EBSTMQ), Electronic Braking Systems Troubleshooting and Maintenance Skill Performance Test (EBSTMSPT), Manual Content Validity Index (MCVI) and Expert Revision Form (ERF). The instruments were subjected to face and content validation by three experts. The reliability of EBSTMQ was established using Cronbach's Alpha statistics and yielded overall reliability coefficient of 0.84 and the reliability of EBSTMSPT was established using Kendall's tau coefficient of concordance and yielded coefficient values of 0.84 and 0.86. Data were collected by administering copies of the instruments through hand delivery. The data collected were analyzed using mean, z-test and Analysis of Covariance (ANCOVA). Findings of the study revealed that: ten items (84%) were found to be troubleshooting objectives, nine items (82%) were found to be maintenance objectives, 122 items ($\bar{X}$=4.56) were found to be troubleshooting contents, 178 items ($\bar{X}$=4.61) were found to be maintenance contents, 11 items ($\bar{X}$=4.59) were found to be troubleshooting facilities and 66 items ($\bar{X}$=4.60) were found to be maintenance facilities for the electronic braking systems manual. The study revealed that there was no significant difference (significant value $\geq$0.05) between the mean responses of teaching and non-teaching SMEs on the contents and facilities for electronic braking systems troubleshooting and maintenances manual. Findings from the study also revealed that, electronic braking systems troubleshooting and maintenance manual is valid (0.92), reliable (0.81) and had positive effect ($\bar{X}$=42.15) on the skill performance of automobile craftsmen in troubleshooting and maintenance of ABS, ATC and ESC. Based on the findings, the study recommended among others that: The National Board for Technical Education should include the identified objectives on troubleshooting and maintenance of electronic braking systems for the manual into the curriculum used for training automobile craftsmen in order to equip them with the competencies in troubleshooting and maintenance of electronic braking systems.

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CHAPTER ONE

1.0. INTRODUCTION

1.1. Background to the Study

Braking system is one of the most important safety systems in automobile that performs the primary function of stopping or decreasing the speed of a moving vehicle. Sangiovanni-Vincentelli and Di-Natale (2017) described braking system as an arrangement of several components for the purpose of retarding the speed of a vehicle. Braking system could be activated either by mechanical, hydraulic, pneumatic or electronic means. Though, according to Skruch and Gutmajer (2015), recent advancement in automobile industry to address the need for effective braking under special events led to the introduction of electronic braking systems.

Electronic braking system as the term implies refers to that type of braking system that uses electronic means of control to achieve braking action. Electronic braking systems are also generally designed to control the speed of the moving vehicle or bring it to rest in a shortest possible distance during special events such as during sudden braking, under slippery road condition among others. Kline (2019) maintained that, electronic braking systems increase braking comfort and improve high degree of safety compare to other type of braking systems. The most common types of electronic braking systems are Anti-lock Braking System, Automatic Traction Control and Electronic Stability Control. However, the effective type of electronic braking system for avoiding skidding is Anti-lock Braking System (Jitesh, 2014).

Anti-lock Braking System (ABS) is a type of electronic braking system that could be seen as an advance safety technology used in modern automobiles to prevent the vehicle wheels from locking as a result of sudden application of service brake. Jitesh (2014) asserted that, ABS on any automobile is simply an additional monitoring and controlling system superimposed on the existing braking system. The ABS maintains better steering ability, reduces braking distance up to 25% or more, tyre wear and guarantees stable braking characteristics on all road surfaces (Divyata & Anjali, 2016). These numerous importance of ABS is seen insufficient in ensuring safety especially in a slippery road condition. This therefore, led to the development of other types of electronic braking system such as Automatic Traction Control.

Automatic Traction Control (ATC) as the term implies refers to that type of electronic braking system that is often found on vehicles equipped with ABS. The ATC is an essential system added to ABS that improves traction by preventing wheel spin from occurring due to acceleration especially on a wet or slick surface. Liqiang *et al.* (2018) revealed that ATC prevents wheel spin by automatically reducing the speed of the drive wheel that is losing traction. Manning and Crolla (2017) further stated that, once ATC is activated, the system reduces engine torque and drive wheel speed as necessary to bring the vehicle under control which improves vehicle stability. Nonetheless, vehicle stability is effectively achieved with Electronic Stability Control.

Electronic Stability Control (ESC) is a safety system equipped in modern vehicles that improve stability by detecting and reducing loss of direction and traction when negotiating a sharp curve or driving in the rain. The ESC automatically applies the brakes to help steer the vehicle to intended direction when loss of steering control is detected. Dang (2014) maintained that, ESC operates automatically and takes corrective action to keep the vehicle on track by offering directional stability during extreme driving situations. This is achieved by reduction in engine torque and additional deceleration. Lie *et al.* (2016) disclosed that, one-third of fatal accidents could be prevented by the use of ESC and other electronic braking systems. The similarity among ABS, ATC and ESC is that, they are operated electronically and receiving electronic signal from the same ECU.

On the other hand, these systems differ as ABS controls wheel skidding during braking, ATC controls wheel spinning while driving and ESC controls wheel lateral movement while driving. Kline (2019) stated that, about 40% of the defects detected on modern automobile correspond to electronic braking systems. The maintenance of these systems requires that automobile craftsmen must be effective in troubleshooting.

Troubleshooting is a form of problem solving often applied to the maintenance of failed products or processes on a system. Troubleshooting could be seen as a logical and systematic search for the source of a problem in order to solve it and make the product or process operational again. According to Michael (2018), troubleshooting is a systematic approach to problem solving which is lacked by technicians in order to effectively carry out maintenance on modern automobiles. Effective troubleshooting of electronic braking systems entails identifying the symptoms of malfunction, determining the most likely causes and eliminating the potential causes. Matthew and Rouse (2018) noted that, vast majority of automobile equipped with electronic braking systems suffer disrepair due to lack of troubleshooting skills on the part of automobile craftsmen. Mazur and Proctor (2012) stated that, lack of troubleshooting skills results to poor maintenance.

Maintenance is a way of repairing or servicing used equipment or machine in order to make it functional or enhanced its functioning capacity. Ugwu *et al.* (2018) defined maintenance as every action taken to preserve an infrastructure in its original state so that it will retain its economic value and durability. Maintenance is the combination of all scientific, technical and managerial actions during the life cycle of an item intended to retain it, or restore it in a state in which it can perform its required function (Eti *et al.*, 2016). Cîmpan *et al.* (2013) argued that, the maintenance of modern automobiles especially those equipped with electronic braking systems is the most challenging task in automobile maintenance industry. The consequences of operational failure of electronic braking systems may result to fatal accident and loss of life or resources. Tashtoush *et al.* (2010) also stressed that, despite the importance of electronic braking systems, car owners are stripped off the full benefits attached to the systems due to lack of effective maintenance skills among automobile craftsmen.

Automobile craftsmen are technical personnel who are trained to specialize in automobile services, repairs and sometimes modification. Automobile craftsmen are graduates of technical college with specialization in Motor Vehicle Mechanic Works. According to Idris and Arah (2015), automobile craftsmen are trained persons with the knowledge, professional experience, skills and techniques related to automobile maintenance. Automobile craftsmen require a high level of troubleshooting and maintenance skill because of the increasing sophistication of the technology used in modern automobile systems. According to Audu *et al.* (2019), majority of the automobile craftsmen in Nigeria lack the basic understanding of electronic systems incorporated in modern automobiles. Edeh (2016) earlier revealed that, it is undoubtedly clear that automobile craftsmen in Nigeria have deficiencies in troubleshooting and maintenance of electronics braking systems in modern automobiles. The deficiencies of these craftsmen in carrying out troubleshooting and maintenance of electronic braking systems may be due to the technological advancement on modern automobiles. Improving the expertise level of automobile craftsmen in troubleshooting and maintenance of electronic braking systems without necessarily engaging them in any form of training capable of taking them away from work could be possible using packages such as manual.

Manual is a book designed to contain self-explanatory sequential procedures for accomplishing various tasks. It is a guide that equip its readers with the detailed descriptions on how to accomplished tasks. Manual is a book or booklet of instruction, designed to improve the quality of performed tasks (Sang, 2010). Manual contains instructions or procedures, processes or operations aimed at production of an object or its maintenance. According to Anjunwa *et al.* (2018), manual is a guide that specifies a number of essential elements of learning to be achieved by a learner through independent active participation of the learner. The benefits of a manual to learner such as automobile craftsmen include its efficacy in connecting new information to former knowledge and self-evaluating skill acquisition process. Rastogi and Nameeta (2013) argued that, manual possessed the capacity to allow learner acquire competencies at their own pace in the absence of experts' guidance.

Manual in the context of this study therefore, refers to a collection of planned activities that detailed the operational, troubleshooting and maintenance of electronic braking systems. Aliyu (2013) revealed that, an effective manual should spell out the objectives, content, facilities to be used, major tasks to be carried out, and specific tasks in sequence with illustrations or diagrams. However, the effectiveness of electronic braking systems troubleshooting and maintenance manual depends much on how it spells out in specific measurable terms the learning objectives.

Objectives are usually one sentence statement that describes the expected learning outcomes to be achieved after an intervention. Sommefeldt and Briggs (2012) defined objectives as brief, clear statements that describe the desired learning outcomes that include specific attitudes, knowledge, skills and values that reflect the broader goal expected for learners to exhibit. According to Lewis (2019), well stated objectives must be generally clear, concise and use direct language to provide information on the expected performance to be achieved by learner which must reflects the overall aim of a manual. The objectives of electronic braking systems troubleshooting and maintenance manual largely determines the contents.

Contents are list of information carefully collected, arranged and packaged with aim of creating changes in the learners. Kapoma and Namusokwe (2011) defined content of a manual as a list of subjects, topics, skills, themes, concepts or works to be learnt by learners. Contents in the context of this study refer to the safety, operational, troubleshooting and maintenance competencies in electronic braking systems that include ABS, ATC and ESC. Timothy *et al*. (2014) disclosed that, contents of troubleshooting and maintenance of electronic braking systems include competencies in the use of On-Board Diagnostic (OBD) in retrieving and translating Data Trouble Codes (DTCs), performing physical inspection, testing, cleaning, repairing, removing and installing the components of ABS, ATC and ESC that include modulator valve, wheel speed sensor, active braking valves, brake pressure sensor, ESC module, steering angle sensor and electronic control unit. These competencies can only be acquired with the use of relevant facilities.

Facilities are the essential concrete features that facilitate a given work or activity. Castali (2013) described facilities as objects which enable a learner to achieve high level competencies that includes workshops, laboratories, studios, equipment, machines, consumable materials and tools. Facilities in the context of this study refer to every object that facilitates the troubleshooting and maintenance of electronic braking systems. Eze (2015) stated that, facilities required for troubleshooting and maintenance of electronic braking systems include standard workshop, OBD II scan tools, wiring diagrams, volts meter, ohmmeter, spanners, saws, pliers, files, chisel, and screws drivers among others. These facilities in addition to the contents of troubleshooting and maintenance of electronic braking systems can help in the development of a manual with the aid of subject matter experts.

Subject Matter Experts (SMEs) are individuals highly knowledgeable and skilful in a particular area of human endeavour. Mohammed (2018) disclosed that, SMEs could either be teaching and non-teaching. In the context of this study, teaching SMEs are trained individuals with minimum qualification of Higher National Diploma or Bachelor Degree in Automobile Technology or related fields that are imparting to students the theoretical and practical contents of automobile electronic systems. While non-teaching SMEs are seen as individuals with technical skills and with more than five-year experience in troubleshooting and maintenance of automobile electronic systems. Arowolo (2017) noted that, SMEs can play significant role in the development of a manual as they will ascertain the suitability and appropriateness of the objectives, contents and tools required as well as determine its validity.

Validity is the degree at which a manual satisfies the need to which it is designed for. Victor (2016) defined validity of a manual as a measure of the extent to which result from SMEs regarding the quality of the manual can be generalized. Manual validity could be seen as the extent to which a manual accurately measures the theoretical and practical concepts it is developed to measure. A valid manual revealed the degree of its reliability. Reliability refers to the consistency or authenticity of measuring or analyzing tools. Jamaludin *et al.* (2011) defined manual reliability as the tendency to which judgment on the content validity of a manual produce the same result when it is measured at least twice. A valid and reliable manual is capable of enhancing the skill performance of automobile craftsmen.

The skill performances of automobile craftsmen described the details of acquired learning objectives demonstrated by the conclusion of a unit of the manual. Abu-Moghli *et al.* (2015) disclosed that skill performance expresses the degree in which the demonstration of learning objectives occurs. Skill performances of automobile craftsmen could be seen as the competences expected to demonstrate after completing reading electronic braking systems troubleshooting and maintenance manual. Audu *et al.* (2019) disclosed that, poor skill performances among automobile craftsmen in Nigeria resulted to poor maintenance of electronic systems incorporated in modern automobiles. This ugly situation calls for a technical skills intervention for all automobile craftsmen regardless of the gender.

Gender refers to the biological and physiological reality of being male or female. Connell (2018) described gender as a psychological term, which describes behaviours and attributes expected of individuals on the basis of being a male or female. The issue of gender bias in the automobile maintenance industry is denying female craftsmen the opportunity to benefit from skill development programmes in Nigeria. Najoli (2019) stated that, the huge gender bias in the technological field of endeavors such as automobile maintenance industry is partly responsible for technical skill shortage among workers (automobile craftsmen). Thus, in order to address the challenge, there is need to develop a skill intervention that is gender bias free such as electronic braking systems troubleshooting and maintenance manual for automobile craftsmen in Nigeria.

From the foregoing, it can be seen that the implication of the lack of a valid and reliable manual capable of enhancing skill performance in troubleshooting and maintenance of electronic braking systems is that, automobile craftsmen in Nigeria may remain in technical disconnection with global trends in automobile maintenance industry. Olaitan and Ikeh (2015) noted that, this technical disconnection negatively affects the socioeconomic development of Nigeria as many automobile craftsmen are jobless or semi jobless which may be due to lack of competencies in troubleshooting and maintenance of electronic systems. Therefore, this study sought to develop electronic braking systems troubleshooting and maintenance manual for automobile craftsmen in Nigeria.

1.2. Statement of the Research Problem

Automobile craftsmen are trained to effectively carry out maintenance services that include general tests procedures, standard fault diagnosis and rectification of components faults in automobiles. Automobiles of nowadays are highly equipped with sophisticated technological innovations to improve on safety, comfort and fuel economy. These improvements possibly made it difficult for automobile craftsmen to discharge their primary functions. Michael (2018) confirmed that, it is a common knowledge that a large proportions of the automobile craftsmen in Nigeria finds it extremely difficult to diagnose, troubleshoot and maintain modern automobiles. This negative development possibly leads to several job lost among automobile craftsmen in Nigeria.

The inability of automobile craftsmen to discharge their functions could be characterized by mismatch between the training received in school and the service demands in the world of work. The possible reason might be due to the lack of adequate electronic braking systems troubleshooting and maintenance competences in the National Board for Technical Education curriculum for National Technical Certificate programme used for training the vast majority of automobile craftsmen in Nigeria. Several studies have been conducted to address these shortcomings. These studies include the development of training manual on the maintenance of automobile battery and charging system by Ogbuanya and Idris (2015), assessment of emerging technology skills required by technical college graduates of Motor Vehicle Mechanic's Work (MVMW) for establishing automobile enterprises by Udogu (2015) and assessment of core on-board diagnostic (OBD) skills required by motor vehicle mechanics for troubleshooting engine performance and transmission system of modern automotive by Alabi *et al.* (2019).

Despite these efforts, the inability of automobile craftsmen to carryout troubleshooting and maintenance services on modern automobiles persists as 80% of the skill deficiencies among Nigerian automobile craftsmen hinges mainly on the electrical/electronic systems of modern vehicles (National Automotive Design and Development Council NADDC, 2019). Thus, it is against this backdrop that the researcher developed electronic braking systems troubleshooting and maintenance manual for automobile craftsmen in Nigeria.

1.3. Aim and Objectives of the Study

The aim of the study was to develop electronic braking systems troubleshooting and maintenance manual for automobile craftsmen in Nigeria. Specifically, the study sought to achieve the following objectives:

i. Determine the objectives of the manual on troubleshooting electronic braking systems for automobile craftsmen in Nigeria.
ii. Identify the objectives of the manual on the maintenance of electronic braking systems for automobile craftsmen in Nigeria.
iii. Determine the contents to be utilized for achieving the objective of the manual on troubleshooting electronic braking systems for automobile craftsmen in Nigeria.
iv. Determine the contents to be utilized for achieving the objective of the manual on the maintenance of electronic braking systems for automobile craftsmen in Nigeria.
v. Identify the troubleshooting facilities for the electronic braking systems manual for automobile craftsmen in Nigeria.
vi. Identify the maintenance facilities for the electronic braking systems manual for automobile craftsmen in Nigeria
vii. Develop the electronic braking systems troubleshooting and maintenance manual for automobile craftsmen in Nigeria.
viii. Find out the effect of electronic braking systems troubleshooting and

maintenance manual on skill performance of automobile craftsmen in troubleshooting and maintenance of ABS, ATC and ESC.

1.4. Significance of the Study

The study will be of benefits to: automobile craftsmen, automobile owners, workshop owners, maintenance industry, academic researchers, National Automotive Design and Development Council (NADDC), Industrial Training Fund (ITF), National Board for Technical Education (NBTE) and Federal Road Safety Corps (FRSC).

Automobile craftsmen will find this study of high relevance if accessed, acquired and utilized the skills contained in the manual by equipping them with the necessary knowledge and technical skills required in troubleshooting and maintenance of electronic braking systems. The acquisition of these skills is capable of addressing the issue of jobs lost among automobile craftsmen, making them fit in the automobile maintenance industry and enhancing their standard of living. Automobile craftsmen can benefit from this study if the developed manual is made available to them by NADDC, ITF and Automobile workshop owners in the quest to improve their skills in troubleshooting and maintenance of electronic braking systems.

Automobile owners will find this study of great benefits if skills contained in the manual are accessed, acquired and utilized by automobile craftsmen as they will enjoy better service delivery and spend less since compounding problem as a result of trial and error which contribute in high service charges will be drastically reduced. Automobile owners will also benefit from this study as optimum maintenance services by automobile skilled and competent craftsmen will guaranteed their safety, comfort and prolong the life span of their automobiles. These can be achieved through the use of the developed manual in training automobile craftsmen on troubleshooting and maintenance of electronic braking systems.

Automobile workshop owners will find the study of much significance if skills contained in the manual are accessed, acquired and utilized by automobile craftsmen as having competent craftsmen equipped with the technical know-how on troubleshooting and maintenance of electronic system will increase customers' patronage which translates to high business profit. Automobile workshop owners will also benefit from this study if skills contained in the manual are accessed, acquired and utilized by automobile craftsmen as having competent employee will give a good name to their company. Automobile workshop owners can achieve these by making the copies of the manual developed available for automobile craftsmen in their workshops.

Automobile maintenance industry will find the study of high importance if skills contained in the manual is accessed, acquired and utilized by automobile craftsmen as the industry will have high statistics of competent members capable of carrying out troubleshooting and maintenance services on modern automobile. This is capable of giving the industry a good name and reduces the number of unskilled craftsmen. However, these can be achieved if copies of the manual developed are made available to automobile craftsmen either by workshop owners, NADDC or ITF.

Academic researchers will find the study of much relevance as the manual will contain valuable information on troubleshooting and maintenance of electronic system which can be used for referencing purposes. The information contained in the manual will tremendously contribute to the world of knowledge useful to students of research in automobile technology and related fields. Academic researchers can benefit these by accessing the copy of the manual developed online or offline as it was published for academic purpose.

The NADDC will profit from the findings of this study as the manual to be developed will serve as a learning material on electronic braking systems troubleshooting and maintenance which can be used by the organization in training automobile craftsmen. This can be achieved as a hard copy of the developed manual will be made available by the researcher to the Director General, NADDC through the Head of Information Department for official use.

The ITF will also profit from the findings of this study as the manual to be developed will serve as a learning material on electronic braking systems troubleshooting and maintenance which can be used by the organization in training automobile craftsmen. This can be achieved as a hard copy of the developed manual will be made available by the researcher to the Director General, ITF through the training manager for official use.

Furthermore, the findings of this study will be useful to the NBTE as it will provide suitable content of electronic braking systems troubleshooting and maintenance for inclusion into the curriculum used for training automobile craftsmen. This can be achieved as a hard copy of the developed manual will be made available by the researcher to the board.

The study will contribute in boosting the economy of Nigeria as the manual will contain saleable knowledge and skills on troubleshooting and maintenance of electronic braking systems. Accessing, acquisition and utilization of such skills is capable of creating new jobs, returning back the number of jobs taken away from automobile craftsmen due to lack of skills, reducing the huge amount of money spent on automobile maintenance requiring the service of foreign experts and also relieving the government of the burden of retraining unskilled craftsmen. This can be achieved if organizations such as NADDC or ITF make the developed manual available for automobile craftsmen.

The FRSC will benefit from the findings of this study as will provide reach information on troubleshooting and maintenance of electronic braking systems capable of reducing road accidents. This information will serve as a guide to be used to train automobile craftsmen in troubleshooting and maintenance of electronic braking systems during its annual skills training programme in order to prevent road accident which will consequently result to loss of lives and properties.

1.5. Scope of the Study

The study was delimited to the electronic components of Anti-lock Braking System (ABS), Automatic Traction Control (ATC) and Electronic Stability Control (ESC) types of electronic braking systems. These components include wheel speed sensor, Electronic Control Unit (ECU), modulator valve, brake pressure sensor, active brake valve, Electronic Stability Module (ESM) and steering angle, yaw rate and lateral sensors. Moreover, other mechanical components of ABS, ATC and ESC such as relay valve, ATC valve, package installation valve and quick release valve were not covered simply because, they shared similar design and operational configuration with the modulator valve which was covered in this study. Equally, other types of electronic braking systems such as Electronic Parking Brake, Brake Assist, Automatic Cruise Control and Autonomous Emergency Braking systems were not covered in this study, simply because vast majority of automobile are not equipped with these systems and exhibited lesser safety advantages when compared to ABS, ATC and ESC.

The study was also delimited to four out of the six stages of troubleshooting as stipulated by Robert (2019) that include fault identification (diagnosis using OBD II), establishing probable cause (physical checks), testing probable cause and verifying system functionality. The other two stages of troubleshooting that include establishing action plan and documenting the process were not covered simply because, they are literary tasks in nature. Furthermore, the study was also delimited to corrective maintenance. This is because, Malfunction Indicator Lamp (MIL) is only activated when electronic systems such as electronic braking system is faulty and requires correction

1.6. Research Questions

The following research questions were raised and answered in the study:

i. What are the objectives of the manual on troubleshooting electronic braking systems for automobile craftsmen in Nigeria?

ii. What are the objectives of the manual on the maintenance of electronic braking systems for automobile craftsmen in Nigeria?

iii. What are the contents to be utilized for achieving the objective of the manual on troubleshooting electronic braking systems for automobile craftsmen in Nigeria?

iv. What are the contents to be utilized for achieving the objective of the manual on the maintenance of electronic braking systems for automobile craftsmen in Nigeria?

v. What are the troubleshooting facilities for the electronic braking systems manual for automobile craftsmen in Nigeria?

vi. What are the maintenance facilities for the electronic braking systems manual for automobile craftsmen in Nigeria?

vii. What is the effect of electronic braking systems troubleshooting and maintenance manual on skill performance of automobile craftsmen in troubleshooting and maintenance of ABS, ATC and ESC?

1.7. Hypotheses

The following null hypotheses were formulated to guide the study and were tested at .05 level of significance:

HO_1: There is no significant difference between the mean responses of teaching and non-teaching SMEs on the contents to be utilized for achieving the objective of the manual on troubleshooting electronic braking systems for automobile craftsmen in Nigeria.

HO_2: There is no significant difference between the mean responses of teaching and non-teaching SMEs on the contents to be utilized for achieving the objective of the manual on the maintenance of electronic braking systems for automobile craftsmen in Nigeria.

HO_3: There is no significant difference between the mean responses of teaching and non-teaching SMEs on the troubleshooting facilities for the electronic braking systems manual for automobile craftsmen in Nigeria.

HO_4: There is no significant difference between the mean responses of teaching and non-teaching SMEs on the maintenance facilities for the electronic braking systems manual for automobile craftsmen in Nigeria.

HO_5: There is no significance difference between the skill performance scores of male and female automobile craftsmen that learnt troubleshooting and maintenance of ABS, ATC and ESC using electronic braking systems troubleshooting and maintenance manual.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1.0 Theoretical Framework of the Study

2.1.1 Andragogy theory

Andragogy theory (Adult Learning Theory) was propounded by Malcom Shepard Knowles in 1968. Knowles described andragogy as the process in which individuals take initiative with or without the help of others in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating learning outcomes. Knowles puts forward three immediate reasons for self-directed learning. First, Knowles argues that there is convincing evidence that people who take the initiative in learning (proactive learners) learn more things, and learn better, than do people who sit at the feet of teachers passively waiting to be taught (reactive learners). They enter into learning more purposefully and with greater motivation. They also tend to retain and make use of what they learn better and longer than do the reactive learners.

Secondly, self-directed learning is more in tune with our natural processes of psychological development. An essential aspect of maturing is developing the ability to take increasing responsibility for our own lives to become increasingly self-directed. Thirdly, many of the new developments in education put a heavy responsibility on the learners to take a good deal of initiative in their own learning. Students entering into these programs without having learned the skills of self-directed inquiry will experience anxiety, frustration, and often failure.

Malcolm Knowles' thoughts were then to put the idea of self-direction into packaged forms of activity that could be taken by educators and learners. These thoughts are embedded in the following assumptions:

Knowles' five assumptions of adult learners

Knowles theory of andragogy identified five assumptions that teachers should make about adult learners.

1. **Self-Concept:** Because adults are at a mature developmental stage, they have a more secure self-concept than children. This allows them to take part in directing their own learning.
2. **Past Learning Experience**: Adults have a vast array of experiences to draw on as they learn, as opposed to children who are in the process of gaining new experiences.
3. **Readiness to Learn:** Many adults have reached a point in which they see the value of education and are ready to be serious about and focused on learning.
4. **Practical Reasons to Learn**: Adults are looking for practical, problem-centered approaches to learning. Many adults return to continuing education for specific practical reasons, such as entering a new field.
5. **Driven by Internal Motivation:** While many children are driven by external motivators such as punishment if they get bad grades or rewards if they get good grades, adults are more internally motivated.

Four principles of andragogy

Based on these assumptions about adult learners, Knowles discussed four principles that educators should consider when teaching adults.

1. Since adults are self-directed, they should have a say in the content and process of their learning.
2. Because adults have so much experience to draw from, their learning should focus on adding to what they have already learned in the past.
3. Since adults are looking for practical learning, content should focus on issues

related to their work or personal life.

4. Additionally, learning should be centered on solving problems instead of memorizing content.

Knowles theory of andragogy is related to this study because its four principles guided the researcher in including automobile craftsmen in the process of evaluating the effectiveness of electronic braking systems troubleshooting and maintenance manual. The theory also guided the researcher in focusing the contents of electronic braking systems on adding to what they have already learned in the past, on issues related to their work and on solving problems instead of memorizing content.

2.1.2 Sidek's manual development model

Sidek's Manual Development Model (SMDM) was propounded by Sidek in 2005. The approach of the model has two different stages which have different goals for each stage. The first is a stage where a developer prepares a manual draft. This stage has nine steps that begin with developing the aims of manual setting identifying theories, needing an assessment, setting objectives, selecting the content, strategy, logistic, media and lastly ends with integrating the draft manual. It is called a draft because the manual has not been validated and measured its reliability. The second stage of the SMDM is to evaluate the draft manual. In this stage, the developed manual needs to be tested in a pilot study in order to ensure the validity and reliability of the manual. If high validity and reliability indices are gained, it can be considered as a complete manual and can be tested for effectiveness. If not, the developer needs to re-assess the manual, starting from the content selection and re-follow every step until getting a good value of validity and reliability.

Sidek stated that, a minimum score of 70 percent score of SMEs responses from a Manual Content Validity Index (MCVI) is sufficient to justify the validity of a manual. This is achieved by dividing the total score given by each expert (X) by the total maximum score (25) of the MCVI and then multiplied by 100. Sidek also disclosed that, a minimum score of 0.7 Cronbach's Alpha coefficient value of the SMEs responses from a Manual Content Validity Index (MCVI) is sufficient to justify the reliability of a manual. Effective evaluation of educational products can be achieved through variety of methods for usability tests involving SMEs and users. Users' feedback using partial least squares structural equation modelling, questionnaire and experimental tests are commonly used to test the effectiveness of a manual. Sidek postulated that, the experimental design used in quantitative research using a true experimental research design remains the best choice to assess the effectiveness of a manual. Nevertheless, after undergoing these two detailed stages, the manual is ready for use and can be employed to target population.

The SMDM was adopted for this study because it is widely employed by researchers in developing manuals and considered most integrated and comprehensive model which has specific and systematic steps in developing manual and testing its validity, reliability and effectiveness. The model proved highly effective in guiding researcher to develop manual and other educational products due it uniqueness in the following manner: guided the researcher in the selection of appropriate instruments and techniques in content assessment, content validity, reliability and effectiveness testing of the manual. Nevertheless, the SMDM was modified and guided the researcher in drawing the conceptual framework for the development of electronic braking system troubleshooting and maintenance manual for automobile craftsmen in Nigeria. The pictorial representation of the SMDM is shown in Figure 2.1.

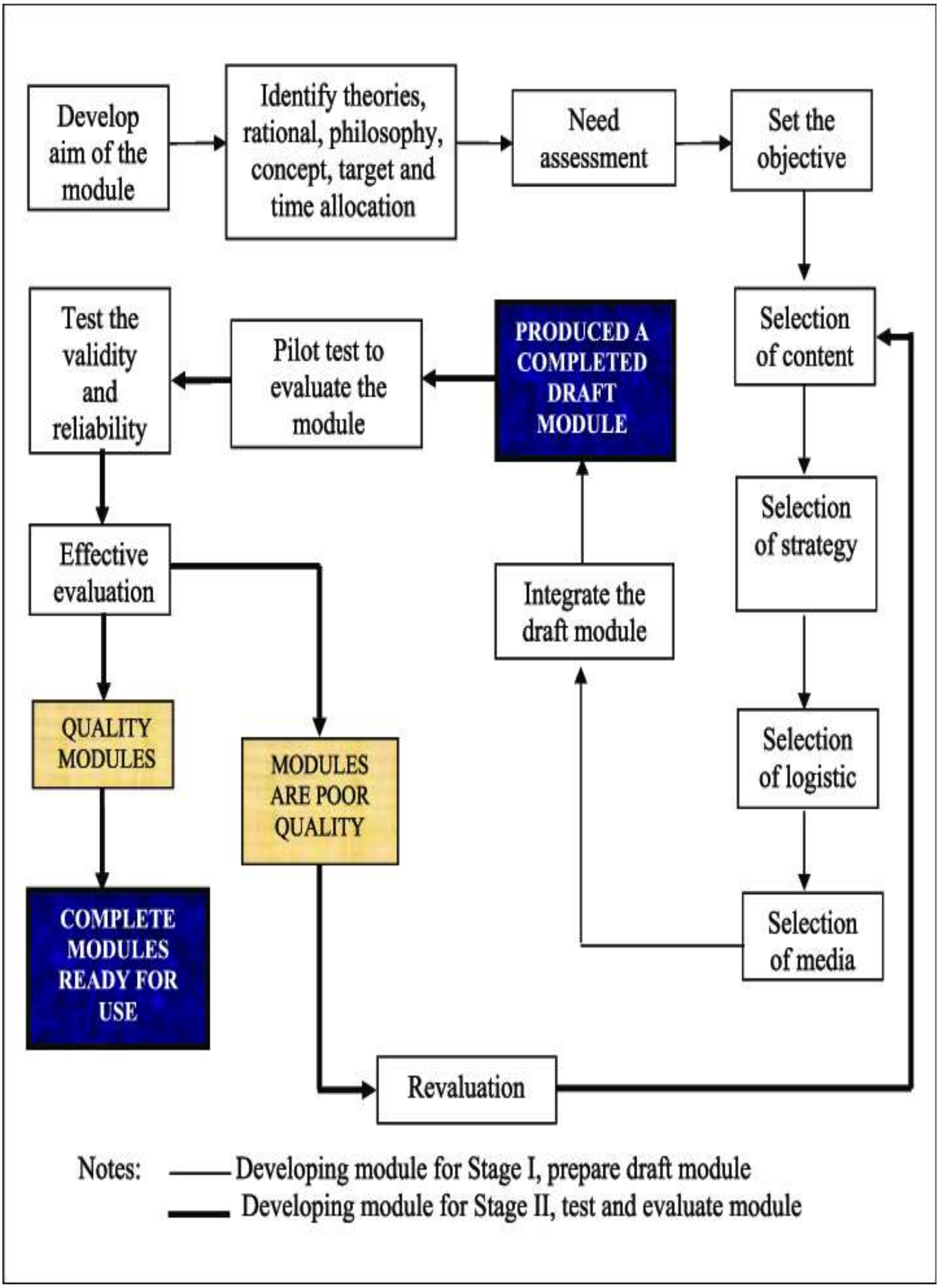

Figure 2.1: Sidek's Manual Development Model

Source: Sidek and Ahmad (2005)

2.2.0 Conceptual Framework of the Study

The Figure 2.2 represents modification of SMDM as conceptual framework for the development of electronic braking system troubleshooting and maintenance manual. The modification made include splitting the two stages into three phases. This is achieved by merging the first eight steps of the SMDM into a phase and making the final step (integrate the draft module) to be a phase in the framework. The modification was based on the fact that; the first eight steps in the SMDM requires assessment needed to achieve objectives one to six while the final step is the only step requiring the service of the developer (in this case, the researcher) to achieve objective seven.

The figure contains three phases of manual development process. Phase one represents the assessment stage. At this stage, objectives, contents and facilities required for troubleshooting and maintenance of electronic braking systems were assessed using descriptive research design. The second phase comprises of two major tasks that include designing and assembling the information obtained from the first phase of the study. These two tasks required the services of experts in the field of automobile electronic from maintenance industries and institutions.

Furthermore, at this phase, a draft electronic braking system troubleshooting and maintenance manual is developed. The third phase comprises of three evaluation stages. At this stage of the study, the draft electronic braking system troubleshooting and maintenance manual will be tested for content validity, reliability and effectiveness. The test of validity and reliability of the manual was done by subject matter experts while the manual effectiveness was tested using automobile craftsmen.

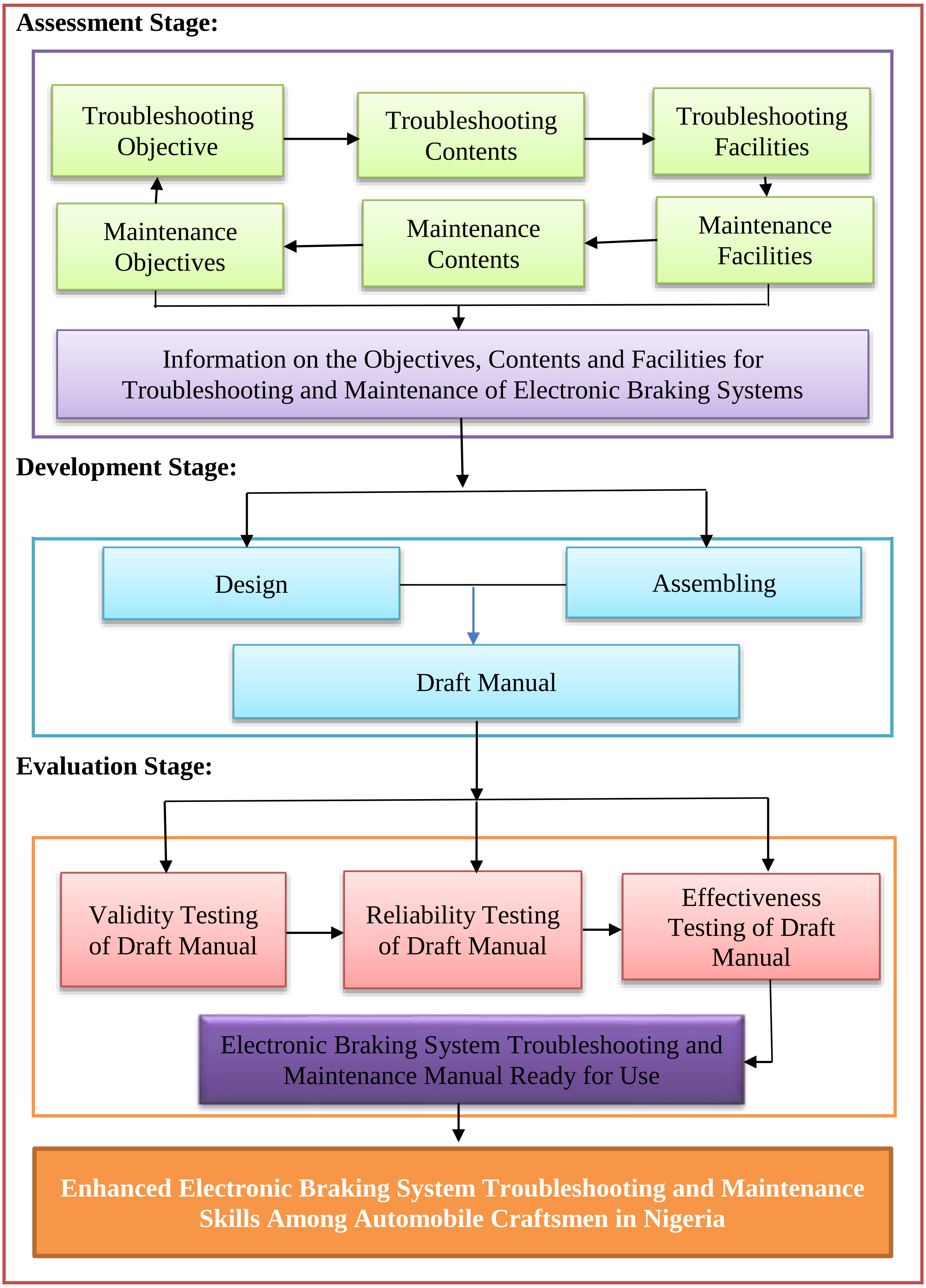

Figure 2.2: Conceptual Framework for the Development of Electronic Braking System Troubleshooting and Maintenance Manual

2.2.1 Electronic braking systems

Electronic braking systems are additional safety systems incorporated into the primary braking system that usually come into play during emergency situations. These systems reduce braking distance by several meters, which can be decisive in some situations. The systems increased braking comfort and improved vehicle safety. Man (2019) disclosed that, the outstanding features of electronic braking systems are: electronic activation of all braking system components, retarder and engine brake integration into the service brake application, brake force distribution adapts to load distribution, brake compatibility between tractor and trailer, comfortable deceleration control and continuous self-testing via integrated diagnostic and monitoring functions. Wabco (2019) confirmed that, Anti-lock Braking System (ABS), Automatic Traction Control (ATC) and Electronic Stability Control (ESC) are the common types of electronic braking systems.

2.2.1.1 Anti-lock braking system

Anti-lock Braking System (ABS) is an automobile safety system designed to prevent vehicle wheels from locking and avoiding uncontrolled skidding as a result of the service brake being applied with too much force, especially on slippery road surfaces. According to Hiroshi and Shingo (2015), ABS maintain cornering forces on braked wheels to ensure that the vehicle or vehicle combination retains its driving stability and maneuverability as far as physically possible. The ABS do not necessarily reduce the stopping distance, and in fact may actually increase stopping slightly on dry pavement. On wet or slick pavement, ABS may reduce the stopping distance up to 25% or more, which could be the difference between a safe stop and an accident (Carley, 2019). The ABS generally offers improved vehicle control and decreases stopping distances on dry and slippery surfaces; however, on loose gravel or snow-covered surfaces, ABS can significantly increase braking distance, although still improving vehicle control. Divyata and Anjali (2016) noted that, ABS have several advantages which include the following:

1. Guarantees stable braking characteristics on all road surfaces, hence avoids overturning of the vehicle.
2. Reduces friction on wheels and road, thus increases efficiency of tires (up to 30%).
3. Vehicle with ABS can be stopped at a lesser distance than a non-ABS vehicle.
4. Steering control is effective which entails that, vehicle can be steered smoothly while braking. Thus, accidents are minimized.
5. A driver without experience can drive ABS vehicle effectively compared to an experienced driver on the non-ABS vehicle.

Typically, ABS consists of wheel speed sensing unit, ABS module, modulator valves, brake pressure sensor among others as shown in Figure 2.3.

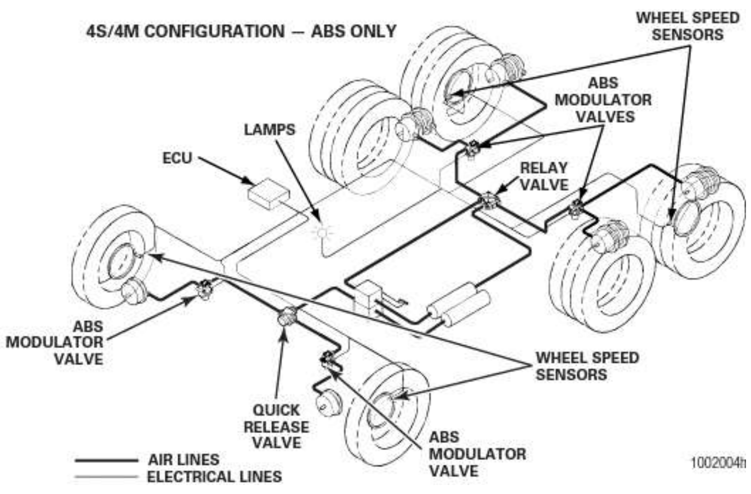

Figure 2.3: Operation of Anti-lock Braking System

Source: Wabco (2019)

Wheel Speed Sensing Unit: Wheel speed sensing unit consist of a tooth wheel mounted on the hub or rotor of each monitored wheel and a wheel speed sensor installed with its end against the tooth wheel. The unit also consist of a sensor clip that holds the sensor in place and against the tooth wheel as shown in Figure 2.4. The sensor continuously sends wheel speed information to the ECU. Each of the ABS wheel speed sensors detects the speed of the corresponding wheel. The sensor consists of a permanent magnet, coil and tone wheel. Chankit *et al*. (2014) stated that, the magnetic flux produced by the permanent magnet changes as each tooth of the tone wheel (which rotates together with the wheel) passes in front of the magnet's pole piece. The changing magnetic flux induces voltages at a frequency corresponding to the wheel speed.

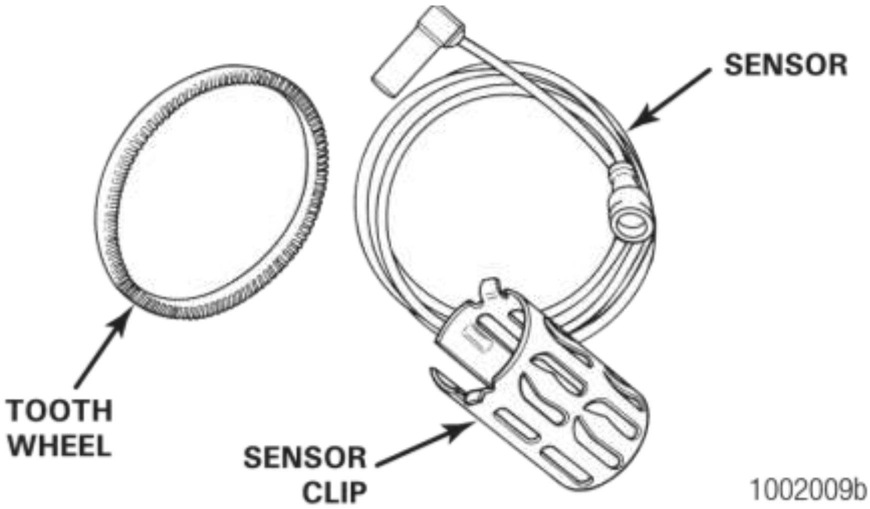

Figure 2.4: Wheels Sensing Unit

Source: Wabco (2019)

Electronic Control Unit (ECU): The ECU is the control center or brain of the ABS, ATC and ESC systems. ABS receives information from the sensors, processes data and sends signals to modulators and active braking valves to achieve different tasks. The work of ECU is to receive, amplify and filter the sensor signals for calculating the speed rotation and acceleration of the vehicle (Ayman *et al*., 2011). The ECU also uses the speeds of road wheels to calculate an estimate for the speed of the vehicle. Jitesh (2014) noted that, the slip of each wheel is obtained by comparing the reference speed with the individual wheel. During wheel slip or wheel acceleration condition, signal is sent to alert the ECU. The ECU send signal that trigger the pressure control valve of the solenoids of the pressure modulator to modulate the brake pressure in the individual wheel brake cylinders. According to Seibum (2018), the ECU reacts to a recognized defect or error by switching off the malfunctioning part of the system or shutting down the entire system. The diagram of ECU is shown in Figure 2.5.

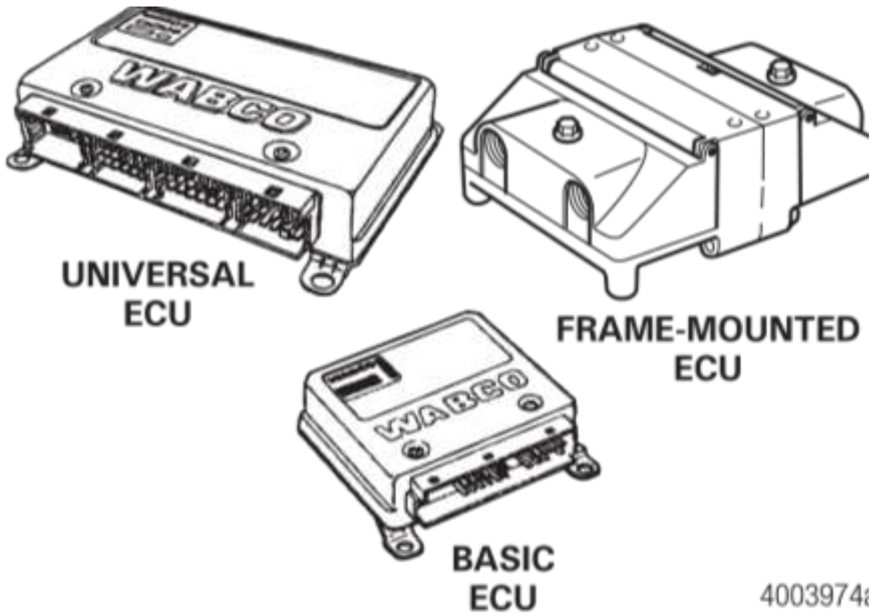

Figure 2.5: Electronic Control Unit

Source: Wabco (2019)

Pressure Modulator Valves: A pressure modulator valve controls air pressure to an affected wheel-end brake during an ABS, ATC or ESC event to reduce speed and prevent wheel lock up. Pressure modulator valves are also used during ATC events to properly gain traction on the affected wheel end. A pressure modulator valve is usually located on a frame rail or cross member near the brake chamber or as part of a valve package. Pressure modulator valve consists of inlet and outlet ports as well as connector unit as shown in Figure 2.6.

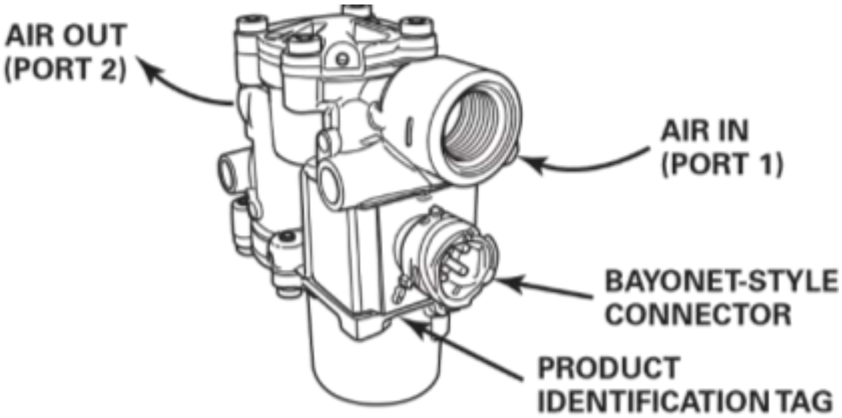

Figure 2.6: Pressure Modulator Valve

Source: Wabco (2019).

The Brake Pressure Sensor: Brake pressure sensor is part of the ABS, ATC and ESC that senses the brake fluid pressure in a hydraulic unit of the systems. The sensor is a type of pressure switch that shows and alerts a fault in the braking system. The sensor is used to detect pressure differentials in the hydraulic system. Dang (2017) stated that, if the car alerts a fault in the hydraulic system and the system checks out, the sensor itself may have failed. The sensor can be located in the primary or secondary delivery circuit depending on the application. A brake pressure sensor is shown in Figure 2.7.

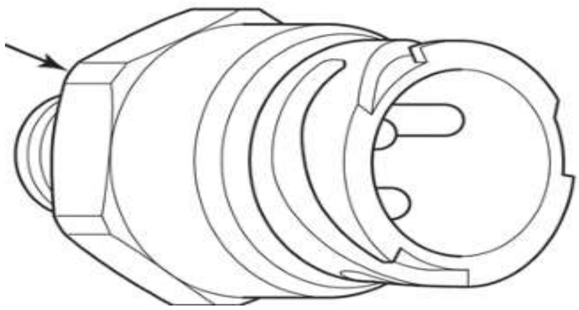

Figure 2.7: Brake Pressure Sensor

Source: Wabco (2019)

2.2.1.2 Automatic traction control system

Automatic Traction Control (ATC) system is an option that is often found on vehicles equipped with ABS. The ATC is essentially an additional feature to ABS that improves traction when the vehicle is accelerating on a wet or slick surface, or is accelerating too quickly for the tires to maintain their grip. Ran *et al.* (2016) disclosed that, ATC prevents wheel spin by applying the brakes on the drive wheel that is losing traction, and/or momentarily reducing engine torque by various methods. The ATC helps improve traction in low traction road conditions. According to Jin *et al.* (2017), ATC reduces the potential of jackknifing caused by excessive wheel spin during acceleration or in curves. The ATC works automatically in two different ways that include the following:

i. When one drive wheel is spinning at a different speed than the other, ATC momentarily applies the brake until traction is regained.
ii. When both drive wheels are spinning on a poor-traction surface, ATC automatically reduces engine power to attain optimum tire-to-road traction.

The ATC will automatically turn on and off as driver's input is not required to turn this feature on. If the vehicle experiences a traction control event, the ATC indicator lamp will come on, indicating ATC is active. The light turns off when the event has ended. The main difference between ABS and ATC, therefore, is that ABS only comes into play when braking while ATC only comes into play while accelerating. According to Yang *et al.* (2015), ATC shares many of the same components and sensor inputs with the ABS system as shown in Figure 2.8. These similarities include the following:

i. A common control module is often used with additional software and control circuits for ATC. In some vehicles, a separate ATC control module may be used.
ii. The same wheel speed sensors are used to monitor wheel speeds.

iii. The same pump and high pressure accumulator are used to generate and store hydraulic pressure for ATC braking.

iv. The same modulator (with a couple of extra solenoid valves) is used to control braking.

Usually, ATC is added an extra solenoid valve sometimes called Active Braking Valves.

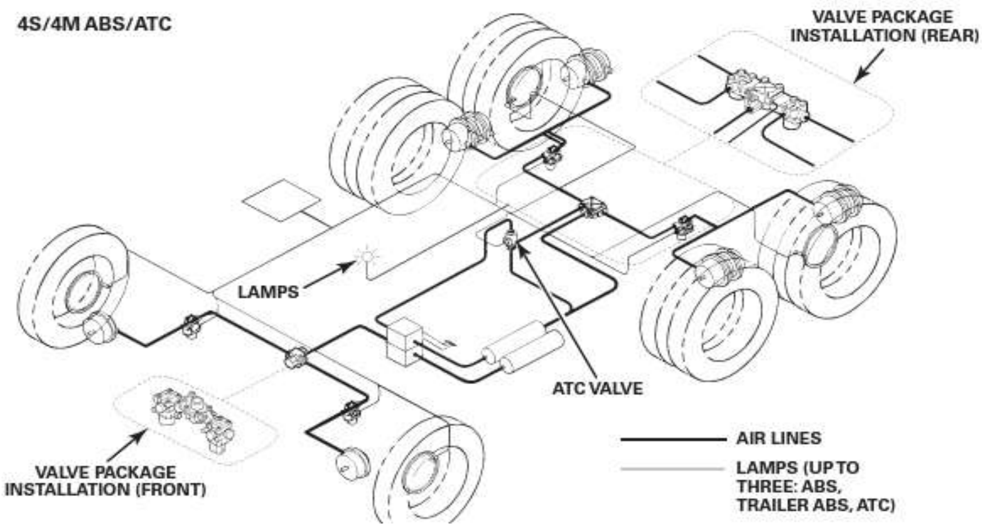

Figure 2.8: Operation of Automatic Traction Control

Source: Wabco (2019)

Active Braking Valves (ABV): ABV is sometimes referred to as 3/2 valve, are solenoid valves used for active braking during ATC or ESC events. The ABV is shown in Figure 2.9. Depending on system configurations, ABVs can be located in the front axle braking system or rear axle braking system in the ABS modulator for each drive wheel's brake circuit. This allows the system to apply pressure to slow the drive wheel if the wheel starts to spin. The ABS solenoids for the same brake circuit may also be called into play to hold, release and reapply pressure as needed until traction is regained. Most ATC systems will discontinue braking after a certain length of time or after so many repeated braking applications to prevent the brakes from overheating (as when driving in mud or snow). If both wheels are losing traction, traction control may brake both wheels equally to slow them down enough so that they can regain traction, and/or it may also send a request to the Electronic Control Unit (ECU) to reduce engine torque until traction is regained.

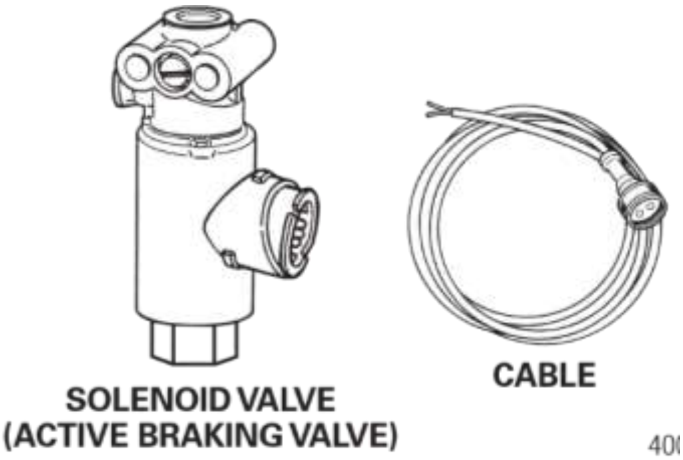

Figure 2.9: Active Braking Valves

Source: Wabco (2019)

2.2.1.3 Electronic stability control

The Electronic Stability Control (ESC) is a safety system that supports the driver in nearly all critical driving situations. The ESC helps drivers to avoid crashes by reducing the danger of skidding, or losing control as a result of over-steering. The ESC becomes active when a driver loses control of their car. According to Pawan (2016), ESC is the most important safety feature since seat belts as it has proven itself as an important technology from time to time by avoiding the vehicle from under steering and over steering preventing roll over and giving better control. The system doesn't work all alone as it uses the automobile other safety and regulatory devices, such as the Anti-lock Braking System (ABS) and Automatic Traction Control (ATC) to correct problems before they become accidents. Kristen (2019) stated that, ESC comprises the functions of the ABS and that of ATC as well as do considerably more in providing lateral safety. The ESC system offers value-added functions that assists the driver when starting off on inclines by independently applying the brakes for around two seconds after the driver has released the brake pedal. The system can also protect vehicles with a high center of gravity from the risk of rolling over (Bosch, 2019). If the vehicle is not going in the direction the driver is steering, the ESC system uses individual wheel brakes to maintain control.

The incorporation of ESC has become a standard in many vehicles produced since 2012. According to Olathe (2016), the ESC systems must meet certain minimum requirements.

i. The ESC system must be able to apply all four brakes individually. It must also have a control of the algorithm that utilizes this capability.
ii. The ESC system must be capable and operational during all phases of driving (acceleration, coasting, and deceleration).
iii. The ESC system must stay operational while the antilock braking system or the traction control system is active.

The ESC system utilizes onboard computers known as electronic stability control module to monitor vehicle direction and stability by receiving data from several sensors as shown in Figure 2.10.

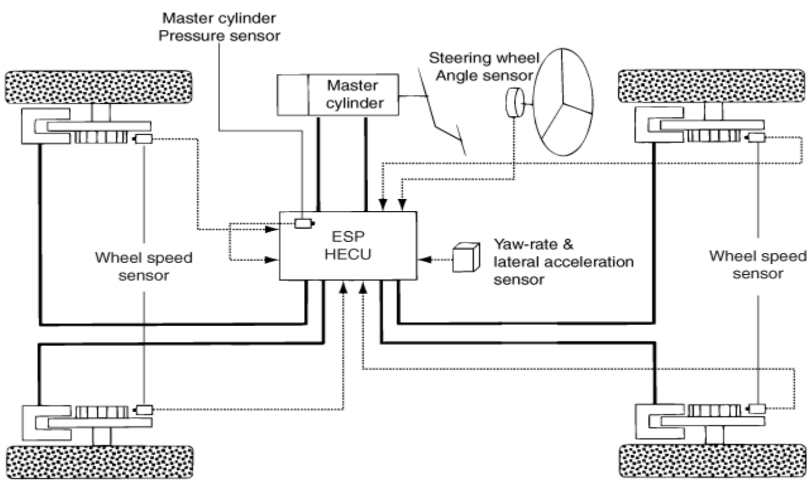

Figure 2.10: Operation of Electronic Stability Control System
Source: Kia (2017)

Electronic Stability Control Module: The electronic stability control module is a control unit that is considered as the processor and the brain of the entire ESC. It receives voltage, earth and CAN communication from the ECU. From this data, the ECU calculates the actual movement of the vehicle, comparing it 25 times per second with the desired direction of travel (Automotive System Engineering Study Guides, 2019). If the values do not correspond, the system reacts in an instant, without any action on the part of the driver. It reduces engine power in order to restore vehicle stability. If that is not sufficient, then it additionally brakes individual wheels. The information generated by the installed sensors of the ESC system, such as the wheel speed, lateral acceleration, yaw and steering angle sensors, is received by the ESC module. Jung *et al.* (2010) noted that, the ESC module then utilizes this data, processes it and generates the electronic signals to ensure that the vehicle's ESC system is effective and prevent the vehicle from losing the traction and remain stable on the roads. The ECU continuously monitors vehicle steering and direction using input data from sensor. These sensors include the wheel speed sensors, steering angle sensors, yaw rate sensors and lateral acceleration sensors.

Steering Angle Sensor: The steering angle sensor is used to inform the ESC module of the drivers intended direction using a dedicated ESC system internal data link. The ESC module supplies the sensor with voltage and earth. It takes this information and compares it to the vehicle's actual direction in order to make an informed braking decision. According to Kalwinder (2013), these decisions are based on factory set parameters. The sensor is located on the steering shaft and looks like a small clock spring. The steering angle sensor must be calibrated using diagnostic tools whenever it is replaced, or when any vehicle steering components are replaced or adjusted. A typical Steering Angle Sensor is shown in Figure 2.11.

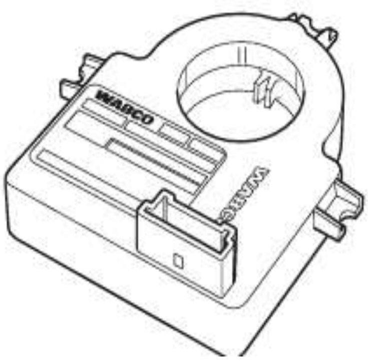

Figure 2.11: Steering Angle Sensor

Source: Wabco (2019)

Yaw Rate Sensor: The yaw rate sensor determines whether the car is developing a tendency to spin around the vertical axis. The yaw rate sensor is a key component in a ESC designed to provide motorists with increased safety, security, and control even in the most difficult driving conditions. It helps the ESC module to determine the current driving-dynamic state of the car. For this purpose, it must be placed close to the vehicle's centre of gravity. According to Kawaguchi *et al.* (2013), yaw rate sensor measures a vehicle's angular velocity about its vertical axis in degrees or radians per second in order to determine the orientation of the vehicle as it hard-corners or threatens to roll-over. By comparing the vehicle's actual yaw rate to the target yaw rate, the on-board computer can identify to what degree the vehicle may be under- or over-steer, and what corrective action, if any is required. Standard Motor (2019) noted that, the corrective action may include reducing engine power as well as applying the brake on one or more wheels to realign the vehicle.

Lateral Acceleration Sensor: The lateral acceleration sensor measures the lateral acceleration of the vehicle in order to determine the actual position of the vehicle. It can be located on the same housing as that of the yaw sensor. According to Koenning and Heger (2019), a typical passive safety sensor like lateral acceleration sensor determines the extent of vehicle crash based on impact velocity, type of crash such as offset crash, full frontal crash, and mass of the crash participant. The key role of the acceleration sensor as discussed by Pack (2015) includes the following:

Pedestrian protection: When lateral acceleration sensor is used in the bumper, it detects the collision with a pedestrian and activates the 'pop up' hood by a pyrotechnical activation thereby reducing the degree of freedom of acceleration of the vehicle, and protecting the pedestrian in case of an unavoidable accident.

Occupant safety: Lateral acceleration sensor generates an optimized firing choreography and activates the available restraint systems to reduce the injury risk of the occupant. Lateral acceleration and yaw rate sensors are located in the middle of the vehicle beneath the driver's seat.

2.2.2 Manual overview

A manual is a self-contained, self-pacing and self-learning material in nature. The module allows the student to pace at his own rate of speed so that learning progress is known to both, learners and instructor at all times and is based on measured understanding. Manual is a self-learning material basically developed as learner centered. These materials are different from other learning materials because they can make a learner think, write and do. Self-learning materials include all the materials such as manual prepared to stimulate independent study or learning (Lund Research, 2012).

Manual refers to technical documents which give guide or assistance to the user to use a particular device or product and are generally associated with engineering products. There are certain distinct characteristics that make manual different from other conventional learning materials such as textbooks and lesson notes as shown in Table 2.1. Manual are designed for a target group of person for the purpose of career development while textbooks are designed for a wider audience. According to Betty (2013), due to the standardized content of manual, learners receive the better experience through self-learning.

Table 2.1: Difference between manual and textbook

Textbooks	Self-learning Materials
1. Assume interest	1. Arouse interest
2. Written mainly for teachers and learners use	2. Written primarily for learner use
3. Designed for a wider market	3. Designed for a particular group or audience
4. Rarely state aims and objectives	4. Always give aims and objectives
5. Structured according to needs of teachers, specialists and learners	5. Structured according to the need of learners
6. Aims at successful teaching	6. Aims at successful learning
7. Little or no self-assessment	7. Major emphasis on self-assessment

Source: Dabban (2016)

Manuals are used by craftsmen, technicians or engineers to perform routine maintenance or to troubleshoot and fix problems or breakdowns. Manuals often describe the theory of how the equipment works and its operating principles, and instructions on how to disassemble and reassemble components. These manuals are often organized by system such as electronic braking systems or by component (Kent, 2006). Manual may be a self-paced (readers do the tutorials at their own rate) or they may be designed for use with a training course. Training manuals seldom try to teach everything, but just try to provide a basic foundation upon which reader can build. They usually start with basic skills and progress to more advanced skills as the readers gain experience and confidence. The main features of a manual according to Betty (2013) are as follows:

1. **Self-explanatory**: The content should be presented in a style so that a learner can go through the material without much external support. The content should be self-explanatory and conceptually clear. For this reason, the content is analyzed logically before it is presented. Thus, manual promote self-learning on the part of the learner.
2. **Self-contained**: Efforts should be made to make the material self-sufficient so that learners may not hunt for additional materials or sources.
3. **Self-directed**: The study material should aim at providing the necessary guidance, hints and suggestions to the learners at each stage of learning. The self-directed materials are presented in the form of easy explanations, sequential development, illustrations, and learning activities and so on.
4. **Self-motivating:** The materials should arouse curiosity, raise problems, relate knowledge to familiar situation, and make the entire learning meaningful for the learners. The study material like a live-teacher should be highly encouraging for the learners.
5. **Self-evaluating:** To ensure optimum learning the learners should know whether they are on the right track. Self-evaluation in the form of self-check questions, activities, exercises, and so on provides the learners with the much needed feedback about their progress, reinforces learning, and motivates the learners for learning.

Manual should provide the learners with study guide such as directions, hints, references, to facilitate learning. Srivastava (2013) noted that, manual has to be such that the learners can interact with it more and learn better. The manual for troubleshooting and maintenance of electronic braking systems ought to be articulated taking into cognizance the above mentioned features to enable it achieve its set objectives.

2.2.2.1 Objectives of manual on troubleshooting electronic braking systems

Objectives are statements that define the expected goal of a curriculum, course, lesson or activity in terms of demonstrable skills or knowledge that will be acquired by learners as a result of instruction. Objectives articulate the knowledge and skills learners are expected to acquire by the end of the course or an intervention. The definition of objectives is (or should be) the foundation of any instructional design. Donkor (2010) pointed out that objectives should serve as basis for all learning in occupational programme such as troubleshooting electronic braking systems. The objectives are of most value, if serving as a basis for assessing students' achievement in occupational programmes. The objectives must contain the task to be performed, the condition at which it will be performed and the criterion for assessment (Amuludun, 2011).

Objectives should break down the task and focus on specific cognitive or psychomotor processes. Nevertheless, using action verbs in stating objectives makes it more easily to measure the degree to which learners can do what you expect them to do. For objectives to measure what is expected of learner, certain consideration must be meet. Offorma (2012) noted that, the considerations for selecting objectives include; the learner, the contemporary society and the subject specialists. These considerations must be screened psychologically and philosophically to ensure that they conform to the developmental needs of the learners and the philosophy of the programme which the manual is being made for.

Objective is also beneficial to trainer because it helps the trainer to measure the progress of trainees and make the required adjustments. Amuludun (2011) reiterated that, objectives should be measurable and cannot be vague because learning objectives should guide the selection of assessments. A well written objective helps to reduce the confusion often associated with instructional assessment, better the selection of appropriate activities to be used in instructional courses and programs and better the organization of activities and efforts leading to the desired outcome. Naukrihub (2011) noted that, objective also benefit the learner by equipping him/her with the necessary information of what is expected out of him/her by the end of the training program. Wilburn and Wilbum (2010) revealed that, good objectives capable of benefiting both trainers and learners should possess the following characteristics:

1. **The learning objective should identify learning outcomes:** The main objective of learning is reflection. The objective needs to state what the learner is to perform, not how the learn lesson.
2. **The learning objective should be consistent with course goal:** It is necessary that the learning objective should be consistent with the course goal. When objective and goals are not consistent two avenues of approached will be available.
3. **The learning objective should be precious:** There should be a free line between choosing objective that reflects an important and meaningful outcome of instructions and objective.

Objectives are statements that define the expected goal in terms of demonstrable skills or knowledge that will be acquired by automobile craftsmen as a result of reading troubleshooting electronic braking systems manual. Objectives of troubleshooting electronic braking systems are simply skills expected to be acquired by automobile craftsmen in diagnosis, or determining the exact cause of a particular problem. According to Mazur and Proctor (2012), these objectives must contain the task in practical terms to be performed by craftsmen in identifying the symptoms of malfunction, determining the most likely cause and eliminating the potential causes in the Anti-lock Braking System (ABS), Automatic Traction Control (ATC) and Electronic Stability Control (ESC). Isermann and Balle (2017) disclosed that, the objectives or skills expected to be acquired by automobile craftsmen to properly troubleshoot ABS, ATC and ESC include fault diagnosing, visual checking and components testing of all components of electronic braking systems.

Fault diagnosing is the process of identifying a malfunctioning system or components in ABS, ATC and ESC using OBD II. The OBD II systems provide access to the health information of an automobile and access to numerous parameters and sensors from the Engine Control Unit (ECU). The OBD II system offers valuable information on automobile health condition in Diagnostic Trouble Codes (DTCs). Creosys (2019) described DTCs as codes that the vehicle's electronic control unit (ECU) generates when it detects malfunction or other issues. Access to the DTCs requires the diagnostics troubleshooting skills. Lin *et al.* (2017) disclosed that, the skills expected to be acquired by automobile craftsmen to troubleshoot ABS, ATC and ESC include the ability to retrieve and translate these DTCs. Nevertheless, the DTCs only tell the malfunctioning components without describing the actual cause of the faults. Ascertaining the actual cause of faults require visual inspection.

Visual inspection is the oldest and most basic method of inspection. It is the process of looking over a piece of equipment using the naked eye to look for flaws. It is a basic check to identify visible signs of defects, damage or deterioration but formal visual inspections are also necessary because they can reveal the majority of potentially dangerous faults. Visual inspection is an important part of a maintenance process that entails the use of no tools to checks or to identify obvious defects or damage (Pickerill, 2010). It requires no equipment except the naked eye of a trained inspector.

Visual inspection can be used for internal and external components inspection of electronic braking systems. According to Roner (2012) revealed that, visual inspection is simple, far more cost effective and less technologically advanced compared to other methods. This is because there is no equipment that is required to perform it. The Visual inspection in troubleshooting electronic braking system is expected to be carried out by automobile craftsmen with the sufficient information and knowledge of the systems. Duffy (2004) confirmed that, to carry out troubleshooting on ABS, ATC and ESC, automobile craftsmen expected to be skilled in visual inspections. Nevertheless, failure of visible signs of defects, damage or deterioration to be identified using visual inspection, the next alternative for automobile craftsmen is the components testing.

Component testing is a troubleshooting technique that entails testing an individual components or units of a system. Component testing is defined as a troubleshooting process in which testing is performed on each individual component separately without integrating with other components (Roner, 2012). The purpose of component testing is to validate that each components of the automobile systems performs as designed. Reppa and Tzes (2011) revealed that, component testing is often the most effective techniques for troubleshooting individual component of automobile systems. This is due to the use of equipment in testing individual components to ascertain voltage, resistance and ohms response. Component testing in electronic braking systems may be done with or without isolation of rest of other components in the system. If it is performed with the isolation of other component, then it is referred to as component testing in small while if it is performed without isolation of other components it is referred to as component testing large. Dutka *et al.* (2017) noted that, component testing competencies are required by automobile craftsmen for troubleshooting electronic braking system. Nevertheless, automobile craftsmen are expected to be skilled in component testing to carry out troubleshooting on ABS, ATC and ESC.

2.2.2.2 Objectives of manual on the maintenance of electronic braking systems

Objectives of the maintenance of electronic braking systems are the expected technical competencies to be learnt by craftsmen in dismantling, cleaning and repairing and installing automobile components or system. According to Mazur and Proctor (2012), these objectives must contain the task in practical terms to be performed by craftsmen in correcting a defect or malfunctioning. The objectives of the maintenance of electronic braking systems are therefore, referred to as practical tasks expected by craftsmen to acquire in returning the full functionality of Anti-lock Braking System (ABS), Automatic Traction Control (ATC) and Electronic Stability Control (ESC). Wireman (2017) disclosed that, maintenance objectives are tasks expected of craftsmen to retain or restore the state in which systems perform the required functions designed for. These systems could be ABS, ATC and ESC. The objectives for the maintenance of ABS, ATC and ESC are the expected learning outcome from craftsmen to provide intervention services that include the ability to dismantle, clean, replace and install all components of electronic braking systems for effective functioning (Saidin *et al.*, 2015).

Dismantling refers to maintenance technique that involves the careful deconstruction of components for repair, re-use, re-purposing or recycling. The process comprising all the activities required to detach all the valuable components from a system to be maintained Katarne *et al.* (2010) defined dismantling as a technical means of uncoupling components or system with the aim of conservation or maintenance services. Dismantling is required on systems where it is necessary to remove faulty components for repair or replacement to restore the system full functioning capacity. Effective maintenance of electronic braking systems requires competencies in dismantling the system to have access to the faulty component. Ciulla (2010) noted that, dismantling skills are learning outcomes expected for the maintenance of electronic braking systems. Nevertheless, gives automobile craftsmen access to components requiring repair, replacement or cleaning.

Cleaning is an essential maintenance service to many industrial systems, to protect sensitive components. Cleaning is a standard maintenance technique for the removal of impurities from the surface of a component. It is widely used for removing unwanted substances such as: grease, fats, oils, waxes, carbon deposits, fluxes, and tars from system components. Haq (2012) revealed that, the most common cleaning chemicals for automobile maintenance industry use are detergent-based products that use a combination of chemical in a liquid or powder form. Liquid cleaning use cleaning agent, typically petroleum, chlorine or alcohol-based solvent, is applied directly to the surface by spraying, brushing or wiping.

Nevertheless, this process removes oil, grease, dirt, loose particles and any other contaminants that may exist on the surface of the electronic braking systems components. Meineke (2019) noted that, one of the most common maintenance chores is cleaning the sensors that monitor wheel speed. These sensors are exposed to dirt and grime, and unclean sensors may cause improper functioning. Vapour cleaning use solvents in vapour form to cleanse the component under maintenance. Tiny electronics automotive parts such as ABS, ATC and ESC components can all be safely, completely and quickly cleaned with this technique. Shahab and Moavenian (2012) posited that, competencies in both liquid and vapour cleaning should be acquired by automobile maintenance personnel such as craftsmen. Nevertheless, cleaning makes it easier for fault identification on components requiring other forms of maintenance such as replacement.

Replacement refers to the process of providing an alternative which is represented as being equivalent to originally specified components. John (2019) defined replacement as a process of changing a defective component with a functional one. Replacement of broken or defective electronic braking system components entails looking for suitable match to be replaced. When replacing a component, it is necessary to look at the main specifications and parameters to ascertain compatibility. Crossman *et al.* (2013) disclosed that, effective maintenance of a system requires the ability to replace a faulty component.

Crossman *et al.* further revealed that, replacement of component in a system such as electronic braking system components requires the ability to select a replacement component of the same material, same functional type of component, same breakdown voltage as well as the ability to check for any special features of the components. This implies that, for effective maintenance of electronic braking system, craftsmen are required or expected to acquire replacement of components of ABS, ATC and ESC. Nevertheless, once the choice of replacement components of ABS, ATC and ESC has been made, then the systems can be assembled.

Assembling is the process of installing or putting together a number of individual components to form a whole system. Assembling of components of electronic braking systems entails adhering to the sequence of assembly, technique in mounting, identification tolerances, and protection of components. Yong-Wha *et al.* (2016) disclosed that, it is important when assembling components in a system, screws should be fastened without being overstressed. St. Rosemary Institution (2019) noted that, assembling competencies are required by technicians for effective maintenance service on any system. Nevertheless, for effective maintenance of electronic braking systems, automobile craftsmen required the ability to successfully assemble components after dismantling.

2.2.2.3 Troubleshooting contents for the electronic braking systems manual

Troubleshooting contents for the electronic braking systems manual refers to the safety and troubleshooting competencies in diagnosing, checking and measuring the components of electronic braking systems that include ABS, ATC and ESC. These competencies include the use of On-Board Diagnostics, electronic measuring instruments and visual inspection in finding faults and causes of the faults.

Fault Diagnosing: Electronic Control Unit (ECU) monitors and manages the system the operating parameters of every component connected to the electronic systems. When the ECU sees a signal that is outside normal limits, or fails to see an expected change in a signal, it stores a Diagnostic Trouble Codes (DTCs). To access DTCs, a scan tool is connected to a Diagnostic Link Connector that is commonly located under the driver's side of the dashboard. According to Leonardo (2019), the scan tool displays any stored DTCs, but that is only the beginning of a full diagnostics troubleshooting. Baek and Jang (2015) confirmed that, diagnosis in troubleshooting automobile systems include the following steps:

1. Locate the OBD-II data link connector (under the driver's side of the dashboard)
2. Plug the standard OBD-II connector into the vehicle's data link connector
3. Turn the car's key on to provide power to the scan tool or code reader.
4. Enter the vehicle-specific information requested.
5. To check for engine codes, press the scan button on the code reader
6. Follow the directions on the screen
7. Record the Diagnostic Trouble Codes
8. Clear the reported Diagnostic Trouble Codes

Nevertheless, the DTCs do not tell if a particular component or system is bad, they only indicate that the ECU has seen something it did not expect in a certain circuit. Draganov *et al.* (2007) stated that, to troubleshoot a problem, the technician starts with retrieving DTC, and then performs additional tests. These can range from visual inspection and individual component testing.

Wheel Speed Sensor: A wheel speed sensor is used by the anti-lock brakes to determine if a wheel is moving at a different speed than the others in order to control the ABS and ATC functions. A faulty wheel speed sensor usually illuminates dashboard lights for the

ABS or ATC systems and the system will likely not function properly. According to David (2011), when troubleshooting a wheel speed sensor, all readings should be taken at the same time and before vehicle is driven because its resistance can change with temperature. Troubleshooting a wheel speed sensor entails competencies in sensor adjustment that include pushing the sensor in until it contacts the tooth wheel and not pushing sensors with sharp objects. Chris (2016) stated that, troubleshooting a wheel speed sensor require electrical testing skills that include testing the resistance of wheel speed sensor, testing the resistance of ECU harness, verifying no change in resistance and no open circuit between sensor and ECU harness. Checking harness for any short-circuit from the battery and the harness. According to Wabco (2019), measurements from testing a wheel speed sensor should read as follows: between sensor leads, 900-2000 ohm; at ECU harness pins with sensor connected, 900-2000 ohm (no more than 1-ohm difference is okay); at ECU harness for DC voltage, no continuity and sensor output voltage should read at least, 0.2 volt.

Electronic Control Unit: The Electronic Control Unit (ECU) is the control center or brain of the automobile electronic systems that receives, amplifies and filters various sensors signals such as the wheel speed sensors signal for calculating the speed rotation and acceleration of the vehicle. A faulty ECU renders all electronic systems as well as the automobile inactive. Troubleshooting ECU entails verifying vehicle batteries, charging system and fuses are in good working condition. According to Gillespie (2013), troubleshooting ECU entails load testing battery and ignition circuits to ground at the ECU harness using a 2-4 amp sealed lamp and verify lamp does not flicker and it is on steady. Nevertheless, Shi *et al.* (2012) stated that, troubleshooting ECU also involve taking measurements at the ECU harness pins. Wabco (2019) noted that, measurements in troubleshooting ECU module should read as shown in table 2.2.

Table 2.2: Electronic control unit locations and measurements

Location	Measurements
Supply Voltage, Battery to chassis Ground	9.0-16.0V for 12V system 18.0-32.0V for 24V system
Supply Voltage, Ignition to chassis Ground	9.0-16.0V for 12V system 18.0-32.0V for 24V system
ECU ground to chassis ground	Less than 1 ohm resistance
Main ground to chassis ground	Less than 1 ohm resistance

Source: Wabco (2019)

Pressure Modulator Valve: A pressure modulator valve controls air pressure to an affected wheel-end brake during an ABS, ATC or ESC event to reduce speed and prevent wheel lock up. A faulty pressure modulator valve usually illuminates dashboard lights for the ABS or ATC systems and the system will likely not function properly. Troubleshooting pressure modulator require skills in electrical testing that include testing the modulator valve for resistance, testing ECU harness and modulator valve together for resistance, verifying no change in resistance or open circuit between valve and harness as well as checking harness for any shorts to battery and shorts to ground. According to Poursamad (2009), if resistance exceeds 9.0 ohm for 12V system (21.0 ohm for 24V system), verify the reading was not taken between the inlet and outlet (as shown in Figure 2.12) and if the correct pins were tested, cleaning the electrical contacts at the modulator is required. Wabco (2019) recommended that, measurements should read as follows: at **i**nlet valve pin to Ground, 4.0-9.0 ohm for 12V system and 11.0-21.0 ohm for 24V system; at outlet valve pin to ground, 4.0-9.0 ohm for 12V system and 11.0-21.0 ohm for 24V system and at ECU harness pins with modulator valve connected, 4.0-9.0 ohm for 12V system and 11.0-21.0 ohm for 24V system (no more than 1-ohm difference is okay).

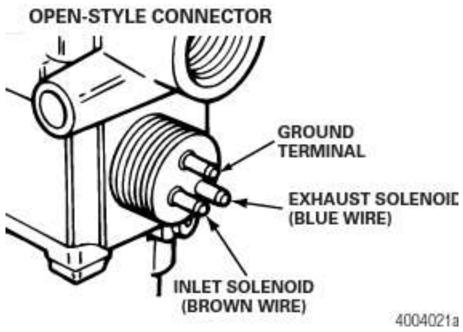

Figure 2.12: Pressure Modulator Valve Connector
Source: Wabco (2019)

Brake Pressure Sensor: The brake pressure sensor is used to detect pressure differentials in the hydraulic system. One of the common failures on an ABS, ATC and ESC is a failed brake pressure sensor. A light generally illuminates on dashboard and there are physical braking issues as well. You may notice wheel lock up under braking, vibration in the brake pedal, or several other issues. According to Jeff (2017), when troubleshooting brake pressure sensor, all of the ECU connectors must be plugged in as the ECU provides voltage and ground to the brake pressure sensor. Troubleshooting brake pressure sensor require skills in electrical testing that include taking measurements at the pressure sensor harness connector, measuring voltage supply to Ground on Pin 1 of the brake pressure sensor connector (Figure 2.13) with key ON. With ECU and brake pressure sensor disconnected, verify continuity end to end on all 3 lines, no shorts to ground or battery on all 3 lines and no continuity between pins as shown in Figure. Nevertheless, according to Wabco (2019), measurements should read as, Voltage supply to Ground, 8.0-16.0V.

Figure 2.13: Brake Pressure Sensor Connector

Source: Wabco (2019)

Active Braking Valves: Active braking valves can be located in the front axle braking system or rear axle braking system in the ABS modulator for each drive wheel's brake circuit of vehicle equipped with ATC. Active braking valve allows the system to apply pressure to slow the drive wheel if the wheel starts to spin. A faulty ABV usually illuminates dashboard lights for the ABS or ATC systems and the system will likely not function properly. Troubleshooting active braking valves require skills in electrical testing that include checking the active braking valves solenoid for resistance, checking the ECU harness and active braking valves solenoid together for resistance, verifying no change in resistance or open circuit between active braking valves and through harness and checking harness for any shorts to battery and shorts to ground. According to Wabco (2019), measurements should read as follows: at active braking valves supply to common, 7.0-14.0 ohm for 12V system 26.3-49.0 ohm for 24V system and at ECU harness pins with active braking valves connected, 7.0-14.0 ohm for 12V system 26.3-49.0 ohm for 24V system (no more than 1-ohm difference is okay).

Electronic Stability Control Module: The electronic stability control module is a control unit that is considered as the processor and the brain of the entire ESC. It receives voltage, earth and CAN communication from the ECU. The information generated by the installed sensors of the ESC system, such as the wheel speed, lateral acceleration, yaw and steering angle sensors, is received by the electronic stability control module. Jung *et al.* (2010) noted that, the ESC module then utilizes this data, processes it and generates the electronic signals to ensure that the vehicle's ESC system effectively prevent the vehicle from losing the traction and remain stable on the roads. ESC light will illuminate on the vehicle's dashboard if the module is not working properly. According to Kristen (2019), all of the ECU connectors must be plugged in as well as the SAS and do not load test across power and earth at the ESC module when troubleshooting.

Troubleshooting ESC module require skills in electrical testing that include taking measurements at the ESC module harness connector (Figure 2.14), measuring voltage supply, CAN high voltage and CAN low voltage with key on. Josh (2018a) noted that, troubleshooting ESC module require measuring terminating resistance across CAN high and low with key Off. Nevertheless, with ECU and ESC module disconnected: verify continuity end to end on each line, no shorts to ground or battery on all lines and no continuity between pins. Wabco (2019) disclosed that, when troubleshooting ESC module, measurements should read as indicated in Table 2.3.

Table 2.3: Electronic stability control module circuit and measurement

Pin	Circuit	Measurement
1	Voltage Supply to Chassis Ground	8.0-16.0V
2	(Frame-mounted only) ESC Ground to Chassis Ground	Less than 1 ohm resistance
2	(Cab-mounted only) ESC Ground	Should have continuity but will not be less than 1 ohm
3 and 4	Terminating Resistance between ESC CAN-High to ESC CAN-Low	Approximately 90 ohms
1	With ECU disconnected, check power supply for battery voltage or ground.	No continuity
2	With ECU disconnected, check ground for battery voltage or ground.	No continuity
3 and 4	With ECU disconnected, check CAN lines for battery voltage or ground.	No continuity
3	CAN High Voltage to Chassis Ground	2.5-5.0V
4	CAN Low Voltage to Chassis Ground	0.1-2.4V

Source: Wabco (2019)

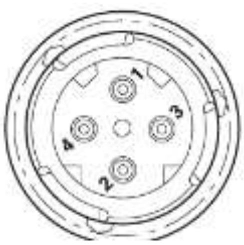

Figure 2.14: Electronic Stability Control Module Connector

Source: Kristen (2019)

Steering Angle Sensor: The steering angle sensor reports the position of the steering wheel (where the driver wants to go) and how fast the steering wheel is being turned. The common failure on ESC is a failed steering angle sensor. ESC light generally illuminates on dashboard if steering angle sensor is malfunctioning. Troubleshooting steering angle sensor require disconnecting and check the terminating resistance across pin 1 and pin 2 of the sensor connector as shown in Figure 2.15. Nyberg and Frisk (2015) revealed that, troubleshooting steering angle sensor include taking measurements at the harness connector side by checking CAN low voltage on pin 1, CAN high voltage on pin 4 and voltage supply on pin 5 with Key On as well as checking resistance across CAN low pin 1 and CAN high pin 4 with Key Off while the ECU and ESC module connectors must be plugged in as the ECU provides all voltage, ground and CAN communications. Wabco (2019) disclosed that, when troubleshooting steering angle sensor, measurements should read as indicated in Table 2.4.

Table 2.4: Steering angle sensor location and measurements

Location	**Measurement**
SAS terminating resistor on sensor	Approximately 180 ohms
CAN High Voltage	2.5-5.0V
CAN Low Voltage	0.1-2.4V
Voltage Supply to Ground	8.0-16.0V
ESC CAN-High to ESC CAN-Low	Approximately 90 ohm
Steering angle sensor harness jumper (Pin 2 to Pin 4 or Pin 2 to Pin 3)	Continuity
ESC CAN-High or CAN-Low to Power or Ground (with ECU, ESC Module and SAS unplugged)	No continuity

Source: Wabco (2019)

Figure 2.15: Steering Angle Sensor Connector

Source: Kristen (2019)

Yaw Rate Sensor: The yaw rate sensor is an electrical component that is stored either in the vehicle's ECU or under the dashboard near the fuse box. It's not commonly subject to wear and tear, and most issues with this device are attributed to problems with one of the three individual sensors it monitors. Stephen (2016) noted that, there are a few warning signs you might recognize when the yaw rate sensor begins to fail that include Malfunction Indicator Lamp (MIL) comes on and ESC or ATC lights illuminate. Troubleshooting yaw rate sensor require checking the CAN bus line for disconnection by turning the ignition switch to the lock position, disconnecting the yaw rate sensor connector (as shown in Figure 2.16) from the yaw rate sensor. According to Toyota (2015), measurements of resistance and voltage in troubleshooting ECU circuit should read as shown in table 2.5.

Table 2.5: Yaw rate sensor connector pin, condition and measurements

Pin	Condition	Measurements
2 (CAN Low)	Ignition switch Off	54 to 69 ohms
3 (CAN High)	Ignition switch Off	54 to 69
1 (GND) -Body ground	Always	Below 1 ohms
5 (IG) - Body ground	Ignition switch On	10 to 14 V

Source: Toyota (2015)

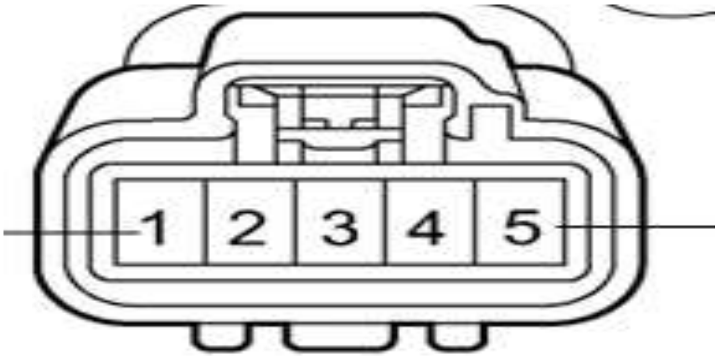

Figure 2.16: Yaw Rate Sensor Connector

Source: Toyota (2015)

Lateral Acceleration Sensor: The lateral acceleration sensor provides a signal based on the lateral or side force presented on the vehicle through the curve. The sensor has a fixed electrode and a movable electrode that changes the capacitance of the sensor when laterally loaded. Mohamad (2019) confirmed that, lateral acceleration sensors have been known to fail, and when they do, MIL, ESC and even ABS lights illuminates. Troubleshooting lateral acceleration sensor involve checking fuses that that power up the sensor. Reinier (2016) stated that, troubleshooting lateral acceleration sensor involve disconnecting the negative battery cable before unplugging the sensor connector (as shown on Figure 2.17), make voltage and the two communication circuits checks. Randy (2019) further noted that, measurements in troubleshooting lateral acceleration sensor should read as 2.6 volts at CAN high (pin 1) and 2.4 volts at CAN low (pin 3) with the car's Key On but engine Off.

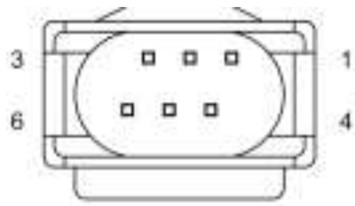

Figure 2.17: Lateral Acceleration Sensor 6 Way Connector

Source: Autozone (2019)

2.2.2.4 Maintenance contents for the electronic braking systems manual

Maintenance contents for the electronic braking systems manual refers to the competencies in removing, cleaning, replacing and installing the components of electronic braking systems that include ABS, ATC and ESC. These competencies include the use of hand tools and other workshop equipment in correcting or restoring the functionality of modulator valve, wheel speed sensor, active braking valves, brake pressure sensor, ESC module, steering angle sensor and electronic control unit.

Wheel Speed Sensor: The wheel speed sensor is also referred to as an ABS sensor, is attached to the hub of a wheel as shown in Figure 2.18. A failing wheel speed sensor commonly impact the operation of ABS, ATC and ESC systems and display certain warning signs that any driver can instantly notice as they drive.

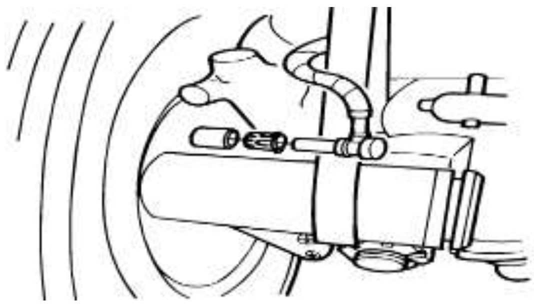

Figure 2.18: Location of Wheel Speed Sensor

Source: Wabco (2019)

The maintenance of wheel speed sensor involves removing, cleaning, replacing and installing the sensor. Larry (2019) stated that, replacement a wheel speed sensor involves jacking the vehicle up, removing the wheels, putting it on axle stands, disconnecting the fasteners that hold the sensor cable to other components, the sensor cable from the chassis harness and removing the sensor from the sensor holder and spring clip (as shown in Figure 2.19).

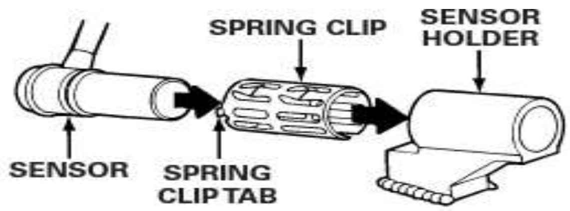

Figure 2.19: Wheel Speed Sensor, Holder and Spring Clip

Source: Wabco (2019)

After removing the wheel speed sensor, cleaning and application of recommended lubricant to the sensor spring clip and sensor or replacement is necessary during maintenance. Nevertheless, Chris (2016) revealed that, installing or assembling a wheel speed sensor involve connecting the sensor cable to the chassis harness, installing the fasteners used to hold the sensor cable and spring clip in place as well as pushing the sensor completely into the sensor spring clip until it contacts the tooth wheel. Finally, other tasks include, placing the wheels back onto the hubs, jacking the vehicle back off the axle stands and test drive the vehicle.

Electronic Control Unit: A faulty ECU illuminates ABS, ATC and ESC lights on the dashboard and renders virtually all the electronic systems including ABS, ATC and ESC as well as the automobile functionality inactive. Valerie (2016) noted that, wearing rubber gloves reduces the chances of static discharge when maintain ECU. The maintenance of ECU module involves removing, cleaning, replacing and installing fuses and other harnesses of the ECU. The replacement of ECU involves parking the vehicle on a leveled surface. Keep the emergency brakes on, disconnecting the battery or remove the cable from the negative terminal, locating the ECU, removing all the connectors, screws and any ties that mount the unit and removing the ECU. According to Josh (2018b), it is necessary to match the old ECU with the new one and clean the mounting surface properly when installing the replacement of ECU. Nevertheless, Jitesh (2014) noted that**,**

installing the ECU involve placing the new module carefully, connecting the wires and other electrical connections, reconnecting the battery to turn on the connection.

Pressure Modulator Valves: A pressure modulator valve controls air pressure to an affected wheel-end brake during an ABS, ATC or ESC event to reduce speed and prevent wheel lock up. A faulty pressure modulator valve usually illuminates dashboard lights for the ABS or ATC systems and the system will likely not function properly. The maintenance of pressure modulator valve involves removing, cleaning, replacing and installing the valve. According to Wong (2015), the replacement of pressure modulator valve involves the following stages: turning the ignition switch to the Off position, application of parking brake, raising the vehicle off the ground and place safety stands under the axle, disconnecting the wiring connector from the valve and the air lines from Ports 1 (air supply) and 2 (air discharge) of the valve (as shown in Figure 2.20) as well as removing the two mounting caps crews and nuts and the valve.

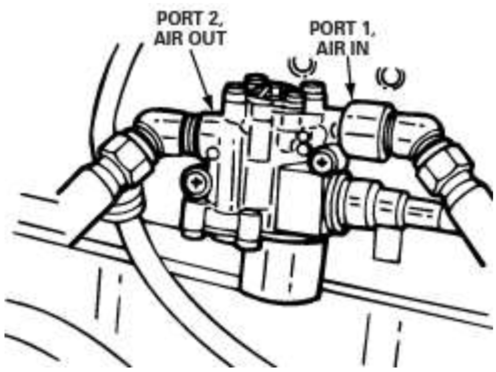

Figure 2.20: Pressure Modulator Valve Ports to be disconnected

Source: Wabco (2019)

After removing the pressure modulator valve, cleaning and ensuring no physical damage is made on the valve or replacement is necessary during maintenance. Nevertheless, Ignizio (2017) noted that, the assembling or installation of pressure modulator valve involve mounting the two cap screws and nuts, tightening the cap screws per the manufacturer's recommendation, connecting the line to the brake chambers to Port 2, the air supply line to Port 1 and the wiring connector to the valve. Furthermore, other tasks include, removing the axle stands, testing the installation by turning the ignition on, applying the brakes and listening for leaks and cycle of the modulator valve. Meineke (2017) noted that, if the valve fails to cycle, check the electrical cable connection, make repairs or replacement as needed and test drive the vehicle.

Brake Pressure Sensor: The common failure on ABS is a failed brake pressure sensor. When brake pressure sensor fail, ABS, ATC and ESC light generally illuminates on dashboard and there are physical braking issues that manifest wheel locking during braking. The maintenance of brake pressure sensor involves removing, cleaning, replacing and installing the sensor. According to Thompson (2016), the typical steps for replacing the brake pressure sensor on most current passenger vehicles include, locating the brake pressure sensor usually found mounted near the brake master cylinder, unplugging the electrical connector (as shown in Plate I) and removing the brake pressure sensor.

Plate I: Unplugging the Electrical Connector of Brake Pressure Sensor

Source: Thompson (2016)

Nevertheless, installing the brake pressure sensor involve threading the replacement into place, tightening the sensor as far as possible by hand, plugging electrical connector. Josh

(2018c) disclosed that, verifying the installation of the brake pressure sensor involve refilling the reservoir to the correct level if any fluid was lost during replacement, starting the vehicle and let it run for 10-15 seconds, pressing on the brake firmly a couple of times. Finally, test driving the vehicle to ensure that the ABS, ATC and ESC indicator lamp goes off.

Active Braking Valves: Depending on the manufacturers' specifications and vehicle system configuration, active braking valves may be located near the rear axle, front axle and in line with control line. A faulty active braking valves usually illuminates dashboard lights for the ATC systems and the system will likely not function properly. The maintenance of active braking valves involves removing, cleaning, replacing and installing the valve. According to Ciulla (2010), the replacement of active braking valves involves turning the ignition switch to the OFF position, application of parking brake, raising the vehicle off the ground and place safety stands under the axle, disconnecting the wiring connector from the valve and the airlines from Port 1 (air supply), Port 2 (air discharge) and Port 3 (treadle) of the ATC valve (as shown in Figure 2.21) as well as removing the two mounting caps crews and nuts and the valve.

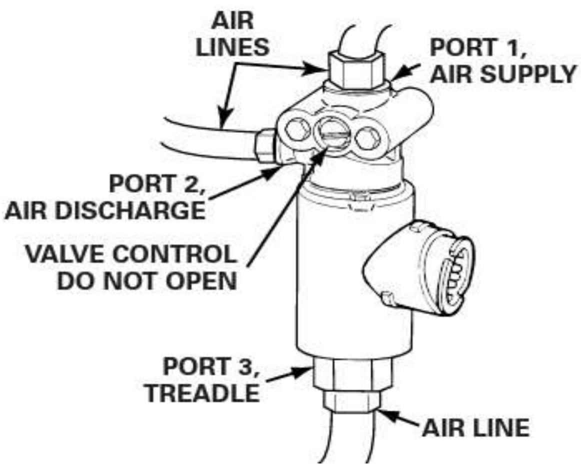

Figure 2.21: Active Braking Valves Ports to be disconnected

Source: Wabco (2019)

After removing the active braking valves, cleaning and ensuring no physical damage is made on the valve or replacement is necessary during maintenance. Nevertheless, the assembling or installation of active braking valves involve mounting the two cap screws and nuts, tightening the cap screws per the manufacturer's recommendation, connecting the air supply, discharge and treadle lines to Ports 1, 2 and 3 of the valve and the harness connector to the valve. Furthermore, other tasks include, removing the axle stands, testing the installation. Kiyotaka *et al.* (2010) disclosed that, testing the installation of active braking valves involve turning the engine fully charging the reservoirs with air, shutting off the vehicle, applying the brakes, listening for air leaks at the valve and releasing the brakes. Finally, other tasks include, verifying correct operation and that there are no active codes, making necessary replacement if needed, test driving the vehicle to ensure that the ATC indicator lamp goes off.

Electronic Stability Control Module: A faulty ESC module illuminates ESC lights on the dashboard and render the systems non-functional. According to Wabco (2019), verifying the ESC module to ensure is correctly leveled and securely mounted and not moving the module to a different location as this will affect the system performance are precautions to be adhered to in the maintenance of ESC module. The maintenance of ESC module involves removing, replacing and installing as the case may be. Replacing the ESC module involve turning the ignition switch to the Off position, applying the parking brake, placing blocks under the front and rear tires to prevent the vehicle from moving, locating the ESC module, disconnecting the wiring harness connector from the module removing the two mounting caps crews and nuts and removing the ESC module. Ronny (2016) noted that, it is important that the module is aligned correctly and the tab on the ESC mounting surface fits into the appropriate hole. Nevertheless, installing the ESC module involve returning the two cap screws and nuts, tightening the cap screws connecting the wiring harness connector to the ESC module, removing the stands and blocks and testing the installation by calibration. Finally, when the calibration procedure is completed, the ABS, ATC or ESC lamps should come on and go back off when ignition power is turned on.

Steering Angle Sensors: The steering angle sensor finds a disparity between the course your vehicle is traveling and the position the steering wheel is held at and send signal to the ESC module to balances out the steering and puts the driver in more control. According to Marvin (2016), if the steering angle sensor is not working, the ATC and ESC lights illuminates, the steering wheel feeling loose and the car driving differently after a front end alignment. The maintenance of steering angle sensor involves removing, cleaning, replacing and installing the sensors. Robert (2015) disclosed that, it is necessary to disable the supplemental restraint system (air bag) to avoid serious personal injury during steering angle sensor maintenance. Removing of steering angle sensor involve turning the ignition switch to the Off position, applying the parking brake, placing blocks under the front and rear tires to prevent the vehicle from moving, locating the sensor on the steering column shaft (as shown in Plate II), disconnecting the wiring harness connector removing three screws attached to the steering column, and slide the sensor off of the steering column shaft.

Plate II: Location of the Steering Angle Sensor on Steering Column Shaft

Source: Marvin (2016)

Nevertheless, after removing the steering angle sensor, cleaning, checking for damage, application of small amount of grease to the tab in the center of the sensor or replacement is necessary during maintenance. Nevertheless, Chris (2016) revealed that, if the steering angle sensor is not installed in the correct orientation, it will not function correctly and may become damaged. Installing or assembling a steering angle sensor involve connecting the sensor installing the sensor with the connector facing the same direction as the original, placing the sensor over the steering column shaft and slide it into place replacing the attaching screws and tighten installing the sensor wiring harness connector by pushing the connector together until the small tab snaps. Furthermore, installing the steering wheel and tighten per the manufacturer's recommendation, removing the blocks and testing the installation by calibration. Finally, when the calibration procedure is completed, the ABS, ATC or ESC lamps should come on and go back off when ignition power is turned on.

Lateral Acceleration and Yaw Rate Sensors: The lateral acceleration and yaw rate sensors are designed to send information regarding the lateral or side force and tilt (the yaw) of vehicle to the ESC module to keep the vehicle within certain safety parameters. Faulty lateral acceleration and yaw rate sensors causes the ESC light to illuminate on dashboard and also causes physical stability issues. The maintenance of lateral acceleration and yaw rate sensors involve removing, cleaning, replacing and installing the sensors. According to Kenneth (2016), the replacement of lateral acceleration and yaw rate sensors involve the following: disconnecting the negative battery cable, disabling air bag system, removing the seat mounting fastener and the front seat from the vehicle, disconnecting the electrical harness, unclipping the harness from the seat bracket, removing the yaw rate & lateral acceleration sensors mounting nuts (1), disconnecting the wiring harness connector (2) removing the yaw rate and lateral acceleration sensors (3) (as shown in Figure 2.22).

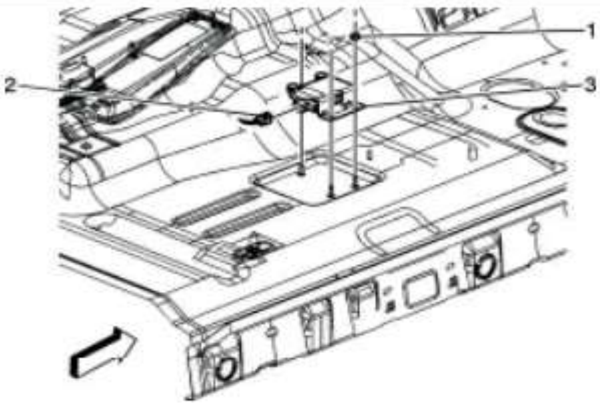

Figure 2.22: Removing the Yaw Rate & Lateral Acceleration Sensor

Source: Kenneth (2016)

Nevertheless, Envoy (2019a) noted that, installing the yaw rate & lateral acceleration sensors involve connecting the wiring harness connector, installing the sensor mounting nuts and the seat to the vehicle, clipping the harness to the seat bracket, connecting the electrical harness, enabling the air bag system, installing the seat mounting fastener covers and connecting the negative battery cable. Finally, ensure that, the ESC indicator lamp goes off.

2.2.2.5 Troubleshooting facilities for the electronic braking systems manual

Troubleshooting facilities for the electronic braking systems manual refers to the physical requirements for finding faults and it causes on electronic braking systems that include ABS, ATC and ESC. These facilities include every object required in diagnostics troubleshooting, visual checking and components testing pressure modulator valve, wheel speed sensor, active braking valves, brake pressure sensor, ECU, ESC module, steering angle sensor and yaw rate and lateral acceleration sensors. According to Lin *et al.* (2017), facilities for diagnostics troubleshooting include OBD II scan tool (code reader, computer and smartphone), adopter, data cable, Data Trouble Codes (DTCs) interpretation among others. Visual checking these components require no tools or equipment. Roner (2012) noted that, visual inspecting the components of electronic braking systems only require skills in checking the physical looks of a component for damage. Nevertheless, Reppa and Tzes (2011) facilities for ABS, ATC and ESC components testing include wiring diagrams, stethoscope, 12-volt test light, volts meter, ohmmeter or millimeter, 2-4 amp sealed lamp, among others. The facilities and their uses for troubleshooting electronic braking systems are contained in Table 2.6.

Table 2.6: Facilities for troubleshooting electronic braking systems and their uses

S/N	Facilities	Uses
1	OBD II scan tool	To retrieve data trouble codes
2	Mechanic's stethoscope	To listen to and track noises found within the vehicle
3	12-volt test light	For testing the supply of voltage in ECU and its harness circuits
4	Circuit tester	For testing a fuse or circuit. If power is present, the bulb will illuminate confirming the circuit has power and is operating properly
5	Voltmeter	For measuring electric potential difference between two points in the ECU CAN, ground and sensors
6	Ohmmeter	For measuring electrical resistance of ECU harness, modulator valve connection and sensors
7	2-4 amp sealed lamp	To illuminate the working area

Source: Researcher (2019)

2.2.2.6 Maintenance facilities for the electronic braking systems manual

Maintenance facilities for the electronic braking systems manual refers to the physical requirements for removing, cleaning, replacing and installing the components of electronic braking systems that include ABS, ATC and ESC. These facilities include workshops, laboratories, studios, equipment, machines, consumable materials and tools. Tools for the maintenance of electronic braking systems are mainly grouped into three groups, which include hand tools, power hand tools and machine tools. These facilities help to effectively actualize the maintenance of electronic braking systems.

Facilities for removing, cleaning, replacing and installing modulator valve, wheel speed sensor, active braking valves, brake pressure sensor, ESC module, steering angle sensor and electronic control unit varies. According to Robert (2016), facilities required for the maintenance of wheel speed sensor include the following: Allen set metric and standard sockets, assorted pliers, assorted, screwdrivers, breaker bar ½ inch drive, brass hammer, combination wrench set, metric and standard, disposable gloves, emery cloth/sandpaper, flashlight and floor jack and jack stands. Larry (2019) further noted that, these facilities include, metric and standard socket set ½ inch drive, pry bar, ratchet ⅜ drive, socket set metric and standard ⅜ drive, socket set metric and standard ¼ drive, torque wrench ⅜ or ½ drive, torque socket set and wheel socket set ½ inch drive.

Nevertheless, the maintenance of ECU and ESC module require the following: clean shop rags, replacement ECU, torque screw set, screwdriver(s) flat and phillips head, socket set and ratchet, blower and alcohol or cleaner (Jamahl, 2016). However, Carpro (2019) noted that, the maintenance of pressure modulator valves and active braking valves require facilities that include driver set, plastic sheet or rubber mat, replacement of pressure modulator and active braking valves, rubber gloves, sockets/ratchet, wrenches-open/box-end, blower, clean microfiber cloth and alcohol or cleaner.

Furthermore, brake pressure sensor maintenance facilities include screwdriver set, shop towels/rags and wrench set (Josh, 2018c). The maintenance of steering angle sensor required different sets of facilities. Robert (2015) noted that, facilities for the maintenance of steering angle sensor include Allen wrench set SAE/Metric, boxed end wrenches, cross tip screwdriver, dental picks, flathead screwdriver, protective gloves, ratchet w/metric and standard sockets, safety glasses, slip joint pliers, snap ring pliers, steering wheel puller kit, torque bit set and wheel chocks.

Maintenance facilities for yaw rate sensor include all objects required for removing and installing yaw rate sensor. According to Envoy (2019b), the maintenance of yaw rate sensor require Allen set (metric & standard sockets), assorted pliers, assorted screw drivers, combination wrench set (metric & standard), disposable gloves, flashlight, metric and standard wrench set, pry bar and ratchet (3/8 drive). Yourmechanic (2019) further noted that, the maintenance of yaw rate sensor require socket set (metric & standard 3/8 drive), socket set (metric & standard 1/4 drive) and torque socket set. The facilities and their uses for the maintenance of electronic braking systems are contained in Table 2.7.

Table 2.7: Facilities for the maintenance of electronic braking systems and their uses

S/N	Facilities	Uses
1	Allen key	For driving bolts and screws with a hexagonal socket on the ECU harness and modulator valve
2	1/2 inch metric and standard sockets	For tightening and loosing nuts and bolts of 14mm, 15mm, 16mm and 17mm standard sizes
3	3/8 inch metric and standard sockets	For tightening and loosing nuts and bolts of 11mm, 12mm, 13mm and 14mm standard sizes
4	1/4 inch metric and standard sockets	For tightening and loosing nuts and bolts of 8mm, 9mm, 10mm and 11mm standard sizes
5	Pry bars	To pull hubs from their location
6	Jack	To lift the vehicle up and put it on jack stands
7	Jack stand	To keep the vehicle firmly suspended from the ground
8	Torque wrench	To remove the bolt that holds the sensor onto the hub/knuckle
9	Assorted screw driver	To screw and unscrew the screws that holds the ECU and its harness

S/N	Facilities	Uses
10	Wheel socket	To remove and place the road wheels
11	Assorted plier	To remove any clips or hold downs that are securing the sensor wiring to the vehicle's chassis/body
12	Emery cloth or sandpaper	To clean off any rust in the areas where the new sensor will be going to ensure it fits easily
13	Disposable gloves	For hand protection against any sharp edges
14	Brass hammer	To install insert the hub/knuckle
15	Shop rag	To clean any surface from unwanted contents
16	Flat screwdriver	For screwing (installing) and unscrewing (removing) screws with flat head on ECU and ECU harness
17	Phillip screwdriver	For screwing (installing) and unscrewing (removing) screws with Phillip head on ECU and ECU harness
18	A torque screw set	To ensure tightening to a specified torque
19	Blower	To blow away unwanted deposit in the ECU and sensors
20	Alcohol or cleaner	For cleaning ECU to avoid malfunctioning due to dust deposit
21	Combination wrenches	Are used for Tightening/loosening nuts and bolts
22	Floor mats	To provide the craftsmen with the comfort and safety while working to remove wheel hub, speed sensor among others
23	Dental pick	To remove deposit and lift sensor from position
24	Safety glasses	To prevent eyes damage while blowing or cleaning ECU with alcohol
25	Steering wheel puller kit	To uninstall the steering wheel from position
26	Slip joint pliers	For removing pins holding sensors
27	Snap ring pliers	For removing snap rings from steering collar

Source: Researcher (2019)

2.2.3 Effects of manual on skill performance

A manual is a book that contains set of learning activities intended to facilitate learners' acquisition and demonstration of particular competency. It increases possibilities for individualization, personalization, independent study and alternative means of instruction. It also permits accurate targeting for development of specific competencies. Manuals have proved to be quite effective for teaching of all school subjects (Goodwin & Miller, 2013). The development of learner-centered educational and training packages such as manual focuses on the needs, abilities and interests and, learning styles of the learner as the teacher acts only as a facilitator of learning. A manual primarily focused on the active role of the learner, these educational and training packages makes the student responsible for their own learning.

Manual provides a form of instructional methodology that gives learners an opportunity to work individually according to their special needs. The advantage of a manual is attractive to the self-motivated learner who has already self-identified knowledge gaps with a planned approach of gaining the missing knowledge (Cha & Kim, 2014). However, learning through the use of manual limits the interactive face-to- face nature of the learning environment; this limits teachers' guidance in critical thinking exercises and thereby alters the nature of the teacher-learner relationships. The lack of face-to-face interaction may be overcome by the package content delivery which described the learning or the necessary information in a real situation manner to simulate human interaction.

Learners are able to learn effectively with self-study techniques, self-motivated learner with clearly delineated learning goals and objectives, a manual can support knowledge acquisition capable of boosting learning outcomes (Cha & Kim, 2014). Learners' skill performances are statements that specify what students will know and be able to do or be able to demonstrate when they have completed or participated in a program. Skill performances are usually expressed as knowledge, skills, attitudes or values (Abu-Moghli *et al.*, 2015). Skill performances are used to express the technical expertise that expected of automobile craftsmen to gain through their contact with a manual. As a result, these skill performances encompass skills considered critically important for automobile craftsmen as they begin productive and impactful careers.

Skill performances describe in detail the behaviors that students will be able to perform at the conclusion of a unit the manual which determine the acceptable level of performance. Also, skill performances address the context in which the demonstration of learning achievement occurs (Abu-Moghli *et al.*, 2015). Skill performances could be seen as statements of what automobile craftsmen are expected to know, understand and/or be able to demonstrate after completing reading electronic braking systems troubleshooting and maintenance manual.

Manual are found to allow learners to learn more effectively by exploring a topic on their own. This encourages learner to actively engage with the manual. According Wagenaar (2016), when learners are engaged and excited about what they are learning, they are able to remember it better and also helps in building study skills to explore new topics or tackle challenging task capable of boosting skill performance. Learners discover more about the content they are studying as the use of manual is all about searching out new information on a topic. Schaber *et al.* (2019) revealed that, manual can boost learners' self-esteem as they do more self-study, many become more confident learners. They are able to see themselves as an independent person who is able to learn new things without anyone helping them. This can be a major motivation boost for students.

Manual can encourage learners to develop their own rules and leadership patterns. Students learn to accept responsibility. They gain the freedom to learn without restrictions. They retain more because they do the work themselves as compared to spoon feeding. Manual provides the opportunity to develop a good work ethic and enhance learners' skill performances. According to Brockett and Hiemstra (2011), manual creates an effective learning environment for the learners to learn enhance skill performances. These contain the answers of all possible queries, confusions and questions that may come in the mind of the learners at the time of learning. These also provide immediate feedback on the skill performance of the learners. Boud (2018) noted that, the immediate feedback reward and motivates them to learn more and more and maintains their interest in the manual. These also help to maintain high interest level and sufficient motivation for the learners which enhances their skill performances. Manual has enriched features such as self-explanatory, contained, directed, motivating and evaluating which help to cater to the needs of all types of learners.

2.2.4 Effects of gender on the skill performance of learners

Gender is a social and cultural construct which distinguishes the difference in the attributes of men and women, boys and girls and accordingly refers to the roles of men and women. Gender refers to the roles and responsibilities of women and men that are created in families, societies and cultures (Yang, 2020). These roles and expectations are learned. They can change over time and they vary within and between cultures (Ambe-Uva, *et al.*, 2018). Gender in its narrowest sense means socially constructed sex roles of female or male. Consequently, there might be differences in male and female behaviours, partly as a product or outcome of gender roles orientation in social construction of a particular environment in which they belong to. Several authors shared divergent view that gender is not a relevant factor to be reckoned with in predicting performance of learners. Adeyemi (2019) stated that the effects of gender on the performance of students have in recent times been attracting attention from researchers and psychologists, and that there has been no consensus among scholars in terms of students' performance in schools.

The performance differences between males and females could have been exaggerated. Hyde and Mezulis (2021) pointed out that there is considerable no difference in the performance scores of males and females in Mathematics and visuals partial tasks. Maina (2021) also revealed that there was no significant interaction effect of treatments and gender on the achievement of motor vehicle mechanics students in technical colleges. However, other studies revealed that female perform better than their male counterparts.

Coley (2021) supported this claim that females had higher reading achievement and better writing skills than the males with the gap widening as students progressed through school. Contrarily, other studies such as Okeke (2016) revealed that boys are superior to girls in school skill performance in technical oriented subjects. Onuoha (2018) is of the view that male and female students perform equally using concept mapping instructional strategy. Gender composition has a significant relationship with learners' performance.

Studies on the biological explanation of gaps in academic performance between male and female learners suggested that differences in brain structure, hormone production, and/or maturation rates may account for differentiated performance in school-related tasks. Gender is one of the personal variables that have been related to differences found in academic performance of learners in school subjects. The difference in the performance of males and female learner has also generally been the concern of researchers. Hence, this study sought to determine the effect of electronic braking systems troubleshooting and maintenance manual on the skill performance of male and female automobile craftsmen in troubleshooting and maintenance of ABS, ATC and ESC.

2.2.5 Automobile craftsmen in Nigeria

Automobile craftsmen are largely responsible for diagnosing, troubleshooting and maintenance of automobile systems. In the maintenance of automobile, the main role of automobile craftsmen is to diagnose the problem accurately, troubleshoot the cause of the problem quickly and replace worn or damaged components. Agbata (2000) noted that, the job of automobile craftsmen may involve the troubleshooting and maintenance of a specific part or the replacement of one or more parts as assemblies. Some automobile craftsmen specialize in specific vehicle systems while others perform maintenance on all kinds of vehicles. A clear understanding of how automotive engines operate is essential to success as automobile craftsmen in prolonging the life span of automobile.

Furthermore, in Nigerian school system, the programme for the education and training of craftsmen for the maintenance of all types of motor vehicles are carried out in technical colleges at the National Technical Certificate (NTC) level (NBTE, 2001). The curriculum used for training automobile craftsmen was blamed for not being adequate and relevant to offer the requisite skills needed to meet the challenges that are involved in the maintenance of modern automobiles. Nice (2017) disclosed that, the incorporation of new technologies with new subsystems and system components into modern automobiles have changed their configurations and made their maintenance a more complex task.

The rapid technological changes on automobiles demands the automobile maintenance industry must cope with the ongoing innovative and technological changes that require it to continually upgrade the existing skills of its automobile craftsmen. The industry must find a way of equipping and attracting new qualified workers to the currently shrinking pool of skilled automotive craftsmen (Kolo, 2006). With the advancements in automobiles, the automobile craftsmen job has evolved from purely mechanical to include electronics technology. Modern vehicles today possess complex computer and electronic system, for this reason automotive craftsmen need to have a broader base knowledge than in the past. Fading quickly is the days of the automobile craftsmen, which need little knowledge of today's computerized system (Stan, 2011). Though, the gaps created between the curriculum and the new technological innovations have made the needed skills for effective maintenance of modern automobiles to be insufficient among automobile craftsmen in Nigeria.

Automobile craftsmen in Nigeria have been finding it quite challenging in meeting up with new developments in automobiles. Jalal (2009) stressed that majority of Nigerian automobile craftsmen may be rendered unemployed as a result of the influx of modern automobiles into the country. He further explained that, it is because modern automobiles those automobile craftsmen whom are trained to fix vehicles in Nigeria are getting out of job. The wide range of modern automobiles imported into the country by individuals, firms and various government organizations, most automobile craftsmen are not conversant with them in terms of troubleshooting and maintenance. Their knowledge of most new system in modern vehicles is generally low, while their inability to read and interpret electronics circuit diagrams is also a big problem. Jalal (2009), also added that our mechanics cannot repair many of the vehicles plying the Nigerian roads today.

Furthermore, for automobile craftsmen to effectively carry out troubleshooting and maintenance of electronic systems, they must have undergone training and experience in electrical and electronics. The automobile craftsmen of today must be able to do well and be specifically trained and equipped with competence in troubleshooting and maintenance of electronic systems, if at all they want to remain in the profession (Malone, 2006). Alabi *et al*. (2019) stated that, automobile craftsmen must be knowledgeable in electrical and computer technology and their knowledge in these areas must be updated to keep up with the rapid changes in modern automobile. They must understand not only the parts, nomenclature and operation, but also understand the diagnostic, troubleshooting and maintenance procedure for each system in the vehicle. The high technological nature of today's vehicles mandates the need for regular training of the automotive craftsmen. As such Nigerian craftsmen need to be re-trained to enable them cope with high level of technological advancement particularly in the field of automobile technology.

The insufficient skills among automobile craftsmen in Nigeria are often unemployable or underemployed while most of the modern automobiles either suffer disrepair or have the new systems replaced by the classical substitute systems that the new ones were meant to improve upon. Yet some are even completely grounded just barely into their expected service lives because of lack of competent automobile craftsmen for their effective maintenance. As measures to keep automobile craftsmen training in tune with the knowledge and skills needed in the effective maintenance of modern automobiles, enriched and updated interventions such as provision of troubleshooting and maintenance manual with sufficient contents needed in the automobile maintenance industries is required. Thus, it was imperative to develop electronic braking systems troubleshooting and maintenance manual for automobile craftsmen in Nigeria.

2.2.6 Subject matter experts

Subject Matter Experts (SMEs) are defined as those individuals with specific expertise and responsibility in a particular area or field (for example, quality unit, engineering, automation, development, operations). The SMEs are individuals that exhibits the highest level of expertise in performing a specialized job, task, or skill within the organization. Isixsigma (2021) stated that, SME might be anybody with in-depth knowledge of the subject you are attempting to document. Individuals designated as subject matter experts are typically sought out by others interested in leveraging their unique expertise to solve specific problems or help meet challenges (John, 2020). Their brains are packed full of the content, experience, and insights your learners need to do their jobs better. They have invested a lot of time in developing their expertise and have a nuanced understanding that goes far beyond just the facts.

The term SMEs is used when developing materials about a topic (a book, an examination, a manual among others), and expertise on the topic is needed by the personnel developing the material. Manuals and technical documentation are developed by technical writers, instructional designers or researchers in conjunctions with SMEs. According to Ricky (2018), SMEs are crucial for a development of high-quality educational materials such as a manual. They help to save a lot of resources and time and also help in making the manual development process better. The goal here is not necessarily to create compelling content but to work with an expert so as to come out with the most effective module or manual. SMEs are often required to sign off on the documents or training developed, checking it for technical accuracy. The service of SMEs in the research phase is not limited to the assessment of contents (to get your facts straight) but needed to be involved in the technical validation of drafts (to make sure that your interpretation of information matches theirs). SMEs helps in crafting learning objectives, create content, and provide valuable feedback. In short, you can't develop effective educational product (manual) without the inputs of SMEs (Articulate, 2015).

Typically, SMEs have developed their expertise in their particular discipline over a long period of time and after a great deal of immersion in the topic. Many subject matter experts have pursued advanced degrees in their area of specialization. Additionally, the experts maintain a rigorous program of continuous study in their field (John, 2020). This helps to ensure that, the SMEs maintain current and complete knowledge of their specific area of expertise. Many SMEs are active as authors and have published books or articles on their topic of expertise. Others serve as educators in college and universities. According to Ricky (2018), the importance of SMEs in manual development includes the following:

1. **Clarify doubts about content**: As we all know content is the most important aspect of a manual and SMEs are individuals that have extensive knowledge on a subject. The SME helps to develop the right content for the manual by keeping the target users (automobile craftsmen) in mind. He also clears the doubts in the process of developing a manual.

2. **Organizing process**: At the beginning of organizing process, it is highly recommended for a manual developer to discuss with the SME and understand their requirements for the content. This ensures smooth flow of communication

and helps in getting ideas to develop the manual that meets the needs of the users (automobile craftsmen).

3. **Re-designing the content to meet manual needs:** SMEs will suggest us to use the interactivities, images, graphics, animations and engaging functionality as per their requirements. They also provide inputs on how to present the content in a most consistent and organized manner.

4. **Reviews the projects and closes** it: As SME has a lot of expertise in their own desired field, they play an important role in validating the content. They ensure the project is on the right track and helps in finishing the project in a quick time.

5. **Helps to develop proper content:** When procedures for performing a given task are not clear, manual developers seek help from the SMEs to understand the content. The SMEs can help the manual developers by providing a proper understanding of the content and by explaining the processes in coming out with highly effective manual.

Furthermore, the importance of SMEs in the development of manual cannot be over emphasis. This is simply because they are crucial for a high quality manual as they help to save a lot of resources and time and also help in making the development process better. It is based on the importance of SMEs in development of a manual, this study will seek their expert services in the development of electronic braking system troubleshooting and maintenance manual for automobile craftsmen in Nigeria.

2.3.0 Review of related empirical studies

Jamaludin *et al.* (2011) developed a drug abused rehabilitation module. The study raised three research questions and one null hypothesis to guide the study. The study used

Sidek’s Manual Development Model (SMDM) and experimental research design. The population of the study consisted of experts in drug addict rehabilitation management, 72 female drug addict from Narcotics Addiction Recovery Center (PUSPEN), Bachok, Kelantan and 66 male drug addict from Narcotics Addiction Recovery Center (PUSPEN), Sepang, Selangor. Purposive sampling technique was used for the selection of three experts and random sampling for the selection of female and male drug addicts. Data collected were analyzed using mean and Analysis of Covariate (ANCOVA). Result from the study shown that, Drug Abused Rehabilitation Module have good validity of 91 percent and high reliability coefficient of .95 using Cronbach’s Alpha. The research findings also indicated an increase of 10.5 percent self-concept among female drug addict and 30.22 percent achievement motivation among male drug addict. Hence, it is concluded that the drug abused rehabilitation module can be used to improve self-concept and achievement motivation among female and male addict.

The relationship between this study and the study reviewed was that, the two studies developed learning support material. The use of SMDM and experimental research design, purposive sampling technique, questionnaire, Cronbach’s Alpha and mean were common in the both studies. However, the two studies differed in terms of area of the study, population and content of the subject matter.

Abd-El-Aziz (2013) developed and validated an Auto Mechanics Intelligent Tutor (AMIT) for teaching Auto-mechanics trades concepts in technical colleges. Six research questions and four null hypotheses were formulated to guide the study. The study made use of Research and Development design. The study was carried out in Lagos State, Nigeria. The population for the study was 231 National Technical Certificate II Motor Vehicle Mechanic Work students. The sample size for this study consisted of 72 participants, with 33 students in the experimental group while 39 students participated in the control group. A multi stage sampling technique was used. Five instruments were developed for the collection of data. The reliability coefficient of Alpha and Beta instruments yielded 0.70 and 0.72 respectively using Cronbach alpha technique; Cognitive achievement yielded 0.817 using K R- 20; while the inter scorer reliability of psychomotor assessment instrument are 0.98 and 0.99.

The research questions were analyzed using mean values and standard deviation and the null hypotheses were tested at 0.05 level of significance using ANCOVA statistics. Findings from the study revealed that, students in the experimental group obtained higher mean scores than in the control group in cognitive and skill performance as well as in cognitive and psychomotor retention. It was recommended that, the teachers should adopt the use of Auto-Mechanics Intelligent Tutor instructional medium for enhancing students' cognitive achievements, skill performance and retention of learning in technical colleges.

The study reviewed is related to this study because the two studies developed learning support material in the field of automobile technology. The two studies shared similarities in the use of questionnaire, Cronbach's Alpha, mean and ANCOVA. Nonetheless, the study reviewed shared no similarity with this study in terms of research design, area of the study, population, sampling and content of the subject matter.

Aliyu (2013) developed a self-instructional manual for sand casting technology in the polytechnics in North-Central States of Nigeria. Eight research questions were formulated to guide the study with a null hypothesis tested at 0.05 level of significance. Restricted steps of Research and Development (R&D) design. The study was conducted in North-Central States, Nigeria. The population for the study is 272 lecturers, instructors, technologists, technicians from all the 12 Polytechnics in the zone. A purposive sampling was adopted for the students of Federal Polytechnics in Bida and Idah, comprising of 60 Students. Three sets of instruments were used for data collection; Sand Casting Technology Training Manual Questionnaire (SCTTMQ), Sand Casting Technology Psychomotor Achievement Test (SCTPAT) and Sand Casting Technology Psychomotor Rating Scale (SCTPRS). The instruments were subjected to both face and content validity by five specialists from both the Polytechnics and the Foundry Industries. Cronbach's Alpha was used to establish the reliability of SCTTMQ, while KR20 was used to establish reliability of SCTPRS and SCTPAT which yielded 0.855 and 0.816 respectively.

Kendall's coefficient of concordance was used to establish the inter-rater reliability of SCTPRS, which yielded 0.801. Mean was used to answer research questions, while ANCOVA was used to test the hypothesis at 0.05 level of significance. The study developed a detailed self-instructional manual for sand casting technology with pictorial illustrations for the Polytechnics. It also found out that, the use of the self-instructional manual facilitated skill acquisition among the Polytechnic students. The study recommended the use of manuals in sand casting skill training in the Polytechnics.

The study reviewed is related to this study because it developed a manual for sand casting technology while this study also developed a manual for the troubleshooting and maintenance of electronic braking system. The studies are alike in the use of purposive sampling technique, questionnaire, psychomotor rating scale, Cronbach's Alpha and Kendall's coefficient of concordance. On the other hand, this study varied from the study reviewed in terms of research design, area of the study and content of the subject matter.

Ogbuanya and Idris (2014) developed automobile battery and charging system maintenance training manual for technical college students. Seven specific purposes, six research questions and a null hypothesis guided the study. Research and Development (R and D) design was adopted for the study. The population of the study was 348 respondents, consisting 76 auto-mechanics teachers, 36 automobile supervisors and 237 students from all the technical colleges in North-Western States of Nigeria. The study employed no sampling technique as all the population were used. The instruments for data collection are; Auto-Electricity Training Manual Questionnaire (ATMQ), Auto-Electricity Psychomotor Test (APT) and Auto-Electricity Rating Scale (ARS). The ATMQ, APT and ARS were subjected to face validation by five experts from Universities, technical colleges and the automobile industry.

Cronbach's Alpha was used to establish the reliability of ATMQ and yielded coefficient of 0.72, 0.81, 0.76, 0.78 and 0.73 respectively. Kendall's coefficient of concordance was used to establish the internal consistency of APT and yielded coefficient of 0.75. Data were analyzed using mean and standard deviation, while ANCOVA was used to test the hypothesis at 0.05 level of significance. The study developed training manual for automobile battery and charging system with pictorial illustrations for technical colleges. The study recommended the use of automobile battery and charging system training manual for practical skills training in technical colleges, so as to achieve their objectives.

The study reviewed is related to this study because it developed automobile starting and lighting system maintenance training manual while this study also developed a manual for troubleshooting and maintaining electronic braking system. The use of questionnaire, psychomotor rating scale, Cronbach's Alpha, Kendall's coefficient of concordance and mean were common to both studies. However, research design, population, sampling technique and content of the subject matter were different from this study.

Idris and Ogbuanya (2015) developed automobile starting and lighting system maintenance training manual for technical college students. Six research questions and a null hypothesis guided the study. Research and Development (R and D) design was adopted for the study. The population of the study is 348, comprising of 76 auto-mechanics teachers, 36 automobile supervisors and 237 students from all the technical colleges in North-Western States of Nigeria. There was no sample for the study; however, purposive sample was used for the students used for trial testing. The instruments for data collection are; Auto-Electricity Training Manual Questionnaire (ATMQ), Auto-Electricity Psychomotor Test (APT) and Auto-Electricity Rating Scale (ARS). The ATMQ, APT and ARS were subjected to face validation by five experts from the University, Technical Colleges and the Automobile Industry. Cronbach Alpha was used to establish the reliability of ATMQ, sections B, C, D, E and F yielded coefficient of 0.72, 0.81, 0.76, 0.78 and 0.73 respectively. Kendall's coefficient of concordance was used to establish the internal consistency of APT and yielded coefficient of 0.75. Data were analyzed using mean and standard deviation, while ANOVA was used to test the hypothesis which yielded a coefficient of 0.044 at 0.05 level of significance. The use of automobile starting and lighting system of training manual was therefore recommended for practical skills training in technical colleges.

The study reviewed is related to this study because it developed automobile battery and charging system maintenance training manual while this study also developed a manual for troubleshooting and maintaining electronic braking systems. The similarities between the two studies included the use of questionnaire, psychomotor rating scale, Cronbach's Alpha, Kendall's coefficient of concordance and mean. However, research design, population, sampling technique and content of the subject matter used were the difference between the two studies.

Maeleera (2015) developed a capacity building modules for technologists in refrigeration and air-conditioning in South-South, Nigeria. Five research question and one hypothesis were formulated to guide the study. Research and Development design was used. The study was conducted in South-South, Nigeria. The total population of the study was 118 which comprised 14 teachers of refrigeration and air-conditioning, 34 technologists, 45 technicians, and 25 students of mechanical engineering used for try-out. The instrument used include: Questionnaire for the Development of Capacity Building Module for Technologist in Refrigeration and Air-conditioning (QDCBMTRA) and Refrigeration and Air-conditioning Psychomotor Rating Scale (RAPRS). The instruments were the subjected to validation by two specialists in refrigeration and air-conditioning industry and two lecturers in the university. Cronbach alpha was used to establish the reliability of the instrument which yielded 0.89 and Kendall concordance correlation was used to determine the reliability of (RAPRS) which yielded 0.88. Mean and standard deviation were used for data analysis.

The developed modules were tried out on 25 final year students of mechanical engineering in Federal Polytechnic, Offa. The pre-test and post-test scores obtained were analyzed using ANCOVA at 0.05 level of significance to test the hypothesis. The result obtained revealed that there was significance difference 0.05 level. The study recommended that National Board for Technical Education should set up curriculum review committee that will use the module content for modification of refrigeration and air-conditioning practical content.

The study reviewed is related to this study because the two studies developed an intervention for capacity building. However, the use of questionnaire, psychomotor rating scale, Cronbach's Alpha, Kendall's coefficient of concordance and mean were common to both studies. However, research design, population and content of the subject matter used were the difference between the two studies.

Udogu (2015) determined the emerging technology skills required by technical college graduates of Motor Vehicle Mechanic's Work (MVMW) for establishing automobile enterprises in Anambra and Enugu States of Nigeria. The study sought to answer six research questions and six null hypotheses were also tested at 0.05 level of significance. A descriptive survey research design was adopted for the study. The population for the study was made up of 120 automobile industry workers and 9 instructors of MVMW totaling 129 respondents from notable automobile manufacturing and maintenance workshops and NBTE accredited technical colleges in Anambra and Enugu States. There was no sampling for the study since the entire population was used. Structured questionnaire was the instrument used for data collection. A reliability index using Cronbach Alpha coefficient method yielded 0.92. Data were analyzed using mean and z-test statistics to answer the research questions and hypotheses respectively at 0.05 level of significance. Findings revealed that emerging technologies in modern automobile systems require the skills of technical college graduates of MVMW programme in the maintenance of engine, ignition, fuel, transmission, brake and on-board diagnostic (OBD) systems for establishing automobile enterprises in Anambra and Enugu State of Nigeria. The study recommended among others that, the identified emerging technology skills should be integrated into the national curriculum of MVMW programme in technical colleges.

The study reviewed is related to this study because it is concerned with emerging technologies on modern automobile as this study developed a manual for troubleshooting and maintaining electronic braking system which is also an aspect of emerging technologies in automobile. The similarities between the two studies included the use of questionnaire, Cronbach's Alpha and mean. However, research design, sampling technique and method of testing hypotheses used were the difference between the two studies.

Dabban (2016) developed a carpentry and joinery self-instructional manual for learning practical skills in Technical Colleges in North Central Nigeria. Six research questions were posed and a null hypothesis formulated to guide the study, subsequently; the null hypothesis was tested at 0.05 level of significance. Research and Development (R & D) design was adopted for the study. The total population of the study was 3,374 carpentry and joinery teachers, technicians, supervisors, carpenters and technical college students. The sample for the study was 251 made up of 61 carpentry and joinery teachers, 41 technicians, 48 supervisors, 41 road side carpenters and 60 Technical College students. The samples were purposively selected based on their ability and willingness to participate in the study. Three sets of instruments that were used for data collection are: Carpentry and Joinery Self-Instructional Manual Questionnaire (CAJSIMQ), Carpentry and Joinery Psychomotor Test (CAJPT) and Carpentry and Joinery Psychomotor Rating Scale (CAJPRS). The CAJPT was validated by three experts from a technical college.

The reliability of CAJSIMQ was established using Cronbach alpha for sections B, C, E and F, and KR20 for section D which yielded reliability coefficients of 0.870 and 0.821 respectively. The inter-rater reliability of CAJPRS was established using Kendall's coefficient of concordance and a coefficient of 0.833 was obtained. The data obtained from the CAJSIMQ were analyzed using mean and standard deviation and used to develop the draft self-instructional manual in carpentry and joinery. The draft manual was trial tested on Carpentry and Joinery students in technical colleges in Bukuru and Makurdi. The research questions were answered using descriptive statistics, while the null hypothesis was tested using ANCOVA at 0.05 level of significance.

The relationship between the study reviewed and this study is that, the study reviewed developed carpentry and joinery self-instructional manual for learning practical skills while this study also developed electronic braking system troubleshooting and maintaining manual. However, common to both studies were the use of questionnaire, psychomotor rating scale, Cronbach's Alpha, Kendall's coefficient of concordance and mean. Though, area of the study, research design, population, sampling technique and content of the subject matter differentiates this study and the study reviewed.

Bakare (2017) developed and validated a cell phone maintenance training modules for national diploma students. Five research questions were answered while five null hypotheses were formulated and tested at 0.05 level of significance. The study adopted Research and Development (R&D) design and was carried out in Lagos State, Nigeria. The population for the study was 137 which comprised 35 Lecturers, 14 Instructors of Electrical/Electronic Technology, 21 Supervisors and 67 Roadside Cell Phone Technicians. Purposive sampling technique was used to select 67 literate road side cell phone technicians. The entire population of the lecturers, instructors and supervisors was involved in the study because of their manageable size. Cell phone maintenance training module questionnaire (CMTMQ) was used for data collection for the study. The instrument was face validated by three experts. Internal consistency of CMTMQ was determined using Cronbach's Alpha reliability method and the overall reliability coefficient of 0.86 was obtained. Factor analysis and mean were used for answering the research questions while Analysis of Variance (ANOVA) was employed for testing null hypotheses at 0.05 level of significance. The findings of the study revealed that 12 objectives and 140 contents were required for the development of cell phone maintenance training modules for national diploma students.

The findings of the study revealed 50 facilities, 58 delivery systems, 33 evaluation techniques and 33 activities were confirmed necessary for implementing cell phone maintenance training modules. The study recommended that National Board for Technical Education and other government agencies should integrate the developed cell phone maintenance training modules to polytechnics, university, colleges of education programmes and secondary school curriculum for training of students.

The study reviewed is related to this study as the two studies developed interventions for capacity building. The studies were common in terms of instrument for data collection, method of establishing the reliability of the instruments for data collection and method of data analysis. In other words, the two studies differed in terms of area of the study, research design, sampling technique and content of the subject matter.

Ajunwa *et al.* (2018) developed a training manual for maintenance of Radio and Digital Versatile Disc (R and DVD) Player for electronics craftsmen. One research question and one hypothesis guided the study. The study was Research and Development (R&D) research and employed the Wheeler's model. The study covered North-Central States of Nigeria. The population for the study was 58 respondents which consist of 32 electronics teachers in the 15 accredited science and technical colleges offering electronics trade and 26 master craftsmen with the National Directorate of Employment (NDE) States head offices in North-Central States. No sampling technique was adopted in the selection of sample for the study. The instrument used for data collection was a structured questionnaire. The reliability coefficient of the instrument was established as 0.91 using Cronbach's Alpha. Data collected was analyzed using mean for research question and z-test for the null hypothesis. Findings revealed that the R and DVD player contents consists of operational tasks, learning objectives, skills for replacing faulty components, teaching requirements and tools and materials required for maintenance of mechanical subsystem.

Recommendation made include R and DVD player maintenance training module should be included in craftsmen training programme in Nigeria, consequently the developed draft training manual should be adopted and used for training and retraining of craftsmen in the maintenance of R and DVD player.

The study reviewed is related to this study because it developed a training manual for maintenance of Radio and Digital Versatile Disc Player for electronics craftsmen while this study developed a manual for troubleshooting and maintaining electronic braking system for automobile craftsmen. However, the two studies were common in terms of population used as well as questionnaire, Cronbach's Alpha and mean. However, the two studies differed in terms of research design and content of the subject matter used.

Kasim and Ahmad (2018) developed a PRO-STEM module for teaching the topic of biodiversity and ecosystem to promote the application of higher order thinking skills (HOTS) and 21st century skills among secondary school students. The study was guided by three research questions and one hypothesis. The study used Sidek Module Development Model. The study was conducted in Malaysia. A total of five experts in STEM and science education were appointed to validate the PRO-STEM module. No sampling technique was involved in the selection of the experts used. The instrument used was a Content Validity Index (CVI). The content validity value of the PRO-STEM module was .98 percent and the reliability coefficient was found to be .924 using Cronbach's alpha. Mean and z-test was used for data analysis. The findings show that PRO-STEM module has good validity and reliability and is capable of being used as a teaching and learning module to integrate STEM in science classrooms. The study recommended the use of PRO-STEM module for teaching and learning science.

The study reviewed is related to this study as the two studies developed a learning support material. The studies shared similarities in the use of Sidek Manual Development Model (SMDM), Content Validity Index (CVI), Cronbach's Alpha, mean and Z-test. Though, the two studies differed in terms of area of the study, population, sampling technique and content of the subject matter.

Alabi *et al*. (2019) identified the core on-board diagnostic (OBD) skills required by motor vehicle mechanics for troubleshooting engine performance and transmission system of modern automotive in Niger State. The study answered two research questions and two null hypotheses were also tested at 0.05 level of significance. A survey research design was employed for the study. The population for the study comprised 833 motor vehicle mechanic master craftsmen and 29 automobile technology lecturers. A structured questionnaire which was designed by the researcher was used for collecting data from the respondents. Cronbach's alpha reliability method was employed to determine the internal consistency of the questionnaire and reliability coefficient of 0.84 was obtained. Mean and standard deviation were used to answer the research questions while z-test statistics was used to test the null hypotheses at 0.05 levels of significance. It was found out that all the forty skills suggested are required by motor vehicle mechanics for troubleshooting engine performance and transmission system of modern for modern automotive. It was therefore recommended that all the skills identified in this study to be included in the training given to motor vehicle mechanics apprentices in Niger State.

The study reviewed is related to this study because it is concerned with OBD skills required by motor vehicle mechanics for troubleshooting which is an aspect covered in the development of electronic braking system troubleshooting and maintenance manual. The two studies were similar in several aspects that include the use of questionnaire, Cronbach's Alpha and mean. In other words, the two studies were different in research design, sampling technique and method of testing hypotheses used.

2.4.0 Summary of literature review

The literature reviewed was carried out under theoretical framework of the study, the conceptual framework of the study, electronic braking systems, manual and review of related empirical studies subheadings. The theoretical framework of the study extensively discussed andragogy theory that provided guidelines on how to offer skills intervention to adult learners and Sidek's Manual Development Model that provided guidelines on the development of learning intervention such as manual. The conceptual framework of the study showed the relationship between various variables that are related to the study in three phases. The variables related to the study such as electronic braking systems (Anti-lock Braking Systems, Automatic Traction Control and Electronic Stability Control) components of a manual (troubleshooting and maintenance objectives, contents and facilities required) were adequately reviewed.

The review of related empirical studies gathered information on studies related to the study. These studies were related to this study as they all dwelled on the development of instructional packages such as module and manual in other aspects of technology education. Furthermore, these studies shared similarities and differences in terms of research design, area of the study, population, sampling technique, instrument for data collection, method of establishing the reliability of the instrument, method of data analysis and content of the subject matter.

In spite of all these studies, large proportion of the automobile craftsmen in Nigeria finds it extremely difficult to troubleshoot and maintain electronic braking systems. The possible cause for this shortcoming may be due to the lack of adequate electronic braking systems troubleshooting and maintenance competences in the National Board for

Technical Education curriculum for National Technical Certificate programme used for training the vast majority of automobile craftsmen in Nigeria. Therefore, this study was designed to develop electronic braking systems troubleshooting and maintenance manual for automobile craftsmen in Nigeria.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Research Design

The study adopted sequential exploratory research design. The sequential exploratory research design is the type of mixed method research design characterized by an initial phase of qualitative data collection and analysis followed by a phase of quantitative data collection and analysis. According to Moser and Kalton (2017), sequential exploratory research design is useful when developing and testing a new instrument or educational package such as electronic braking system troubleshooting and maintenance manual for automobile craftsmen. Nevertheless, the study utilized phenomenology to collect qualitative data, Instructional Systems Design (ISD) using Sidek's Manual Development Model (SMDM) to guide the development of the manual and True Experimental Research Design (TERD) using one group pretest-posttest design to collect quantitative data for the study.

Phenomenology is used to identify phenomena and focus on subjective experiences and understanding the structure of those lived experiences. According to Statistics (2021), phenomenology is used to describe, in depth, the common characteristics of the phenomena that have occurred. The primary data collection method is through face-to-face interviews. The study adopted face-to-face interview to collect in-depth qualitative data on the objectives on troubleshooting and maintenance of electronic braking systems for the manual. This is simply due to the fact that, it allows for in-depth collection of qualitative data and probing for explanations of responses (DeFranzo, 2021).

The ISD involves systematic process of designing and developing digital and physical instructional packages and programmes that brings greater efficiency and effectiveness in helping learners acquire knowledge or skills. The ISD is considered suitable for this study, simply because it is the most appropriate design that solely focused on the development of instructional packages such as module or manual that provide guidelines to ensure that learning meets the desired expectations (William & Fairwyn, 2019). There are widely ISD models in use today by educational institutions that include SMDM (Training, 2020). The SMDM comprises of two stages. The first stage consists of nine steps that includes: developing the aim of the manual, identifying theories, need assessment, setting of objectives, selection of: content, strategy, logistic, media and ends with integrating the draft manual.

These steps were articulated into two comprehensive steps that consists of need assessment and development of the draft manual to suit the need for the study. The second stage, consists of three steps that includes: testing the validity, reliability and effectiveness of the draft manual. The SMDM is considered suitable for this study because it provides comprehensive reliability and validity testing platform that yields numerical values on the content validity and reliability of the draft manual (Sidek, 2005).

The TERD is an empirical interventional study with at least one independent variable (electronic braking system troubleshooting and maintenance manual) that is experimentally manipulated and with at least one dependent or outcome variable (skill performance as in this study) (Encyclopedia of Research Design, 2010). The distinguishing feature of true experimental design is that, the subjects of study are randomly assigned to control and experimental groups (Handley *et al.*, 2018). In other words, TERD entails the researcher randomly assigns test units and treatment to the experimental group. TERD is considered suitable for this study because of the following reasons: Automobile craftsmen in Nigeria are graduates of technical colleges that can-not be traced in an intact class. Hence, using them for whatever kind of experimental study requires randomization of subjects which is only allowed using TERD.

Furthermore, this study involved a single independent variable (electronic braking systems troubleshooting and maintenance manual) experimentally manipulated. Having other independent variable (such as teaching methods) was not possible since the contents of electronic braking systems troubleshooting and maintenance were not contained (as a course) in the curriculum used for training of automobile craftsmen that were involved in this study, as such, no time and resource persons were allocated for it and cannot be created as it will violate an existing set up of the training programme. This implied that, using other designs such as quasi experimental research design which require more than one independent variable to be experimentally manipulated was not possible for this study. Hence, the TERD is suitable because it allowed one independent variable to be experimentally manipulated and therefore adopted for this study.

3.2 Area of the Study

The study was conducted in Federal Capital Territory (FCT), Abuja, Kaduna, Kano, Lagos and Plateau States, Nigeria. The FCT Abuja is located in the North-Central region of Nigeria at latitude of 9.07 and longitude of 7.49 with Global Positioning System (GPS) coordinates of 9° 4' 20.15" N and 7° 29' 28.69" E. Kaduna is located in the North-Western Nigeria at latitude of 10.61 and longitude of 7.43 with GPS coordinates of 10° 36' 33.5484" N and 7° 25' 46.2144" E. Kano is located in the North-Western Nigeria at latitude of 12.00 and longitude of 8.57 with GPS coordinates of 12° 0' 0.000" N and 8° 31' 0.0012" E. Lagos is located in the South-Western Nigeria at latitude of 6.47 and longitude 3.41 with GPS coordinates of 6° 27' 55.52" N and 3° 24' 23.21" E. Plateau is located in the North-Central region of Nigeria at latitude of 9.34 and longitude of 7.04 with GPS coordinates of 9° 34' 0.00" N and 9° 04' 60.00" E (Articles in Nigeria, 2020).

FCT Abuja, Kaduna, Kano, Lagos and Plateau States were selected because the two major stakeholders in the automobile maintenance industry, National Automotive Design and

Development Council (NADDC) and Industrial Training Fund (ITF) used for this study were situated. Though, the need for other cities in Nigeria to represent North-East, South-East and South-South was not important since the study was not a pure survey nor a curriculum content development study where representation of respondent play significant role in generalization of opinion (in the case of survey study) or bridging cultural and social differences (in the case of curriculum content development study). The development of electronic braking system troubleshooting and maintenance manual required universally unique skills not opinion. This entailed, a manual can be developed in one part of the world and be used in another due to universal uniqueness of the skills involved just as in the case of a textbook. Hence, representation of respondents has little or no significance to this study and lacks scholarly basis.

3.3 Population of the Study

The targeted population for the study was 174 consisting of all the 43 non-teaching Subject Matter Experts (SMEs) from NADDC and ITF, and all the 56 teaching SMEs and 75 automobile craftsmen (48 males and 27 females) from the six NADDC and ITF owned and affiliated institutions offering automobile mechatronics training programme that include: Autolady Engineering Technology Nigeria Limited, Abuja, Lady Mechanic Initiative, Lagos, AFEME Workshop, Mogadishu Cantonment, Abuja, ITF Model Skills Training Centres in Abuja, Kano and Lagos, and Business Apprenticeship Training Centre, Zaria (see Appendix A, page 141).

The NADDC and ITF were chosen for this study because they are considered the two major stakeholders in the automobile maintenance industry known for developing manual and training automobile craftsmen in Nigeria as well as endowed with sufficient modern facilities and highly skilled experts for the development, validating and testing the effect of the electronic braking systems troubleshooting and maintenance manual developed.

The selection of Craftsmen from the selected institutions allows the stakeholders (SMEs from the selected institutions) to be part of the manual validation process as suggested by Sidek (2005). The selection of the other six institutions is based on the fact that, they are offering automobile mechatronics training programme for craftsmen, they have the availability and adequacy of experienced personnel used for assessing the contents of the manual, adequacy of training facilities used for testing the effectiveness of the manual and presence of automobile craftsmen. Nevertheless, the institutions were notified and requested to take part in the study by the researcher (as shown in Appendix B, page 147).

3.4 Sample and Sampling Technique

The study utilized the whole population of the study. Though, Purposive Sampling Technique (PST) was used to select nine SMEs for the face-to-face interview to collect the qualitative data for answering research questions one and for validating the electronic braking systems troubleshooting and maintenance manual developed. The selection of the nine SMEs in validating the developed manual was deemed sufficient as it is in line with the postulation of Abu-Talib (2015) on the appropriate number of experts required for development and validation of a manual. The selection of the nine SMEs was also supported by Othman in Mohammad *et al.* (2013) who argued that, six to nine SMEs are adequate in examining the constructs validity of a module or manual. The nine SMEs were chosen because of their vast experience and expertise in troubleshooting and maintenance of electronic braking systems, manual development, and teaching. The PST is considered suitable for this study because it gives the researcher the opportunity to enjoy the services of SMEs that can shape the study in important ways (Crossman, 2018).

3.5 Instruments for Data Collection

The instruments used for data collection includes: Electronic Braking System Troubleshooting and Maintenance Objectives Interview Protocol (EBSTMOIP), Electronic Braking Systems Troubleshooting and Maintenance Questionnaire (EBSTMQ), Electronic Braking Systems Troubleshooting and Maintenance Skill Performance Test (EBSTMSPT), Electronic Braking Systems Troubleshooting and Maintenance Skill Performance Rating Scale (EBSTMSPRS), Electronic Braking Systems Troubleshooting and Maintenance Skill Performance Test Scoring Sheet (EBSTMSPTSS), Manual Content Validity Index (MCVI) and Expert Revision Form (ERF).

The EBSTMOIP is a qualitative instrument developed by the researcher that consists of opening statement, two structured questions to collect qualitative data on the objectives for the manual on troubleshooting and maintenance of electronic braking systems and closing remarks as shown in Appendix C, page 146. The EBSTMQ was developed by the researcher through observation, document analysis and extensive review of literatures. The instrument consisted of a total of 377 items designed on a five-point(s) rating scale labeled with Strongly Agree, Agree, Disagree, Strongly Disagree and Undecided with numerical values of 5, 4, 3, 2 and 1 point(s) respectively. The instrument was divided into 4 parts consisting of: A, B, C and D (as shown in Appendix D, page 149). The Part A consisted of 122 items that identified the contents of the manual on troubleshooting electronic braking systems, part B contained 178 items that identified the contents of the manual on the maintenance of electronic braking systems, part C consisted of 11 items that determined the facilities required for troubleshooting electronic braking systems and part D contained 66 items that determined the facilities required for the maintenance of electronic braking systems.

The EBSTMSPT was developed by the researcher and consisted of two practical questions (as shown in Appendix E, page 164). The two practical questions were used to assess automobile craftsmen skill performance in troubleshooting and maintenance of electronic braking systems. The EBSTMSPRS was developed by the researcher on a five-point rating scale that consisted of part A and B (as shown in Appendix F, page 165). Part A consisted of nine items that provided basis for grading the craftsmen skill performances in troubleshooting and part B consists of eight items that provided basis for grading the automobile craftsmen skill performances in the maintenance of electronic braking systems. The EBSTMSPTSS was also developed by the researcher containing provisions to record the skill performances scores of automobile craftsmen in troubleshooting and maintenance of electronic braking systems (Appendix G, page 167).

The MCVI was adopted from Rowena (2015) and modified to suit the study. The modifications made on the MCVI include altering the numeric values of the scale to lower the statistical blunders of using mean to analyze data collected using instrument designed on Likert's scale. The instrument was designed on a five-point rating scale, consisting of five parts with five items each (as shown in Appendix H, page 168). The detail of MCVI is contained in Table 3.1. The MCVI was used to establish the content validity of the manual based on objectives, subject matter, organization, language and usefulness.

Table 3.1: Details of Manual Content Validity Index

		Interpretation				
Scale	**Range**	**Objectives**	**Subject Matter**	**Organization**	**Language**	**Usefulness**
5	4.50-5.00	Strongly Agree	Much Sufficient	Highly Effective	Highly Effective	Very Useful
4	3.50-4.49	Agree	Sufficient	Effective	Effective	Useful
3	2.50-3.49	Disagree	Not Sufficient	Not Effective	Not Effective	Not Useful
2	1.50-2.49	Strongly Disagree	Not Much Sufficient	Not Highly Effective	Not Highly Effective	Not Very Useful
1	1.00-1.49	Undecided	Undecided	Undecided	Undecided	Undecided

Source: Rowena (2015)

Furthermore, the ERF was adopted from Sidek (2005) and modified by featuring the subheadings of the manual developed to suit the need for this study. It consisted of ten items in-line with major headings in the manual developed with ten empty spaces corresponding to each item (as shown in Appendix I, page 171). The empty spaces were to accommodate experts' comments regarding the need for revision or correction to be made on the manual developed.

3.6 Validation of the Instruments

The EBSTMOIP, EBSTMQ, EBSTMSPT, EBSTMSPRS, MCVI and EFR were subjected to content validation by three experts, one each from Department of Industrial and Technology Education, Federal University of Technology (FUT), Minna, Nigeria, Department of Examination Development (Auto Mechanic Unit), National Examination Council (NECO), Minna, Nigeria and Department of Automobile Electrical/Electronics, Automedics Nigeria Limited, Abuja, to ascertain the appropriateness, suitability and usefulness of the items in relation to the objectives of the study. The experts were requested to identify and correct ambiguous words or terms, inappropriate items, missing items, make general comments or suggestions for the improvement of the instruments (see Appendix J, page 172). The validation certificate was also signed as shown in Appendix K, page 173. Suggestions for changes observed by the experts include the use of earth instead of ground, similar words for multiple items on same instrument should be avoided, splitting items with multiple tasks among others.

3.7 Reliability of the Instruments

The reliability of EBSTMQ was established by trial testing the instruments on a randomly selected 10 SMEs from FUT, Minna, Niger State College of Education, Minna, Automobile Motors, Minna and Kaura Danali Motors, Minna, Nigeria. Cronbach's Alpha statistics was used to determine the reliability indices of both EBSTMQ and MCVI. The

Part A, B, C and D of EBSTMQ yielded the reliability coefficient values of: 0.72, 0.83, 0.89 and 0.91 respectively with overall reliability coefficient of 0.84 (as shown in Appendix L, page 174). Cronbach's Alpha statistics was used because it is the most suitable technique for establishing the reliability coefficient of instruments designed with non-dichotomous items (Vehkalahti *et al.,* 2016).

The reliability indices of EBSTMSPT were established by trial testing the instruments on 8 ascertained automobile craftsmen from Kaura Danali Motors, Minna, Niger State, Nigeria. Kendall's tau coefficient of concordance was used to establish the inter-rater reliability of EBSTMSPT and yielded 0.84 and 0.86 (as shown in Appendix M, page 176). Kendall's coefficient of concordance was used because; it is considered more appropriate statistics technique for determining the degree of association when ordinal rating scales are involved (Automotive Industry Action Group AIAG, 2010).

Furthermore, the reliability of EBSTMOIP was tested using two respondents consisting of SMEs in Automobile Motors, Minna and Kaura Danali Motors, Minna, Nigeria. The reliability of EBSTMOIP was achieved as the respondent agreed with the transcribed contents of the face-to-face interview to have corresponded to their exact responses.

3.8 Procedures for the Development of the Manual

The procedure for the development of electronic braking systems troubleshooting and maintenance manual consisted of three major phases that include the following:

Assessment Phase: Face-to-face interview was used to ascertain the objectives while assessment survey was used to ascertain the contents and facilities for troubleshooting and maintenance of electronic braking systems included in the manual developed.

Development Phase: Development of the final copy of the electronic braking systems troubleshooting and maintenance manual was done by assembling the ascertained objectives, contents and required facilities collected from the assessment phase by the researcher as shown in Appendix P, page 188. The manual was assigned an International Standard Book Number (ISBN: 978-978-993-194-1) to fulfil the requirement for developing and publishing books in Nigeria and also to ensure its acceptability and usability by automobile craftsmen.

Evaluation Phase: Evaluation of the draft of electronic braking systems troubleshooting and maintenance manual developed was achieved in three stages which include: validation, trial testing and effectiveness testing.

The Validation Stage: During this stage, the draft copies of electronic braking systems troubleshooting and maintenance manual was validated using MCVI by nine SMEs in order to establish its contents validity index as requested in Appendix N, page 177. Each of the SMEs were given a copy of the developed electronic braking systems troubleshooting and maintenance manual, MCVI and experts' revision form where critique and suggestions by the SMEs for the improvement were recorded. The contents validity index of the developed electronic braking systems troubleshooting and maintenance manual is shown in Table 3.2.

Table 3.2: Experts' Mean Scores and Content Validity Index of Electronic Braking Systems Troubleshooting and Maintenance Manual for Automobile Craftsmen in Nigeria

S/N	Experts	Mean Scores Obtained	MCVI (Scores Obtained/Total Obtainable Score 25)	Decision
1	Objectives	22.89	0.92	Highly Valid
2	Subject Matter	22.78	0.91	Highly Valid
3	Organization	22.89	0.92	Highly Valid
4	Language	23.22	0.93	Highly Valid
5	Usefulness	23.11	0.92	Highly Valid
	Overall	**22.98**	**0.92**	**Highly Valid**

Table 3.2 shows that, the MCVI obtained on the objectives, subject matter, organization, language and usefulness of the electronic braking systems troubleshooting and

maintenance manual for automobile craftsmen in Nigeria ranged between 0.91-0.93 and with overall validity index of 0.92. These indices indicated that, the content of electronic braking systems troubleshooting and maintenance manual for automobile craftsmen in Nigeria is highly valid.

The Reliability Testing Stage: The reliability coefficient of the developed electronic braking systems troubleshooting and maintenance manual was obtained using the data collected with MCVI during the manual validation stage. The reliability index of the developed manual is shown in Table 3.3.

Table 3.3: Reliability Index of Electronic Braking Systems Troubleshooting and Maintenance Manual for Automobile Craftsmen in Nigeria

S/N	Experts	Number of Items	Cronbach's Alpha	Decision
1	Objectives	5	0.85	Highly Reliable
2	Subject Matter	5	0.88	Highly Reliable
3	Organization	5	0.72	Highly Reliable
4	Language	5	0.76	Highly Reliable
5	Usefulness	5	0.72	Highly Reliable
	Overall	**25**	**0.81**	**Highly Reliable**

Table 3.3 shows that, the Cronbach's Alpha values obtained on the objectives, subject matter, organization, language and usefulness of the electronic braking systems troubleshooting and maintenance manual for automobile craftsmen in Nigeria ranged between 0.72-0.88 and with overall reliability index of 0.81. These indices indicated that, the electronic braking systems troubleshooting and maintenance manual for automobile craftsmen in Nigeria is highly reliable.

The Effectiveness Testing Stage: The developed electronic braking systems troubleshooting and maintenance manual was tested for effectiveness on automobile craftsmen's skill performance as detailed in the experimental procedure.

3.9 Method of Data Collection

Qualitative data for the study were collected by conducting a face-to-face interview using EBSTMOIP. The face-to-face interview was conducted within two weeks by the researcher. The two weeks' period is considered sufficient time to allow the researcher interview the nine SMEs selected for the face-to-face interview. Furthermore, quantitative data were collected by administering copies of the EBSTMQ to the SMEs through hand delivery to elicit information on the contents and facilities required for troubleshooting and maintenance of electronic braking systems and the EBSTMSPT were administered to automobile craftsmen to measure their performance in troubleshooting and maintenance of electronic braking systems. Moreover, the administration of the instruments was achieved by the help of research assistants. Six research assistants, one each from the automobile craftsmen training centres in the study area were used by the researcher. The research assistants were briefed by the researcher on how and when to effectively administer the instruments in order to achieve high return rate.

3.10 Experimental Procedure

The experiment was conducted in three stages within three weeks to measure the effectiveness of the electronic braking systems troubleshooting and maintenance manual on the skill performance of automobile craftsmen. The first stage of the experiment involved the administration of EBSTMSPT to all the automobile craftsmen by their instructors in the first week of the study as pre-test to measure the skills they possessed in troubleshooting and maintenance of electronic braking systems.

The second stage of the experiment involved the administration of the developed electronic braking systems troubleshooting and maintenance manual to all the automobile craftsmen by their instructors immediately after the first stage of the experiment. At this stage, the automobile craftsmen were expected to self-learn the contents of the manual for the period of two weeks. The two weeks was considered enough time to allow automobile craftsmen self-study the manual. Nevertheless, the third stage of the experiment involved the administration of EBSTMSPT to all the automobile craftsmen by their instructors in the third week of the study as post-test to measure the skill performance in troubleshooting and maintenance of electronic braking systems.

However, in order to decrease the variability in the findings on skill performance in troubleshooting and maintenance of electronic braking systems, students that were not qualified to be craftsmen in the selected institutions were not featured in the study. Hence, there interaction with the craftsmen selected for the study had little or no effect on the validity of the findings since they do not constitute the subjects used for this study.

3.11 Method of Data Analysis

The qualitative data collected were analyzed using thematic analysis while quantitative data collected were analyzed using mean, z-test and Analysis of Covariance (ANCOVA). The thematic analysis involved data transcription, coding, categorization and analysis using percentage. Any response regarding the objectives for the manual on troubleshooting and maintenance of electronic braking systems with 70% score and above was regarded as acceptable while response with less than 70% score was regarded as not acceptable. The 70% bench mark is in line with the acceptability of responses as stipulated by Laed (2020).

The mean was used to analyze data that answered research questions 3-7, Z-test was used in testing the null hypotheses 1-4 and ANCOVA was used in testing the null hypothesis 5. The choice of mean to answer research question 1-7 was based on the fact that, it is the common measure of central tendency used on instruments designed with multiple response options in educational research (Achilleas, 2013). The choice of z-test in testing the hypotheses 1-4 was because, it is the most appropriate test to measure the significant difference between the mean scores of two groups of respondents above 30 in number (Stephanie, 2015).

Furthermore, the choice of ANCOVA in testing hypothesis 5 was because it takes care of the effect of extraneous variables (Uzoagulu, 2011). Statistical Package for Social Sciences (SPSS) version 27 was used for all data analysis. Decision on the hypotheses was taken by comparing the significant value of Sig. two tailed with 0.05 level of significance. The Sig. two tailed values were found to be above 0.05 and considered as there was no significant difference while decision on the research questions 3-6 was based on the concept of real limits of numbers as indicated in Table 3.4.

Table 3.4: Real Limit of Numbers on Five Point Scale

S/N	Lower Limit		Upper Limits	Decision
1	4.50	-	5.00	Strongly Agree
2	3.50	-	4.49	Agree
3	2.50	-	3.49	Disagree
4	1.50	-	2.49	Strongly Disagree
5	1.00	-	1.49	Undecided

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Research Question 1

What are the objectives of the manual on troubleshooting electronic braking systems for automobile craftsmen in Nigeria? The result for answering research question one is presented in Table 4.1.

Table 4.1: Summary of the Qualitative Responses of SMEs on the Objectives of Troubleshooting Electronic Braking Systems for the Manual N=9

S/N	Themes	*n*	Percentage
1	Using On-Board Diagnostics II	9	100%
2	Wheel speed sensor	8	89%
3	Electronic Control Unit (ECU)	9	100%
4	Pressure modulator valve	8	89%
5	Brake pressure sensor	8	89%
6	Active braking valves	8	89%
7	Electronic stability control module	8	89%
8	Steering angle sensor	8	89%
9	Yaw rate sensor	8	89%
10	Lateral acceleration sensor	8	89%

Table 4.1 revealed that using On-Board Diagnostics (OBD) II and Electronic Control Unit (ECU) had 100% while wheel speed sensor, pressure modulator valve, brake pressure sensor, active braking valves, electronic stability control module, steering angle sensor, yaw rate sensor and lateral acceleration sensor had 89%. Based on the stated acceptability criteria of 70%, to provide automobile craftsmen with a step by step outlines in the troubleshooting of: Electronic Control Unit (ECU), wheel speed sensor, pressure modulator valve, brake pressure sensor, active braking valves, electronic stability control module, steering angle sensor, yaw rate sensor and lateral acceleration sensor using On-Board Diagnostics (OBD) II were considered as the objectives of the manual on troubleshooting electronic braking systems for automobile craftsmen in Nigeria.

4.2 Research Question 2

What are the objectives of the manual on the maintenance of electronic braking systems for automobile craftsmen in Nigeria? The result for answering research question two is presented in Table 4.2.

Table 4.2: Summary of the Qualitative Responses of SMEs on the Objectives on Maintenance of Electronic Braking Systems for the Manual N=9

S/N	Themes	*n*	Percentage
1	Wheel speed sensor	8	89%
2	Electronic Control Unit (ECU)	9	100%
3	Pressure modulator valve	8	89%
4	Brake pressure sensor	8	89%
5	Active braking valves	8	89%
6	Electronic stability control module	8	89%
7	Steering angle sensor	8	89%
8	Yaw rate sensor	8	89%
9	Lateral acceleration sensor	8	89%

Table 4.2 shows that Electronic Control Unit (ECU) had 100% while wheel speed sensor, pressure modulator valve, brake pressure sensor, active braking valves, electronic stability control module, steering angle sensor, yaw rate sensor and lateral acceleration sensor had 89%. Based on the stated acceptability criteria of 70%, to provide automobile craftsmen with a step by step outlines in the maintenance of: Electronic Control Unit (ECU), wheel speed sensor, pressure modulator valve, brake pressure sensor, active braking valves, electronic stability control module, steering angle sensor, yaw rate sensor and lateral acceleration sensor were considered as the objectives of the manual on the maintenance of electronic braking systems for automobile craftsmen in Nigeria.

4.3 Research Question 3

What are the contents to be utilized for achieving the objective of the manual on troubleshooting electronic braking systems for automobile craftsmen in Nigeria? The result for answering research question three is presented in Table 4.3.

Table 4.3: Mean Responses of the Respondents on Clustered Contents to be utilized for Achieving the Objective of the Manual on Troubleshooting Electronic Braking Systems N1=56, N2=43

S/N	Clustered contents to be utilized for achieving the objective of the manual on troubleshooting electronic braking systems	$\bar{X}_1$	$\bar{X}_2$	$\bar{X}_A$	Remark
1	Contents for Diagnostics Troubleshooting using On-Board Diagnostics II	4.54	4.58	4.56	Strongly Agreed
2	Contents for Troubleshooting Wheel Speed Sensor	4.54	4.59	4.56	Strongly Agreed
3	Contents for Troubleshooting Electronic Control Unit	4.53	4.57	4.55	Strongly Agreed
4	Contents for Troubleshooting Pressure Modulator Valve	4.54	4.58	4.56	Strongly Agreed
5	Contents for Troubleshooting Brake Pressure Sensor	4.55	4.58	4.56	Strongly Agreed
6	Contents for Troubleshooting Active Brake Valve	4.51	4.54	4.52	Strongly Agreed
7	Contents for Troubleshooting Electronic Stability Control Module	4.52	4.56	4.54	Strongly Agreed
8	Contents for Troubleshooting Steering Angle Sensor	4.54	4.58	4.56	Strongly Agreed
9	Contents for Troubleshooting Yaw Rate Sensor	4.55	4.59	4.57	Strongly Agreed
10	Contents for Troubleshooting Lateral Acceleration Sensor	4.53	4.58	4.54	Strongly Agreed
	Grand Mean	**4.54**	**4.58**	**4.56***	**Strongly Agreed**

Keys: N1= Teaching SMEs, N2=Non-Teaching SMEs, $\bar{X}_1$ = Mean responses of Teaching SMEs, $\bar{X}_2$ = Mean responses of Non-Teaching SMEs, $\bar{X}_A$ =Average Mean responses of Teaching and Non-Teaching SMEs.

Table 4.3 displays the mean responses of the respondents on ten clusters with 122 items for determining the contents to be utilized for achieving the objective of the manual on troubleshooting electronic braking systems for automobile craftsmen in Nigeria with average grand mean of 4.56. Based on the stated criteria for real limit of numbers, this implied that, the respondents strongly agreed with the 10 clusters with 122 items as the contents to be utilized for achieving the objective of the manual on troubleshooting electronic braking systems for automobile craftsmen in Nigeria as shown in Appendix O, page 178.

4.4 Research Question 4

What are the contents to be utilized for achieving the objective of the manual on the maintenance of electronic braking systems for automobile craftsmen in Nigeria? The result for answering research question four is presented in Table 4.4.

Table 4.4: Mean Responses of the Respondents on Clustered Contents to be utilized for Achieving the Objective of the Manual on the Maintenance of Electronic Braking Systems

S/N	Clustered contents to be utilized for achieving the objective of the manual on the maintenance of electronic braking systems	$\bar{X}_1$	$\bar{X}_2$	$\bar{X}_A$	Remark
1	Contents for the Maintenance of Wheel Speed Sensor	4.54	4.59	4.57	Strongly Agreed
2	Contents for the Maintenance of Electronic Control Unit (ECU)	4.53	4.55	4.54	Strongly Agreed
3	Contents for the Maintenance of Pressure Modulator Valves	4.54	4.60	4.57	Strongly Agreed
4	Contents for the Maintenance of Brake Pressure Sensor	4.55	4.59	4.57	Strongly Agreed
5	Contents for the Maintenance of Active Braking Valves	4.53	4.58	4.56	Strongly Agreed
6	Contents for the Maintenance of Electronic Stability Control Module	4.54	4.56	4.55	Strongly Agreed
7	Contents for the Maintenance of Steering Angle Sensors	4.58	4.62	4.60	Strongly Agreed
8	Contents for the Maintenance of Lateral Acceleration and Yaw Rate Sensors:	4.58	4.63	4.60	Strongly Agreed
	Grand Mean	**4.59**	**4.63**	**4.61***	**Strongly Agreed**

Table 4.4 shows the mean responses of the respondents on 8 clusters with 178 items for determining the contents to be utilized for achieving the objective of the manual on the

maintenance of electronic braking systems for automobile craftsmen in Nigeria with average grand mean of 4.61. Based on the stated criteria for real limit of numbers, this implied that, the respondents strongly agreed with the 8 clusters with 178 items as the contents to be utilized for achieving the objective of the manual on the maintenance of electronic braking systems for automobile craftsmen in Nigeria as shown in Appendix O, page 178.

4.5 Research Question 5

What are the troubleshooting facilities for the electronic braking systems manual for automobile craftsmen in Nigeria? The result for answering research question five is presented in Table 4.5.

Table 4.5: Mean Responses of the Respondents on Troubleshooting Facilities for the Electronic Braking Systems Manual

S/N	Troubleshooting Facilities for the Electronic Braking Systems Manual	$\bar{X}_1$	$\bar{X}_2$	$\bar{X}_A$	Remark
	Facilities for Diagnostics Troubleshooting:				
1	OBD II scan tool (code reader, computer and smartphone)	4.56	4.63	4.59	Strongly Agreed
2	Adopter	4.59	4.79	4.68	Strongly Agreed
3	Data cable	4.61	4.69	4.65	Strongly Agreed
4	Data Trouble Codes (DTCs) interpretation	4.61	4.77	4.68	Strongly Agreed
	Facilities for Components Testing:				
5	Wiring diagrams	4.63	4.72	4.67	Strongly Agreed
6	Stethoscope	4.48	4.42	4.45	Agreed
7	12 volt test lamp	4.64	4.60	4.63	Strongly Agreed
8	Voltmeter	4.64	4.65	4.65	Strongly Agreed
9	Ohmmeter	4.70	4.77	4.73	Strongly Agreed
10	Circuit tester	4.45	4.44	4.44	Agreed
11	2-4 amp sealed lamp	4.55	4.63	4.59	Strongly Agreed
	Grand Mean	**4.58**	**4.60**	**4.59***	**Strongly Agreed**

Table 4.5 shows the mean responses of the respondents on 11 items for ascertaining troubleshooting facilities for the electronic braking systems manual with average grand

mean of 4.59. Based on the stated criteria for real limit of numbers, this implied that, the respondents strongly agreed with the 11 items to be the troubleshooting facilities for the electronic braking systems manual for automobile craftsmen in Nigeria.

4.6 Research Question 6

What are the maintenance facilities for the electronic braking systems manual for automobile craftsmen in Nigeria? The result for answering research question six is presented in Table 4.6.

Table 4.6: Mean Responses of the Respondents on Clustered Maintenance Facilities for the Electronic Braking Systems Manual

S/N	Clustered Maintenance Facilities for the Electronic Braking Systems Manual	$\bar{X}_1$	$\bar{X}_2$	$\bar{X}_A$	Remark
1	Facilities for the Maintenance of Wheel Speed Sensor:	4.53	4.59	4.56	Strongly Agreed
2	Facilities for the Maintenance of ECU and ESC Module:	4.52	4.53	4.53	Strongly Agreed
3	Facilities for the Maintenance of Pressure Modulator Valves and Active Braking Valves:	4.55	4.61	4.58	Strongly Agreed
4	Facilities for the Maintenance of Brake Pressure Sensor:	4.55	4.58	4.56	Strongly Agreed
5	Facilities for the Maintenance of Steering Angle Sensor:	4.53	4.58	4.56	Strongly Agreed
6	Facilities for the Maintenance of Yaw Rate and Lateral Acceleration Sensors:	4.58	4.61	4.59	Strongly Agreed
	Grand Mean	**4.58**	**4.61**	**4.60***	**Strongly Agreed**

Table 4.6 displays the mean responses of the respondents on 6 clusters with 66 items for determining maintenance facilities for the electronic braking systems manual with average grand mean of 4.60. Based on the stated criteria for real limit of numbers, this implied that, the respondents strongly agreed with the 6 clusters with 66 items as the maintenance facilities for the electronic braking systems manual for automobile craftsmen in Nigeria as shown in Appendix O, page 178.

4.7 Research Question 7

What is the effect of electronic braking systems troubleshooting and maintenance manual on skill performance of automobile craftsmen in troubleshooting and maintenance of ABS, ATC and ESC? The result for answering research question seven is presented in Table 4.7.

Table 4.7: Skill Performance Scores of Automobile Craftsmen that Learnt Troubleshooting and Maintenance of ABS, ATC and ESC using Electronic Braking Systems Troubleshooting and Maintenance Manual

Craftsmen	N	Pre-test Mean	Post-test Mean	Mean Gain
Male	48	34.04	76.00	42.97
Female	27	33.03	75.37	41.33

Table 4.7 shows that, the male automobile craftsmen had a mean score of 34.04 in the pre-test and 76.00 in the post-test with a pre-test, post-test mean gain of 42.97. The female automobile craftsmen had a mean score of 33.03 in the pre-test and 75.37 in the post-test with a pre-test, post-test mean gain of 41.33. These mean gains implied that, electronic braking systems troubleshooting and maintenance manual had positive effect on skill performance of both male and female automobile craftsmen in troubleshooting and maintenance of ABS, ATC and ESC.

4.8 Hypothesis One

There is no significant difference between the mean responses of teaching and non-teaching SMEs on contents to be utilized for achieving the objective of the manual on troubleshooting electronic braking systems. The result for testing the null hypothesis one is presented in Table 4.8.

Table 4.8: z-test Analysis for the test of Significant Difference between the mean Responses of Teaching and Non-teaching SMEs on Contents to be utilized for Achieving the Objective of the Manual on Troubleshooting Electronic Braking Systems

Levene's Test for Equality of Variances			z-test for Equality of Means						
	F	Sig.	z	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Equal variances assumed	5.48	0.02	-0.53	97	0.59	-.045	.084	-.213	.122
Equal variances not assumed			-0.54	95.70	0.58*	-.045	.082	-.209	.119

Table 4.8 shows the z-test analysis for the test of significant difference between the mean responses of teaching and non-teaching SMEs on contents to be utilized for achieving the objective of the manual on troubleshooting electronic braking systems. The result of the analysis showed that, the significant (2-tailed) value of z-test for equality of means with variance not assumed was 0.58 which is greater than the stated level of significance. Since 0.58 is greater than 0.05, the difference between the mean responses of teaching and non-teaching SMEs on contents to be utilized for achieving the objective of the manual on troubleshooting electronic braking systems is not significant. Hence, the null hypothesis is retained.

4.9 Hypothesis Two

There is no significant difference between the mean responses of teaching and non-teaching SMEs on contents to be utilized for achieving the objective of the manual on the maintenance of electronic braking systems. The result for testing the null hypothesis two is presented in Table 4.9.

Table 4.9: z-test Analysis for the test of Significant Difference between the mean Responses of Teaching and Non-teaching SMEs on Contents to be utilized for Achieving the Objective of the Manual on the Maintenance of Electronic Braking Systems

	Levene's Test for Equality of Variances		z-test for Equality of Means						
	F	Sig.	z	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Equal variances assumed	5.73	.02	-.52	97	0.60	-.043	.082	-.207	.121
Equal variances not assumed			-.53	95.62	0.59*	-.043	.081	-.204	.118

Table 4.9 shows the z-test analysis for the test of significant difference between the mean responses of teaching and non-teaching SMEs on contents to be utilized for achieving the objective of the manual on the maintenance of electronic braking systems. The result of the analysis showed that, the significant (2-tailed) value of z-test for equality of means with variance not assumed was 0.59 which is greater than the stated level of significance. Since 0.59 is greater than 0.05, the difference between the mean responses of teaching and non-teaching SMEs on contents to be utilized for achieving the objective of the manual on the maintenance of electronic braking systems is not significant. Hence, the null hypothesis is retained.

4.10 Hypothesis Three

There is no significant difference between the mean responses of teaching and non-teaching SMEs on troubleshooting facilities for the electronic braking systems manual. The result for testing the null hypothesis three is presented in Table 4.10.

Table 4.10: z-test Analysis for the test of Significant Difference between the mean Responses of Teaching and Non-teaching SMEs on Troubleshooting Facilities for the Electronic Braking Systems Manual

	Levene's Test for Equality of Variances		z-test for Equality of Means						
	F	Sig.	z	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Equal variances assumed	7.57	0.01	-.75	97	0.46	-.061	.084	-.223	.101
Equal variances not assumed			-.76	95.84	0.45*	-.061	.080	-.220	.098

Table 4.10 shows the z-test analysis for the test of significant difference between the mean responses of teaching and non-teaching SMEs on troubleshooting facilities for the electronic braking systems manual. The result of the analysis showed that, the significant (2-tailed) value of z-test for equality of means with variance not assumed was 0.45 which is greater than the stated level of significance. Since 0.45 is greater than 0.05, the difference between the mean responses of teaching and non-teaching SMEs on troubleshooting facilities for the electronic braking systems manual is not significant. Hence, the null hypothesis is retained.

4.11 Hypothesis Four

There is no significant difference between the mean responses of teaching and non-teaching SMEs on maintenance facilities for the electronic braking systems manual. The result for testing the null hypothesis four is presented in Table 4.11.

Table 4.11: z-test Analysis for the test of Significant Difference between the mean Responses of Teaching and Non-teaching SMEs on Maintenance Facilities for the Electronic Braking Systems Manual

	Levene's Test for Equality of Variances		z-test for Equality of Means						
	F	Sig.	z	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Equal variances assumed	6.08	0.02	-.56	97	0.58	-.047	.084	-.214	.120
Equal variances not assumed			-.57	95.84	0.57*	-.047	.082	-.210	.117

Table 4.11 shows the z-test analysis for the test of significant difference between the mean responses of teaching and non-teaching SMEs on maintenance facilities for the electronic braking systems manual. The result of the analysis showed that, the significant (2-tailed) value of z-test for equality of means with variance not assumed was 0.57 which is greater than the stated level of significance. Since 0.57 is greater than 0.05, the difference between the mean responses of teaching and non-teaching SMEs on maintenance facilities for the electronic braking systems manual is not significant. Hence, the null hypothesis is retained.

4.12 Hypothesis Five

There is no significance difference between the skill performance scores of male and female automobile craftsmen that learnt the troubleshooting and maintenance of ABS, ATC and ESC using electronic braking systems troubleshooting and maintenance manual. The result for testing the null hypothesis five is presented in Table 4.12.

Table 4.12: Analysis of Covariate on the Significance Difference between the Skill Performance Scores of Male and Female Automobile Craftsmen that Learnt the Troubleshooting and Maintenance of ABS, ATC and ESC Using Electronic Braking Systems Troubleshooting and Maintenance Manual

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	22.735[a]	2	11.368	.827	.441
Intercept	1696.699	1	1696.699	123.488	.000
Pretest	15.985	1	15.985	1.163	.284
Group	11.276	1	11.276	.821	.368*
Error	989.265	72	13.740		
Total	429664.000	75			
Corrected Total	1012.000	74			

a. R Squared = .022 (Adjusted R Squared = -.005)

Table 4.12 shown the F calculated value for the groups is .821 with a significant of F at **.**368 which is above **.**05 stated level of significance. The results indicated that there is no statistically significance difference between the skill performance scores of male and female automobile craftsmen that learnt the troubleshooting and maintenance of ABS, ATC and ESC using electronic braking systems troubleshooting and maintenance manual. Hence, the null hypothesis stated was withheld.

4.13 Findings

1. Providing automobile craftsmen with a step by step outlines in troubleshooting: using On-Board Diagnostics II, wheel speed sensor, Electronic Control Unit (ECU), modulator valve, brake pressure sensor, active brake valve, Electronic Stability Control (ESC), steering angle, yaw rate and lateral sensors were found to be objectives on troubleshooting electronic braking systems for the manual.

2. Providing automobile craftsmen with a step by step outlines in the maintenance of: wheel speed sensor, Electronic Control Unit (ECU), modulator valve. Brake pressure sensor, active brake valve, Electronic Stability Control (ESC), steering angle, yaw rate and lateral sensors were found to be objectives on the maintenance of electronic braking systems for the manual.

3. Ten clusters with 122 items were found to be the contents to be utilized for achieving the objectives of the manual on troubleshooting electronic braking systems.

4. Eight clusters with 178 items were found to be the contents to be utilized for achieving the objectives of the manual on the maintenance of electronic braking systems.

5. OBD II scan tool (code reader, computer and smartphone), adopter, data cable, Data Trouble Codes (DTCs) interpretation, wiring diagrams, Stethoscope, 12volt test lamp, Voltmeter, Ohmmeter, circuit tester and 2-4 amp sealed lamp were found to be troubleshooting facilities for the electronic braking systems manual**.**

6. Six clusters with 66 items were found to be the maintenance facilities for the electronic braking systems manual for automobile craftsmen in Nigeria.

7. The electronic braking systems troubleshooting and maintenance manual had positive effect on the skill performance of automobile craftsmen in troubleshooting and maintenance of ABS, ATC and ESC.

8. There was no significant difference between the mean responses of teaching and non-teaching SMEs on the contents to be utilized for achieving the objective of the manual on troubleshooting electronic braking systems for automobile

craftsmen in Nigeria.

9. There was no significant difference between the mean responses of teaching and non-teaching SMEs on the contents to be utilized for achieving the objective of the manual on the maintenance of electronic braking systems for automobile craftsmen in Nigeria.

10. There was no significant difference between the mean responses of teaching and non-teaching SMEs on the troubleshooting facilities for the electronic braking systems manual for automobile craftsmen in Nigeria.

11. There was no significant difference between the mean responses of teaching and non-teaching SMEs on the maintenance facilities for the electronic braking systems manual for automobile craftsmen in Nigeria.

12. There was no significance difference between the skill performance scores of male and female automobile craftsmen that learnt troubleshooting and maintenance of ABS, ATC and ESC using electronic braking systems troubleshooting and maintenance manual.

4.14 Discussion of Findings

Findings on research question one regarding the objectives for the electronic braking systems manual on troubleshooting revealed providing automobile craftsmen with a step by step outlines in troubleshooting: wheel speed sensor, ECU, modulator valve, brake pressure sensor, active brake valve, ESC, steering angle, yaw rate and lateral sensors. The findings entailed that, learning contents developed based on wheel speed sensor, ECU, modulator valve, brake pressure sensor, active brake valve, ESC, steering angle, yaw rate and lateral sensors were potentially effective in achieving troubleshooting of electronic braking systems. The finding is in agreement with the view of Isermann and Balle (2017) that viewed objectives or skills expected of automobile craftsmen to properly troubleshoot ABS, ATC and ESC include fault diagnosing, visual checking and components testing of all components of electronic braking systems. The findings formed a strong base to which troubleshooting contents and facilities were carefully selected for the electronic braking system troubleshooting and maintenance manual developed.

The findings also agreed with the assertion of Mazur and Proctor (2012) that these objectives must contain the task in practical terms to be performed by craftsmen in identifying the symptoms of malfunction, determining the most likely cause and eliminating the potential causes in the ABS, ATC and ESC. The implication of this finding is that, contents developed based on the identified objectives hold the potential to equip automobile craftsmen with the requisite skills in troubleshooting electronic braking systems.

Findings on research question two regarding the objectives for the electronic braking systems manual on maintenance revealed providing automobile craftsmen with a step by step outlines in troubleshooting: wheel speed sensor, ECU, modulator valve, brake pressure sensor, active brake valve, ESC, steering angle, yaw rate and lateral sensors. The findings connoted that, learning contents developed based on wheel speed sensor, ECU, modulator valve, brake pressure sensor, active brake valve, ESC, steering angle, yaw rate and lateral sensors were effective in achieving the maintenance of electronic braking systems. The finding is in agreement with Saidin *et al.* (2015) that revealed the objectives for the maintenance of ABS, ATC and ESC are the expected learning outcome to provide craftsmen with the ability to dismantle, clean, replace and install all components of electronic braking systems for effective functioning.

The identified objective laid the foundation to which maintenance contents and facilities were selected for the electronic braking system troubleshooting and maintenance manual developed. The findings also supported the claim of Wireman (2017) that disclosed the maintenance objectives are tasks expected of craftsmen to retain or restore the state in which systems such as electronic braking systems perform the required functions designed for. The implication of the finding is that, contents developed based on the identified objectives were effective in equipping automobile craftsmen with the requisite skills in the maintenance of electronic braking systems.

Findings on research question three regarding the contents to be utilized for achieving the objective of the manual on troubleshooting electronic braking systems for automobile craftsmen in Nigeria revealed 122 items. The findings implied that, the 122 items are the logical steps or procedures to be observed in achieving effective troubleshooting of electronic braking systems. The findings enshrined the assertion of Draganov *et al.* (2007) that revealed, troubleshooting faulty electronic braking systems, starts with the retrieving DTC and additional tests. The findings included items on visual inspection and individual component testing on wheel speed sensor, ECU, modulator valve, brake pressure sensor, active brake valve, ESC, steering angle, yaw rate and lateral sensors. The finding is particularly important as it provide guidelines that guided the development of contents on effective troubleshooting of electronic braking systems. The finding implied that, contents for achieving the objective of the manual on troubleshooting electronic braking systems were effective in equipping automobile craftsmen with the requisite skills in troubleshooting ABS, ATC and ESC.

Though, findings on the test for significant difference between the mean responses of teaching and non-teaching SMEs on the contents to be utilized for achieving the objective of the manual on troubleshooting electronic braking systems for automobile craftsmen in

Nigeria revealed that there is no statistical significant. This entailed that, both teaching and non-teaching SMEs unanimously agreed with the contents to be utilized for achieving the objective of the manual on troubleshooting electronic braking systems for automobile craftsmen in Nigeria. The findings concord with the finding of Alabi *et al*. (2019) that revealed no significant difference between the mean responses of Motor Vehicle Mechanic's Work (MVMW) master craftsmen and automobile technology lecturers on the core on-board diagnostic (OBD) skills required by motor vehicle mechanics for troubleshooting engine performance and transmission system of modern automotive in Niger State. The findings clearly indicate little or no conflict of knowledge between teaching and non-teaching SMEs on the contents to be utilized for achieving the objective of the manual on troubleshooting electronic braking systems for automobile craftsmen in Nigeria.

Findings on research question four regarding the contents to be utilized for achieving the objective of the manual on the maintenance of electronic braking systems for automobile craftsmen in Nigeria revealed 178 items. The findings clearly inferred that, the 178 items constituted the logical steps or techniques to be observed in achieving effective maintenance of electronic braking systems. The findings are in agreement with major tasks in the maintenance of electronic braking systems stipulated by Saidin *et al.* (2015) which included that ability to: dismantle, clean, replace and install components. The findings included items on dismantling, cleaning, replacement and installment of components wheel speed sensor, ECU, modulator valve, brake pressure sensor, active brake valve, ESC, steering angle, yaw rate and lateral sensors. The finding is particularly important as it provide procedures that guided the development of contents on effective maintenance of electronic braking systems. The finding implied that, contents for achieving the objective of the manual on the maintenance of electronic braking systems were effective in equipping automobile craftsmen with the requisite skills in the maintenance of ABS, ATC and ESC.

In addition, findings on the test for significant difference between the mean responses of teaching and non-teaching SMEs on the contents to be utilized for achieving the objective of the manual on the maintenance of electronic braking systems for automobile craftsmen in Nigeria revealed there is no statistical significant. This indicated that, there was strong agreement between teaching and non-teaching SMEs regarding the contents to be utilized for achieving the objective of the manual on troubleshooting electronic braking systems for automobile craftsmen in Nigeria. Udogu (2015) revealed similar findings of no significant difference between the mean responses of automobile industry workers and instructors of MVMW on the emerging technology skills required by technical college graduates of MVMW for establishing automobile enterprises in Anambra and Enugu States, Nigeria. The finding is of importance as it revealed the level of agreement between the responses of teaching and non-teaching SMEs on the contents to be utilized for achieving the objective of the manual on the maintenance of electronic braking systems for automobile craftsmen in Nigeria.

Findings on research question five regarding the troubleshooting facilities for the electronic braking systems manual for automobile craftsmen in Nigeria revealed OBD II scan tool, adopter, data cable, Data Trouble Codes (DTCs) interpretation, wiring diagrams, Stethoscope, 12volt test lamp, Voltmeter, Ohmmeter, circuit tester and 2-4 amp sealed lamp. The finding implied that, the facilities are required for effective troubleshooting of electronic braking system. The finding is in line with Lin *et al.* (2017) that revealed, facilities for diagnostics troubleshooting include OBD II scan tool, adopter, data cable, Data Trouble Codes (DTCs) interpretation among others. The finding is also concords with Reppa and Tzes (2011) that revealed, facilities for ABS, ATC and ESC components testing include wiring diagrams, stethoscope, 12-volt test light, volts meter, ohmmeter or millimeter, 2-4 amp sealed lamp, among others. This finding played a vital role in ascertaining the troubleshooting facilities for the electronic braking systems troubleshooting and maintenance manual developed. The implication of the finding is that; automobile craftsmen are provided with the insights on requisite facilities for ensuring effective troubleshooting of electronic braking systems.

Notwithstanding, findings on the test for significant difference between the mean responses of teaching and non-teaching SMEs on the troubleshooting facilities for the electronic braking systems manual for automobile craftsmen in Nigeria revealed that, there is no statistical significant. This clearly pointed out that, the mean responses of teaching and non-teaching SMEs did not differ on the troubleshooting facilities for the electronic braking systems manual for automobile craftsmen in Nigeria. The finding is similar to the findings of Ogbuanya and Idris (2014) that revealed no difference between the mean responses of auto-mechanics teachers and automobile supervisor on contents for the development of automobile battery and charging system maintenance training manual for technical college students in North-Western States of Nigeria. The findings revealed the similarity level between the responses of teaching and non-teaching SMEs on the troubleshooting facilities for the electronic braking systems manual for automobile craftsmen in Nigeria.

Findings on research question six regarding the maintenance facilities for the electronic braking systems manual for automobile craftsmen in Nigeria revealed 66 items. The finding implied that, the 66 items are facilities required for effective maintenance of electronic braking system. The finding is in line with Robert (2016) who revealed that, facilities required for the maintenance of electronic braking systems include: Allen set metric and standard sockets, assorted pliers, assorted, screwdrivers, breaker bar ½ inch drive, brass hammer, combination wrench set, metric and standard, disposable gloves, emery cloth/sandpaper, flashlight and floor jack and jack stands among others. This finding played a vital role in ascertaining the maintenance facilities for the electronic braking systems troubleshooting and maintenance manual developed. The implication of the finding is that; automobile craftsmen are provided with the insights on requisite facilities for ensuring effective maintenance of electronic braking systems.

Also, findings on the test for significant difference between the mean responses of teaching and non-teaching SMEs on the maintenance facilities for the electronic braking systems manual for automobile craftsmen in Nigeria revealed that, there is no statistical significant. In order word, the findings entailed that, both teaching and non-teaching SMEs unanimously agreed on the maintenance facilities for the electronic braking systems manual for automobile craftsmen in Nigeria. The finding is similar to the findings of Maeleera (2015) that revealed no statistical difference between the mean responses of teachers of refrigeration and air-conditioning and technologists on the contents for the development of a capacity building modules for technologists in South-South, Nigeria. The finding evidently revealed no disagreement between the responses of teaching and non-teaching SMEs on the maintenance facilities for the electronic braking systems manual for automobile craftsmen in Nigeria.

Finding on the effect of electronic braking systems troubleshooting and maintenance manual on skill performance of automobile craftsmen in troubleshooting and maintenance of ABS, ATC and ESC revealed positive. This implied that, electronic braking systems troubleshooting and maintenance manual enhanced the skill performance of automobile craftsmen in troubleshooting and maintenance of ABS, ATC and ESC. The finding is related to the findings of Abd-El-Aziz (2013) on development and validation of an Auto Mechanics Intelligent Tutor (AMIT) for teaching Auto-mechanics trades concepts in technical colleges that revealed students that were taught Auto-mechanics trades concepts using AMIT obtained higher mean scores in cognitive and skill performance than others.

The positive effect of the manual on the skill performance of automobile craftsmen in troubleshooting and maintenance of ABS, ATC and ESC could be due to the enriched contents presented in logical manner. However, the implication of this finding is that, the electronic braking systems troubleshooting and maintenance manual if utilized is capable of adequately enhancing the skill performance of automobile craftsmen in troubleshooting and maintenance of ABS, ATC and ESC.

Furthermore, the test for significance difference between the skill performance scores of male and female automobile craftsmen that learnt the troubleshooting and maintenance of ABS, ATC and ESC using electronic braking systems troubleshooting and maintenance manual revealed not statistical significant. The finding is related to the finding of Maina (2021) on the effect of petrol engine model on academic achievement and interest of motor vehicle mechanics students in technical colleges in Borno State, Nigeria that revealed there was no significant effect of treatments and gender on the achievement of motor vehicle mechanics students in technical colleges. The no significance difference between the skill performance scores of male and female automobile craftsmen is a clear indication that, the electronic braking systems troubleshooting and maintenance manual is not gender biased in equipping automobile craftsmen with the requisite skills in troubleshooting and maintenance of electronic braking systems.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The findings of the study identified objectives, contents and facilities and also developed valid, reliable and effective electronic braking systems troubleshooting and maintenance manual capable of enhancing the skill performance of automobile craftsmen in Nigeria. These promising findings justified the need for the use of electronic braking systems troubleshooting and maintenance manual by automobile craftsmen in Nigeria. Thus, the manual when judiciously and persistently used would help the intended automobile craftsmen to achieve better self-development throughout their career. The findings of the study will encourage stakeholders in automobile maintenance industry to adopt such an approach to develop a diverse range of manual to foster the skill performance of automobile craftsmen in troubleshooting and maintenance of other electronic systems. Though, the study did not ascertain the effects of the manual on the cognitive performance and interest of automobile craftsmen. Therefore, it is concluded that the electronic braking systems troubleshooting and maintenance manual is valid, reliable and capable of improving the skill performance of automobile craftsmen in Nigeria significantly.

5.2 Recommendations

Based on the findings of the study, the following recommendations were made:

1. The National Board for Technical Education should include the contents of electronic braking systems into Motor Vehicle Mechanic Works curriculum used for training automobile craftsmen through the process of curriculum review in order to equip them with the competencies in troubleshooting and maintenance of electronic braking systems.

2. The Industrial Training Fund should ensure that the electronic braking systems

troubleshooting and maintenance manual is accessible to automobile craftsmen in Nigeria by using the developed manual as learning a material for use during its regional retraining programme for automobile craftsmen in Nigeria.

3. The National Automotive Design and Development Council should make the developed manual readily available by making mass production of it and offer it to automobile craftsmen either for free or at subsidized amount in order to equip them with the requisite competencies in troubleshooting and maintenance of electronic braking systems.

4. Automobile workshop owners should provide enabling environment for automobile craftsmen to use the developed manual through the provision of the identified facilities in order to ensure effective troubleshooting and maintenance of electronic braking systems.

5. Automobile craftsmen should also embrace the use of the developed manual by acquiring it either online or from the Industrial Training Fund and National Automotive Design and Development Council in order to enhance their skill performance in troubleshooting and maintenance of electronic braking systems.

Furthermore, the following suggestions were made for further studies based on the findings of the study:

1. Effect of electronic braking systems troubleshooting and maintenance manual on cognitive achievement of automobile craftsmen in Nigeria.

2. Effect of electronic braking systems troubleshooting and maintenance manual on interest of automobile craftsmen in Nigeria.

3. Strategies for ensuring the availability and utilization of electronic braking systems troubleshooting and maintenance manual among automobile craftsmen in Nigeria.

4. Acceptability of electronic braking systems troubleshooting and maintenance manual among automobile craftsmen in Nigeria.

5. Translation of the electronic braking systems troubleshooting and maintenance manual into Nigerian languages for effective understanding among automobile craftsmen in Nigeria.

5.3 Contributions to Knowledge

The study makes significant contributions to the field of industrial and technology education as it provides a novel approach to equip automobile craftsmen with the requisite skills to effectively carryout the troubleshooting and maintenance of electronic braking systems by developing a valid and reliable manual. This approach has not been previously explored in the literature and thus, represents a significant advancement in enhancing the skill performance of automobile craftsmen in the troubleshooting and maintenance of electronic braking systems which is capable of lowering the rate of road accidents and consequently loss of life and properties in Nigeria.

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APPENDIX A

DISTRIBUTION OF TEACHING, NON TEACHING EXPERTS AND AUTOMOBILE CRAFTSMEN POPULATION

S/N	Industry/Institution	Expert 1	Expert 2	Craftsmen		Total
				Male	Female	
	Abuja					
1	National Automotive Design and Development Council	-	18	-		18
2	Industrial Training Fund (ITF) Cooperate Office	-	8	-		8
3	ITF Model Skills Training Centre	8	2	10	6	26
4	Autolady Engineering Technology Nigeria Limited	5	3	-	6	14
5	AFEME Workshop, Mogadishu Cantonment	8	6	11	4	29
	Kaduna					
6	Business Apprenticeship Training Centre, Zaria	5	5	10	2	22
	Kano					
7	ITF Model Skills Training Centre	6	2	10	2	20
	Lagos					
8	ITF Model Skills Training Centre	8	2	7	3	20
9	The Lady Mechanic Initiative	4	4	-	4	12
	Plateau					
10	Industrial Training Fund (ITF) Headquarters	-	5	-		5
	Total	**43**	**56**	**48**	**27**	**174**

Key: Expert 1 = Teaching Subject Matter Experts, Expert 2 = Non-teaching Subject Matter Experts

Sources: NADDC, ITF, Autolady Engineering Technology Nigeria Limited, Lady Mechanic Initiative and AFEME Workshop

NATIONAL AUTOMOTIVE DESIGN AND DEVELOPMENT COUNCIL

[NADDC]

13 David Ejoor Street, Garki, Abuja

*Our Re:f*____________ *Your Ref:*____________ *Date:* 18-02-20

Saidu Abubakar Arah,

RE: REQUEST FOR INFORMATION AND SERVICE OF EXPERTS

Sequel to your request, I write to convey to you the information requested on the number and locations of craftsmen and experts in our offices that can be useful to your research work.

Below is breakdown of the information:

1. 18 experts in Head office, Abuja
2. 5 teaching, 5 non-teaching experts and 12 craftsmen in Zaria centre.

We look forward to provide the services you requested.

Wish you success in your research.

NATIONAL AUTOMOTIVE DESIGN AND DEVELOPMENT COUNCIL
NADDC
Information Department
19/2/20.

Okechuku Israel

INDUSTRIAL TRAINING FUND (ITF)

ITF Corporate Office
6 Ademola Adetokumbo Crescent, Maitama, Abuja

Our Re:f ________ Date: 2:2:2020 ________ Your Ref: ________

MR. SAIDU ABUBAKAR ARAH,

RE: REQUEST FOR INFORMATION

Sequel to your request, find below the number and locations of craftsmen, teaching and non-teaching experts in our corporate, head offices and skills training centres:

S/N	Location	Teaching Expert	Non-Teaching Expert	Craftsmen	Total
	Abuja				
1	Industrial Training Fund (ITF) Cooperate Office	Nil	8	Nil	8
2	ITF Model Skills Training Centre	8	2	16	26
	Kano				
3	ITF Model Skills Training Centre	6	2	12	20
	Lagos				
4	ITF Model Skills Training Centre	8	2	10	20
	Plateau				
5	Industrial Training Fund (ITF) Headquarters	Nil	5	Nil	5
	Total	**22**	**19**	**38**	**79**

Best wishes in your research.

INDUSTRIAL TRAINING FUND
Sign: [signature] Corporate Manger
Date: 3/2/2020
Office of The Corporate Manager

LADY MECHANIC INNITIATIVE

Empowering The Girl Child

Abijo GRA, Commercial City, Lekki Epe Express Way, Lagos

Your Ref:……………………………………

Our Ref:……………………………………… Date: 20th May, 2021

Mr. Saidu Abubakar Arah

Please find the number of experts and craftsmen in our organization that can be helpful in conducting your research.

Than you.

1. Teaching experts	4
2. Non-Teaching experts	4
3. Craftswomen	4

LADY MECHANIC INNITIATIVE NIGERIA LIMITED

Sandra

CEO, Lady Mechanic Initiative

Departmen of Industrial and Technology Education,
Federal Un versity of Technology, Minna,
P.M.B 65.
5th February, 2020.

The Commanding Officer,
AFEME Workshop, Mogadishu Cantonment,
Abuja, Nigeria.

Through:

The Head of Mechatronics School,
AFEME Workshop, Mogadishu Cantonment,
Abuja, Nigeria.

REQUEST FOR INFORMATION AND SERVICE OF EXPERTS

Referencing the above subject matter, I write to request for information on the number of experts (individual with Bachelor, Master or PhD degree) in Automobile Engineering/Technology or any related field in your organization as well as their professional services.

My name is Abubakar Saidu Arah with registration number: Ph.D/SSTE/2018/7691. I am currently carrying out a research on the "Development of Electronic Braking Systems Troubleshooting and Maintenance Manual for Automobile Craftsmen in Nigeria".

The services required from the experts include responding to questionnaire on the appropriateness and suitability of contents for the manual and validating the manual.

I wish my request will be granted. Thank you, Sir.

Please, find attached a copy of an introductory letter.

Yours Faithfully,

Abubakar Saidu Arah
08065488404

Original Copy was collected by me
AB IBRAHIM 5 Feb 20
Major
Head of AMS

AUTOLADY SYNERGY
ENGINEERING TECHNOLOGY LIMITED

Plot 538, Kubwa Extension II, FCDA Scheme, Dutse Junction by Bwari Road, Abuja

Your Ref:……………………………………… Our Ref:………………………………

Date: 26/05/2021.

Re: SAIDU Abubakar Arah

The number of experts and craftsmen in our organization you requested for your research work are stated below.

Note: you are not allowed to use the information stated for any purpose aside from the research you are conducting.

S/N	Experts/Craftsmen	Number
1	Teaching experts	5
2	Non-Teaching experts	3
3	Craftswomen	6

AUTOLADY SYNERGY COY

Joyce

APPENDIX B

REQUEST FOR INFORMATION AND SERVICE OF EXPERTS

Department of Industrial and Technology Education,
Federal University of Technology, Minna,
P.M.B 65.
5th February, 2020.

…………………………………….

…………………………………….

……………………………………..

……………………………………..

Sir/Ma,

REQUEST FOR INFORMATION AND SERVICE OF EXPERTS

Referencing the above subject matter, I write to request for information on the number and locations of craftsmen, teaching and non-teaching experts in your organization (Headquarters and Branch offices) in Nigeria to be used as population of my study and the professional services of the experts.

My name is Abubakar Saidu Arah with registration number: Ph.D/SSTE/2018/7691. I am currently carrying out a research on the **''Development of Electronic Braking Systems Troubleshooting and Maintenance Manual for Automobile Craftsmen in Nigeria''**.

Craftsmen in this context are graduates of technical colleges receiving training in automotive mechatronics in your institutions. Teaching experts are individuals with either Higher National Diploma, Bachelor, Master or PhD degree in Automobile Engineering/Technology or any related field teaching automotive mechatronics. Non-teaching experts are individuals with practical competencies in the maintenance of automobile electronic systems.

The services required from the experts include responding to questionnaire on the appropriateness and suitability of contents for the manual to be developed and validating it after development. The craftsmen are also to be used for testing the effect of the manual after development.

I wish my request will be granted. Thank you, Sir.

Yours Faithfully,

Abubakar Saidu Arah
08065488404

APPENDIX C

ELECTRONIC BRAKING SYSTEM TROUBLESHOOTING AND MAINTENANCE OBJECTIVES INTERVIEW PROTOCOL

Introduction:

1. Thank you very much for accepting my invitation to be interviewed.
2. My name is SAIDU, Abubakar Arah, a PhD Candidate from Department of Industrial and Technology Education, Federal University of Technology, Minna.
3. I am conducting research for my PhD on a topic "Development of electronic braking system trouble-shooting and maintenance manual for automobile craftsmen in Nigeria".
4. This interview session will be recorded for the purpose of data analysis and for this research only.
5. Information given will be kept confidential and be used for the purpose of reporting of this study.

Interview Question:

1. What are the functional indicators for post evaluating buildings in higher institutions?
2. What are the technical indicators for post evaluating buildings in higher institutions?

Closure:

1. Thank you very much once again for participating in this interview session and information shared.
2. Recording of this interview session will be transcribed and your corporation is highly appreciated to verify content of the transcript before it is analyzed.

APPENDIX D

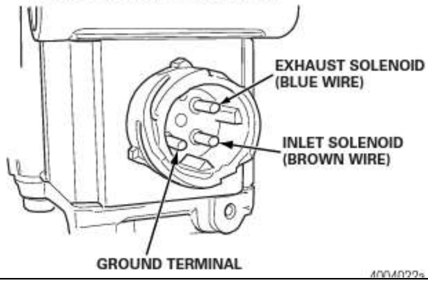
ELECTRONIC BRAKING SYSTEMS TROUBLESHOOTING AND MAINTENANCE QUESTIONNAIRE

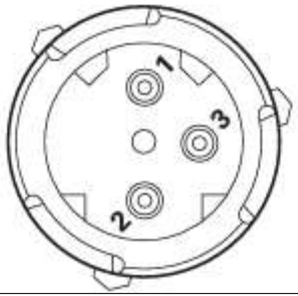
Instructions: Please read the following statements carefully and express your opinion on the extent to which you agree or otherwise with each of the statements by checking in any of the five responses of: Strongly Agree (SA), Agree (A), Disagree (D), Strongly Disagree (SD) and Undecided (UD) in the appropriate column.

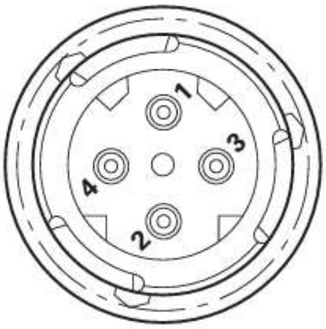
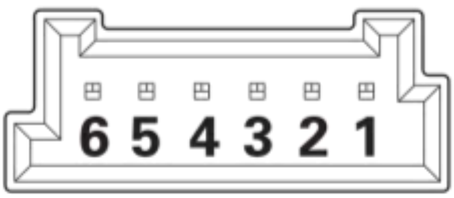
PART A: What are the contents to be utilized for achieving the objective of the manual on troubleshooting electronic braking systems for automobile craftsmen in Nigeria?

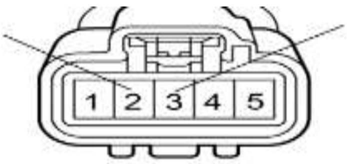
S/N	Contents for Diagnostics Troubleshooting using On-Board Diagnostics II	SA	A	D	SD	UD
1	Select the right diagnostic tool					
2	Ensure the diagnostic tool is functional					
3	Check the dashboard light					
4	Access the steering hood					
5	Locate the OBD-II data link connector (under the driver's side of the dashboard)					
6	Plug the standard OBD-II connector into the vehicle's data link connector 					
7	Turn the car's key to provide power to the scan tool or code reader					
8	Enter the vehicle-specific information requested					
9	To check for engine codes, press the scan button on the code reader					
10	Follow the directions on the screen					
11	Record the Diagnostic Trouble Codes					
12	Translate the Diagnostic Trouble Codes					
13	Clear the reported Diagnostic Trouble Codes					
	Contents for Troubleshooting Wheel Speed Sensor					
14	Ensure the ABS lamp is operating					
15	All readings should be taken at the same time and before vehicle is driven					

S/N	Items:	SA	A	D	SD	UD
16	Do not pry or push sensors with sharp objects					
17	Push the sensor in until it contacts the tooth wheel					
18	Check the resistance of wheel speed sensor					
19	Check the resistance of ECU harness					
20	Verify no change in resistance					
21	Verify no open circuit between sensor and ECU harness					
22	Check harness for any shorts to battery					
23	Check harness for any shorts to ground					
24	Ensure measurement between sensor leads is 900-2000 ohm					
25	Ensure measurement at ECU harness pins with sensor connected is 900-2000 ohm					
26	Ensure no continuity at ECU harness for DC voltage or ground					
27	Ensure sensor output voltage is at least, 0.2 volt					
	Contents for Troubleshooting Electronic Control Unit					
28	ECU connectors must be plugged in before troubleshooting					
29	Do not load test across power and earth at the ECU when troubleshooting					
30	Verify vehicle batteries connections for tightness					
31	Verify charging system for good operation					
32	Verify fuses					
33	Load testing battery and ignition circuits to ground at the ECU harness					
34	Ensure that lamp does not flash					
35	Take measurements at the ECU harness pins					
36	Ensure measurement of supply voltage at battery to chassis ground reads 9.0-16.0V for 12V system					
37	Ensure measurement of supply voltage at battery to chassis ground reads 18.0-32.0V for 24V system					
38	Ensure measurement of supply voltage at ignition to chassis ground reads 9.0-16.0V for 12V system					
39	Ensure measurement of supply voltage at ignition to chassis ground reads 18.0-32.0V for 24V system					
40	Ensure measurement at ECU ground to chassis ground reads less than 1 ohm resistance					
41	Ensure measurement at main ground to chassis ground reads less than 1 ohm resistance					

S/N	Items:	SA	A	D	SD	UD
	Contents for Troubleshooting Pressure Modulator Valve					
42	If resistance exceeds 9.0 ohm for 12V system (21.0 ohm for 24V system), verify whether the reading was not taken between the inlet and outlet					
43	If the correct pins were tested, clean the electrical contacts at the modulator and retest					
44	Check pressure modulator valve for resistance					
45	Check ECU harness and modulator valve together for resistance					
46	Verify no change in resistance or open circuit between valve and through harness					
47	Check harness for any shorts to battery and shorts to ground					
48	Ensure measurement at inlet valve pin to ground reads 4.0-9.0 ohm for 12V system 					
49	Ensure measurement at inlet valve pin to ground reads 11.0-21.0 ohm for 24V system					
50	Ensure measurement at outlet valve pin to ground reads 4.0-9.0 ohm for 12V system					
51	Ensure measurement at outlet valve pin to ground reads 11.0-21.0 ohm for 24V system					
52	Ensure measurement at ECU harness pins with modulator valve connected reads 4.0-9.0 ohm for 12V system					
53	Ensure measurement at ECU harness pins with modulator valve connected reads 11.0-21.0 ohm for 24V system					
54	Ensure no continuity at ECU harness for battery voltage or ground					
	Contents for Troubleshooting Brake Pressure Sensor					
55	ECU connectors must be plugged in when testing brake pressure sensor harness connector for voltage					
56	ECU connectors must be unplugged when verifying short to ground and continuity					
57	Take measurements at the brake pressure sensor harness connector					

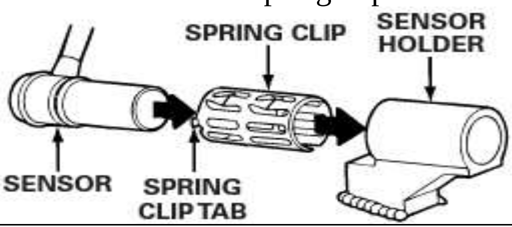
S/N	Items:	SA	A	D	SD	UD
58	Measure voltage supply to ground on pin 1 of the brake pressure sensor with connector key on					
59	Verify continuity end to end on all 3 lines 					
60	Ensure no shorts to ground or battery on all 3 lines					
61	Ensure no continuity between pins					
	Contents for Troubleshooting Active Brake Valve					
62	Check ABV 3/2 solenoid for resistance					
63	Check ECU harness and active brake valve 3/2 solenoid together for resistance					
64	Verify no change in resistance or open circuit between active brake valve and through harness					
65	Check harness for any shorts to battery and shorts to ground					
66	Ensure measurement at active brake valve reads 7.0-14.0 ohm for 12V system					
67	Ensure measurement at active brake valve reads 26.3-49.0 ohm for 24V system					
68	Ensure measurement at ECU harness pins with active brake valve connected reads 7.0-14.0 ohm for 12V system					
69	Ensure no continuity at ECU harness for battery voltage or ground					
	Contents for Troubleshooting Electronic Stability Control Module					
70	Do not load test across power and ground at the ESC Module					
71	ECU connectors must be plugged in when testing resistance and voltage on ESC module					
72	ECU connectors must be unplugged when testing continuity and short on ESC module					
73	Take measurements at the ESC module harness connector					
74	Measure voltage supply with key on					
75	Measure Communication Area Network (CAN) high voltage with key on					
76	Measure CAN high voltage with key on					
77	Measure terminating resistance across CAN high and low with key off					

S/N	Items:	SA	A	D	SD	UD
78	Verify continuity end to end on each line with ECU and ESC module disconnected					
79	Verify no shorts to ground or battery on all lines with ECU and ESC module disconnected					
80	Verify no continuity between pins with ECU and ESC module disconnected					
81	Ensure Voltage Supply to Chassis Ground at pin 1 reads 8.0-16.0V 					
82	Ensure ESC ground to chassis ground at pin 2 reads less than 1 ohm resistance					
83	Ensure terminating resistance between ESC CAN-high to ESC CAN-low (pin 3 and 4) reads approximately 90 ohms					
84	With ECU disconnected, check power supply for battery voltage or ground at pin 1 and 2 and ensure no continuity					
85	With ECU disconnected, check CAN lines for battery voltage or ground at pin 3 and 4 and ensure no continuity					
86	Ensure CAN high voltage to chassis ground at pin 3 reads 2.5-5.0V					
87	Ensure CAN low voltage to chassis ground at pin 4 reads 0.1-2.4V					
88	Ensure that ESC harnesses are connected					
	Contents for Troubleshooting Steering Angle Sensor					
89	ECU and ESC module connectors must be plugged in when testing steering angle sensor connector for voltage					
90	Do not load test across power and ground at the steering angle sensor					
91	Disconnect steering angle sensor and check terminating resistance across Pin 1 and Pin 2 					

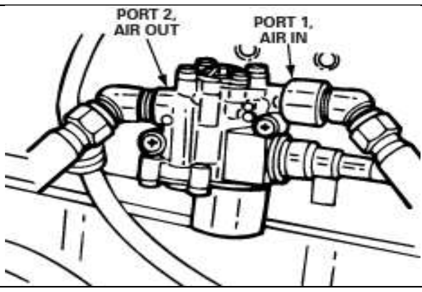
S/N	Items:	SA	A	D	SD	UD
92	Take measurements at the steering angle sensor harness connector side					
93	With key on, check CAN low voltage on pin 1					
94	With key on, check CAN high voltage on pin 4					
95	With key on, check voltage supply on Pin 5					
96	With key off, check resistance across CAN low Pin 1 and CAN high Pin 4					
97	Ensure measurement at steering angle sensor terminating resistor reads approximately 180 ohms					
98	Ensure measurement at CAN high voltage reads 2.5-5.0V					
99	Ensure measurement at CAN low voltage reads 0.1-2.4V					
100	Ensure voltage supply to ground reads 8.0-16.0V					
101	Ensure measurement at ESC CAN-high to ESC CAN-low reads approximately 90 ohm					
102	Ensure continuity at steering angle sensor harness jumper (Pin 2 to Pin 4 or Pin 2 to Pin 3)					
103	Ensure no continuity at ESC CAN-high or CAN-low to power or ground (with ECU, ESC Module and steering angle sensor unplugged)					
	Contents for Troubleshooting Yaw Rate Sensor					
104	Take measurements at the yaw rate sensor connector					
105	Disconnect the yaw rate sensor connector					
106	Take measurements at the yaw rate sensor connector					
107	With key off, check CAN low resistance on pin 2 					
108	With key off, check CAN high resistance on pin 3					
109	With key on/off, check body ground resistance on Pin 1					
110	With key on, check body ground voltage on Pin 5					
111	Ensure measurement at CAN low resistance reads 54 to 69 ohms					
112	Ensure measurement at CAN high resistance reads 54 to 69 ohms					

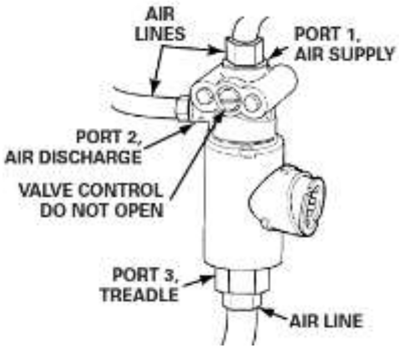
S/N	Items:	SA	A	D	SD	UD
113	Ensure measurement at body ground resistance reads less than 1 ohms					
114	Ensure measurement at body ground voltage reads 10 to 14 V					
	Contents for Troubleshooting Lateral Acceleration Sensor					
115	Check fuses that power up the sensor					
116	Unplug the sensor connector					
117	Take measurements at the lateral acceleration sensor connector					
118	With key on, check CAN high voltage on pin 1					
119	With key on, check CAN low voltage on pin 3					
120	Ensure measurement at volts at CAN high (pin 1) voltage reads 2.6 volts					
121	Ensure measurement at volts at CAN low (pin 3) voltage reads 2.4 volts					
122	Ensure no short to the ground					

PART D: What are the contents to be utilized for achieving the objective of the manual on the maintenance of electronic braking systems for automobile craftsmen in Nigeria?

S/N	**Contents for the Maintenance of Wheel Speed Sensor**	SA	A	D	SD	UD
1	Park the vehicle on a level surface					
2	Wedge the wheels to prevent the vehicle from moving					
3	Apply the parking brake					
4	Jack the vehicle up					
5	Put the vehicle on axle stands					
6	Remove the road wheels					
7	Disconnect the fasteners that hold the sensor cable to other components					
8	Disconnect the sensor cable from the chassis harness					
1	Remove the sensor from the sensor holder					
10	Remove the sensor spring clip 					
11	Clean the sensor					
12	Apply a recommended lubricant to the sensor spring clip and sensor					
13	Replace the sensor (if necessary)					
14	Connect the sensor cable to the chassis harness					
15	Install the fasteners used to hold the sensor cable in place					

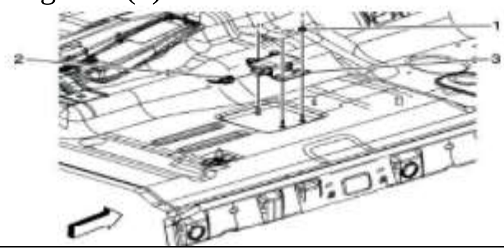
S/N	Items:	SA	A	D	SD	UD
16	Install the sensor spring clip					
17	Push the sensor spring clip into the bushing in the steering knuckle until the clip stops					
18	Push the sensor completely into the sensor spring clip until it contacts the tooth wheel					
19	Place the road wheels back onto the hubs					
20	Remove the safety stands					
21	Torque the wheels					
22	Jack the vehicle back off the jack stands					
23	Test drive the vehicle					
	Contents for the Maintenance of Electronic Control Unit (ECU)					
24	Apply the parking brake					
25	Disconnect the battery or remove the cable from the negative terminal					
26	Locate the ECU (usually on the bonnet)					
27	Remove all the ECU connectors					
28	Remove screws and any ties that mounts the unit					
29	Remove the ECU					
30	Clean the ECU					
31	Carry out physical checks					
32	Replace the ECU (if necessary)					
33	Match the old ECU with the new one					
34	Clean the mounting surface properly when installing the replaced ECU					
35	Place the new module carefully					
36	Connect the wires and other electrical connections to the ECU					
37	Reconnect the battery					
38	Turn on the connection					
	Contents for the Maintenance of Pressure Modulator Valves					
39	Park the vehicle on a level surface					
40	Turn the ignition switch Off					
41	Apply the parking brake					
42	Wedge the wheels to prevent the vehicle from moving					
43	Jack the vehicle up					
44	Put the vehicle on axle stands					
45	Locate the pressure modulator valves					
46	Disconnect the wiring connector from the pressure modulator valves					
47	Disconnect the air lines from Ports 1 (air supply) and 2 (air discharge) of the ABS valve					

						
S/N	**Items:**	**SA**	**A**	**D**	**SD**	**UD**
48	Remove the two mounting cap screws and nuts					
49	Remove the pressure modulator valves					
50	Clean the pressure modulator valves					
51	Check for damages					
52	Make repairs as needed					
53	Replace the pressure modulator valves (if necessary)					
54	Install the pressure modulator valves with two mounting cap screws and nuts					
55	Tighten the cap screws to the manufacturer's recommendation					
56	Connect the line to the brake chambers to Port 2 of the pressure modulator valves					
57	Connect the air supply line to Port 1 of the pressure modulator valves					
58	Connect the wiring connector to the pressure modulator valves (hand tighten only)					
59	Remove the stands					
60	Test the installation by applying the brake pedal					
61	Observe for leaks at the pressure modulator valve					
62	Turn the ignition on and listen to the modulator valve cycle					
63	If the valve fails to cycle, check the electrical cable connection					
64	Verify that the ABS indicator lamp operates correctly					
	Contents for the Maintenance of Brake Pressure Sensor					
65	Park the vehicle on a level surface					
66	Turn the ignition switch Off					
67	Apply the parking brake					
68	Locate the brake pressure sensor (usually found mounted near the brake master cylinder)					
69	Unplug the electrical connector 					
70	Remove the brake pressure sensor					

S/N	Items:	SA	A	D	SD	UD
71	Clean the brake pressure sensor					
72	Check for damage					
73	Replace the brake pressure sensor					
74	Thread the replacement into place					
75	Tighten the sensor as far as possible by hand					
76	Plug electrical connector					
77	Verify the installation of the brake pressure sensor					
78	Refill the reservoir to the correct level if any fluid was lost during replacement					
79	Start the vehicle and let it run for 10-15 seconds					
80	Press on the brake firmly a couple of times					
81	Ensure that the ABS, ATC and ESC indicator lamp goes off					
	Contents for the Maintenance of Active Braking Valves					
82	Park the vehicle on a level surface					
83	Turn the ignition switch Off					
84	Apply the parking brake					
85	Wedge the wheels to prevent the vehicle from moving					
86	Jack the vehicle up					
87	Locate active braking valves near the rear axle or front axle					
88	Disconnect the wiring from the valve					
89	Remove the two mounting cap screws and nuts					
90	Disconnect the air lines from Port 1 (air supply), Port 2 (air discharge) and Port 3 (treadle) of the active braking valves 					
91	Remove the active braking valves					
92	Clean the active braking valves					
93	Check for damages					
94	Make repairs as needed					
95	Replace the active braking valves (if necessary)					
96	Install the valve with two mounting cap screws and nuts					
97	Tighten the cap screws based on manufacturer's recommendation					
98	Connect the air supply, discharge and treadle lines to Ports 1, 2 and 3 of the valve					

S/N	Items:	SA	A	D	SD	UD
99	Connect the harness connector to the valve (hand tighten only)					
100	Remove the stands					
101	Turn the ignition to the on position					
102	Verify that the ATC/ESC lamp operates correctly					
103	Start the vehicle					
104	Fully charge the reservoirs with air					
105	Shut off the vehicle					
106	Apply the brakes					
107	Observe for air leaks at the valve					
108	Release the brakes					
109	Verify correct operation and that there are no active codes					
110	Verify that, the ATC indicator lamp operates correctly					
	Contents for the Maintenance of Electronic Stability Control Module					
111	Turn the ignition switch Off					
112	Apply the parking brake					
113	Wedge the wheels to prevent the vehicle from moving					
114	Jack the vehicle up					
115	Locate the ESC module					
116	Disconnect the wiring harness connector from the ESC module					
117	Remove the two mounting cap screws and nuts					
118	Remove the ESC module					
119	Check for damages					
120	Clean the ESC module					
121	Replace the ESC module (if necessary)					
122	Install the ESC module with the two cap screws and nuts					
123	Tighten the cap screws per the manufacturer’s recommendation					
124	Connect the wiring harness connector to the ESC module (hand tighten only)					
125	Remove the wedge					
126	Test the installation					
127	Calibrate the system					
128	The ABS and ATC/ESC lamps should come on and go back off when ignition power is turned on					
	Contents for the Maintenance of Steering Angle Sensors					
129	Center the steering wheel with the front wheels positioned straight ahead					
130	Turn the ignition switch Off					
131	Apply the parking brake					
132	Wedge the wheels to prevent the vehicle from moving					

S/N	Items:	SA	A	D	SD	UD
133	Locate the steering angle sensors on the steering column shaft, either near the universal joint on the bottom of the column or under the steering wheel near the top of the column					
134	Remove the vehicle steering wheel using the recommended steering wheel puller					
135	Remove the three screws to the steering column with the center tab located in the grooved steering column shaft					
136	Disconnect the wiring harness connector from the steering angle sensors (Note: the position of the connector either facing up or down.)					
137	Remove the attaching screws					
138	Slide the steering angle sensors off of the steering column shaft					
139	Remove the steering angle sensor 					
140	Clean the steering angle sensor					
141	Replace the steering angle sensors (if necessary)					
142	Apply a small amount of the supplied grease to the tab in the center of the steering angle sensor and to the machined groove on the steering shaft					
143	Install the steering angle sensor with the connector facing the same direction as the original					
144	Place the steering angle sensor over the steering column shaft					
145	Slide the steering column shaft into place with the steering angle sensor tab placed in the groove that is machined on the steering column shaft.					
146	Replace the attaching screws					
147	tighten the screws in accordance to manufacturers' recommendations					
148	Install the steering angle sensor wiring harness connector					
149	Install the steering wheel and tighten per the manufacturer's recommendation					
150	Remove the wedge					
151	Test the installation					
152	Calibrate the system					

S/N	Items:	SA	A	D	SD	UD
153	The ABS and ATC/ESC lamps should come on and go back off when ignition power is turned on					
	Contents for the Maintenance of Lateral Acceleration and Yaw Rate Sensors:					
154	Turn the ignition switch Off					
155	Apply the parking brake					
156	Wedge the wheels to prevent the vehicle from moving					
157	Disconnect the negative battery cable					
158	Disable air bag system					
159	Remove the seat mounting fastener					
160	Remove the front seat from the vehicle					
161	Locate the yaw rate & lateral acceleration sensors					
162	Disconnect the electrical harness					
163	Unclip the harness from the seat bracket					
164	Remove the yaw rate & lateral acceleration sensors mounting nuts (1) 					
165	Disconnect the wiring harness connector (2)					
166	Remove the yaw rate & lateral acceleration sensors (3)					
167	Clean the yaw rate & lateral acceleration sensors					
168	Replace the yaw rate & lateral acceleration sensors (if necessary)					
169	Install the yaw rate & lateral acceleration sensors					
170	Connect the wiring harness connector					
171	Install the sensor mounting nuts					
172	Install the seat to the vehicle					
173	Clip the harness to the seat bracket					
174	Connect the electrical harness					
175	Enable the air bag system					
176	Install the seat mounting fastener covers					
177	Connect the negative battery cable					
178	Ensure that, the ESC indicator lamp goes off					

PART E: What are the troubleshooting facilities for the electronic braking systems manual for automobile craftsmen in Nigeria?

S/N	Facilities for Diagnostics Troubleshooting:	SA	A	D	SD	UD
1	OBD II scan tool (code reader, computer and smartphone)					
2	Adopter					
3	Data cable					
4	Data Trouble Codes (DTCs) interpretation					

S/N	Items:	SA	A	D	SD	UD
	Facilities for Components Testing:					
5	Wiring diagrams					
6	Stethoscope					
7	12 volt test lamp					
8	Voltmeter					
9	Ohmmeter					
10	Circuit tester					
11	2-4 amp sealed lamp					

PART F: What are the maintenance facilities for the electronic braking systems manual for automobile craftsmen in Nigeria?

S/N	Facilities for the Maintenance of Wheel Speed Sensor:	SA	A	D	SD	UD
1.	Allen set metric and standard sockets					
2.	Assorted pliers					
3.	Assorted screwdrivers					
4.	Breaker bar ½ inch drive					
5.	Brass hammer					
6.	Combination wrench set, metric and standard					
7.	Disposable gloves					
8.	Emery cloth/sandpaper					
9.	Flashlight					
10.	Floor jack and jack stands					
11.	Metric and standard socket set ½ inch drive					
12.	Pry bar					
13.	Ratchet ⅜ drive					
14.	Socket set metric and standard ⅜ drive					
15.	Socket set metric and standard ¼ drive					
16.	Torque wrench ⅜ or ½ drive					
17.	Torque socket set					
18.	Wheel socket set ½ inch drive					
	Facilities for the Maintenance of ECU and ESC Module:					
19.	Shop clean rags					
20.	ECU replacement					
21.	Torque screw set					
22.	Screwdriver(s) flat					
23.	Screwdriver(s) Phillips head					
24.	Socket set					
25.	Ratchet					
	Facilities for the Maintenance of Pressure Modulator Valves and Active Braking Valves:					
26.	Screwdriver(s) flat					
27.	Screwdriver(s) Phillips head					
28.	Plastic sheet or rubber mat					
29.	Replacement of pressure modulator and active braking valves					

S/N	Items:	SA	A	D	SD	UD
30.	Rubber gloves					
31.	Socket set					
32.	Ratchet					
33.	Wrenches-open/box-end					
34.	Blower					
35.	Clean microfiber cloth					
36.	Alcohol or cleaner					
	Facilities for the Maintenance of Brake Pressure Sensor:					
37.	Screwdriver(s) flat					
38.	Screwdriver(s) Phillips head					
39.	Shop towels/rags					
40.	Wrench set					
	Facilities for the Maintenance of Steering Angle Sensor:					
41.	Allen wrench set SAE/Metric					
42.	Boxed end wrenches					
43.	Cross tip screwdriver					
44.	Dental picks					
45.	Flathead screwdriver					
46.	Protective gloves					
47.	Ratchet					
48.	Standard sockets					
49.	Safety glasses					
50.	Slip joint pliers					
51.	Snap ring pliers					
52.	Steering wheel puller kit					
53.	Torque bit set					
54.	Wheel chocks					
	Facilities for the Maintenance of Yaw Rate and Lateral Acceleration Sensors:					
55.	Allen set (metric & standard sockets)					
56.	Assorted pliers					
57.	Assorted screw drivers					
58.	Combination wrench set (metric & standard)					
59.	Disposable gloves					
60.	Flashlight					
61.	Metric and standard wrench set					
62.	Pry bar					
63.	Ratchet (3/8 drive)					
64.	Socket set (metric & standard 3/8 drive)					
65.	Socket set (metric & standard 1/4 drive)					
66.	Torque socket set					

APPENDIX E

ELECTRONIC BRAKING SYSTEMS TROUBLESHOOTING AND MAINTENANCE SKILL PERFORMANCE TEST

Instruction:

You are expected to attempt the two questions. You should note that marks will be awarded based on step by step execution of the tasks.

Time allow: Six Hours

Requirements:

The followings should be made available for the conduct of the examination:

1. Vehicle with Anti-lock Braking System (ABS), Automatic Traction Control (ATC) and Electronic Stability Control (ESC) malfunction indicated lights illuminated
2. Diagnostics kits
3. Testing equipment
4. Complete tools box
5. Flash light
6. Standard equipped workshop

Questions

1. On the vehicle provided, carry out troubleshooting services on ABS, ATC and ESC.
2. On the vehicle provided, carry out maintenance services on ABS, ATC and ESC.

APPENDIX F

ELECTRONIC BRAKING SYSTEMS TROUBLESHOOTING AND MAINTENANCE SKILL PERFORMANCE RATING SCALE

PART A:

S/N	Performance Tasks in Troubleshooting ABS, ATC and ESC	Excellent	Very Good	Good	Poor	Very Poor
		5	**4**	**3**	**2**	**1**
1	Observation of safety precautions					
2	Selection of right tools for use					
3	Ability to conduct diagnostics troubleshooting					
4	Ability to retrieve Data Trouble Codes (DTCs)					
5	Competence in translating DTCs					
6	Location of components					
7	Competence in carrying out visual inspection on components					
8	Competence in carrying out components testing					
9	Competence in faults identification					
	Scores: $= \frac{\text{Obtained Score}}{45} \times \frac{100}{1}$					

PART B:

S/N	Performance Tasks in the Maintenance of ABS, ATC and ESC	Excellent	Very Good	Good	Poor	Very Poor
		5	**4**	**3**	**2**	**1**
1	Observation of safety precautions					
2	Selection of right tools for use					
3	Location of components					
4	Competence in removing components					
5	Competence in carrying out repair on a faulty components					
6	Competence in testing the components					
7	Competence in installing components					
8	Ability to test installation by putting the ignition switch on					
	Scores: $= \frac{\text{Obtained Score}}{40} \times \frac{100}{1}$					

APPENDIX G

ELECTRONIC BRAKING SYSTEMS TROUBLESHOOTING AND MAINTENANCE SKILL PERFORMANCE TEST SCORING SHEET

S/N	Craftsmen	1	2	3	4	5	6	7	8	9	Total	%
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												

APPENDIX H

ELECTRONIC BRAKING SYSTEMS TROUBLESHOOTING AND MAINTENANCE MANUAL CONTENT VALIDITY INDEX

Instructions: Please read the following statements on the validity of electronic braking systems troubleshooting and maintenance manual carefully and express your opinion on the extent to which you agree or otherwise with each of the statements by checking in any of the five responses of:

		Interpretation				
Scale	**Range**	**Objectives**	**Subject Matter**	**Organization**	**Language**	**Usefulness**
5	4.50-5.00	Strongly Agree	Much Sufficient	Highly Effective	Highly Effective	Very Useful
4	3.50-4.49	Agree	Sufficient	Effective	Effective	Useful
3	2.50-3.49	Disagree	Not Sufficient	Not Effective	Not Effective	Not Useful
2	1.50-2.49	Strongly Disagree	Not Much Sufficient	Not Highly Effective	Not Highly Effective	Not Very Useful
1	00-1.49	Undecided	Undecided	Undecided	Undecided	Undecided

PART A:

S/N	Objectives	Responses				
		SA	A	D	SD	UD
1.	The general objectives include the development of logical skills					
2.	The specific objectives are clearly stated.					
3.	The specific objectives are measurable and attainable.					
4.	The objectives guide the craftsmen to have a full grasp of the concepts to be discussed in each of the manual					
5.	The learning objectives of each module are aligned with the aim of the manual					

PART B:

S/N	Subject Matter	Responses				
		MS	S	NS	MNS	UD
1.	The topics in the manual are appealing.					
2.	The information provided is relevant and up to-date.					
3.	The information is adequate in acquiring the knowledge in each objective					
4.	The activities/ exercise are relevant to the concepts being developed in each objective					
5.	The activities help the students understand better the concepts discussed					

PART C:

S/N	Organization and Presentation	Responses				
		HE	E	NE	HNE	UD
1.	The presentation of topics is sequential					
2.	The discussion of topics is clear and well presented in a logical and orderly sequence					
3.	The variety of activities is sufficient enough to realize the objectives					
4.	The illustrations, examples, figures, and exercises are instruments to attain the learning process					
5.	Instruments for assessment of the targeted objectives are included					

PART D:

S/N	Language and Style	Responses				
		HE	E	NE	HNE	UD
1.	Language used is simple easy to understand in terms of vocabulary and technical terminologies.					
2.	Language structure avoids misinterpretation and free of grammatical errors					
3.	There is enough vocabulary to ensure ease of learning					
4.	There are sufficient provisions for learning new meaning					
5.	The language and style are suited to the ability of the students					

PARTD E:

S/N	Usefulness	Responses				
		VU	U	NU	VNU	UD
1.	The manual enable the students to analyze and apply information/ theories in real life situations					
2.	The manual are engaging, beneficial to students learning and supportive of higher level thinking skills					
3.	Learners can learn, understand and answer the guide questions thoroughly by reviewing illustrations, which are provided per topic					
4.	The manual can make the students learn and understand the subject matter by reviewing the illustrations at his pace					
5.	The manual have well-defined accommodations to support a diversity of learner					

APPENDIX I

ELECTRONIC BRAKING SYSTEMS TROUBLESHOOTING AND MAINTENANCE MANUAL REVISION FORM

S/N	Part of the Manual	Revision Required
1	Cover page	
2	Tittle page	
3	Forward	
4	Acknowledgements	
5	Objectives of Troubleshooting Electronic Barking Systems	
6	Contents for Troubleshooting Electronic Barking Systems	
7	Facilities Required for Troubleshooting Electronic Barking Systems	
8	Objectives of the Maintenance of Electronic Barking Systems	
9	Contents for the Maintenance of Electronic Barking Systems	
10	Facilities Required for the Maintenance of Electronic Barking Systems	
11	References	

APPENDIX J

LETTER OF REQUEST FOR VALIDATION OF RESEARCH INSTRUMENT

Department of Industrial and Technology Education,
Federal University of Technology, Minna,
Niger State.
18th August, 2019.

Sir/Madam,

REQUEST FOR VALIDATION OF RESERCH INSTRUMENT

I am a postgraduate student of the above mentioned Department and University with Registration Number: PhD/SSTE/2018/7691. I am carrying out a research on the topic: **Development of Electronic Braking Systems Troubleshooting and Maintenance Manual for Automobile Craftsmen in Nigeria.**

I humbly request that you honestly validate the research instruments to ascertain its appropriateness, suggest corrections and amendments to make the instrument measure what it is designed to measure. Your professional suggestions will be duly taken into consideration while developing the final draft of the instrument.

Thank you.

Yours Faithfully,

SAIDU, Abubakar Arah
(PhD/SSTE/2018/7691)
08065488404
(Researcher)

APPENDIX K

VALIDATION CERTIFICATE

This is to certify that, the research instrument titled: Electronic Braking Systems Troubleshooting and Maintenance Questionnaire, Electronic Braking Systems Troubleshooting and Maintenance Skill Performance Test, Manual Content Validity Index and Experts Revision Form were validated by:

Expert's Name: Dr. A. M. Idris

Institution: F.U.T Minna

Department: I.T.E

Signature: ... 27-09-2019

Expert's Name: Dr. Saifullahi A. GAZALI.

Institution: National Examinations Council, Minna

Department: Exam. Development {AUTO. Mech. Unit}

Signature: ... 25/09/19

Expert's Name: Engr. Odetoro Mathew

Institution: Automedics Nigeria Limited, Abuja

Department: Automobile Electrical/Electronics

Signature: ...

APPENDIX L

CRONBACH'S ALPHA CORRELATION TEST RESULT FOR ELECTRONIC BRAKING SYSTEMS TROUBLESHOOTING AND MAINTENANCE QUESTIONNAIRE

Part A:

Case Processing Summary

		N	%
Cases	Valid	10	100.0
	Excluded[a]	0	.0
	Total	10	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.723	122

Part B:

Case Processing Summary

		N	%
Cases	Valid	10	100.0
	Excluded[a]	0	.0
	Total	10	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.834	178

Part C:

Case Processing Summary

		N	%
Cases	Valid	10	100.0
	Excluded[a]	0	.0
	Total	10	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.891	11

Part D:

Case Processing Summary

		N	%
Cases	Valid	10	100.0
	Excluded[a]	0	.0
	Total	10	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.912	66

Overall coefficient

Case Processing Summary

		N	%
Cases	Valid	10	100.0
	Excluded[a]	0	.0
	Total	10	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.84	377

APPENDIX M

KENDALL'S TAU COEFFICIENT OF CONCORDANCE TEST RESULT FOR ELECTRONIC BRAKING SYSTEMS SKILL PERFORMANCE TEST AND RATING SCALE

PART A:

Correlations

			Assessor 1	Assessor 2
Kendall's tau_b	Assessor 1	Correlation Coefficient	1.000	.837**
		Sig. (2-tailed)	.	.006
		N	8	8
	Assessor 2	Correlation Coefficient	.837**	1.000
		Sig. (2-tailed)	.006	.
		N	8	8

**. Correlation is significant at the 0.01 level (2-tailed).

Kendall's tau-b correlation coefficient, τ_b, is .837, and that this is statistically significant ($p = .006$).

PART B:

Correlations

			Assessor 1	Assessor 2
Kendall's tau_b	Assessor 1	Correlation Coefficient	1.000	.857**
		Sig. (2-tailed)	.	.006
		N	8	8
	Assessor 2	Correlation Coefficient	.857**	1.000
		Sig. (2-tailed)	.006	.
		N	8	8

**. Correlation is significant at the 0.01 level (2-tailed).

Kendall's tau-b correlation coefficient, τ_b, is .837, and that this is statistically significant ($p = .006$).

APPENDIX N

LETTER OF REQUEST FOR VALIDATION OF A MANUAL

Department of Industrial and Technology Education,
Federal University of Technology, Minna,
Niger State.
28th May, 2021.

Sir/Madam,

REQUEST FOR VALIDATION OF A MANUAL

I am a postgraduate student of the above mentioned Department and University with Registration Number: PhD/SSTE/2018/7691. I am carrying out a research aimed at **Developing Electronic Braking Systems Troubleshooting and Maintenance Manual for Automobile Craftsmen in Nigeria.** The objectives of the manual are designed to equip automobile craftsmen with the knowledge of Anti-lock Braking System (ABS), Automatic Traction Control (ATC) and Electronic Stability Control (ESC) as well as skills in troubleshooting and maintenance of electronic braking systems components that include wheel speed sensor, Electronic Control Unit (ECU), modulator valve, brake pressure sensor, active brake valve, Electronic Stability Module (ECM) and steering angle, yaw rate and lateral sensors.

I humbly request that you honestly validate the manual to ascertain its appropriateness, suggest corrections and amendments to make the manual achieve the aim stated as well as fill the Content Validity Index. Your professional suggestions will be duly taken into consideration while developing the final draft of the manual.
Thank you.

Yours Faithfully,

SAIDU, Abubakar Arah
(PhD/SSTE/2018/7691)
08065488404

APPENDIX O

DETAILS OF CLUSTERED ITEMS

RESEARCH QUESTION THREE

Mean of the Respondents on Clustered Contents to be utilized for Achieving the Objective of the Manual on Troubleshooting Electronic Braking Systems

S/N	Contents to be Utilized for Achieving the Objective of the Manual on Troubleshooting Electronic Braking Systems	$\bar{X}_1$	$\bar{X}_2$	$\bar{X}_A$	Remark
	Contents for Diagnostics Troubleshooting using On-Board Diagnostics II:				
1	Select the right diagnostic tool	4.61	4.65	4.63	Strongly Agreed
2	Ensure the diagnostic tool is functional	4.67	4.70	4.68	Strongly Agreed
3	Check the dashboard light	4.41	4.40	4.40	Agreed
4	Access the steering hood	4.50	4.60	4.55	Strongly Agreed
5	Locate the OBD-II data link connector (under the driver's side of the dashboard)	4.57	4.72	4.64	Strongly Agreed
6	Plug the standard OBD-II connector into the vehicle's data link connector	4.59	4.67	4.63	Strongly Agreed
7	Turn the car's key to provide power to the scan tool or code reader	4.57	4.65	4.61	Strongly Agreed
8	Enter the vehicle-specific information requested	4.39	4.35	4.37	Agreed
9	To check for engine codes, press the scan btton on the code reader	4.63	4.58	4.61	Strongly Agreed
10	Follow the directions on the screen	4.61	4.65	4.63	Strongly Agreed
11	Record the Diagnostic Trouble Codes	4.66	4.70	4.68	Strongly Agreed
12	Translate the Diagnostic Trouble Codes	4.39	4.37	4.38	Agreed
13	Clear the reported Diagnostic Trouble Codes	4.50	4.60	4.55	Strongly Agreed
	Contents for Troubleshooting Wheel Speed Sensor:				
14	Ensure the ABS lamp is operating	4.57	4.72	4.64	Strongly Agreed
15	All readings should be taken at the same time and before vehicle is driven	4.59	4.67	4.63	Strongly Agreed
16	Do not pry or push sensors with sharp objects	4.57	4.65	4.61	Strongly Agreed
17	Push the sensor in until it contacts the tooth wheel	4.36	4.30	4.33	Agreed
18	Check the resistance of wheel speed sensor	4.61	4.65	4.63	Strongly Agreed
19	Check the resistance of ECU harness	4.66	4.70	4.68	Strongly Agreed
20	Verify no change in resistance	4.38	4.35	4.36	Agreed
21	Verify no open circuit between sensor and ECU harness	4.50	4.60	4.55	Strongly Agreed
22	Check harness for any shorts to battery	4.57	4.72	4.64	Strongly Agreed
23	Check harness for any shorts to ground	4.59	4.67	4.63	Strongly Agreed
24	Ensure measurement between sensor leads is 900-2000 ohm	4.57	4.65	4.61	Strongly Agreed
25	Ensure measurement at ECU harness pins with sensor connected is 900-2000 ohm	4.38	4.33	4.35	Agreed
26	Ensure no continuity at ECU harness for DC voltage or ground	4.61	4.65	4.63	Strongly Agreed
27	Ensure sensor output voltage is at least, 0.2 volt	4.66	4.70	4.68	Strongly Agreed
	Contents for Troubleshooting Electronic Control Unit:				
28	ECU connectors must be plugged in before troubleshooting	4.38	4.30	4.34	Agreed
29	Do not load test across power and earth at the ECU when troubleshooting	4.50	4.60	4.55	Strongly Agreed
30	Verify vehicle batteries connections for tightness	4.57	4.72	4.64	Strongly Agreed
31	Verify charging system for good operation	4.59	4.67	4.63	Strongly Agreed
32	Verify fuses	4.57	4.65	4.61	Strongly Agreed
33	Load testing battery and ignition circuits to ground at the ECU harness	4.36	4.28	4.32	Agreed
34	Ensure that lamp does not flash	4.63	4.58	4.61	Strongly Agreed
35	Take measurements at the ECU harness pins	4.61	4.65	4.63	Strongly Agreed
36	Ensure measurement of supply voltage at battery to chassis	4.66	4.70	4.68	Strongly Agreed

	ground reads 9.0-16.0V for 12V system				
37	Ensure measurement of supply voltage at battery to chassis ground reads 18.0-32.0V for 24V system	4.34	4.30	4.32	Agreed
38	Ensure measurement of supply voltage at ignition to chassis ground reads 9.0-16.0V for 12V system	4.50	4.60	4.55	Strongly Agreed
39	Ensure measurement of supply voltage at ignition to chassis ground reads 18.0-32.0V for 24V system	4.57	4.72	4.64	Strongly Agreed
40	Ensure measurement at ECU ground to chassis ground reads less than 1 ohm resistance	4.59	4.67	4.63	Strongly Agreed
41	Ensure measurement at main ground to chassis ground reads less than 1 ohm resistance	4.57	4.65	4.61	Strongly Agreed
	Contents for Troubleshooting Pressure Modulator Valve:				
42	If resistance exceeds 9.0 ohm for 12V system (21.0 ohm for 24V system), verify whether the reading was not taken between the inlet and outlet	4.41	4.37	4.40	Agreed
43	If the correct pins were tested, clean the electrical contacts at the modulator and retest	4.63	4.58	4.61	Strongly Agreed
44	Check pressure modulator valve for resistance	4.61	4.65	4.63	Strongly Agreed
45	Check ECU harness and modulator valve together for resistance	4.66	4.70	4.68	Strongly Agreed
46	Verify no change in resistance or open circuit between valve and through harness	4.38	4.40	4.38	Agreed
47	Check harness for any shorts to battery and shorts to ground	4.50	4.60	4.55	Strongly Agreed
48	Ensure measurement at inlet valve pin to ground reads 4.0-9.0 ohm for 12V system	4.57	4.72	4.64	Strongly Agreed
49	Ensure measurement at inlet valve pin to ground reads 11.0-21.0 ohm for 24V system	4.59	4.67	4.63	Strongly Agreed
50	Ensure measurement at outlet valve pin to ground reads 4.0-9.0 ohm for 12V system	4.57	4.65	4.61	Strongly Agreed
51	Ensure measurement at outlet valve pin to ground reads 11.0-21.0 ohm for 24V system	4.61	4.65	4.63	Strongly Agreed
52	Ensure measurement at ECU harness pins with modulator valve connected reads 4.0-9.0 ohm for 12V system	4.66	4.70	4.68	Strongly Agreed
53	Ensure measurement at ECU harness pins with modulator valve connected reads 11.0-21.0 ohm for 24V system	4.36	4.35	4.35	Agreed
54	Ensure no continuity at ECU harness for battery voltage or ground	4.50	4.60	4.55	Strongly Agreed
	Contents for Troubleshooting Brake Pressure Sensor:				
55	ECU connectors must be plugged in when testing brake pressure sensor harness connector for voltage	4.57	4.72	4.64	Strongly Agreed
56	ECU connectors must be unplugged when verifying short to ground and continuity	4.59	4.67	4.63	Strongly Agreed
57	Take measurements at the brake pressure sensor harness connector	4.57	4.65	4.61	Strongly Agreed
58	Measure voltage supply to ground on pin 1 of the brake pressure sensor with connector key on	4.38	4.33	4.35	Agreed
59	Verify continuity end to end on all 3 lines	4.63	4.58	4.61	Strongly Agreed
60	Ensure no shorts to ground or battery on all 3 lines	4.61	4.65	4.63	Strongly Agreed
61	Ensure no continuity between pins	4.66	4.70	4.68	Strongly Agreed
	Contents for Troubleshooting Active Brake Valve:				
62	Check ABV 3/2 solenoid for resistance	4.38	4.30	4.32	Agreed
63	Check ECU harness and active brake valve 3/2 solenoid together for resistance	4.50	4.60	4.55	Strongly Agreed
64	Verify no change in resistance or open circuit between active brake valve and through harness	4.57	4.72	4.64	Strongly Agreed
65	Check harness for any shorts to battery and shorts to ground	4.59	4.67	4.63	Strongly Agreed
66	Ensure measurement at active brake valve reads 7.0-14.0 ohm for 12V system	4.57	4.65	4.61	Strongly Agreed
67	Ensure measurement at active brake valve reads 26.3-49.0 ohm for 24V system	4.39	4.35	4.37	Agreed

68	Ensure measurement at ECU harness pins with active brake valve connected reads 7.0-14.0 ohm for 12V system	4.63	4.58	4.61	Strongly Agreed
69	Ensure no continuity at ECU harness for battery voltage or ground	4.61	4.65	4.63	Strongly Agreed
	Contents for Troubleshooting Electronic Stability Control Module:				
70	Do not load test across power and ground at the ESC Module	4.66	4.70	4.68	Strongly Agreed
71	ECU connectors must be plugged in when testing resistance and voltage on ESC module	4.41	4.40	4.40	Agreed
72	ECU connectors must be unplugged when testing continuity and short on ESC module	4.50	4.60	4.55	Strongly Agreed
73	Take measurements at the ESC module harness connector	4.57	4.72	4.64	Strongly Agreed
74	Measure voltage supply with key on	4.59	4.67	4.63	Strongly Agreed
75	Measure Communication Area Network (CAN) high voltage with key on	4.57	4.65	4.61	Strongly Agreed
76	Measure CAN high voltage with key on	4.34	4.28	4.31	Agreed
77	Measure terminating resistance across CAN high and low with key off	4.63	4.58	4.61	Strongly Agreed
78	Verify continuity end to end on each line with ECU and ESC module disconnected	4.61	4.65	4.63	Strongly Agreed
79	Verify no shorts to ground or battery on all lines with ECU and ESC module disconnected	4.66	4.70	4.68	Strongly Agreed
80	Verify no continuity between pins with ECU and ESC module disconnected	4.38	4.37	4.37	Agreed
81	Ensure Voltage Supply to Chassis Ground at pin 1 reads 8.0-16.0V	4.50	4.60	4.55	Strongly Agreed
82	Ensure ESC ground to chassis ground at pin 2 reads less than 1 ohm resistance	4.57	4.72	4.64	Strongly Agreed
83	Ensure terminating resistance between ESC CAN-high to ESC CAN-low (pin 3 and 4) reads approximately 90 ohms	4.59	4.67	4.63	Strongly Agreed
84	With ECU disconnected, check power supply for battery voltage or ground at pin 1 and 2 and ensure no continuity	4.57	4.65	4.61	Strongly Agreed
85	With ECU disconnected, check CAN lines for battery voltage or ground at pin 3 and 4 and ensure no continuity	4.29	4.21	4.25	Agreed
86	Ensure CAN high voltage to chassis ground at pin 3 reads 2.5-5.0V	4.61	4.65	4.63	Strongly Agreed
87	Ensure CAN low voltage to chassis ground at pin 4 reads 0.1-2.4V	4.66	4.70	4.68	Strongly Agreed
88	Ensure that ESC harnesses are connected	4.36	4.37	4.36	Strongly Agreed
	Contents for Troubleshooting Steering Angle Sensor:				
89	ECU and ESC module connectors must be plugged in when testing steering angle sensor connector for voltage	4.50	4.60	4.55	Strongly Agreed
90	Do not load test across power and ground at the steering angle sensor	4.57	4.72	4.64	Strongly Agreed
91	Disconnect steering angle sensor and check terminating resistance across Pin 1 and Pin 2	4.59	4.67	4.63	Strongly Agreed
92	Take measurements at the steering angle sensor harness connector side	4.57	4.65	4.61	Strongly Agreed
93	With key on, check CAN low voltage on pin 1	4.38	4.33	4.35	Agreed
94	With key on, check CAN high voltage on pin 4	4.63	4.58	4.61	Strongly Agreed
95	With key on, check voltage supply on Pin 5	4.61	4.65	4.63	Strongly Agreed
96	With key off, check resistance across CAN low Pin 1 and CAN high Pin 4	4.66	4.70	4.68	Strongly Agreed
97	Ensure measurement at steering angle sensor terminating resistor reads approximately 180 ohms	4.38	4.30	4.34	Agreed
98	Ensure measurement at CAN high voltage reads 2.5-5.0V	4.50	4.60	4.55	Strongly Agreed
99	Ensure measurement at CAN low voltage reads 0.1-2.4V	4.57	4.72	4.64	Strongly Agreed
100	Ensure voltage supply to ground reads 8.0-16.0V	4.59	4.67	4.63	Strongly Agreed

101	Ensure measurement at ESC CAN-high to ESC CAN-low reads approximately 90 ohm	4.57	4.65	4.61	Strongly Agreed
102	Ensure continuity at steering angle sensor harness jumper (Pin 2 to Pin 4 or Pin 2 to Pin 3)	4.36	4.30	4.33	Agreed
103	Ensure no continuity at ESC CAN-high or CAN-low to power or ground (with ECU, ESC Module and steering angle sensor unplugged)	4.63	4.58	4.61	Strongly Agreed
	Contents for Troubleshooting Yaw Rate Sensor:				
104	Take measurements at the yaw rate sensor connector	4.61	4.65	4.63	Strongly Agreed
105	Disconnect the yaw rate sensor connector	4.67	4.70	4.68	Strongly Agreed
106	Take measurements at the yaw rate sensor connector	4.38	4.37	4.37	Agreed
107	With key off, check CAN low resistance on pin 2	4.50	4.60	4.55	Strongly Agreed
108	With key off, check CAN high resistance on pin 3	4.57	4.72	4.64	Strongly Agreed
109	With key on/off, check body ground resistance on Pin 1	4.59	4.67	4.63	Strongly Agreed
110	With key on, check body ground voltage on Pin 5	4.57	4.65	4.61	Strongly Agreed
111	Ensure measurement at CAN low resistance reads 54 to 69 ohms	4.34	4.28	4.31	Agreed
112	Ensure measurement at CAN high resistance reads 54 to 69 ohms	4.63	4.58	4.61	Strongly Agreed
113	Ensure measurement at body ground resistance reads less than 1 ohms	4.61	4.65	4.63	Strongly Agreed
114	Ensure measurement at body ground voltage reads 10 to 14 V	4.66	4.70	4.68	Strongly Agreed
	Contents for Troubleshooting Lateral Acceleration Sensor:				
115	Check fuses that power up the sensor	4.40	4.37	4.38	Agreed
116	Unplug the sensor connector	4.50	4.60	4.55	Strongly Agreed
117	Take measurements at the lateral acceleration sensor connector	4.57	4.72	4.64	Strongly Agreed
118	With key on, check CAN high voltage on pin 1	4.59	4.67	4.63	Strongly Agreed
119	With key on, check CAN low voltage on pin 3	4.57	4.65	4.61	Strongly Agreed
120	Ensure measurement at volts at CAN high (pin 1) voltage reads 2.6 volts	4.36	4.30	4.33	Agreed
121	Ensure measurement at volts at CAN low (pin 3) voltage reads 2.4 volts	4.63	4.58	4.61	Strongly Agreed
122	Ensure no short to the ground	4.63	4.58	4.61	Strongly Agreed
	Grand Mean	**4.54**	**4.58**	**4.56***	**Strongly Agreed**

RESEARCH QUESTION FOUR

Mean of the Respondents on Clustered Contents to be Utilized for Achieving the Objective of the Manual on the Maintenance of Electronic Braking Systems

S/N	Contents to be Utilized for Achieving the Objective of the Manual on the Maintenance of Electronic Braking Systems	$\bar{X}_1$	$\bar{X}_2$	$\bar{X}_A$	Remark
	Contents for the Maintenance of Wheel Speed Sensor				
1	Park the vehicle on a level surface	4.61	4.65	4.63	Strongly Agreed
2	Wedge the wheels to prevent the vehicle from moving	4.67	4.70	4.68	Strongly Agreed
3	Apply the parking brake	4.41	4.40	4.40	Agreed
4	Jack the vehicle up	4.50	4.60	4.55	Strongly Agreed
5	Put the vehicle on axle stands	4.57	4.72	4.64	Strongly Agreed
6	Remove the road wheels	4.59	4.67	4.63	Strongly Agreed
7	Disconnect the fasteners that hold the sensor cable to other components	4.57	4.65	4.61	Strongly Agreed
8	Disconnect the sensor cable from the chassis harness	4.39	4.35	4.37	Agreed
9	Remove the sensor from the sensor holder	4.63	4.58	4.61	Strongly Agreed
10	Remove the sensor spring clip	4.61	4.65	4.63	Strongly Agreed
11	Clean the sensor	4.67	4.70	4.68	Strongly Agreed

12	Apply a recommended lubricant to the sensor spring clip and sensor	4.39	4.37	4.38	Agreed
13	Replace the sensor (if necessary)	4.50	4.60	4.55	Strongly Agreed
14	Connect the sensor cable to the chassis harness	4.57	4.72	4.64	Strongly Agreed
15	Install the fasteners used to hold the sensor cable in place	4.59	4.67	4.63	Strongly Agreed
16	Install the sensor spring clip	4.57	4.65	4.61	Strongly Agreed
17	Push the sensor spring clip into the bushing in the steering knuckle until the clip stops	4.36	4.30	4.33	Agreed
18	Push the sensor completely into the sensor spring clip until it contacts the tooth wheel	4.61	4.65	4.63	Strongly Agreed
19	Place the road wheels back onto the hubs	4.67	4.70	4.68	Strongly Agreed
20	Remove the safety stands	4.38	4.35	4.36	Agreed
21	Torque the wheels	4.50	4.60	4.55	Strongly Agreed
22	Jack the vehicle back off the jack stands	4.57	4.72	4.64	Strongly Agreed
23	Test drive the vehicle	4.59	4.67	4.63	Strongly Agreed
	Contents for the Maintenance of Electronic Control Unit (ECU)				
24	Apply the parking brake	4.57	4.65	4.61	Strongly Agreed
25	Disconnect the battery or remove the cable from the negative terminal	4.38	4.33	4.35	Agreed
26	Locate the ECU (usually on the bonnet)	4.61	4.65	4.63	Strongly Agreed
27	Remove all the ECU connectors	4.67	4.70	4.68	Strongly Agreed
28	Remove screws and any ties that mounts the unit	4.38	4.30	4.34	Agreed
29	Remove the ECU	4.50	4.60	4.55	Strongly Agreed
30	Clean the ECU	4.57	4.72	4.64	Strongly Agreed
31	Carry out physical checks	4.59	4.67	4.63	Strongly Agreed
32	Replace the ECU (if necessary)	4.57	4.65	4.61	Strongly Agreed
33	Match the old ECU with the new one	4.36	4.28	4.32	Agreed
34	Clean the mounting surface properly when installing the replaced ECU	4.63	4.58	4.61	Strongly Agreed
35	Place the new module carefully	4.61	4.65	4.63	Strongly Agreed
36	Connect the wires and other electrical connections to the ECU	4.67	4.70	4.68	Strongly Agreed
37	Reconnect the battery	4.34	4.30	4.32	Strongly Agreed
38	Turn on the connection	4.50	4.60	4.55	Strongly Agreed
	Contents for the Maintenance of Pressure Modulator Valves				
39	Park the vehicle on a level surface	4.57	4.72	4.64	Strongly Agreed
40	Turn the ignition switch Off	4.59	4.67	4.63	Strongly Agreed
41	Apply the parking brake	4.57	4.65	4.61	Strongly Agreed
42	Wedge the wheels to prevent the vehicle from moving	4.41	4.37	4.39	Agreed
43	Jack the vehicle up	4.63	4.58	4.61	Strongly Agreed
44	Put the vehicle on axle stands	4.61	4.65	4.63	Strongly Agreed
45	Locate the pressure modulator valves	4.66	4.70	4.68	Strongly Agreed
46	Disconnect the wiring connector from the pressure modulator valves	4.38	4.40	4.38	Agreed
47	Disconnect the airlines from Ports 1 (air supply) and 2 (air discharge) of the ABS valve	4.50	4.60	4.55	Strongly Agreed
48	Remove the two mounting cap screws and nuts	4.57	4.72	4.64	Strongly Agreed
49	Remove the pressure modulator valves	4.59	4.67	4.63	Strongly Agreed
50	Clean the pressure modulator valves	4.57	4.65	4.61	Strongly Agreed
51	Check for damages	4.61	4.65	4.63	Strongly Agreed
52	Make repairs as needed	4.66	4.70	4.68	Strongly Agreed
53	Replace the pressure modulator valves (if necessary)	4.38	4.35	4.35	Agreed
54	Install the pressure modulator valves with two mounting cap screws and nuts	4.50	4.60	4.55	Strongly Agreed
55	Tighten the cap screws to the manufacturer's recommendation	4.57	4.72	4.64	Strongly Agreed
56	Connect the line to the brake chambers to Port 2 of the pressure modulator valves	4.59	4.67	4.63	Strongly Agreed

57	Connect the air supply line to Port 1 of the pressure modulator valves	4.57	4.65	4.61	Strongly Agreed
58	Connect the wiring connector to the pressure modulator valves (hand tighten only)	4.38	4.33	4.35	Agreed
59	Remove the stands	4.67	4.58	4.61	Strongly Agreed
60	Test the installation by applying the brake pedal	4.61	4.65	4.63	Strongly Agreed
61	Observe for leaks at the pressure modulator valve	4.66	4.70	4.68	Strongly Agreed
62	Turn the ignition on and listen to the modulator valve cycle	4.34	4.30	4.32	Agreed
63	If the valve fails to cycle, check the electrical cable connection	4.50	4.60	4.55	Strongly Agreed
64	Verify that the ABS indicator lamp operates correctly	4.57	4.72	4.64	Strongly Agreed
	Contents for the Maintenance of Brake Pressure Sensor				
65	Park the vehicle on a level surface	4.59	4.67	4.63	Strongly Agreed
66	Turn the ignition switch Off	4.57	4.65	4.61	Strongly Agreed
67	Apply the parking brake	4.42	4.40	4.41	Agreed
68	Locate the brake pressure sensor (usually found mounted near the brake master cylinder)	4.64	4.60	4.63	Strongly Agreed
69	Unplug the electrical connector	4.64	4.65	4.65	Strongly Agreed
70	Remove the brake pressure sensor	4.70	4.72	4.71	Strongly Agreed
71	Clean the brake pressure sensor	4.44	4.44	4.44	Agreed
72	Check for damage	4.55	4.63	4.59	Strongly Agreed
73	Replace the brake pressure sensor	4.59	4.74	4.66	Strongly Agreed
74	Thread the replacement into place	4.61	4.70	4.65	Strongly Agreed
75	Tighten the sensor as far as possible by hand	4.57	4.65	4.61	Strongly Agreed
76	Plug electrical connector	4.34	4.28	4.31	Agreed
77	Verify the installation of the brake pressure sensor	4.63	4.58	4.61	Strongly Agreed
78	Refill the reservoir to the correct level if any fluid was lost during replacement	4.61	4.65	4.63	Strongly Agreed
79	Start the vehicle and let it run for 10-15 seconds	4.66	4.70	4.68	Strongly Agreed
80	Press on the brake firmly a couple of times	4.38	4.37	4.37	Agreed
81	Ensure that the ABS, ATC and ESC indicator lamp goes off	4.50	4.60	4.55	Strongly Agreed
	Contents for the Maintenance of Active Braking Valves				
82	Park the vehicle on a level surface	4.57	4.72	4.64	Strongly Agreed
83	Turn the ignition switch Off	4.59	4.67	4.63	Strongly Agreed
84	Apply the parking brake	4.57	4.65	4.61	Strongly Agreed
85	Wedge the wheels to prevent the vehicle from moving	4.29	4.21	4.25	Agreed
86	Jack the vehicle up	4.61	4.65	4.63	Strongly Agreed
87	Locate active braking valves near the rear axle or front axle	4.66	4.70	4.68	Strongly Agreed
88	Disconnect the wiring from the valve	4.36	4.37	4.36	Agreed
89	Remove the two mounting cap screws and nuts	4.50	4.60	4.55	Strongly Agreed
90	Disconnect the air lines from Port 1 (air supply), Port 2 (air discharge) and Port 3 (treadle) of the active braking valves	4.57	4.72	4.64	Strongly Agreed
91	Remove the active braking valves	4.59	4.67	4.63	Strongly Agreed
92	Clean the active braking valves	4.57	4.65	4.61	Strongly Agreed
93	Check for damages	4.38	4.33	4.35	Agreed
94	Make repairs as needed	4.63	4.58	4.61	Strongly Agreed
95	Replace the active braking valves (if necessary)	4.61	4.65	4.63	Strongly Agreed
96	Install the valve with two mounting cap screws and nuts	4.66	4.70	4.68	Strongly Agreed
97	Tighten the cap screws based on manufacturer's recommendation	4.38	4.30	4.34	Agreed
98	Connect the air supply, discharge and treadle lines to Ports 1, 2 and 3 of the valve	4.50	4.60	4.55	Strongly Agreed
99	Connect the harness connector to the valve (hand tighten only)	4.57	4.72	4.64	Strongly Agreed
100	Remove the stands	4.59	4.67	4.63	Strongly Agreed
101	Turn the ignition to the on position	4.57	4.65	4.61	Strongly Agreed
102	Verify that the ATC/ESC lamp operates correctly	4.36	4.30	4.33	Agreed
103	Start the vehicle	4.64	4.58	4.61	Strongly Agreed

104	Fully charge the reservoirs with air	4.61	4.65	4.63	Strongly Agreed
105	Shut off the vehicle	4.66	4.70	4.68	Strongly Agreed
106	Apply the brakes	4.38	4.37	4.37	Agreed
107	Observe for air leaks at the valve	4.50	4.60	4.55	Strongly Agreed
108	Release the brakes	4.57	4.72	4.64	Strongly Agreed
109	Verify correct operation and that there are no active codes	4.59	4.67	4.63	Strongly Agreed
110	Verify that, the ATC indicator lamp operates correctly	4.57	4.65	4.61	Strongly Agreed
	Contents for the Maintenance of Electronic Stability Control Module				
111	Turn the ignition switch Off	4.34	4.28	4.31	Agreed
112	Apply the parking brake	4.63	4.58	4.61	Strongly Agreed
113	Wedge the wheels to prevent the vehicle from moving	4.61	4.65	4.63	Strongly Agreed
114	Jack the vehicle up	4.66	4.70	4.68	Strongly Agreed
115	Locate the ESC module	4.39	4.37	4.38	Agreed
116	Disconnect the wiring harness connector from the ESC module	4.50	4.60	4.55	Strongly Agreed
117	Remove the two mounting cap screws and nuts	4.57	4.72	4.64	Strongly Agreed
118	Remove the ESC module	4.59	4.67	4.63	Strongly Agreed
119	Check for damages	4.57	4.65	4.61	Strongly Agreed
120	Clean the ESC module	4.36	4.30	4.33	Agreed
121	Replace the ESC module (if necessary)	4.63	4.58	4.61	Strongly Agreed
122	Install the ESC module with the two cap screws and nuts	4.63	4.58	4.61	Strongly Agreed
123	Tighten the cap screws per the manufacturer's recommendation	4.43	4.40	4.41	Agreed
124	Connect the wiring harness connector to the ESC module (hand tighten only)	4.64	4.60	4.63	Strongly Agreed
125	Remove the wedge	4.64	4.65	4.65	Strongly Agreed
126	Test the installation	4.70	4.72	4.71	Strongly Agreed
127	Calibrate the system	4.45	4.44	4.44	Agreed
128	The ABS and ATC/ESC lamps should come on and go back off when ignition power is turned on	4.55	4.63	4.59	Strongly Agreed
	Contents for the Maintenance of Steering Angle Sensors				
129	Center the steering wheel with the front wheels positioned straight ahead	4.59	4.74	4.66	Strongly Agreed
130	Turn the ignition switch Off	4.61	4.70	4.65	Strongly Agreed
131	Apply the parking brake	4.48	4.44	4.46	Agreed
132	Wedge the wheels to prevent the vehicle from moving	4.66	4.65	4.66	Strongly Agreed
133	Locate the steering angle sensors on the steering column shaft, either near the universal joint on the bottom of the column or under the steering wheel near the top of the column	4.66	4.70	4.68	Strongly Agreed
134	Remove the vehicle steering wheel using the recommended steering wheel puller	4.70	4.72	4.71	Strongly Agreed
135	Remove the three screws to the steering column with the center tab located in the grooved steering column shaft	4.45	4.44	4.44	Agreed
136	Disconnect the wiring harness connector from the steering angle sensors (Note: the position of the connector either facing up or down.)	4.55	4.63	4.59	Strongly Agreed
137	Remove the attaching screws	4.61	4.77	4.68	Strongly Agreed
138	Slide the steering angle sensors off of the steering column shaft	4.63	4.72	4.67	Strongly Agreed
139	Remove the steering angle sensor	4.48	4.42	4.45	Strongly Agreed
140	Clean the steering angle sensor	4.64	4.60	4.63	Strongly Agreed
141	Replace the steering angle sensors (if necessary)	4.64	4.65	4.65	Strongly Agreed
142	Apply a small amount of grease to the tab in the center of the steering angle sensor and to the groove on the steering shaft	4.70	4.77	4.73	Strongly Agreed
143	Install the steering angle sensor with the connector facing the same direction as the original	4.45	4.44	4.44	Agreed
144	Place the steering angle sensor over the steering column shaft	4.55	4.63	4.59	Strongly Agreed

145	Slide the steering column shaft into place with the steering angle sensor tab placed in the groove that is machined on the steering column shaft.	4.59	4.79	4.68	Strongly Agreed
146	Replace the attaching screws	4.61	470	4.65	Strongly Agreed
147	tighten the screws in accordance to manufacturers' recommendations	4.43	4.40	4.41	Agreed
148	Install the steering angle sensor wiring harness connector	4.64	4.60	4.63	Strongly Agreed
149	Install the steering wheel and tighten per the manufacturer's recommendation	4.64	4.65	4.65	Strongly Agreed
150	Remove the wedge	4.70	4.72	4.71	Strongly Agreed
151	Test the installation	4.45	4.44	4.44	Agreed
152	Calibrate the system	4.55	4.63	4.59	Strongly Agreed
153	The ABS and ATC/ESC lamps should come on and go back off when ignition power is turned on	4.59	4.74	4.66	Strongly Agreed
	Contents for the Maintenance of Lateral Acceleration and Yaw Rate Sensors:				
154	Turn the ignition switch Off	4.61	4.70	4.65	Strongly Agreed
155	Apply the parking brake	4.48	4.44	4.46	Agreed
156	Wedge the wheels to prevent the vehicle from moving	4.66	4.65	4.66	Strongly Agreed
157	Disconnect the negative battery cable	4.66	4.70	4.68	Strongly Agreed
158	Disable air bag system	4.70	4.72	4.71	Strongly Agreed
159	Remove the seat mounting fastener	4.45	4.44	4.44	Agreed
160	Remove the front seat from the vehicle	4.55	4.63	4.59	Strongly Agreed
161	Locate the yaw rate & lateral acceleration sensors	4.61	4.77	4.68	Strongly Agreed
162	Disconnect the electrical harness	4.63	4.72	4.67	Strongly Agreed
163	Unclip the harness from the seat bracket	4.48	4.42	4.45	Agreed
164	Remove the yaw rate & lateral acceleration sensors mounting nuts (1)	4.64	4.60	4.63	Strongly Agreed
165	Disconnect the wiring harness connector (2)	4.64	4.65	4.65	Strongly Agreed
166	Remove the yaw rate & lateral acceleration sensors (3)	4.70	4.77	4.73	Strongly Agreed
167	Clean the yaw rate & lateral acceleration sensors	4.45	4.44	4.44	Agreed
168	Replace the yaw rate & lateral acceleration sensors (if necessary)	4.50	4.63	4.59	Strongly Agreed
169	Install the yaw rate & lateral acceleration sensors	4.59	4.79	4.68	Strongly Agreed
170	Connect the wiring harness connector	4.61	4.70	4.65	Strongly Agreed
171	Install the sensor mounting nuts	4.61	4.77	4.68	Strongly Agreed
172	Install the seat to the vehicle	4.63	4.72	4.67	Strongly Agreed
173	Clip the harness to the seat bracket	4.48	4.42	4.45	Agreed
174	Connect the electrical harness	4.64	4.60	4.63	Strongly Agreed
175	Enable the air bag system	4.64	4.65	4.65	Strongly Agreed
176	Install the seat mounting fastener covers	4.70	4.77	4.73	Strongly Agreed
177	Connect the negative battery cable	4.45	4.44	4.44	Agreed
178	Ensure that, the ESC indicator lamp goes off	4.55	4.63	4.59	Strongly Agreed
	Grand Mean	**4.59**	**4.63**	**4.61***	**Strongly Agreed**

RESEARCH QUESTION SIX

Mean of the Respondents on Clustered Maintenance Facilities for the Electronic Braking Systems Manual

S/N	Maintenance Facilities for the Electronic Braking Systems Manual	$\bar{X}_1$	$\bar{X}_2$	$\bar{X}_A$	Remark
	Facilities for the Maintenance of Wheel Speed Sensor:				
1	Allen set metric and standard sockets	4.57	4.72	4.64	Strongly Agreed
2	Assorted pliers	4.59	4.67	4.63	Strongly Agreed
3	Assorted screwdrivers	4.57	4.65	4.61	Strongly Agreed
4	Breaker bar ½ inch drive	4.36	4.30	4.33	Agreed
5	Brass hammer	4.61	4.65	4.63	Strongly Agreed

6	Combination wrench set, metric and standard	4.67	4.70	4.68	Strongly Agreed
7	Disposable gloves	4.38	4.35	4.36	Agreed
8	Emery cloth/sandpaper	4.50	4.60	4.55	Strongly Agreed
9	Flashlight	4.57	4.72	4.64	Strongly Agreed
10	Floor jack and jack stands	4.59	4.67	4.63	Strongly Agreed
11	Metric and standard socket set ½ inch drive	4.57	4.65	4.61	Strongly Agreed
12	Pry bar	4.38	4.33	4.35	Agreed
13	Ratchet (⅜ drive)	4.61	4.65	4.63	Strongly Agreed
14	Socket set (metric and standard ⅜ drive)	4.66	4.70	4.68	Strongly Agreed
15	Socket set (metric and standard ¼ drive)	4.38	4.30	4.34	Agreed
16	Torque wrench (⅜ or ½ drive)	4.50	4.60	4.55	Strongly Agreed
17	Torque socket set	4.57	4.72	4.64	Strongly Agreed
18	Wheel socket set (½ inch drive)	4.59	4.67	4.63	Strongly Agreed
	Facilities for the Maintenance of ECU and ESC Module:				
19	Shop clean rags	4.57	4.65	4.61	Strongly Agreed
20	ECU replacement	4.36	4.28	4.32	Agreed
21	Torque screw set	4.63	4.58	4.61	Strongly Agreed
22	Screwdriver(s) flat	4.61	4.65	4.63	Strongly Agreed
23	Screwdriver(s) Phillips head	4.66	4.70	4.68	Strongly Agreed
24	Socket set	4.34	4.30	4.32	Agreed
25	Ratchet	4.50	4.60	4.55	Strongly Agreed
	Facilities for the Maintenance of Pressure Modulator Valves and Active Braking Valves:				
26	Screwdriver(s) flat	4.57	4.72	4.64	Strongly Agreed
27	Screwdriver(s) Phillips head	4.59	4.67	4.63	Strongly Agreed
28	Plastic sheet or rubber mat	4.57	4.65	4.61	Strongly Agreed
29	Replacement of pressure modulator and active braking valves	4.41	4.37	4.39	Agreed
30	Rubber gloves	4.63	4.58	4.61	Strongly Agreed
31	Socket set	4.61	4.65	4.63	Strongly Agreed
32	Ratchet	4.66	4.70	4.68	Strongly Agreed
33	Wrenches-open/box-end	4.38	4.40	4.38	Agreed
34	Blower	4.50	4.60	4.55	Strongly Agreed
35	Clean microfiber cloth	4.57	4.72	4.64	Strongly Agreed
36	Alcohol or cleaner	4.59	4.67	4.63	Strongly Agreed
	Facilities for the Maintenance of Brake Pressure Sensor:				
37	Screwdriver(s) flat	4.57	4.65	4.61	Strongly Agreed
38	Screwdriver(s) Phillips head	4.61	4.65	4.63	Strongly Agreed
39	Shop towels/rags	4.66	4.70	4.68	Strongly Agreed
40	Wrench set	4.36	4.35	4.35	Agreed
	Facilities for the Maintenance of Steering Angle Sensor:				
41	Allen wrench set SAE/Metric	4.50	4.60	4.55	Strongly Agreed
42	Boxed end wrenches	4.57	4.72	4.64	Strongly Agreed
43	Cross tip screwdriver	4.59	4.67	4.63	Strongly Agreed
44	Dental picks	4.57	4.65	4.61	Strongly Agreed
45	Flathead screwdriver	4.38	4.33	4.35	Agreed
46	Protective gloves	4.63	4.58	4.61	Strongly Agreed
47	Ratchet	4.61	4.65	4.63	Strongly Agreed
48	Standard sockets	4.66	4.70	4.68	Strongly Agreed
49	Safety glasses	4.34	4.30	4.32	Agreed
50	Slip joint pliers	4.50	4.60	4.55	Strongly Agreed
51	Snap ring pliers	4.57	4.72	4.64	Strongly Agreed
52	Steering wheel puller kit	4.59	4.67	4.63	Strongly Agreed
53	Torque bit set	4.57	4.65	4.61	Strongly Agreed
54	Wheel chocks	4.43	4.40	4.41	Agreed
	Facilities for the Maintenance of Yaw Rate and Lateral Acceleration Sensors:				

55	Allen set (metric & standard sockets)	4.64	4.60	4.63	Strongly Agreed
56	Assorted pliers	4.64	4.65	4.65	Strongly Agreed
57	Assorted screw drivers	4.70	4.72	4.71	Strongly Agreed
58	Combination wrench set (metric & standard)	4.45	4.44	4.44	Agreed
59	Disposable gloves	4.55	4.63	4.59	Strongly Agreed
60	Flashlight	4.59	4.74	4.66	Strongly Agreed
61	Metric and standard wrench set	4.61	4.70	4.65	Strongly Agreed
62	Pry bar	4.57	4.65	4.61	Strongly Agreed
63	Ratchet (3/8 drive)	4.34	4.28	4.31	Agreed
64	Socket set (metric & standard 3/8 drive)	4.63	4.58	4.61	Strongly Agreed
65	Socket set (metric & standard 1/4 drive)	4.61	4.65	4.63	Strongly Agreed
66	Torque socket set	4.67	4.70	4.68	Strongly Agreed
	Grand Mean	**4.58**	**4.61**	**4.60***	**Strongly Agreed**