ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY SCHOOL

OF MECHANICAL, CHEMICAL AND MATERIALS ENGINEERING

MSc. Thesis on

Comparative study of Conventional Construction Equipment Operation Training and Simulator-Based Training in ERA

By

Endalkachew K/mariam

Program: MSc Automotive Engineering

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Approved by board of Examiners

______________________	__________	__________
Chairman, Department graduate committee	**Signature**	**Date**
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Adviser	**Signature**	**Date**
______________________	__________	__________
Internal Examiner	**Signature**	**Date**
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CANDIDATE'S DECELARATION

I hereby declare that the work which is being presented in this thesis entitled "Comparative Study of Conventional Construction Equipment Operation Training to Simulator-Based Training in ERA" is a study in Ethiopian Road Authority (ERA) at Alemgena Machine Based Technology Training Center (AMBTTC) is original work of my own, has not been presented for a degree of any other university and that all sources of material used for the thesis have been duly acknowledged.

____________________________ ________________________

Endalkachew K/mariam Date

(Candidate)

This is to certify that the above declaration made by the candidate is correct to the best of my knowledge.

____________________________ ________________________

Asst. Prof. Date

(Thesis Advisor)

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ABSTRACT

Construction work is used to make various kinds of structures such as, railroads, building, dams, runway, tunnel, roads etc. in the fields to improve our life, and keep our life comfortable. Earth moving equipment's are consisting of mainly Dozers, Loaders, Excavators, and Graders. All implement tools of machines controlled and operated by hydraulic system. Nowadays almost all the construction work is done by machinery. However, since operators operate these machines, the quality and quantity of work depends upon the ability of operators. So it needs skillful operator to operate the machine. To upgrade the level of skill of operators conducting training is of paramount importance. But there are many problems during operator training. The problems are: increased machine failure, fuel and oils consumption, emission, training time, total training cost etc. This thesis is focused on the comparative study of conventional construction equipment operation training and simulator-based of construction equipment operation training in Ethiopian Road Authority (ERA) at Alemgena Machine Based Technology Training Center (AMBTTC). The two training are given at AMBTTC and the amount of fuel and oils consumption found from the documentation. Data were collected by use of direct observations, questionnaires, and interviews regarding fuel and oil consumption, etc. Skill and knowledge gained by the trainees from the two training sections were also determined by interview, direct observation, time table and trainer evaluation report. There are ten simulators in the training center. The cost of each simulator was ten million Ethiopian Birr with two years guaranty, and imported from South Africa, but there was a maintenance problem due to lack of spare part and maintenance expert. From the questionnaire and interview, most of trainer's response was M, because of maintenance problem and training schedule. Most of trainees were more satisfied in Dozer, Loader and Excavator, but in Grader was less satisfied. Fuel and oil consumption of conventional training for one round was 55,230L and 735.92L respectively, and in simulator-based training 36,846L & 439.29L respectively, so that the reduction in consumption was the profit of training center.

Key words:- construction machinery, conventional training, simulator based training, comparative study, training cost.

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LIST OF ACRONYMS AND SYMBOLS

ERA	Ethiopian Road Authority
AMBTTC	Alemgena Machine Based Technology Training Center
CoC	Certificate of Competency
CT	Conventional Training
SBT	Simulator Based-Training
AWD	All Wheel Drive
GPS	Global Position System
GNSS	Global Navigation Satellite System
$\mathbf{F_{C(CT)}}$	Fuel Consumption of Conventional Training
$\mathbf{F_{C(SBT)}}$	Fuel Consumption of Simulator-Based Training
$\mathbf{EO_{CCT}}$	Engine Oil Consumption of Conventional Training
$\mathbf{EO_{C(SBT)}}$	Engine Oil Consumption of Simulator-Based-Training
ATTC	Alemgena Training and Testing Centre
MCU	Motion Control Unit
SMCP	Simulator Motion Control Program
LCD	Liquid Crystal Display
A/D	Analog to Digital converter
IES	Intelligent Excavation System
PTDI	Professional Truck Driver Institute
CDL	Commercial Driver License
DMV	Department of Motor Vehicle
DOT	Department of Transport

CHAPTER ONE

INTRODUCTION

In the case of huge construction projects, properly assigned of the appropriate machines contribute to economy, quality, safety, speed and timely completion of a project. Equipment use for construct highway, runway, railway, dam, irrigation, building, power projects etc. 15 - 30% of total project cost has been accounted towards equipment's and machinery. Construction equipments (Heavy duty vehicles) are a type of vehicles that power plant construction is similar to automobiles. But other parts are partly or completely different. The equipment have strong frame, chassis, blade, implement tool, chain etc. all these parts during hard work condition resist strong force and shock. Even if parts are very strong, during training mainly failure occurs. To reduce these failures use construction machine simulator. Heavy equipment refers to heavy-duty vehicles, specially designed for executing construction task, most frequently ones involving earthwork operations. They are also known as heavy machines, heavy vehicles, construction equipment, engineering equipment, heavy trucks, or heavy hydraulics. They usually comprise five equipment systems: implement traction, structure, power train, control and information. Heavy equipment functions through the mechanical advantage of a simple machine, the ratio between input force applied and force exerted is multiplied. Some equipment uses hydraulic drives as a primary source of motion.

Construction Machinery and Related Equipment Manufacturing: Internal combustion engines and fluid power cylinders, actuators, pumps, control valve & motors for use in heavy off-road use in construction, mining, forestry, agricultural, marine, and other equipment. The selection of the appropriate type and size of construction equipment often affects the required amount of time and effort and thus the job-site productivity of a project. It is therefore important for site managers and construction planners to be familiar with the characteristics of the major types of equipment most commonly used in construction [1].

In order to increase job-site productivity, it is beneficial to select equipment with proper size and characteristics most suitable for the work conditions at a construction site or area. No single machine is perfect for every application or site condition. Whatever your job needs, Empire CAT's new heavy equipment sales team can pull the right system together from the largest selection of construction machinery and equipment in the industry [1].

It suggest that simulation-based training (SBT) offers many advantages as an approach for management education, and in an effort to guide and encourage its appropriate use, to provide several practical guidelines regarding how best to implement simulation-based training in the classroom. Simulation-based training encompasses a continuum of technology intended for training purposes.

Simulation, in general, is any artificial or synthetic environment that is created to manage an individual's (or team's) experiences with reality. Training is the systematic acquisition of attitudes, concepts, knowledge, rules, or skills that should result in improved performance. As a consequence, simulation-based training can be conceptualized as any synthetic practice environment that is created in order to impart these competencies (i.e., attitudes, concepts, knowledge, rules, or skills) that will improve a trainee's performance. Simulation-based training is just one training approach that particularly focuses on providing trainees with the opportunities to develop and practice the required competencies and receive feedback [9].

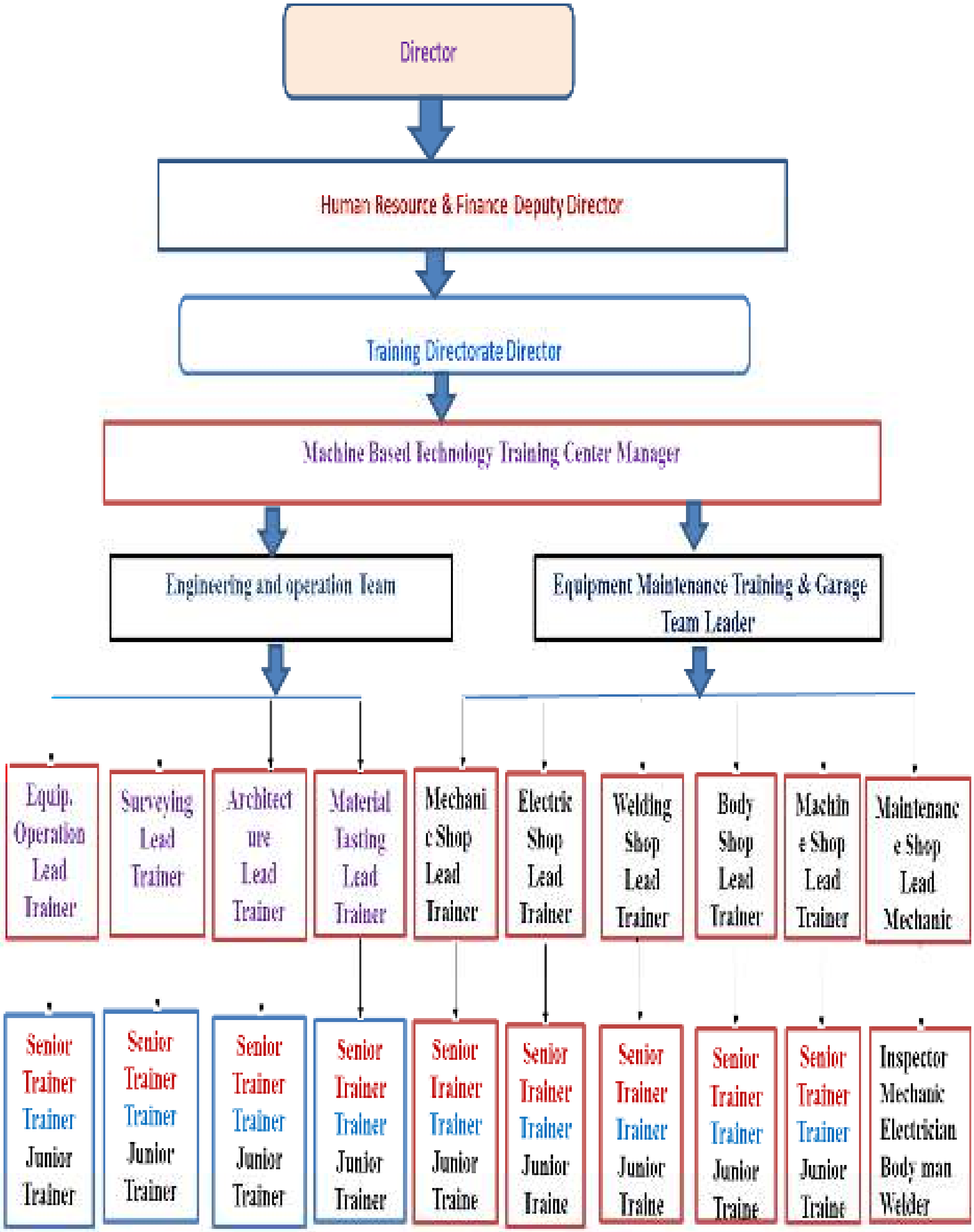

Fig.1.1 Organizational Chart of Ethiopian Roads Authority AMBTTC [4]

1.1 Background of ERA and AMBTTC

Ethiopian Road Authority (ERA) established in 1951 and Alemgena Machine Based Technology Training Center (AMBTTC) establishment in 1956. AMBTTC has been contributing a lot to construction Industry in general and the road construction sector in particular by providing skilled Middle level construction technicians, Heavy construction Machine operators and Equipment maintenance technicians as a sole public organization under the auspices of the Ethiopian Roads Authority. Currently the center has updated its training curricula in line with the new Occupational Standard developed for road construction. Besides, familiarization, refreshment, and tailor made trainings the center is receiving trainees with construction technology, mechanics, electronics education back ground, 10th grade and above as per the new educational policy and trains focusing mostly on practical issues & support to graduate with Certificate of Competence (CoC) after trainees proved themselves competent through Competence Assessment which is handled by Competence centers. Starting from 2011 until now more than 6000 trainees have trained on various occupations and also assessed for competence. AMBTTC is well equipped with modern technological Teaching aid like state-of the –art heavy construction machinery simulators and up -to-date machineries for practical trainings. The brand of these simulators is 5DT and imported from South Africa. The instructors engaged in training have much years of experience in construction industry and well equipped with the knowledge of modern construction technology in the fields of their respective assignment.

1.2 Statement of the problem

During training of construction equipment (heavy duty vehicles) the new trainees do not control the machine easily. They operate the machine improperly, so this is the cause of machine failure, therefore the downtime of machine increase during maintenance, and also increase the downtime due to lack of spare parts. In addition serious accident occurred on the machine and trainees. The training cost is increased day to day because of the cost of fuel, oil, spare part, etc. The training cost increased automatically when the fuel price increased. To reduce the training expense, fuel and oil consumption, emission, machine failure, training time, etc. better give the training by combining conventional construction equipment with construction machine simulator (Simulator-Based Training). Machine fails due to push or excavate unbalanced load, e.g. hydraulic hose burst, Engine over heat due to unbalanced load pushing beyond the capacity of engine output power, damage of implement tools due to improperly use, working parts are loose, wear or broken easily, leakage of hydraulic, engine, transmission, oil etc. And also accident occurs during training e.g. collision with fence, other machines, etc. so these needed high maintenance cost to repair the damaged parts.

1.3 Objectives of the study

1.3.1 General objective:

- The general objective of this thesis is the comparative study of CT to SBT in ERA at AMBTTC to increase quality and quantity of construction equipment operator by using modern training system with a minimum training cost / expense to provide skillful construction machines operator for the construction sector or road sector throughout the country. And identify the problem of both training and improve the training by optimum training method.

1.3.2 Specific objective

- To determine the amount of fuel and oil consumption of both training, and clearly show their difference.
- To give detail explanation on their weakness and strength of simulator-based training by using recorded data, questionnaire, direct observation and oral question.
- To show better training way from the conventional and simulator-based training.
- To measure knowledge and skills by interview, direct observation and recorded time of each round from simulator trainers.
- To prepare a new training strategy for effective training.

1.4 Significant

Ethiopia is one of the developing countries, and it needs many construction machine and operator. So it should be establish new construction equipment simulator training centre to train enough operator throughout the country. The research result is very important for AMBTTC and any other governmental or private training centre and also the one who wants to open a new modern construction equipment operation simulator-based training center. A direction can be obtained for better construction equipment simulator based training, because of the technology is improving and updating. Therefore the significant of this study is useful for the training sector throughout the country.

1.5 Scope of the study

Construction equipment performs heavy duty with in short period of time. So it needs skillful operator to operate the machine. But there are many problems during training such as machine failure and accident. So the scope of the study is to show the benefit of simulator based training compared to conventional training of construction machine operation training. And also detail analysis of the training by using direct observation, interview and questionnaire.

1.6 Limitation of the study

The research took place only at ERA at AMBTTC. Simulator training is given in Sure Construction at Addis Ababa and Rise Engineering in Tigray region, but the researcher could not include those training center. And also the scarcity of reference materials and research papers relevant to construction equipment simulator-based operation training. However, it was attempted to make the study as complete as possible.

CHAPTER TWO

LITERATURE REVIEW

2. CONSTRUCTION MACHINE TRAINING

2.1 Operational Requirements

2.1.1 Operators.

Allow only authorized personnel to operate mobile equipment. Assign operators only to equipment they are qualified and licensed to operate. Provide operators with the instructions and training that their jobs require and ensure that operators:

• Meet the physical requirements of their job

• Meet the DOT licensing requirements for on-highway operations.

• Do not operate mobile equipment for over 12 hours in any 24-hour period

• Comply with applicable operating instructions, limitations, regulations, and written safety programs and plans

Do not allow the operation to begin or continue if the operator is not physically,

Mentally, and emotionally capable of operating the vehicle or equipment safely[26].

2.1.2 Operator Training

Train and evaluate employees before assigning them to operate powered industrial trucks. Train operators include the name of the operator, the date of the training, the date of the evaluation, and the identity of the person(s) performing the training or evaluation in the certification that the training and evaluation has been completed. A training program must consist of the following three parts:

• Formal instruction that includes lectures, discussions, interactive computer learning, videos, or written material.

• Practical, hands-on training that includes demonstrations performed by the trainer and practical exercises performed by the trainee. Conduct the training on the particular equipment the trainee will be operating on the job.

• Evaluate the operator’s ability to handle the truck safely in the workplace [26].

What determines proficiency for an operator of heavy equipment and specialty tracked equipment?

(a) Service policy (Authorization, Training, and Safety Requirements) states that before operators may operate heavy equipment for the Service, they must complete the eight hour Heavy Equipment Safety Training program (or approved equivalent), which includes three hours of pre-class work, four hours of classroom work, and one hour of operation time.

(b) Supervisors are responsible for the safety of operators and accurate documentation of the operator's proficiency by recording it on the form.

(c) We encourage supervisors to develop a means of documenting the employee's progression of proficiency before allowing him/her to operate independently on projects with a high risk factor for accidents (examples of high risk operations include, but are not limited to, slope operations, drop offs, operating in wild land fire applications, etc.). Supervisors can assist employees to gain proficiency in several ways. Examples include, but are not limited to; pairing new operators with senior operators and having them attend Maintenance Action Team (MAT) projects.

(d) The operator must be able to perform common tasks and be knowledgeable of all instruments, equipment controls, and equipment limitations (restrictions) to operate in varying terrains and environmental conditions they typically encounter. The operator must be able to react instinctively in an emergency situation should the need arise. Proficiency can only be achieved by time in the seat operating in various situations. We cannot measure it only by the amount of time they spend, but we must consider the quality as well when factoring in the operator's ability to comprehend the limitations of each type of machine he/she is operating and their own limitations [27].

2.1.3 Construction Safety Training System (CSTS)

To reduce the number of accidents and injuries in construction industry, employers must ensure that all workers are trained in basic workplace safety. The Construction Safety Training System assists employers by offering flexible training options. CSTS equips workers with practical skills and proven prevention strategies to stay safe on the job. That's what makes it one of the leading programs [27].

The Challenge:- Workers on roadway construction sites face the risk of death or serious injury from passing motorists, construction vehicles and equipment. From 1992–2000 there were 910 worker fatalities in work zones, and over 90 percent of these deaths involved a motor vehicle, a piece of construction equipment, or both. Workers on foot accounted for more than 500 of these work zone deaths [27].

The goal of a Heavy Equipment Safety Instructor

Each instructor's goal is to provide instruction and materials that equip employees with sufficient knowledge, skills, and abilities to operate heavy equipment in safe condition. Achieving these goals impacts not only the operator, but the many visitors who are close by during our operations. Meeting these goals also gives operators a greater knowledge of maintenance requirements for heavy equipment, which extends the useful life of the equipment and minimizes repair and replacement costs. The instructor's knowledge and skills are important resources for the Region and for the Service to support equipment acquisition and readiness, and to identify resource capabilities and limitations [27].

Worker Participation in Developing Training Programs

Training programs help ensure that safe jobs are no accident. Safe jobs exist because employers make a conscious decision, each and every day of the year, to make protecting workers a priority in the workplace. When this effort includes participation from workers, workplace injury and illness prevention programs are improved because workers can identify missing safety procedures, make recommendations for changes and help ensure a safe workplace. When workers have a voice in the workplace and input about how training is developed, training programs are more accurately focused on specific work place hazards [27].

2.2. Types and Purpose of Construction Equipment

2.2.1 Bull Dozer

A bulldozer that has blade at the front and ripper at the rear with crawler type undercarriage can doze and dig strongly. The main ground pressure is low and it is possible to work at weak ground or rough terrain. Dozers are machines designed primarily for cutting and pushing the material over relatively short distances [5].

Crawler Tractors are designed for finish grading and general dozing. They can be equipped with either open or enclosed ROPS (Roll Over Protection System) cabs as well as numerous styles of blades, ripper sand winches. Common options include over size pads, hydraulic third valves, cab equipment including AC, heat and defrosters and work lights [7].

Fig.2.1 Bulldozer machine

Bulldozer is the most important equipment on construction projects. It can perform large number of operation with minor changes at the blade. E.g. Straight dozer, Push dozer, Bucket dozer, Tree dozer, Rack dozer, U-dozer, Tilt dozer, Angle dozer.

Bull dozer:- The heavy blade attached to the tractor pushes the material from one place to another. The tractor can be of the crawler or the wheeled type.

Classification of bull dozer

Position of blades

a) Bull dozers in which the blade perpendicular to the direction of movement.

b) Angle dozers in which the blade is set at an angle with the direction of movement.

Applications:- Bull dozers are mainly used for the following operations

1. For spreading the earth fill.
2. back-filling trenches at construction sites by dragging the earth from one place to another place.
3. Clearing construction sites.
4. Maintaining haul roads.
5. Clearing land from the trees and stumps.
6. For opening up pilot roads through mountainous and rocky terrains.

2.2.2 Wheel Loader

Come in various sizes and are designed for fast movement, clearing and loading of materials. They can be equipped with either open or enclosed ROPS (Roll Over Protection System) cabs as well as numerous styles of buckets and accessories. Common options include additional counter weights, hydraulic third valves, cab equipment including AC, heat and defrosters and work lights. Wheel loader is convenient for transporting and mostly applicable for to load soil, sand, borrow etc [7].

Fig.2.2 Wheel Loader

Fig.2.3 A Loader during loading on dump track.

2.2.3 Excavator

The excavator is used for loading and digging of earth that is below the machine. The upper swing unit can rotate 360°. Excavators are designed for multiple applications including clearing, backfilling, excavating and loading. They can be equipped with numerous styles of buckets and accessories. Crawler models are often equipped with hydraulically extend able tracks and oversize pads. Outriggers are standard on wheeled models and may be manual, power up and down or hydraulically extendable. Common options include raised operator station, oversize pad, additional counterweights, hydraulic third valves, cab equipment including AC, heat and defroster sand work lights [7].

Fig.2.4 Excavator

2.2.4 Backhoe Loader

The Backhoe loader has a front bucket. It is used for light digging and loading of earth and sand mainly. It has also a backhoe attachment unit can rotate 180° used for excavating a lot kind of works. Back hoe Loaders have the versatility to dig like an excavator and load like a wheel loader. Major options include extendable booms all wheel drive, (AWD) (Extend hoes), semiautomatic (Power Shift) transmissions and hydraulic and mechanical quick couplers [7].

Fig.2.5 Backhoe loader.

2.2.5 Grader

The motor grader is used for leveling, digging and repairing of unpaved road. As the blade can be controlled accurately, the precise cutting is possible. Motor Graders are designed for long pass finish grading. The long wheelbase design allows for steep angling of the moldboard (plow) [1].

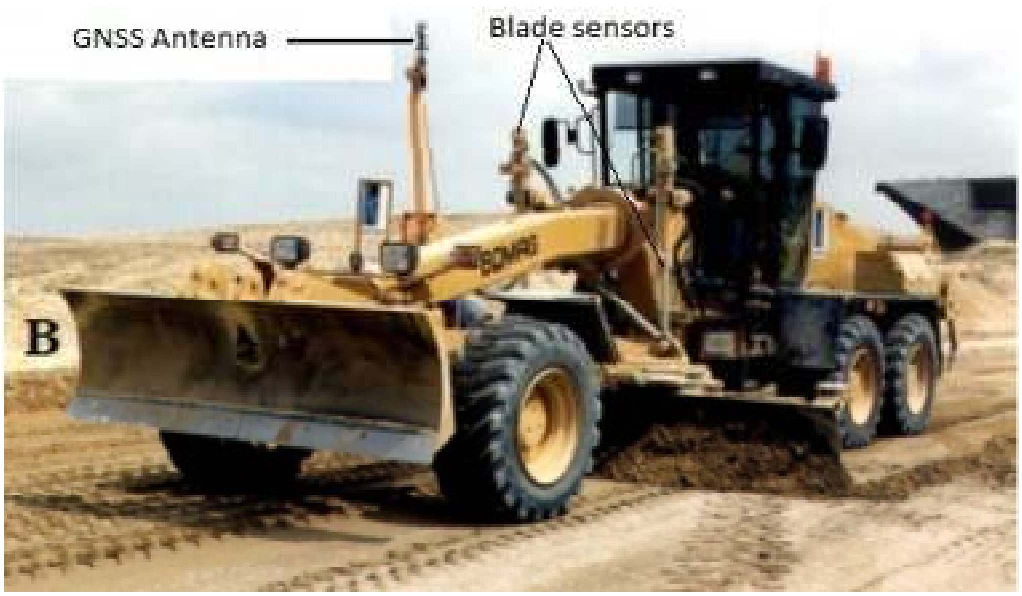

Fig.2. 6 Grader operation by automatic blade control system

The function of grader equipment is to bring the earthwork to the desired shape and elevation. Major types of grading equipment include motor graders and grade trimmers. The former is an all-purpose machine for grading and surface finishing, while the latter is used for heavy duty construction because of its higher operating speed [2].

2.2.6 Compactors

The function of compaction equipment is to produce higher density in soil mechanically. The basic forces used in compaction are static weight, kneading, impact and vibration. The degree of compaction that may be achieved depends on the properties of soil, its moisture content, the thickness of the soil layer for compaction and the method of compaction.

Supply of water forms an integral part of the compaction operation. Dry soil needs additional water to reach the correct moisture content at which level the soils are more effectively compacted. In most cases this involves transporting water from an appropriate source to the work site. Water tanks or bowsers are normally fitted on a flatbed truck or mounted on wheels and towed by a tractor In order to fill the water bowser, it needs to be equipped with a pump and the appropriate amount of hoses.

A spreader is often mounted directly to the tank. If large quantities of water are required, it may be more efficient to carry out the watering of the soils manually with a hose [14].

Fig.2.7 Asphalt Vibratory Compactors are designed for compaction and finishing of road surfaces.

Fig.2.8 Pneumatic Asphalt Compactors are designed for compaction and finishing of road surfaces.

2.3 Hydraulic System

All implement tools of equipment's like blade, ripper, bucket, arm, etc. are operated and controlled by hydraulic system. Hydraulic system consists of actuators, pump, tank, selector valve, hydraulic oil, filter, pressure regulator valve, safety valve, Cooler, Accumulator, hose, pipe, fitting, pressure and temperature gauges, etc.

The extensive use of hydraulics to transmit power is due to the fact that a properly constructed hydraulic system possesses a number of favorable characteristics:

- A hydraulic system eliminates the need for complicated systems using gears, cams, and levers.
- Motion can be transmitted without the slack inherent in the use of solid machine parts.
- The fluids used are not subject to breakage as are mechanical parts.
- Hydraulic system mechanisms are not subjected to great wear.

If the system is well adapted to the work it is required to perform and is not misused, it can provide smooth, flexible, uniform action free of vibration and unaffected by variation of load. Hydraulic systems can provide widely variable motions in both rotary and straight-line transmission of power. The need for control by hand can be minimized. In addition, they are economical to operate [20].

2.4 Maintenance of Equipment

Regular maintenance of the equipment prevents breakdowns and ensures a long equipment lifetime. The project manager must ensure that:-(a) The operators are aware of the required maintenance and service of their equipment,(b) That the site has access to adequate workshop facilities, and (c) That service and repairs are carried out at the right time. Each piece of equipment comes with an operator manual, which specifies when and where lubrication and adjustments are required. A heavy equipment operator drives and operates heavy equipment used in engineering and construction projects. Typically only skilled workers may operate heavy equipment, and there is specialized training for learning to use heavy equipment [7].

The control and information systems: - Enable the operator to direct and control all the other systems and provide information to guide operations or to monitor the performance and health of the equipment. These are:-*Pre-Operational, Pre-start & post operation checks.*

2.4.1 Pre-Operational Checks

- ***walk around inspection -*** While walking around the machine observe any foreign object or animal on, under or near by the machine.

- ***Physical checking -*** Check for loose, worn out, damaged, broken parts. Engine oil level,Hydraulic oil level, Radiater water level,Transmission oil level, Fuel level and also show Dust indicator and Air cleaner. If Air cleaner has dust,clean by pressurized air.

- **Check fan belt tension -** Check the tension of the belt by pushing with your thumb down ward. The slackness should not exceed one inch. If not adjust to the specified limit.

- **Inspection of electrical system -** Turn on the switch for each light and assure that the light is properly lit up.
- **Check Battery level & clamp -** Check the level of electrolyte is above the plate/labeled at maximum mark on the case. Check battery clamp not loose and not dirty.

2.4.2 Pre-start checking

Switch on the ignition key andWatch the indicators, gauges & instruments. Check the Illumination of parking brake warning light, Oil pressure warning light, battery charge warning light, etc. if they are not lighted check electrical connections.

If it is correct all the gauges - Start the engine, listen the engine sound normal or not, watch the indicators, gauges & instruments reading with prescribed range. After start the engine, check liquid air leakages again.

2.4.3 Post-operation check

Is a type of maintenance which has to be performed daily after operation of any equipment. It include mainly walk around inspection by observing physical checking such as leakage of exhaust gas pipe, generally roller condition & during operation loosened, worn out, lost& damaged parts.

- Park the machine on level surface.
- Run the engine in idle about five minutes.

2.5 Problem of Training

Most of the construction machines are not adequate seat or space in cab when the trainer guide or instruct the trainee at the time of machine operation. Then during training of construction equipment (heavy duty vehicles) the new trainees do not control the machine easily. They operate the machine improperly, so this is the cause of machine failure, there for the downtime of machine increase during maintenance, and also increase the down time due to lack of spare parts.

Some of the failures are as follow:

- Engine over heat due to unbalanced load pushing beyond the capacity of engine output power.
- Damage of implement tools due to improperly use
- Working parts are loose, wear or broken easily.
- Leakage of hydraulic, engine, transmission, oil etc.
- And also accident occurs during training.

  So the solution may be to reduce machine failure and accident, support the training by advanced construction simulator-Based machine.

2.6 Construction Equipment Simulator

Construction machine Simulator is a computerized machine used to give training for machine operators. The trainees train by simulator machine before practice to the real machine on the field. Construction equipment simulators have been developed by equipment manufacturers to train operators for the stressful and tough construction environments without the need to employ an actual machine. Eliminating machine use saves fuel, mechanical wear, and the inherent risks of damage to machine and man. Simulators are currently available for a variety of construction equipment types including bulldozer, motor graders, excavators, backhoe loader, cranes, haul trucks, and wheel loaders, etc. They can be used to familiarize operators with new equipment controls, evaluate potential operators, or develop operator skills in terms of productivity and safety. And also simulator can be used to air craft, maritime, military weapon, etc. training.

Simulation:- simulation is a method based on 'here and now' experience shared by all learners. It involves assigning definite roles to each participant and having them act out a situation according to the given roles. It is carried on long enough to generate responses and reactions based on real feelings as participants need to genuinely 'get into their role'. However, learning takes place without any serious risk because the situation is after all 'make-believe' [21].

Advantages

- Allows an exploration of real life situations, social processes and behaviors in a relatively non threatening manner/ situation.
- It allows for the study of very complex social processes.
- It is entirely controlled by the learners' pace.
- It involves activity and universal participation.
- Learning takes place at the awareness level

Disadvantages

- It requires that participants cooperate and internalize the roles.
- It is a difficult method and requires an experienced and skilled adult educator to conduct it.
- Mismatch of roles may lead to poor performances by the learners.
- Critical skills are needed to handle feelings generated in the process.

2.6.1 Development of Simulator for excavating system

Nowadays, many safety accidents are occurring at construction sites. Excavation accidents that concern construction machines are among the leading safety hazards in construction accidents. Therefore, the need for excavation experts is increasing. In this paper, an excavator simulator is presented for training human operators and for tasking in virtual earthworks. In this system, the operator controls a virtual excavator in a control station with a joystick, pedals, a graphic display, and sound effects. The operating environment that was the same as the actual excavator test environment was realized for the training of excavator operators. This system consists of hardware, which include the motion and control systems, and software, which is the image system.

The simulator in this study, which was developed for training of excavator operators, is a virtual reality system that models the excavator and construction site based on the actual design information and controls the excavator using a joystick and a pedal. This simulator is meaningful in that it can be used by experts as well as ordinary people via 3D modeling of the construction site. Not only the excavator but also its boom, arm, and bucket can be controlled as necessary to ensure smooth excavation operation. By using this simulator to train skilled operators, the fuel cost of the excavator can be reduced, and its safety can be improved. This excavator simulator will be combined with the task planning algorithm of the intelligent excavation system (IES) to improve the simulation level to that of the actual excavation work [22].

2.6.2 Structure of the Simulator

As shown in Figure 2.9, the simulator structure consists of the motion system (Hard Ware) for the excavator operation; the image system (Soft Ware) for the virtual environment modeling, the work the hardware of this simulator has image and motion systems. The image system has a 50” LCD monitor at the operator seat, which shows the motion synchronized to the operation by the operator. As shown in Figure 2.9, the motion system has a hydraulic motion base with 6 degrees of freedom and a seating part. SIMUINE’s hydraulic motion base, which is driven by a brushless servo motor with a 1,500kg payload, was used. The motion system was 3 m long, 2 m wide, and 2.5 m high. The seat part of the actual excavator was used. The station, and the total control system that includes the ADC controller. The front cover was not attached to ensure the operator’s good vision, and a joystick and a pedal were installed. The image system and operation in the seat part were synchronized [22].

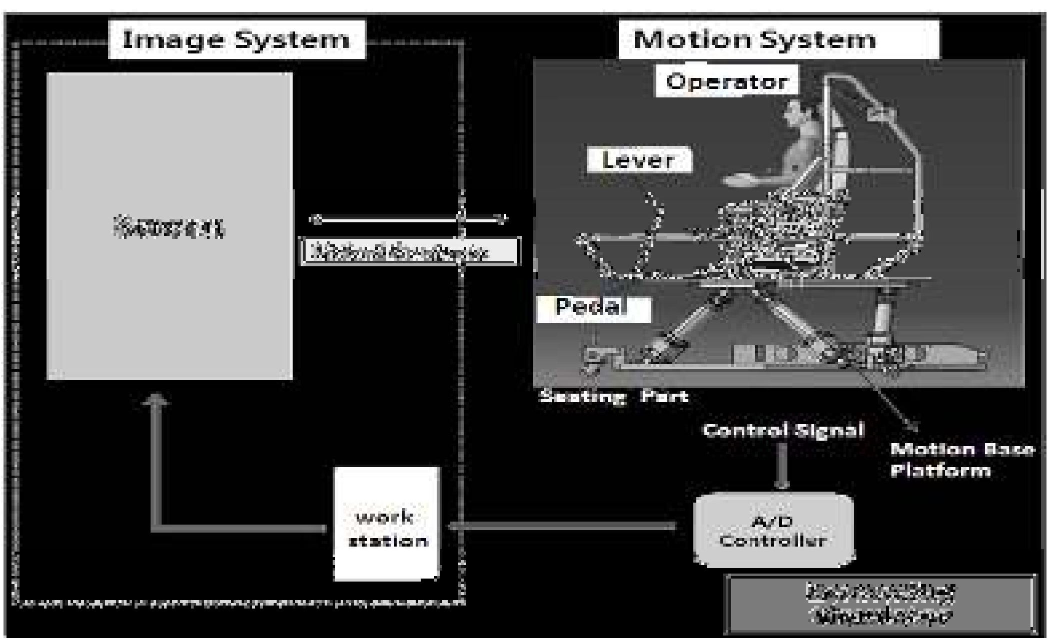

Fig. 2.9 Structure of the Excavating Simulator

Control system:- the control system consists of the motion control unit (MCU) and the simulator motion control program (SMCP), which are required to control the motion base; the motion solver system, which is used to synchronize the screen, gauge, and sound; and the host system, which is used to externally control the overall system. When the operator moves the joystick and pedal in the motion system, the motion is synchronized with the image system in real time [22].

2.6.3 Driving simulator

Driving simulation has much to offer as a training tool. In particular, relative to training in an actual vehicle, simulation provides trainees with the opportunity to practice a range of driving maneuvers in a safe, risk-free environment. Simulation also allows for greater quality of formal training in a given period of time. Exact situations needed to learn given skills are readily available, and more trials can be presented in a given time frame providing increased opportunity for skills practice (Morgan, et al, 2011; Thompson, et al 2009; Triggs, 1994). Realizing the potential benefits associated with simulation-based training is not a trivial undertaking. While there are many types of simulator available, a system with a high level of physical realism is not necessarily better when it comes to training (e.g., Triggs, et al 2008). The level of realism that is appropriate, and indeed whether simulation itself is appropriate and likely to be effective, will depend on several considerations, including the overall purpose of the training, the specific task to be trained, cost, the trainees, and the capability and motivation of the trainer. Moreover, for best effect, simulators need to be integrated into the total training program, which involves several training methods, strategies and tools, for addressing the overall training requirements (Salas, et al 2006; Trigg's et al., 2008) [11].

2.6.4 Current Issues and Future Directions in Simulation-Based Training

The complexity and dynamicity of the current business environment increasingly requires employees to possess competencies that are not only specialized but also flexible enough to be adapted to changing circumstances. Research suggests that to develop this adaptive expertise, trainees should be active participants in the learning process and learning should occur in a meaningful or relevant context (Bell & Kozlowski, in press; Cannon-Bowers & Bowers, in press; Moreno & Mayer, 2005). Recent advances in technology have positioned simulations as a powerful tool for creating more realistic, experiential learning environments and thereby helping organizations meet these emerging training challenges (Bell & Kozlowski, 2007). The result has been an increased prevalence of simulation-based training in both academia and industry [11].

The increased prevalence of simulations is due, in part, to the many potential benefits they offer as a training medium. Like other types of distributed learning systems, simulations allow training to occur almost anywhere and anytime, and this flexibility can be used to reduce or eliminate many of the variable costs associated with traditional training, such as classrooms and instructors (Summers, 2004). Simulations also possess unique features that create the potential for instructional benefits not offered by other instructional mediums. For example, simulations can be used to create a synthetic- or micro-world that immerses trainees in a realistic experience and exposes them to important contextual characteristics of the domain (Schiflett, Elliott, Salas, & Coovert, 2004). Simulations can also be used as realistic practice environments for tasks that are too dangerous to be practiced in the real world or to provide opportunities for practice on tasks that occur infrequently (Cannon-Bowers & Bowers, in press) [11].

2.6.5 Simulation-Based Training Defined

Simulations are generally defined as artificial environments that are carefully created to manage individuals' experiences of reality. For instance, Jones (1998) defines a simulation as an exercise involving "reality of function in a simulated environment." Cannon- Bowers and Bowers (in press) note that an essential feature of simulations and other synthetic learning environments (e.g., virtual reality) is, "the ability to augment, replace, create, and/or manage a learner's actual experience with the world by providing realistic content and embedded instructional features." Although not all simulations utilize technology (e.g., board games, role-plays), our focus in the current article is computer-based simulations because of their growing use and the pressing need for research on their effectiveness. There are a number of constructs that conceptually overlap with simulations. For instance, *games* represent a specific type of simulation that features competitive engagement, adherence to a set of rules, and a scoring system (Cannon-Bowers & Bowers, in press; Teach, 1990). Thavikulwat (2004) notes that games and simulations are terms that are used relatively inter changeably (e.g., simulation-based games). Also, *virtual worlds* represent very elaborate simulations that allow for interactions among multiple players as well as between players and objects in the world (Cannon-Bowers & Bowers, in press). In the current article we use the term simulation-based training to refer broadly to all types of computer-based simulations that are used create synthetic learning environments [11].

2.6.6 Benefits of Simulation-Based Training

A number of emerging challenges, including globalization, economic pressures, the changing nature of work, and work-life issues, have combined to create a business environment that demands innovative, flexible training solutions (Bell & Kozlowski, 2007). Technological advances have served to position technology-based training applications as practical tools for addressing these challenges (summers, 2004). Technological advances have expanded both the breadth and depth of training technologies (Salas, et al 2002), and today's high-end technologies offer the capability to provide information-rich content and immerse trainees in high fidelity, dynamic simulations. This focus on technology is evident in the simulation-based training literature as many studies have focused on either describing the technological features of simulations (e.g., Summers, 2004) or on describing specific training systems and applications (e.g., Draiger & Schenk, 2004)[11].

2.7 How simulator training is structured

Trainees begin with familiarization with machine controls: trainees are drilled on the functions of each machine control until these movements become instinctive. Trainees then learn basic machine tasks and advance to more complex operations, in a simple but effective "building block" approach. In all cases, the simulators focus on tasks that mimic what trainees are likely to encounter on a real job site [9].

For each training module, the software captures data that summarizes how quickly and how carefully each jobsite task is performed, and including the following:

- Cycle times
- Loading and accuracy of implement placement
- Collisions with other equipment, etc.

Data generated by the simulator enables field trainers to clearly see areas where trainees need to improve, so they can coach trainees how to correct these weak spots. In AMBTTC there are ten simulators, from these four are hexagonal structures (fig. 2.10) and six are cubic structures (fig. 2.11).

Fig.2.10 Hexagonal structure Simulator in ERA at AMBTTC

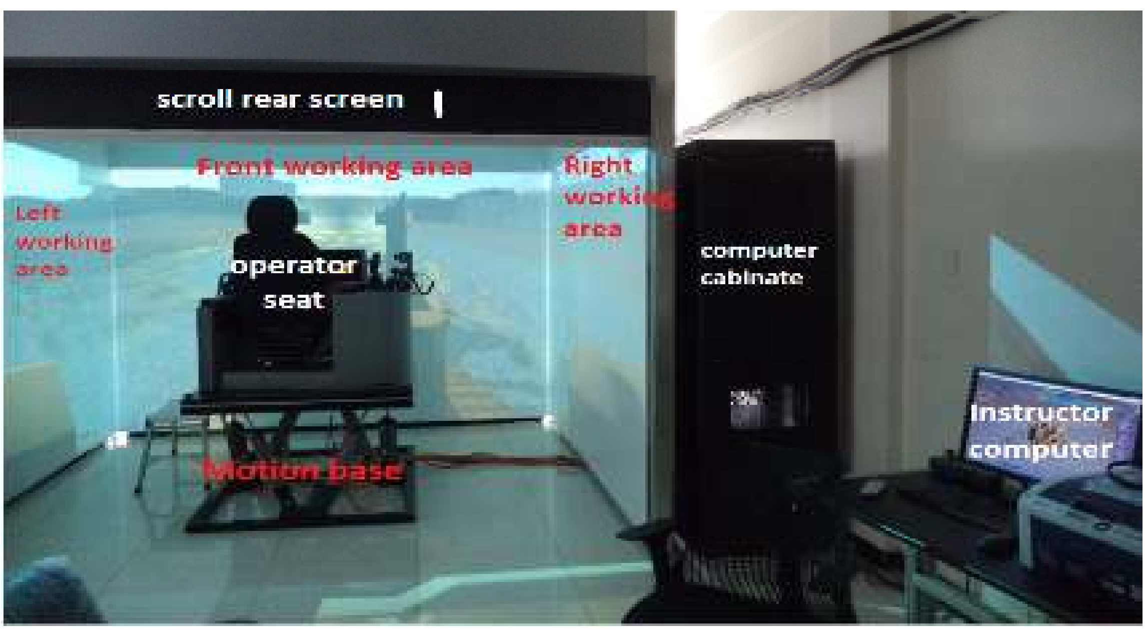

Fig.2.11 Cubic structure Simulator in ERA at AMBTTC

A number of customers have successfully used these simulators to identify operator candidates with the greatest natural aptitude prior to hiring them. This enables trainers to focus their time, money and manpower into hiring and training those individuals with the best natural operating ability. In settings like underground utility work, where operators are working around gas lines and fiber optic cables, having the safest, most proficient operators at the controls of your equipment is critically important [9].

2.8 Simulator included the following features

2.8.1 Real-life

The details create the experience. That is why the Volvo simulator uses inputs from real life. The simulation is based on a Volvo excavator, with all measurements, weights, specifications and sounds from the real one. All objects included in the simulation also have real physical values. The screen is mounted to the platform and follows all movements for a realistic field of high quality view. To obtain a realistic operator experience requires more than extraordinary software. A Volvo original operator environment enables the operator to develop correct instinctive behavior [9].

2.8.2 Feedback

An electric motion platform recreates all movements taking place in the simulation. Adding one further sensory perception enables the operator to achieve even better training results. The fact that you can actually feel the machine's movements while working in sloping terrain is an essential factor for training [9].

2.8.3 Dynamic training

The exercises included are developed in co-operation with experienced instructors ensuring high quality training. This step-by- step exercises focus on training skills and safety in practice. They are divided into four different blocks: machine knowledge, machine handling, task training and risk training. The operator must satisfactorily achieve the goals of the current exercise before proceeding to the following one [9].

2.8.4 Why use simulators in operator training

Using a simulator in training is not just about optimizing and improving operator training. It is also about health and safety at work and caring for the environment. Simulator-based training is good for your business and the environment. By helping to eliminate costly mistakes and pollution, you are contributing to a better environment. Your operators can train on dangerous and uncommon situations, without risk of injuries. When facing the hazards of real life, they are well prepared to meet them [9].

2.8.5 Training with an environmental awareness

Every hour using the simulator instead of the machine, means less impact on the environment. Besides that, the operator learns how to operate the machine in an ECO-efficient manner. Data such as fuel consumption and emissions are constantly being measured for evaluation. The fact that the operator trains in a classroom environment, knowing that there are no risks or external distractions enables a fast learning process. The operator can focus more on learning the skills instead of worrying about what might happen [9].

2.8.6 Simplify and focus instructor's work

The training simulator is designed to simplify day-to-day operations and enable the instructor's main focus to shift to providing training on the actual machine. In the simulator the operators train all by themselves while the instructor focuses on training them on the machinery itself. Later on, the instructors can see the operator's performance and progress using an ordinary PC. It is also a very good tool to integrate with group dynamics. The inexperienced operators can train more in the simulator than the experienced ones [9].

2.8.7 Economy

With the simulator care is translated into action. Care about your operators and the environment. The economic benefits are a by-product of this approach - but what a by- product! Using the Volvo training simulator decreases wear and tear, fuel costs and machine damage. Add to this a more efficient use of resources and the invaluable experience given to the operators [9].

2.8.8 Training focuses on skills and safety risk management

The training focuses on learning the skills and safety in operation that an excavator operator needs to know. A step-by-step training program, developed in cooperation with experienced instructors, ensures that the operators learn the right things - the right way. An evaluation module is included in the training programmer, all to simplify and help the instructor in their daily work. Experience comes from a previously perceived situation or event. Imagine the possibility of providing your operators with that experience, in a classroom environment, without exposing them to risks. Such care for human resources is invaluable. The operator also learns the elements of risk that come with the job and how to handle them [9].

2.8.9 Machine knowledge and handling

Before even operating the simulator, it is important to know the different components and check points of the machine. Basic exercises where the operator, for example, learns to use functions simultaneously, moving and placing the machine and connecting attachments.

Step-by-step, the operator learns how to execute a specific task, including safety and risk assessments that may arise. The operator learns the skills and risks in digging a trench in the country or in a city environment [9].

Fig.2.12 Dozing operation in the simulator by a dozer in ERA at AMBTTC

Fig.2.13 Excavator loading on the dump truck in the simulator in ERA at AMBTTC

2.8.10 Evaluation

Trainees are prompted to log in when using the simulator, enabling a powerful evaluation module. During all training, extensive data collection is carried out (e.g. fuel consumption, tire wear and tear, collisions, mistakes) to help the instructor in the work of evaluation [9].

The advanced training simulator focuses on safety at all levels. All exercises include potentially risky and dangerous situations which can occur while executing the job. Different tasks and environments mean different risks. There are also exercises dedicated to common risky situations e.g. loading excavator onto a low bed trailer or how to react to a landslip [9].

2.9 Advantage of simulator

- Reduce frequent machine failure.
- Increase machine durability.
- Decrease operating cost (maintenance cost, fuel consumption etc.)

- Reduced emission.
- The trainee can easily understand and manage the training.
- The trainees can get adequate knowledge.
- Reduce machine contact/practice duration in the field training.
- Reduce total training cost and total training time.
- Can introduce to the trainee for machine control/machine guidance in unmanned construction operation. Remote control type construction machine used in dangerous areas where there is a risk of secondary disasters. The operator performs as a simulator while the actual work is done on the site at far distance, the communication between operator and machine through GPS (global position system)&GNSS(global navigation satellite system)instruments[9].

Fig.2.14 Unmanned construction machine in Japan.

Table 2.1 The difference between conventional and simulator-based training**.**

No	**Conventional training**	**Simulator-Based training**
1.	Trainee can't operate risk area.	Trainee can operate risk area.
2.	The trainee can get opinion from trainer/other trainee.	Each trainee errors recorded during operation and finally the trainee can show his error in soft/hard copy.
3.	There is no trigger failure. The gauge only show, when actual problem occurs.	The trainee can learn trigger failure (during machine failure gauges, indicators and alarms show every defect on the dash board).
4.	It is difficult to operate during rain and muddy sites.	Can operate any weather condition like rain, slippery, dust, etc.
5.	Take long period of time to get much knowledge.	The trainees get much knowledge in a short period of time.
6.	Use fuel as a source of power, etc.	Use electricity as a source of power, etc.

2.10 Simulator Based compared to conventional Training

Trained operator perform:- At Volvo Construction Equipment, we understand that today's customers do not buy machines - they buy productivity. While the Volvo machine is the enabler, it's up to the skills of the operator to get the job done safely, efficiently and cost effectively. This is why we have developed advanced training simulators for Volvo Construction Equipment. Simulator-based training helps to train your operators for a more productive and profitable for machinery ownerships [9].

Exercises and training programs: Our advanced training simulators for Volvo Construction Equipment feature a multitude of different exercises, each handcrafted to focus on a certain operator skill or ability. The training instructor can either use one of the predefined Volvo Training Packages or create tailor made exercise packs for different student groups· Our simulator-based training for Volvo Excavators, Volvo Wheel Loaders and Volvo Articulated Haulers includes a basic training program. It familiarizes operators with the controls &functions of the relevant machine, with particular focus on basic operating methods and skills [9].

CHAPTER THREE

3. MATERIAL AND METHODES

3.1 Material of the study

This research (experiment) included the following list of materials :- equipment and materials in ERA at AMBTTC had the following things: lecture room (safety, technique, operation, material selection, etc.) , actual construction equipment (Bulldozer, Loader, Grader, Excavator, transport vehicles, etc.), practical training area, simulator machines, and all necessary things (fuel, oil etc. consumption), computer, flash, paper, recording pad, pen, questioner, printing and photo copy payment, transportation payment, allowance or payment to follow the training at site, etc.

The study (experiment) was very important to ERA at AMBTTC. The training center has actual training equipment, simulator machine, trainers, trainees and all necessary data were available. Currently in ERA at AMBTTC there are two bulldozers, three loaders, four excavators and four graders and also two hundred trainees. The duration of each training took two months.

The organization gave the training for the first batch by conventional *construction machinery* and gave the training for the second batch by simulator-based training that means almost one-$3^{rd}(1/3)$ of the training given by simulator machine and two-$3^{rd}(2/3)$ of the training given by conventional machinery, this is the optimum division, but in other simulator the division may differ.

Then the researcher recorded all data during both training. The data include:- total fuel consumption, operating time of the machine, number and type of failure of the machine, total training time in days and hours, and also prepare questioner's and oral question for trainee's and trainers, in addition observation of the trainees ability, etc. and finally recorded how many trainees pass or fail in the assessment. So finally compare the result of the two groups. At the end of study/experiment the optimum one training is in detail explained by using tables and graphs. And also by using data analysis, direct observation, interview or scientific method, to make a comparison of the optimum one of conventional and combined conventional with simulator (simulator-based) training.

The entrance criteria of trainee's: Age ≥ 18, Education ≥ 10^{th}grade, sex : both (male or female), good physical fitness and healthy, etc.

3.2 Training method in ERA at AMBTTC

Five years ago the training centre gave the training by real machines only, but ERA at AMBTTC has given the training by conventional construction machine and construction machine simulator. In short this training is called simulator-based training. The two kinds of training as given below:

1. Conventional construction Equipment operation training.
2. Construction Equipment operation Simulator-based Training.

3.3 Method of Study

The method of research included:- data collection, direct observation, interview and questionnaire. Observe and follow conventional and simulator-based training at simulator room and practical area, and then collect and record amount of fuel consumption from the two training. By this data can draw the graph and show their difference. Prepare questionnaire and interview for trainees and trainers and then evaluate and analyse their response about simulator-based training. The method of comparing the conventional construction machine to construction machine simulator-based training are:- two kinds of training as given below.

1. The first batch (round) training is given by only construction machine and
2. The second batch (round) training is given by construction simulator machine and conventional construction machine.

The data required for the study (experiment) is collected from fuel and oils supply staff of the organization and also site trainers. Direct observation, oral question (interview) and questionnaires were helpful to get feedback on the strength and weakness of the existing training. Relevant data and information collected from trainers and trainees.

3.4 Data gathering tools

The desired information for the study was gathered through different tools. Accordingly, **questionnaires, interview, direct observation and document analysis** were employed to gather detailed information about the case under study.

3.4.1 Procedures of Data Collection

To answer the research questions raised, the researcher has gone through series of data gathering procedures. Accordingly, first of all, the intended questionnaires, interview, document analysis were prepared. The researcher made clear the objective of the study to all respondents to avoid unnecessary confusions and enhance the reliability of the study before getting the questionnaires filled and the interviewee responded. To get high rate of return in the desired time, the questionnaires were distributed with some extra questionnaires. To make the questionnaires understandable for trainees it was translated from English language to Amharic.

3.5 Capacity and method of training in AMBTTC

The average training duration of each group is two months. In the organization there are four construction equipment simulators. They are Dozer, Loader, Grader, and Excavator. Total numbers of trainee's are *two hundred* for four machineries for each batch. The advantage of advanced simulator based training is mentioned in the above, but we do not know how much percentage obtain (earn) from simulator-based training.

So the following questions are necessary for this thesis. At the end of study (experiment) these questions are explanation in detail with tables and graphs.

The questions are:-

- How much percentage of fuel consumption reduced?
- How much percentage of oil consumption reduced?
- How much percentage of maintenance cost reduced?
- How much percentage reduction in total training cost and total training time?
- How much percentage of emission reduced?
- How do the trainees understanding capacity from simulator training?
- How much extra knowledge and skills the trainee's gain from simulator training?

Table 3.1 Number of machine operator trainees in one Bache for four machines.

No.	Type of machinery	Number of trainees per Bache
1	Dozer	28
2	Loader	48
3	Grader	60
4	Excavator	64
	Total	**200**

The organization gave conventional construction machinery training for one batch and gave simulator-based construction machinery training for the other batch.

Then it is necessary to record all data during both training. The data include:- total fuel consumption, operating time of the machine, number and type of failure of the machine, total training time in days & hours, and also prepare questioner's and oral question for trainee's and trainers, in addition observation the trainees ability (by direct observation and CoC assessment result), etc. and finally recorded how many trainees pass or fail in the assessment. So finally the researcher compared the amount of fuel and oil consumption, training time, trainee skills, etc. from the two batch (round) training.

Table 3.2 Schedule of conventional construction equipment operator training

Week	Content of Training	Place & type of training
$1^{st}week$	Technical part, safety of Equipment, etc. (most of theoretical training and also identify the components in the show room)	Classroom training (theory)
$2^{nd}week$	Surveying, material selection, operational technique of Equipment etc. (theoretical training)	Classroom training (theory)
$3^{rd}week$	Familiarization, starting and shutdown procedure, implement tool movement, etc. (practical training)	Field training (practical)
$4^{th}week$	Basic machine movement, manoeuvring, etc. (practical training)	Field training (practical)
$5^{th}week$	performing basic tasks like dozing, excavating, digging, etc. (practical training)	Field training (practical)
$6^{th}week$	Performing levelling, foundation, material production, etc. (practical training)	Field training (practical)
$7^{th}week$	Perform ditching, mixing of material, loading, spreading, etc. (practical training)	Field training (practical)
$8^{th}week$	Perform levelling, ditching, foundation, loading, spreading, etc. (practical training)	Field training (practical)
$9^{th}week$	Time of assessment	Field

The drawback of CT: in the real machine there is only one seat, the trainer couldn't guide the new trainee properly, because there is no enough space inside the cab. Especially in doze machine the problem was very high, because the machine is very big and truck chain. So in terms of safety, the accident is very dangerous. The new trainees took long time to operate the machine in every activity.

Table 3.3 Types of machine, model, number of trainees and number of training machine in conventional training of one batch for four machines

No.	Type of machinery	model	Number of trainees	Number of training machine currently use for this training
1	Dozer	D6R D8R	28	2
2	Loader	CAT-950 CAT-950 Komatsu	48	3
3	Grader	CAT-140H CAT-140H Komatsu Komatsu	60	4
4	Excavator	CAT-320C CAT-320C CAT-320D CAT-320D	64	4
	Total		200	13

Note:- The study was include on all four types of machine training.

3.6 Conventional and simulator-based training fuel consumption

3.6.1 Conventional training total fuel consumption

Table 3.4 Conventional training total fuel consumption of each machine

Type of machine	Model	Average Fuel Consumption in litre(L)/day	Fuel Consumption in litre for one batch training (42 days for one batch training)	Total Fuel Consumption in litre for one batch training of four machines.
Bull Dozer	CAT-D6R	140	140*42 = 5880	15120
	CAT-D8R	220	220*42 = 9240	
Loader	CAT 950H large	85	85*42 = 3570	10290
	CAT 950H small	75	75*42 = 3150	
	KOMATSU	75	75*42 = 3150	
Grader	CAT 140H	95	95*42 = 3990	16380
	CAT 140H	95	95*42 = 3990	
	KOMATSU	100	100*42 = 4200	
	KOMATSU	100	100*42 = 4200	
Excavator	CAT 320C	80	80*42 = 3360	13440
	CAT 320C	80	80*42 = 3360	
	CAT 320D	80	80*42 =3360	
	CAT 320D	80	80*42 = 3360	
Total				**55230**

Total Fuel Consumption of Conventional Training ($F_{C(CT)}$)

$F_{C(CT)}$ = 15120 L + 10290 L + 16380 L + 13440 L

$F_{C(CT)}$ **= <u>55230</u> L**

Table 3.5 Types, model, number of machine trainees and number of training machine in simulator- based training of one Bache for four machines

No.	Type of machinery	Model	Number of trainees	Number of training machine currently use for this training	Number of training simulator currently use for this training
1	Dozer	D6R D8R	28	2	1
2	Loader	CAT950 CAT-950 Komatsu	48	3	1
3	Grader	CAT-140H CAT-140H Komatsu Komatsu	60	4	1
4	Excavator	CAT-320D CAT-320D CAT-320D CAT-320D	64	4	1
	Total		200	13	4

The training centre used all machines for both training, but in SBT number of failure reduced, for example: hydraulic hose burst, shear pin brake, oil leakage due to wear or lose parts, etc. So maintenance cost reduced in SBT compared to CT.

Note: In theoretical part all trainees trained together, but in simulator and real machine training, every trainee trained only their assigned machine (one machine).

Table 3.6 Schedule of simulator-based construction equipment operator training

Week	Type of Training	Place & type of training
1^{th} week	Technical part, safety of Equipment, etc. most of theoretical training and identify the equipment component in the show room.	Class room training(theory)
2^{nd} week	Surveying, material selection, operational technique of Equipment etc. (theoretical training)	Class room training(theory)
3^{rd} week	Familiarization, starting and shutdown procedure, implement tool control lever movement, manoeuvring, basic machine movement etc. (practical training in the simulator& field)	Simulator and Field training in shift (practical)
4^{th} week	Familiarization, starting and shutdown procedure, implement tool control lever movement, manoeuvring, basic machine movement etc. (practical training in the simulator & field)	Simulator and Field training in shift (practical)
5^{th} week	performing basic task like dozing, excavating, digging, material production, etc. and advanced task like levelling, foundation, loading, ditching, spreading, etc. (practical training in the simulator & field)	Simulator and Field training in shift (practical)
6^{th} week	performing basic task like dozing, excavating, digging, material production, etc. and advanced task like levelling, foundation, ditching, mixing of material, loading, spreading, etc. (practical training in the simulator & field)	Simulator and Field training in shift (practical)
7^{th} week	Perform advanced task like levelling, foundation, ditching, mixing of material, loading, spreading, etc. (practical training)	Field training (practical)
8^{th} week	Perform advanced task like levelling, foundation, ditching, mixing of material, loading, spreading, etc. (practical training in the real machine)	Field training (practical)
9^{th} Week	Time of assessment	At field

3.6.2 Simulator-Based Training Total Fuel Consumption

Table 3.7 Simulator-based training total fuel consumption of each machine

Type of machine	Model	Average Fuel Consumption in litre/day	Fuel Consumption in litre for one batch training(28 days per one batch training)	Total Fuel Consumption in litre for one batch training of four machine
Bull Dozer	CAT-D6R	140	130*28 = 3640	9240
	CAT-D6R	220	200*28 = 5600	
Loader	CAT 950H	85	85*28 = 2380	6580
	CAT 950H	75	75*28 = 2100	
	COMATSU	75	75*28 = 2100	
Grader	CAT 140H	95	95*28 = 2660	10920
	CAT 140H	95	95*28 = 2660	
	COMATSU	100	100*28 = 2800	
	COMATSU	100	100*28 = 2800	
Excavator	CAT 320C	80	80*28 = 2240	8960
	CAT 320C	80	80*28 = 2240	
	CAT 320D	80	80*28 =2240	
	CAT 320D	80	80*28= 2240	
Total				35700

Fuel Consumption of Simulator-Based Training of four machines ($F_{C(SBT)}$)

$F_{C(SBT)}$ = 9240 L + 6580 L + 10920 L + 8960 L

= 35700 L

The simulator needed electric power but ordinary electric power supply from Ethiopian electric power corporation (EEPC) was not constantly available. This will damage electrical components of simulator and also interrupt the training. So to eliminate this problem, use appropriate power supply generator.

Daily fuel consumption of the generator is 40 L.

Total fuel consumption of generator for one batch training is (40 L * 28 days) = 1120 L.

So 1120 L is added to fuel consumption of simulator-based training value (35700L)

There for

$F_{C(SBT)}$ = Fuel consumption of Simulator-Based + fuel consumption of generator

$F_{C(SBT)}$ = 35700 L + 1120 L

$F_{C(SBT)}$ = **36820 L.**

Calculate the difference of conventional to simulator-based training fuel consumption

Then the difference is **55230 L – 36820 L = 18410 L**

Final percentage of fuel reduction is **18410 L/55230 L *100% = 33.3%**

So simulator-based training can save 18410 L of fuel for one batch training of fuel from the total fuel consumption of convention training.

Generator fuel consumption of four simulators for one round was 1120L. Therefore the average fuel consumption of one simulator was 1120L/4 = 280L, so that 280L is added to each machine of simulator-based training.

Table 3.8 Generator and field training fuel consumption.

Type of machine	Simulator-Based Training fuel consumption of each machine
Dozer	9240 + 280 = 9520 liter
Loader	6580 + 280 = 6886 liter
Grader	10920 + 280 = 11200 liter
Excavator	8960 + 280 = 9240 liter

Table 3.9 Fuel consumption of conventional and simulator-based training

No	Types of machines	No of Trainees for each machine training	Conventional Training (in L)	Simulator-Based Training (in L)
1	Dozer	28	15120	9520
2	Loader	48	10290	6886
3	Grader	60	16380	11200
4	Excavator	64	13440	9240

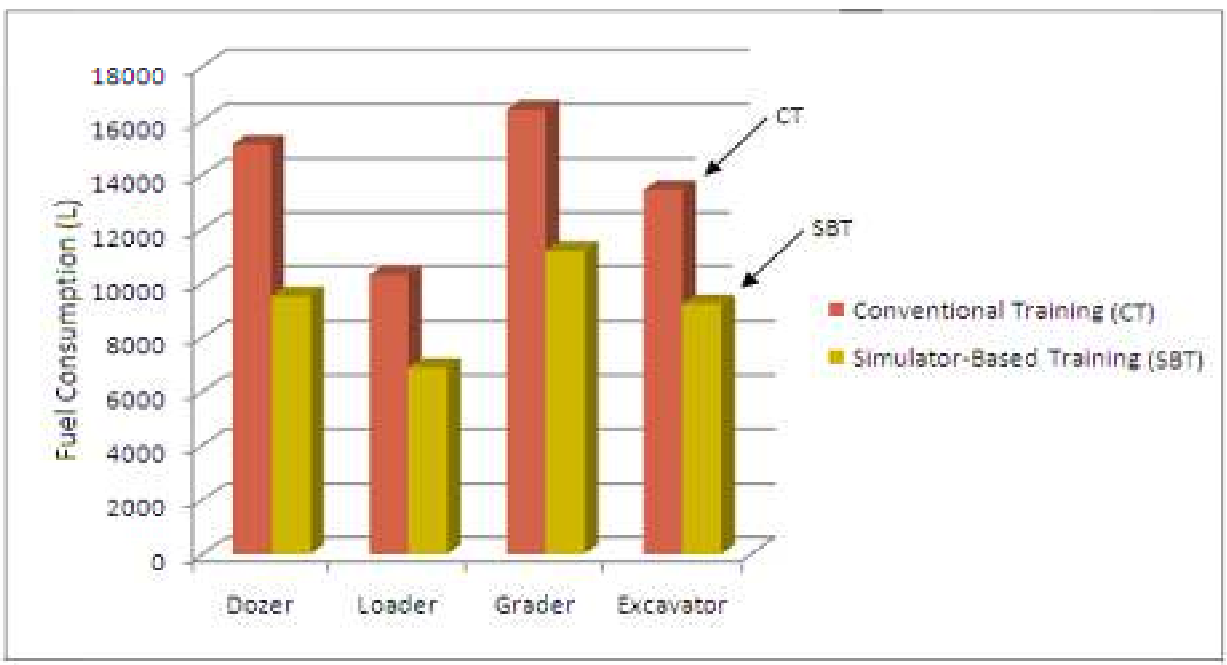

Fig. 3.1 Fuel consumption of Conventional and simulator-Based training.

Emission reduction

The Transportation sector includes the movement of people and goods by cars, trucks, trains, ships, airplanes, and other vehicles. The majority of greenhouse gas emissions from transportation are carbon dioxide(CO_2), emissions resulting from the combustion of petroleum-based products, like gasoline, in internal combustion engines.

Emission is one the serious problem in the world. When fuel is burning there different gases release from it. Such as Hydrocarbon (HC), Carbon dioxide (CO_2), Carbon mono oxide (CO), Nitrogen peroxide (NO_x), Particulate matter (PM), smoke, etc.

There is a direct relationship between combustion and emission, thus the saving of 33.3 % fuel prevent from combustion, result in 33.3 % of emission reduction from the training, because fuel combustion decreased and also emission or air pollution reduced.

3.7 Engine oil consumption of conventional and simulator-based training

3.7.1 Engine oil consumption of conventional training in one round

To calculate: Engine oil consumption of conventional training is:

In conventional training took 42 days for practical training and the training time of each day was 10 hrs, so 42 days * 10 hrs/day = 420 hrs. Therefore the engine run 420 hrs in one round training.

420 hrs – 250 hrs = 170 hrs, because each machine engine oil changes every 250 hrs, this data can find from operating and service manual.

1. Bulldozer Engine oil consumption of conventional training

<u>For D8R CAT bulldozer</u>: Total Engine oil capacity changed every 250 hr is 37 litres, and then

250 hrs = 37 L, by using systematic calculation

Engine oil consumption for 170 hrs was 25.16 L

Consumption of oil throughout 420 hrs (one batch training) = 37 L + 25.16 L = 62.16 L

Top up oil consumption is 10 L.

SoD8R bulldozer oil consumption throughout one Bache training = 62.16L+10 L = **72.16L**

<u>For D6R CAT bulldozer</u>: Total Engine oil capacity changed every 250 hrs is 28 litres,

250 hrs = 28 L, by using systematic calculation

Engine oil consumption for 170 hrs was 19.04 L

Consumption of oil throughout 420 hrs (one batch training) = 28 L + 19.04 L = 47.04 L

Average top up oil consumption is 8 L.

SoD6R bulldozer oil consumption throughout one batch training = 47.04 L + 8 L = **55.04 L**

There for D8R and D6R bull dozers total oil consumption throughout one batch training is

72.16 L + 55.04 L = <u>127.2</u> L

2. Loader Engine oil consumption of conventional training

For Loader: Total Engine oil capacity changed every 250 hrs is 30 litres,

250 hrs = 30 L, by using systematic calculation

Engine oil consumption for 170 hrs was 20.4 L

Consumption of oil throughout 420 hrs (one batch training) = 30 L + 20.4 L = 50.4 L

Top up oil consumption is 10 L.

So CAT- 950H Loader oil consumption throughout one batch training = 62.16 L + 10 L = **60.4 L**

There are three Loaders and there crankcase capacity is the same, therefore the total consumption of oil through out one batch training = **3 * 60.4 L = <u>181.2</u> L**

3. Grader Engine oil consumption of conventional training

For Grader: Total Engine oil capacity changed every 250 hrs is 27 litres,

250 hrs = 27 L, by using systematic calculation

Engine oil consumption for 170 hrs was 18.36 L

Consumption of oil throughout 420 hrs (one batch training) = 27 L + 18.36 L = 45.36 L

Top up oil consumption is 9 L.

So 140H grader oil consumption throughout one batch training = 45.36 L + 9 L = **54.36 L**

There are four graders and their crankcase capacity is the same, there for the total consumption oil throughout one batch training = **4 * 54.36 L = <u>217.44</u> L**

4. Excavator Engine oil consumption of conventional training

For excavator: Total Engine oil capacity changed every 250 hrs is 26.5 litres,

250 hrs = 26.5 L, by using systematic calculation

Engine oil consumption for 170 hrs was 18.52 L

Consumption of oil throughout 420 hrs (one batch training) = 26.5 L + 18.02L = 44.52 L

Top up oil consumption is 9 L.

So CAT-320C oil consumption throughout one batch training = 53.52 L + 9 L = 52.52 **L**

There are four excavators and their crankcase capacity are the same, therefore the total consumption of oil through out one batch training = **4 * 52.52 L = <u>210.08</u> L**

Total Engine oil consumption of all machines throughout one round conventional construction machine training (Engine oil consumption of conventional Training) = (EO_{CCT})

EO_{CCT}= Dozer + Loader + Grader + Excavator

EO_{CCT} = 127.2 L + 181.2 L + 217.44 L + 210.08 L

EO_{CCT}= <u>735.92</u> L

3.7.2 Engine Oil Consumption of Simulator-Based Training(EO_{CSBT}) in one round)

To calculate: Engine oil consumption of Simulator-Based training is:

In Simulator-Based training took 28 days for practical training and the training time of each day was 10 hrs, so 28 days * 10 hrs/day = 280 hrs. Therefore the engine runs 280 hrs in one round training. 280 hrs – 250 hrs = 30 hrs, because each machine engine oil changes every 250 hrs, this data can find from operating and service manual.

1. Bulldozer Engine oil consumption of Simulator-Based training

For D8R CAT bulldozer: Total Engine oil capacity changed every 250 hrs is 37 litres, so

250 hrs = 37 L, by using systematic calculation

Engine oil consumption for 30 hrs was 4.44 L

Consumption of oil throughout 280 hrs (one batch training) = 37 L + 4.44 L = 41.44 L

Top up oil consumption is 6.66 L.

So D8R bulldozer oil consumption throughout one batch training =41.44 L+6.66 L= **48.1L**

For D6R CAT bulldozer: Total Engine oil capacity changed every 250 hrs is 28 litre,

250 hrs = 28 L

Engine oil consumption for 30 hrs was 3.36 L

Consumption of oil throughout 280hrs (one batch training) = 28 L + 3.36 L = 31.36 L

Average top up oil consumption is 5.33 L.

So D6R bulldozer oil consumption throughout one batch training =31.36 L + 5.33L=**36.69 L**

Therefore D8R and D6R bulldozers total oil consumption throughout one batch training is

48.1 L + 36.69 L = 84.79 L

2. Loader Engine Oil consumption of Simulator-Based training

For Loader: Total Engine oil capacity changed every 250 hrs is 30 litres,

250 hrs = 30 L, by using systematic calculation

Engine oil consumption for 30 hrs was 3.6 L

Consumption of oil throughout 280 hrs (one batch training) = 30 L + 3.6 L = 33.6L

Top up oil consumption is 6.66 L.

So CAT-950H oil consumption throughout one batch training = 33.6 L + 6.66 L = **40.26L**

There are three Loaders and there crankcase oil capacity are the same, therefore the total oil consumption of throughout one batch training = **3 * 40.26 L = <u>120.78</u> L**

3. Grader engine oil consumption of Simulator-based training

For Grader: Total Engine oil capacity changed every 250 hrs is 27 litre,

250 hrs = 27 L, by using systematic calculation

Engine oil consumption for 30 hrs was 3.24 L

Consumption of oil throughout 280 hrs (one batch training) = 27 L + 3.24 L = 30.24 L

Average top up oil consumption is 6 L.

So 140H Grader oil consumption throughout one batch training = 30.24 L + 6 L = **36.24 L**

There are four Graders and there crankcase capacity are the same, therefore the total oil consumption of throughout one batch training= **4 * 36.24 L = <u>144.96</u> L**

4. Excavator engine oil consumption of Simulator-Based training

For excavator: Total Engine oil capacity changed every 250 hrs is 26.5 litres,

250 hrs = 26.5 L, by using systematic calculation

Engine oil consumption for 30 hrs was 3.18 L

Consumption of oil throughout 280 hrs (one batch training) = 26.5 L + 3.18L = 29.68 L

Average top up oil consumption is 6 L.

So 320C excavator oil consumption throughout one batch training = 29.68 L + 6 L=35.68**L**

There are four excavators and there crankcase oil capacity are the same, therefore the total oil consumption of throughout one batch training= **4 * 35.68 L = <u>142.72</u> L**

Total Engine Oil Consumption of all machines throughout one batch of Simulator-Based Training ($EO_{C(SBT)}$) is:

($EO_{C(SBT)}$) = Bulldozer + Loader + Grader + Excavator

$EO_{C(SBT)}$= 84.8 L + 120.81 L + 144.96 L + 142.72 L

$EO_{C(SBT)}$= <u>493.25</u> L

The difference between conventional and simulator-based training of oil consumption is:

($EO_{C(CT)}$) - ($EO_{C(SBT)}$) **= 735.92 L – 493.25 L = 242.63 L**

So oil consumption reduced by **= 242.63 L / 735.92 * 100% = 33 %**

3.8 The population, the sample and sampling techniques

Alemgena Machine Based Technology training center structured by Training manager at the top comprised of three teams namely equipment maintenance training team, Engineering and equipment operation training team, and administration and finance team. As the study focused on the Engineering and equipment operation training team and this team comprised 40% of the total size of the training center teams and consequently, felt well representative. The sample size stood on the proportion of the target population in the training center (see table 3.11). The Trainer & Trainees were selected using simple random sampling technique and purposely.

Table 3.10 Population, Population sample and Sample techniques

No	Respondents	Population	Sample Size	Sample Techniques
1	Dozer trainees	56	28 (50%)	Simple random
2	Loader trainees	96	48 (50%)	Simple random
3	Grader trainees	120	60 (50%)	Simple random
4	Excavator trainees	128	64 (50%)	Simple random
5	Trainers	26	16 (61.5%)	purposely
Total		426	216 (50.9%)	

3.9 Sampling method and sampling size

From **table 3.11**, the sampling method of trainees has taken from the two batch training. Number of trainees for each batch was 200, and the 100 trainees selected randomly from each batch. In simple random sampling method every member of the population has an equal and independent chance of being selected for sample. The trainees came from different parts of the country and they had different kinds of culture and attitude. The training system and the questionnaire were the same for the two round trainees. The sampling size of trainees from the two rounds was 50%, thus total selected trainees were 200 from the two rounds.

The sampling method of trainers was purposely and total number of trainers was twenty six, from these eight were senior trainers, six were trainers and twelve were junior trainers. The researcher took six members from senior trainers, four members from trainers and six members from junior trainers. So the sampling size of all trainers was 61.5%, thus the selected trainers were 16 from 26 trainers.

The sample size of trainees was enough for the research, but the sample has taken from only two rounds. Since the researcher had not access to find the previous round trainees, after the training completed. In the other hand the researcher had a chance to communicate orally from the previous trainees and gathered a lot of information about the simulator-based training.

The sample size of trainers was enough for the research because most of trainers had adequate knowledge and experience about the training. Work experience of trainers from six years up to thirty-six years.

The trainees age from the younger (eighteen) up to forty-five years old, and their educational level were from grade 10^{th} up to diploma (level four), and also the trainers age from the younger (twenty-five) up to the older (fifty-eight) years old, and their educational level were from diploma (level three) up to BSc degree. The researcher decided that the size of the sample was enough and adequate for this research.

CHAPTER FOUR

4. RESULT AND DISCUSSION

4.1 Engine oil consumption of CT and SBT

Based on the above calculation result: - transmission oil, hydraulic oil, etc. simulator-based training compared to Conventional training of oil consumption reduced by **33%.**

Table 3.11 Engine oil consumption of conventional and simulator-based training

No	Type of Machine	Conventional Training(L)	Simulator-Based Training(L)
1	Bull dozer	127.2	84.8
2	Loader	181.2	120.81
3	Grader	217.44	144.96
4	Excavator	210.08	142.72

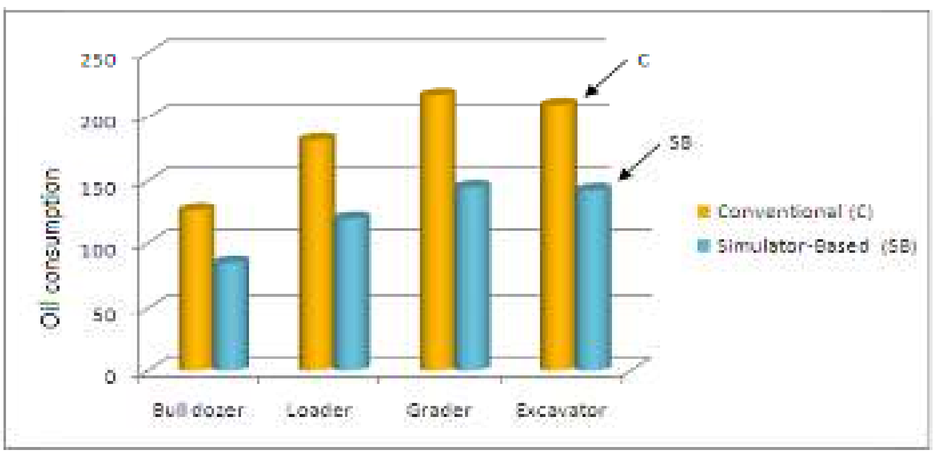

Fig. 3.2 Engine oil consumption of Conventional and Simulator-Based training.

In Simulator-Based training also maintenance cost, down time of machine, frequently failure of machine, training expense and time, etc. reduced by 33 %. The trainees also got invaluable knowledge especially from trigger failure and pre-simulator training. In CT the number of trainees passed the CoC assessment not more than 90%, but in SBT the number of trainees passed the CoC assessment more than 95%.

4.2 Result and Discussion of Questionnaires Response by Trainees in Each Machine

VH = Very High H = High M = Medium L = Low VL = Very Low

1. Result and Discussion of Bulldozer Simulator-based trainee's response

From **Table A**, Bulldozer Simulator-based trainee's response of (No.1), and the benefit of simulator-based training most of trainee's response were H and VH, and the rest were zero. At (No 2) the relationship (similarity) between simulators to conventional machine most of trainee's responses were H, and few of response were VH and M, and the rest were zero. At (No 3) contribute of simulator machine training to the real machine training of trainees response were VH and H, the rest were zero. At (No 4) the program suitability of trainee's response were VH and H only, so the rest were zero. At (No 5) the capacity of simulator to transmit skills and knowledge in a short time of most trainees' response were VH and H, few trainees responses were M. At (No 6) the interest of trainee's to train by simulator most of trainees response were L, few trainee's responses were VH, H and M, and zero for L. At last (No 7) the training methodology of simulator-based trainees response were VH and H only, the rest were zero.

Generally in all questionnaires VL response was zero, except No 6, from No 1 to No 7. Most of trainee's responses were VH and H and few trainees' response were M. But in No 6 most of trainees response were L and few trainee's response were VH, H and M. This showed dozer trainees were lower number compared to other trainees, so that they got much time to train by simulator. Direct observation from 2012-2017G.C. and interview, most of the trainees didn't want to train simulator for much time. And also the questionnaire from 2016 and 2017 G.C. trainee's response were the same. So from this can concluded no need to train much time on simulator. In the average 5 hrs training was enough for simulator machine training for one trainee. In Dozer, the number of trainees were low, thus the trainees trained by simulator more than 5 hrs so the trainees got enough knowledge and skills, at this time the trainees were less interested to train by simulator for additional time. Therefore accurate training time program must be needed to solve this problem.

2. Result and Discussion of Loader Simulator-based trainee's response

From **Table B**, Loader Simulator-based trainee's response of (No.1) the benefit of simulator-based training was almost H and VH, and the rest were zero. At (No 2) the relationship (similarity) between simulators to conventional machine most of trainee's responses were H and few of response were VH and M, and the rest were zero. At (No 3) contribute of simulator machine training to the real machine training of trainees response were VH and H, and the rest were zero. At (No 4) the program suitability of trainees response were VH and H, the rest were zero. At (No 5) the capacity of simulator to transmit skills and knowledge in a short time of most trainee's response were VH and H, few response were M. At (No 6) the interest of trainee's to train by simulator machines of trainees response were VH and H, the rest was zero. At last (No 7) the training methodology of simulator-based of trainees response were VH and H, the rest were zero.

In general from No 1 to No 7 most of the trainee's response' were VH and H and very few trainee's response were M. In all questionnaires, all trainees' responses were zero for L and VL. From this concluded that the Loader training was more satisfied.

3. Result and Discussion of Grader Simulator-based trainee's response

From **Table C**, Grader Simulator-based trainee's response of (No.1) the benefit of simulator-based training was almost VH, H and M, the rest were zero. At (No 2) the relationship (similarity) between simulators to conventional machine of trainee's response were VH, H, M, and L, and VL was zero. At (No 3) contribute of simulator machine training to the real machine training of trainee's response were VH, H, M, and L, and VL was zero. At (No 4) the program suitability of trainees response were H, M and L, the rest were zero. At (No 5) the capacity of simulator to transmit skills and knowledge in a short time of most trainees' response were VH, H and M, few responses were L and VL was zero. At (No 6) the interest of trainee's to train by simulator of most trainees response were VH, some responses were H, and L and VL was zero. At last (No 7) the training methodology of simulator-based of most trainees response were H and M, and few were L and VL, and also 0% VH.

In general from No 1 to No 7 half of the trainee's response were VH and H, one-third trainee's response were M, few were L and 0% for VL except No 7. Especially in No 2 and No 4 had low performance. From this concluded that the training was less satisfied.

4. Result and Discussion of Excavator Simulator-based trainee's response

From **Table D**, Excavator Simulator-based trainee's response of (No.1) the benefit of simulator-based training was almost VH, H and M, the rest were zero. At (No 2) the relationship (similarity) between simulator to conventional machine of trainee's response were VH, H, M, and L , and VL was zero. At (No 3) contribute of simulator machine training to the real machine training of trainee's response were VH, H, M, and L, and VL was zero. At (No 4) the program suitability most of trainee's responses were VH and H, and the rest were M, L and VL. At (No 5) the capacity of simulator to transmit skills and knowledge in a short time of most trainees' response were VH, few responses were H and M, and 0% was L and VL. At (No 6) the interest of trainee's to train by simulator of most trainees response were VH, some responses were H, and L and VL was zero. At the last (No 7) the training methodology of simulator-based of most trainee's response were VH and H, and some were M, and 0% was L and VL.

In general from No 1 to No 7 most of trainee's response were VH and H, and few trainee's response were M, L and VL. From this concluded that the training was almost satisfied.

4.2.1 Percentage of Trainee's response of each questionnaire for four machines

1. Four machines trainee's response in percentage for No.1 questionnaire

(No.1) the benefit of simulator-based training of **Dozer** trainees responses were 15/28 (53.5%) for VH, and 13/28 (46.4%) for H, 0% for M, L and VL.

(No 1) the benefit of simulator-based training of **Loader** trainees responses were 21/48 (43.7%) for VH, and 27/48 (56.2%) for H, and 0% for M, L and VL.

(No 1) the benefit of simulator-based training of **Grader** trainees response were 17/60 (28.3%) for VH, and 8/60 (13.3%) for H, and 35/60 (58.3) for M, and 0% for L and VL.

(No 1) the benefit of simulator-based training of **Excavator** trainees responses were 6/60 (10%) for VH, and 39/60 (65%) for H, and 14/60 (23.3%) for M and 5/60 (8.3%) for L and 0% for VL.

In short Dozer 39.8% was VH and 42.8% was H, so that 82.6% VH and H, Loader 43.7% was VH and 56.2% H, so that 100% was VH and H, Grader 28.3% was VH and 13.3% was H, so that 41.6 % only VH and H, Excavator 65% was VH and 23.3% was H, so that 88.3% was VH and H.

This showed in Dozer, Loader and Excavator above 88% was VH and H thus the training was more satisfied but in Grader only 41.6% VH and H, from this concluded that the training was less satisfied.

2. Four machines trainee's response in percentage for No 2 questionnaire

(No. 2) the relationship (similarity) between simulator to conventional machine of **Dozer** trainee's response were 4/28 (14.2%) for VH, and 21/28 (75%) for H, and 3/28 (10.7%) for M, and 0% for L and VL.

(No. 2) the relationship (similarity) between simulator to conventional machine of **Loader** trainee's response were 5/48 (10.4%) for VH, and 38/48 (79.1%) for H, and 5/48 (10.4%) for M, and 0% for L and VL.

(No. 2) the relationship (similarity) between simulator to conventional machine of **Grader** trainee's response were 11/60 (18.3%) for VH, and 19/60 (31.6%) for H, and 13/60 (21.6 %) for M, and 17/60 (28.3) for L, and 0% for VL.

(No. 2) the relationship (similarity) between simulator to conventional machine of **Excavator** trainee's response were 29/64 (45.3%) for VH, and 14/64 (21.8%) for H, and 17/64 (26.5 %) for M, and 0% for L and VL.

In short Dozer 14.2 % was VH and 75 % was H so that 89.2 % VH and H, Loader 10.4% was VH and 79.1 % H so that 89.5 % was VH and H, Grader 18.3 % was VH and 31.6 % was H so that 49.9 % only VH and H, Excavator 45.5% was VH and 21.8 % was H so that 67. 3 % was VH and H.

This showed in Dozer and Loader above 89% was VH and H, so that the training was more satisfied, in Excavator 67.3 % was VH and H, so that the training was satisfied in "medium" choice, but in grader only 49.9 % was VH and H, from this concluded that the training was less satisfied.

3. Four machines trainee's response in percentage for No 3 questionnaire

(No 3) contribute of simulator machine training to the real machine training of **Dozer** trainee's response were 15/28 (53.5%) for VH, and 13/28 (46.4%) for H, 0% for M, L & VL.
(No 3) contribute of simulator machine training to the real machine training of **Loader** trainee's response were 27/48 (56.2%) for VH, and 21/48 (43.7%) for H, 0% for M, L & VL.
(No 3) contribute of simulator machine training to the real machine training of **Grader** trainee's response were 12/60 (20%) for VH, and 24/60 (40%) for H, and 18/60 (30%) for M, and 6/60 (10%) for L, and 0% for VL.
(No 3) contribute of simulator machine training to the real machine training of **Excavator** trainee's response were 35/64 (54.6%) for VH, and 27/64 (42.2%) for H, and 2/64 (3%) for M, and 0% for L and VL.

In short Dozer 53.5 % was VH and 46.4 % was H so that 100 % VH and H, Loader 56.2 % was VH and 43.7 % was H so that 100% was VH and H, Grader 20 % was VH and 40 % was H so that 60 % VH and H, Excavator 54.6% was VH and 42.2 % was H, so that 96.8 % was VH and H.
This showed in Dozer, Loader and Excavator above 96% was VH and H thus the training was more satisfied, but in Grader only 60 % was VH and H, from this concluded that the training was less satisfied.

4. Four machines trainee's response in percentage for No 4 questionnaire

(No 4) the program suitability of trainees response of **Dozer** were 18/28 (64.3%) for VH, and 10/28 (35.7%), and 0% for M, L, and VL.
(No 4) the program suitability of trainees response of **Loader** were 27/48 (56.2%) for VH, and 21/48 (43.7%), and 0% for M, L, and VL.

(No 4) the program suitability of trainees response of **Grader** were 0% for VH, and 18/60 (30%), and 25/60 (41.6%) for M and 17/60 (28.3%) for L, and 0% for VL.

(No 4) the program suitability of trainees response of **Excavator** were 24/64 (37.5%) for VH, and 27/64 (42.2%), and 1/64 (1.5%) for M and 7/64 (11%) for L, and 5/64 (7.8%) for VL.

In short Dozer 64.3 % was VH and 35.7% was H so that 100 % VH and H, Loader 56.2 % was VH and 43.7 % was H so that 100% was VH and H, Grader 0 % was VH and 30 % was H so that 30 % VH and H and 42.2% was medium, Excavator 37.5% was VH and 42.5 % was H so that 80 % was VH and H.

This showed in Dozer, Loader and Excavator above 80 % was VH and H, thus the training was more satisfied, but in Grader only 30 % was VH and H, from this concluded that the training was very low to satisfy the trainees. Thus the schedule was not good for Grader trainees.

5. Four machines trainee's response in percentage for No 5 questionnaire

(No 4) the capacity of simulator to transmit skills and knowledge in a short time of **Dozer** were 15/28 (53.5%) for VH, and 10/28 (35.7%), and 3/28 (10.7%) for M and 0% for L, and VL.

(No 4) The capacity of simulator to transmit skills and knowledge in a short time of **Loader** were 16/48 (33.3%) for VH, and 27/48 (56.2) for H, and 5/48 (10.4%) for M, and 0% L and VL.

(No 4) The capacity of simulator to transmit skills and knowledge in a short time of **Grader** were 19/60 (31.6%) for VH, and 17/60 (28.3%), and 19/60 (31.6%) for M and 5/60 (8.3%) for L, and 0% for VL.

(No 4) The capacity of simulator to transmit skills and knowledge in a short time of **Excavator** were 43/64 (67.1%) for VH, and 9/64 (14%), and 12/64 (18.7%) for M, and 0% for L and VL.

In short Dozer 53.5 % was VH and 35.5% was H so that 89 % VH and H, Loader 33.3 % was VH and 56.2 % was H so that 89.5 % was VH and H, Grader 31.6 % was VH and 28.3 % was

H so that 60 % VH and H, Excavator 67.1 % was VH and 14 % was H so that 81.1 % was VH and H.
This showed in Dozer, Loader and Excavator above 81 % were VH and H thus the training was more satisfied, but in Grader 60% was VH and H, from this concluded that the training was satisfied in 'medium' and so the trainees gain low skills and knowledge in a short time.

6. Four machines trainee's response in percentage for No 6 questionnaire

(No 4) the interest of trainee's to train by simulator of **Dozer** were 2/28 (7.1%) for VH, and 3/28 (10.7%), and 3/28 (10.7%) for M, and 20/28 (71.4%) for L and 0% for VL.
(No 4) the interest of trainee's to train by simulator of **Loader** were 27/48 (56.2%) for VH, and 21/48 (43.7%) for H, and 0% M, L and VL.
(No 4) the interest of trainee's to train by simulator of **Grader** were 35/60 (58.8%) for VH, and 12/60 (20%) for H, and 2/60 (3.3%) for M and 11/60 (18.3%) for L, and 0% for VL.
(No 4) the interest of trainee's to train by simulator of **Excavator** were 41/64 (64%) for VH, and 21/64 (32.8%), and 2/64 (3.1%) for M, and 0% for L and VL.

In short Dozer 7.1 % was VH and 10.7 % was H so that 17.8 % VH and H, Loader 56.2 % was VH and 43.7 % was H so that 100 % was VH and H, Grader 58.8 % was VH and 20 % was H so that 78.8 % VH and H, Excavator 64 % was VH and 32.8 % was H so that 96.8 % was VH and H.
This showed in Loader, grader and Excavator above 78 % was VH and H thus the training was more satisfied, but in Dozer was only 17.8 VH and H, from this concluded that the training was not satisfied. This showed to train much time in simulator did not gain additional skills and knowledge.

7. Four machines trainee's response in percentage for No 7 questionnaire

(No 4) the training methodology of simulator-based of **Dozer** were 13/28 (46.4%) for VH, and 15/28 (53.6%), and 0% for M, L, and VL.
(No 4) the training methodology of simulator-based of **Loader** were 26/48 (54.1%) for VH, and 22/48 (45.8%) for H, and 0% M, L and VL.

(No 4) the training methodology of simulator-based of **Grader** were 0 %) for VH, and 17/60 (28.3%), and 31/60 (51.6%) for M and 13/60 (11.6%) for L, and 5/60 (8.3%) for VL. (No 4) the training methodology of simulator-based of **Excavator** were 32/64 (50%) for VH, and 19/64 (29.6%), and 13/64 (20.3%) for M, and 0% for L and VL.

In short Dozer 46.4% was VH and 53.6% was H so that 100% VH and H, Loader 54.1% was VH and 45.8% was H so that 100% was VH and H, Grader 0% was VH and 28.3% was H so that 28.3% VH and H, Excavator 50% was VH and 29.6% was H so that 79.6% was VH and H.

This showed in Dozer, Loader and Excavator above 78 % were VH and H, thus the training was more satisfied, but in Grader was only 28.3 VH and H, from this concluded that the training program or methodology was not good for trainees and low quality of simulator.

Table 4.1 Average trainee's response of four machines in simulator-based training

No	Types of Machines	V H	H	M	L	V L
1	Dozer	39.8%	42.8%	5.3%	12%	0
2	Loader	41.1%	55.9%	2.98%	0	0
3	Grader	22.4%	27.4%	34%	15%	1.1%
4	Excavator	48.4%	33.6%	14.1%	2.8%	1.2%

In table 4 .1 showed that the response of most trainee's were VH and H (82.6%) for Dozer, 97% for Loader, 49.8% for Grader and 82% for Excavator training. The trainee's response of in Dozer, loader and Excavator were more than 82% VH and H, this showed simulator-based training was very nice, but in Grader only 49.8% was VH and H, from this concluded that the trainees didn't satisfied very well in the simulator training. In generally from the average trainee's response, simulator-based training was very important and valuable.

4.3 Result and Discussion of Questionnaire response of Trainers in four machines

Y = Yes N = No M = Medium

From **Table E**, at (No. 1) all of trainer's responses were Y and M, so that simulator-based training supported actual machine training. At (No. 2) most of trainers response were Y and M, and few trainers response were N, so that the trainees could easily operated the actual machine after simulator training. At (No. 3) most of trainers response were Y and M, and few trainers response were N, so that the simulator training can reduce training time on the actual machine. At (No. 4) most of trainers response were Y and M, and few trainers response were N, so that simulator training reduced failure on the actual machine. At (No. 5) most of trainers response were Y and M, and few trainers response were N, so that simulator training decreased fuel consumption. At (No. 6) most of trainers response were Y and M, and few trainers response were N, so that simulator training reduced accident during on the actual machine training. At (No. 7) all of trainer responses were Y and M, so that the trainee's operated at dangerous working area in safe condition in simulator training. At (No. 8) most of trainers response were N, and few trainers response were Y and M, so that the number of trainees and number of machines didn't balance. At (No. 9) most of trainers response were Y and M, and few trainers response were N, so that the training program was all most enough to complete the training. At (No. 10) most of trainers response were N, and few trainers response were M, and zero Y, from this concluded that the simulator training schedule completely didn't suitable for training. At (No. 11) all of trainer's responses were Y and M, from this concluded that simulator training reduced tiredness of actual machine trainer very much. At (No. 12) most of trainers response were N, and few trainers response were M and Y, from this concluded that there was no much difference between younger and older trainees in catching-up the training.

In short from all questionnaires except No. 8, 10, 12 most of trainers response were Y and M, and few trainers response were N. This showed that the training was going well. But on No. 8, 10 the training needs improvement very much. From this concluded that the simulator training schedule shall revise and then suitable for training, and also the number of trainees and number of training machines shall be balance or equivalent.

4.4 Performance of simulator-based and conventional training

From the comparison study of CT and SBT, simulator-based construction equipment training was more effective and efficient than conventional construction equipment training. The cost of simulator-based construction equipment training was lower than 33.3% compared to conventional construction equipment training. The trainees were more interested to train by simulator machine in Loader, Grader and Excavator, but in Dozer the trainees were low interest. So the trainees can easily gain much knowledge in a short period of time. If the training time increased, the trainee's didn't gain additional skills and knowledge. So the trainee's felt boring or not interested to train by simulator machine. To solve this problem, the training times don't greater than the optimum training time (5 hrs).

If the number of trainees proportional to the number of simulator machine and trainers, the SBT cost can lower than 50% compared to CT. The max capacity of this construction simulator machine supported the training about 50%. If the qualities of simulator increase, the maximum capacity of support training will be increase. I got information from Ethiopian Air Lines, the maximum capacity of that simulator machine support the training about 65%. In America the capacity of construction machine Simulator training very high, because they certified the trainees only by simulator training. In simulator to Identify gauges and levers, start-up and shut-down procedure, implement tools movement, are almost the same as the actual machine training. But dozing, loading, excavating, etc. the simulator soil feeling was very low compared to the actual soil. And also the feeling of simulator machine driving on rough surface was similar to the actual machine.

From the questionnaire response, most of the trainees are satisfied by simulator training. The simulator trainees answered the questionnaire were VH and H in dozer, loader, and excavator training, but in grader simulator trainee's response were medium (M). The reason of M in grader simulator training were: their teaching methodology wasn't suitable for trainees, poor time management, the size of machine was not proportional to the driving and working area and rear driving view wasn't clear, the quality and design of simulator wasn't good. Poor time management and teaching methodology were the problem of trainers, but the design of simulator was the problem of Manufac. Company.

4.5 Graphical representation of simulator-based and conventional training

The researcher has observed directly and interviewed simulator-based trainers for five years (2012 G.C- 2017 G.C), and also take recorded time of each round from simulator trainer. In ERA at AMBTTC there were ten up to fifteen trainees in one group, each trainee could train on the simulator machine from 30 to 40 min per day. The maximum training time for each trainee in simulator machine was five hrs. If the simulator machine continued to train beyond 5 hrs, the trainees didn't gain any skills and knowledge. The researcher got the capacity of simulator performance from trainer's recorded training time and interview.

Table 4.2 Time verses knowledge and skill of Simulator machine training by recorded training time, direct observation, questionnaire and interview

Time(hrs)	Skills and Knowledge (%)
0	0
1	12
2	24
3	35
4	45
5	50
6	50.5
7	50.7
8	50.9
9	51

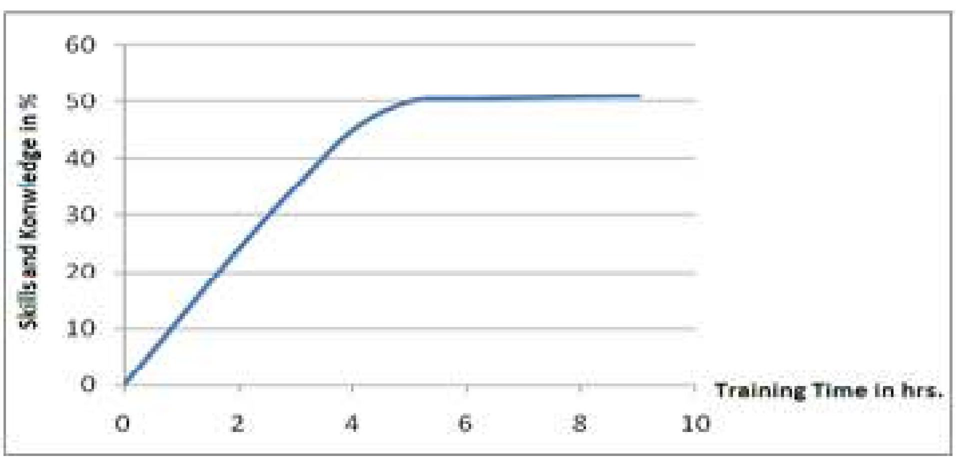

Fig. 4.1 performance curve of training time verses skill and knowledge in simulator machine training.

Fig 4.1 showed that the maximum efficiency of simulator training was 50%. So the trainees have got about 50% of skills and knowledge from the simulator in five hrs training. Even if the training time increased above five hrs, the trainees did not gain extra skills and knowledge from the simulator machine training.

- In 1 hr training the trainees completed 12% of the mission, these include familiarization (control lever, gauge, indicator identification), implement tool movement, start-up and shut down procedure.
- The next 1 hr training the trainees completed 12% of the mission, these include, basic machine movement, normal and advanced driving.
- The next 1 hr training the trainees completed 11% of the mission, these include dozing, damping, excavating, grading.
- The next 1 hr training the trainees completed 10% of the mission; these include leveling, ripping, material production, spreading.
- The next 1 hr training the trainees completed 5% of the mission, these includesditching, loading, foundation, mixing.
- If added any extra training time, the trainees didn't get additional skills. It was only 0.5% this is approached to zero.

Table 4.3 Time verses knowledge and skill of CT by observation, questionnaire & interview

Time(hrs)	Skills and knowledge (%)
0	0
2	13
4	26
6	39
8	52
10	65
12	78
14	91
16	100
18	107
20	111

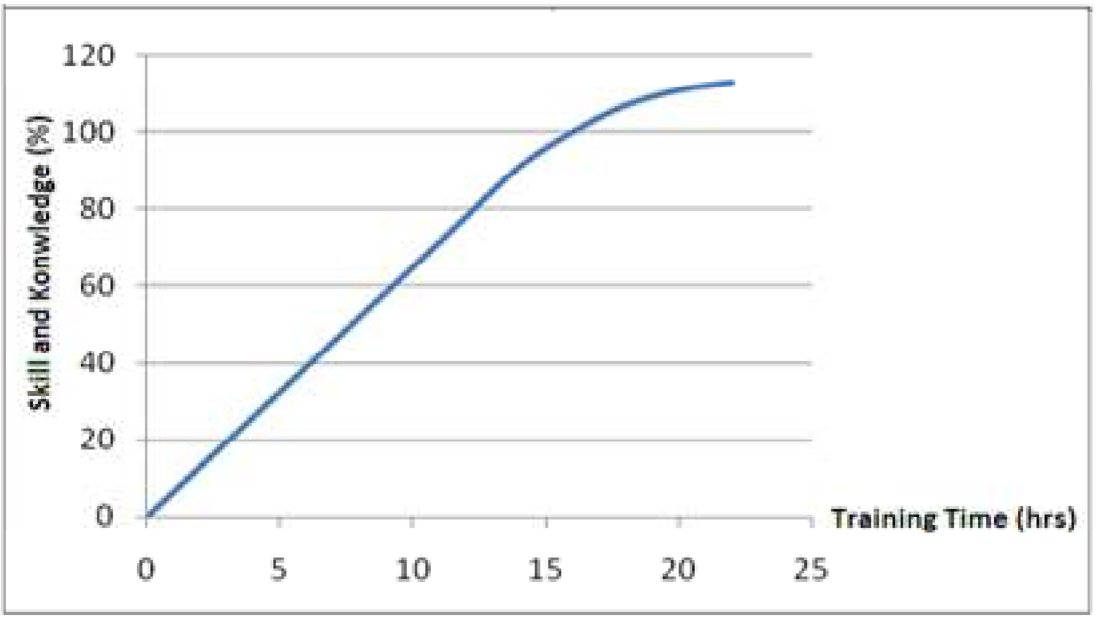

Fig.4.2 performance curve of training time verses skills and knowledge in Conventional machine training.

Fig.4.2 showed that the conventional machine training covered 100% of the training standard. So the trainees have got about 100% or more than 100% of skills and knowledge from the conventional machine training. So the training time increase, the trainees also gain extra skills and knowledge in some extent.

- In 2 hrs training the trainees completed 13% of the mission, these include familiarization (control lever, gauge, indicator identification), start-up and shut down procedure.

- The next 2 hrs training the trainees completed 13% of the mission, these include, implement tool movement, basic movement.

- The next 2 hrs training the trainees completed 13% of the mission, these include, normal and advance driving.

- The next 2 hrs training the trainees completed 13% of the mission, these include, dozing, excavating, stock piling, damping.

- The next 2 hrs training the trainees completed 13% of the mission, these include, dozing, excavating, damping, ripping, grading.
- The next 2 hrs training the trainees completed 13% of the mission, these include: slot dozing, excavating, material production, scarifying.
- The next 2 hrs training the trainees completed 13% of the mission, these include: leveling, ditching, loading, spreading, foundation.
- The next 2 hrs training the trainees completed 9% of the mission, these include: leveling, ditching, loading, foundation, mixing.
- The next 2 hrs training the trainees completed 7% of the mission, these include: leveling, ditching, loading, foundation.
- If added any extra training time, the trainees didn't get much skill. It was only gain 2% per hr, so this showed the value was decreasing.

The researcher always followed the trainee's performance by direct observation and oral question. 100% is the national Certificate of Competency (CoC) standard of the country. ERA at AMBTTC gave the training up to 100% or more than 100% of the standard value of skills, knowledge and attitude. The trainee's have got enough skills and knowledge from simulator-based training and well satisfied from the training.

4.6 New Training Strategy

If ERA planned new training program this simulator can support the training up to 50%. Basically the simulator is designed to give training before the trainees go to real machine training at site, but currently in ERA the training is given by side by side system. In one round, the new trainees divided in to two or three or four groups according to the number of trainees. And then one group is assigned to simulator the rest are assigned to the real machines. By shifting methods all groups are trained on simulator. But this training system was not effective compared to the new training method. The new training program should be included the following pre-condition.

- ➢ The number of trainees should be proportional to the number of simulator and real machine.
- ➢ Well organized maintenance group for simulator and real machine should establish.
- ➢ If possible, reserve simulator and real machine should be included.

The training program has three sequences (steps)

1. Theoretical part included: - technique, safety and operation.
2. Simulator:-start up and shut down procedure, lever movement, driving, pre-simulator, trigger failure, dozing, leveling, excavating, loading, etc.
3. Real machine:- start up and shut down procedure, lever movement, driving, dozing, leveling, excavating, loading, ditching, material production, etc.

Some trainees said that, there was confusion from real machine training back to simulator. So shifting training was not a correct training sequence (step) method. Simulator training is the prerequisite for real machine. This showed that the new training program is a correct training sequence. The training center trained 800 trainees per year in **four rounds**, but the new training program will train 800 trainees per year in **six rounds**. The training program is as shown below.

Table 4.4 Current Equipment Training Program in ERA at AMBTTC

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
1st Round	Oct 1 - Nov 30								
2nd Round			Dec 11 - Feb 10						
3rd Round					Feb 21 - Apr 20				
4th Round								May 1 - June 30	

The Current training program included below.

1. 10 days gap between the rounds.
2. Training duration is 60 days (theory, simulator & real)
3. Simulator and real machine training is given parallels.

The new training program include the following

1. The training duration will take 50 days (theory, simulator and real machine training).
2. 5 days overlap between the two rounds.
3. Simulator and real machine training will give respectively. All trainees must Complete simulator training before go to the real machine training, because simulator machine is designed for to give the training, the trainee before go to practice on the real (actual) machine. The reverse or parallel method training was not effective training, because the aim of simulator and the training method contradiction.

The simulator training time was not fixing strictly, most of trainers gave the training lower than 5 hrs and some trainers gave the training higher than 5 hrs.

In Excavator and Grader, the numbers of trainees were very high, thus the trainees trained by simulator less than 5 hrs, so the trainees didn't get enough knowledge and skills, at this time the trainees were more interested to train by simulator. But in Dozer, the number of trainees were low, thus the trainees trained by simulator more than 5 hrs so the trainees got optimum knowledge and skills, at this time the trainees were less interested to train by simulator for excess time. The questionnaire response showed that, Dozer trainees were low interested to train by simulator.

The new training strategy will avoid this problem, and all trainees train by simulator for 5 hrs before goes to train on the real machine.

And also operation technique didn't give in the current training, so that in the new training strategy, operation technique lecture must be included. If the trainees get enough knowledge about how to operate, make foundation, spread, cut and fill, etc. The trainees in practical training can understand and make the activities easily. The training can proceed from simple to complex smoothly.

Table 4.5 The new Training time Table

	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
1st round	**Sep 26 - Nov 15**									
2nd round			**Nov 11- Dec 30**							
3rd round				**Dec 26 - Feb 15**						
4th round						**Feb 11- Mar 30**				
5th round							**Mar 26 - May 15**			
6th round									**May 11 - June 30**	

Some trainee's response at interview and questionnaire, in shifting training method was not good, because the trainees from the actual (real) machine training back to simulator (artificial environment) training made confusion. The researcher observed that, in simulator at the first training program, all trainees attended and followed the training attentively, but after returned real machine to simulator their interest became lower and their participation of the training decreased. Some trainees asked permission and some were absent from the training, so this kind of training was less effective. Therefore the new training strategy is one of the better solutions of training method.

If every trainee will train on simulator in the optimum time (5 hrs), so the training time on the real machine decrease, and then the training cost will be reduce from 33% to 50%, because in optimum training time, the trainees can gain 50% of skills and knowledge from the simulator training and the rest 50% of skills and knowledge gain from the real machine training. From this, the training center become more beneficial in terms of training expense reduction and the trainees also beneficial, because they gain enough skills and knowledge in a short period of time in safe condition.

CHAPTER FIVE

SUMMARY, CONCLUSION, RECOMMENDATION AND FUTURE PLAN

5.1 Summary

The comparison study of conventional to simulator-based construction equipment operation training is very important to Ethiopian Road Authority (ERA) and any other construction operation equipment training center throughout the country or abroad.

- Knowledge, skills and attitude are essential for employee for efficiently performing any activity by using construction equipment.
- Skilled operator gave priority for equipment and personal safety, when operating the machine, so that skilled manpower must be needed to operate the machine.
- Simulator-based construction equipment training was the new method of operator training. This simulator designed to train new trainees before go to practice on the real machine.
- The researcher document collected from wear house (fuel and oil supply), maintenance section, trainers, direct observation at practical area and simulator room, and also prepared necessary questionnaire and interview (oral question) for trainee's and trainers.
- The amount of fuel consumption of Bulldozer, Loader, Grader, Excavator and Generator collected from the recorded data, but the amount of oil consumption obtained from each machine by simple calculation.
- Simulator-based training saves fuel, oil, etc. 33% compared to conventional training.
- The researcher gathered much information next to questionnaire from direct observation and oral question from the current and previous trainees.
- From the training time table and the trainer evaluation report, the researcher could determine the trainee's performance in simulator-based and conventional training.
- The researcher improved the current program and made a new training strategy.

5.2 Conclusion

This study took place in ERA at AMBTTC. Simulator-based training was advantageous. The benefit of simulator-based training is shown below:-

- ✓ Fuel, engine oil, hydraulic oil, transmission oil consumption and emission etc. reduced, and also maintenance and spare part expense reduced by 33.3%,
- ✓ In addition the trainees could get much skills and knowledge in a short period of time compared to conventional training method.
- ✓ The simulator machine use only electric power and also in simulator additional training devices were installed such as trigger failure and pre-simulator.
- ✓ The trainee can operate in dangerous area without accident and increase confidence
- ✓ Operate any environmental weather condition and no need for demonstration or practical area.

The current training

- ➢ Simulator-based construction equipment training was better than conventional construction equipment training, because to reduced training cost by 33.3% compared to conventional construction equipment training and increased the trainee's skill highly in some extent, thus the number of trainees passed in CoC assessment in SBT was higher than CT.
- ➢ From the trainees response showed that most of the trainee's response were VH (very high) and H (high). The trainee's response of in M (medium) value was lower. Few number of trainee's response were L (low) and V L (very Low).
- ➢ This showed that most trainee's satisfied from simulator-based training, from this concluded that Simulator-based training was important training system.

The new training strategy

- ❖ The researcher designed a new training strategy in simulator-based training to maximize the training efficiency.
- ❖ If the training center uses this new training strategy and balance number of trainees and number of training machines, the training will be more efficient, effective and successful and thus the training expense will decrease to 50%.

5.3 Recommendation

AMBTTC did not use the simulator machine effectively. Some of the problems were: the number of trainers and simulator machine is not proportional.

- ➢ So all trainees did not get chance to practice by simulator machine before go to practice on the real machine in each task.
- ➢ In short there is no correct training sequence. The maximum efficiency of simulator-based training is given by simulator machine before the trainees go to practice the real machine.
- ➢ If ERA balanced the number of trainees and the number of simulator machine, the training center will get maximum profit by decreasing training cost in addition increasing the skills of trainees.
- ➢ In ERA currently there are ten simulators at AMBTTC, but from ten simulators currently only four simulators are functional. The others are not functional because of lack spare part and simulator trainers.
- ➢ If ERA properly maintained the defected simulator machine and join additional simulator trainers, the capacity of training center will increase.

The new training program strategy is one of the most important training systems.

- ❖ Actually the simulator is designed to give training before the trainees go to real machine training. Currently in ERA the training is given by shifting (parallel) method, therefore the simulator didn't give maximum efficiency, because ERA training method and the aim of designed simulators were contradict.
- ❖ In the future ERA adjust the correct program, the training become more effective and efficient.
- ❖ If ERA will import better and high performance simulator, join additional simulator trainer and simulator maintenance expert, the training expense will become very low and the training center can train many number of skilled manpower with high quality and low cost.

5.4 Future plan

- The real machine and simulator machine technology are improving day to day.
- So in the future the simulator machine performance increases compared to the existing one.
- Now a day in USA, there is a construction equipment simulator training machine. The trainees train by this simulator machine and then certified without the trainees trained by real machine.
- If this (the above) simulator machine has high quality, and the performance will equal or approach to the conventional machine (real machine) training, thus the training cost will decrease very much.

In the future

- The researcher will study comparative analysis of real and the latest simulator machine training of construction equipment, especially for trainee's certified by simulator machine only.
- And also the researcher will detail analysis of the back ground of simulator from the beginning up to the current situation in there electro- mechanical co-ordination and operation system.
- Now a day most of construction equipment, light and heavy duty vehicles, etc, operation system is Electro-mechanical. Simulator operation system is also electro-mechanical, so in the future to make detail research and model in the form of animation or simulation about this technology.

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APPENDIX

1. Questionnaires response of Trainees in each machine

Table A. Trainees Response of Bulldozer simulator-based training

No	Questioners	Trainees responses (28 Trainees)				
		V H	H	M	L	V L
1	How is the benefit of simulator machine (simulator-based) training?	15	13	0	0	0
2	How is the relationship (similarity) between simulator and conventional machine?	4	21	3	0	0
3	How much simulator machine training contributed to the real machine training?	13	15	0	0	0
4	Dose the program of simulator machine and conventional machine in simulator-based training Suitable for trainees?	18	10	0	0	0
5	The capacity of simulator machine training transmit skills and knowledge in a short period of time	15	10	3	0	0
6	How is the interest of trainees to train by this modern technology construction simulator machine?	2	3	3	20	0
7	How is the training methodology of simulator-based training with related to the training scope?	13	15	0	0	0

VH = Very High **H = High** **M = Medium** **L = Low** **VL = Very Low**

Table B. Trainees response of Loader simulator-based training

No	Questioners	Trainees responses (48 Trainees)				
		V H	H	M	L	V L
1	How is the benefit of simulator machine (simulator-based) training?	21	27	0	0	0
2	How is the relationship (similarity) between simulator and conventional machine?	5	38	5	0	0
3	How much simulator machine training contributed to the real machine training?	27	21	0	0	0
4	Dose the program of simulator machine and conventional machine in simulator-based training Suitable for trainees?	16	32	0	0	0
5	The capacity of simulator machine training transmit skills and knowledge in a short period of time	16	27	5	0	0
6	How is the interest of trainees to train by this modern technology construction simulator machine?	27	21	0	0	0
7	How is the training methodology of simulator-based training with related to the training scope?	26	22	0	0	0

Table C. Trainees response of Grader simulator-based training

No	Questioners	Trainees responses (60 Trainees)				
		V H	H	M	L	V L
1	How is the benefit of simulator machine (simulator-based) training?	17	8	35	0	0
2	How is the relationship (similarity) between simulators to conventional machine?	11	19	13	17	0
3	How much simulator machine training contributed to the real machine training?	12	24	18	6	0
4	Dose the program of simulator machine and conventional machine in simulator-based training Suitable for trainees?	0	18	25	17	0
5	The capacity of simulator machine training transmit skills and knowledge in a short period of time	19	17	19	5	0
6	How is the interest of trainees to train by this modern technology construction simulator machine?	35	12	2	11	0
7	How is the training methodology of simulator-based training with related to the training scope?	0	17	31	7	5

Table D. Trainees Response of Excavator simulator-based training

No	Questioners	Trainees responses (64 Trainees)				
		V H	H	M	L	V L
1	How is the benefit of simulator machine (simulator-based) training?	6	39	14	5	0
2	How is the relationship (similarity) between simulator and conventional machine?	30	16	18	0	0
3	How much simulator machine training contributed to the real machine training?	35	27	2	0	0
4	Dose the program of simulator machine and conventional machine in simulator-based training Suitable for trainees?	24	27	1	7	5
5	The capacity of simulator machine training transmit skills and knowledge in a short period of time	43	9	12	0	0
6	How is the interest of trainee's to train by this modern technology construction simulator machine?	41	21	2	0	0
7	How is the training methodology of simulator-based training with related to the training scope?	32	19	13	0	0

2. Questionnaires response of Trainers for all machines

Table E. Trainers Questionnaire Response on simulator-based training

No	Questioner	Trainer Response		
		Yes (Y)	No (N)	Medi um(M)
1	Does Simulator-based training support actual machine training?	6	0	10
2	Are the trainees can easily operate the actual machine after simulator training?	8	2	6
3	Is the training time on actual machine decrease because of the trainee trained by simulator?	10	2	4
4	Does simulator training reduce failure on the actual machine?	5	1	10
5	Does simulator training decrease fuel consumption?	11	1	4
6	Does simulator training reduced accident during on the actual machine training?	8	3	5
7	Can the trainee's operate at dangerous working area in safe condition in simulator training?	12	0	4
8	Are the numbers of trainees and number of machines balance?	1	12	3
9	Is the training program enough to complete the training?	6	2	8
10	Is the simulator training schedule suitable for trainees?	0	14	2
11	Dose simulator training reduced tiredness of actual machine trainer?	12	0	4
12	Is there a difference between younger and older trainees in catching-up the training?	2	11	3

ADAMA SCENCE AND TECHNOLOGY UNIVERSITY

SCHOOL OF MECHANICAL, CHEMICAL AND MATERIAL ENGINEERING
DEPARTMENT OF MECHANICAL AND VEHICLE ENGINEERING
MSC.PROGRAMIN AUTOMOTIVE ENGINEERING

1. Questionnaire

1.1 Questionnaires to be filled by Trainees.

Questionnaire for trainees prepared in English and Amharic language.

Dear respondent trainees:

The purpose of this questionnaire is to evaluate the objective of Road construction equipment operation training administered at Alemgena Machine Based Technology Training Center (AMBTTC) in Equipment operation Training Team. You have been answered this questionnaire. The information that you provide will be used only for the research purpose and it would be keep confidential. Your cooperation in filling the questionnaire contributes a lot to make the study more meaning full and complete, so please try to answer all the questions.

General Instructions:

1. Please don’t write your name.

2. Sex: …………….

3. Age: …………….

4. Title …………………………..

5. Education Level: ……………………………

Part one:- Please read each question very carefully. Make sure you understand what is being asked, and then answer the correct one.

1. How is the benefit of simulator machine (simulator-based) training?

A) very high B) high C) medium D) low E) very low

2. How is the relationship (similarity) between simulators to conventional machine?

A) very high B) high C) medium D) low E) very low

3. How much simulator machine training contribute to the real machine training

A) very high B) high C) medium D) low E) very low

4. The Suitability of schedule for simulator machine and conventional machine in simulator-based training

A) very high B) high C) medium D) low E) very low

5. The capacity of simulator machine training transmit skills and knowledge in a short period of time

A) very high B) high C) medium D) low E) very low

6. How is the interest of trainees to train by this modern technology construction simulator machine?

A) very high B) high C) medium D) low E) very low

7. How is the training methodology of simulator-based training with related to the training scope?

A) very low B) low C) medium D) high E) very low

Part two:- Please read each question very carefully. Make sure you understand what is being asked, and then write the answer clearly and shortly.

8. How much percentage simulator machine training to support the real machine training?
………………………………………………………………………………………………………

9. Write the advantage of simulator-based training? ……………………………………………………
………………………………………………………………………………………………………

10. Write the drawback of simulator-based training? …………………………………………………..
………………………………………………………………………………………………………

11. Write any supportive or improvement idea about simulator training? ………………………
……..
……..
………………………………………………………………………………………………………

Thank you so much for your cooperation!

ለአዳማ ሳይንስና ቴክኖሎጂ ዩኒቨርስቲ ድህረ ምረቃ ትምህርት ክፍል

በኢትዮጵያ መንገዶች ባለስልጣን የዓለም ገና ማሽን-ቤዝድ ስልጠና ማዕከል በስልጠና ላይ ባሉት ሰልጠኞች የሚሞላ መጠይቅ

<u>የመጠይቁ አላማ</u>

የዚህ መጠይቅ አላማ በአለም ገና ማሽን ቤዝድ ቴክኖሎጂ ማሠልጠኛ ማዕከል ለመሳሪያዎች ኦፐሬሽን ሲሙሌተር-ቤዝድ ስልጠናን መገምገም ይሆናል፡፡

ስም መጻፍ አያስፈልግም፤ ጾታ …… ዕድሜ …… የትምህርት ደረጃ ……………… የሚሰለጥኑበት የማሽን ዓይነት …………..

<u>ክፍል አንድ</u>

እባክዎ ጥያቄዎችን በደንብ ካነበቡት በኃላ ከቀረቡት አምስት አማራጮች ውስጥ የሚስማማዎትን አማራጭ ፊደሉን በማክበብ ይመልሱ፡፡

1. የሲሙሌተር ስልጠና ጠቀሜታ

ሀ. በጣም ከፍተኛ ለ. ከፍተኛ ሐ. መካከለኛ መ. በጣም ዝቅተኛ ሠ. ዝቅተኛ

2. የሲሙሌተር ስልጠና መስክ ካለው የስልጠና ማሽን ጋር ያለው ተዛመጅነትና ተመሳሳይነት

ሀ. በጣም ከፍተኛ ለ. ከፍተኛ ሐ. መካከለኛ መ. በጣም ዝቅተኛ ሠ. ዝቅተኛ

3. የሲሙሌተር ስልጠና መስክ ላይ ላለው ለዋናው ማሽን ስልጠና ምን ያህል አስተዋፅኦ (ድጋፍ) ያበረክታል

ሀ. በጣም ከፍተኛ ለ. ከፍተኛ ሐ. መካከለኛ መ. በጣም ዝቅተኛ ሠ. ዝቅተኛ

4. በሲሙሌተርና በዋናው ማሽን ላይ የስልጠና ፕሮግራም አወጣጥ ቅደም ተከተልና ተስማሚነት

ሀ. በጣም ከፍተኛ ለ. ከፍተኛ ሐ. መካከለኛ መ. በጣም ዝቅተኛ ሠ. ዝቅተኛ

5. የሲሙሌተር ስልጠና በአጭር ጊዜ ውስጥ እውቀትና ክህሎት የማስተላለፍ አቅም

ሀ. በጣም ከፍተኛ ለ. ከፍተኛ ሐ. መካከለኛ መ. በጣም ዝቅተኛ ሠ. ዝቅተኛ

6. ሰልጣኞች በሲሙሌተር ማሽን የመሰልጠንና እውቀት የማግኘት ፍላጎት

ሀ. በጣም ከፍተኛ ለ. ከፍተኛ ሐ. መካከለኛ መ. በጣም ዝቅተኛ ሠ. ዝቅተኛ

7. የስልጠናው አሰጣጥ ዘዴ ሰልጣኞችን የማርካትና የስልጠናውን ግብ የማሳካት አቅሙ

ሀ. በጣም ከፍተኛ ለ. ከፍተኛ ሐ. መካከለኛ መ. በጣም ዝቅተኛ ሠ. ዝቅተኛ

<u>ክፍል ሁለት</u>

በጥያቄው መሰረት ተገቢ ነው ብለው ያመኑበትን መልስ ባጭሩ ይፃፉ

8. የሲሙሌተር ስልጠና መስክ ላይ ላለው ለዋናው ማሽን ሰልጠና ምን ያክል ፐርሰንት ያግዛል? ………

9. የሲሙሌተር ማሽን ስልጠና ጠቀሜታ ባጭሩ ይዘርዝሩ? …………………………………………

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

10. የሲሙሌተር ማሽን ስልጠና ተፅኖ ካለ ባጭሩ ይግለፁ? …………………………………………

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

11. በስልጠና ዙሪያ ሊሻሻሉና ሊበረታቱ የሚገባቸው ሀሳቦች ካሉ ይጥቀሱ

……………………………………………………………………………………………

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

ስለትብብርዎ በጣም አመሰግናለሁ!

ADAMA SCENCE AND TECHNOLOGY UNIVERSITY

SCHOOL OF MECHANICAL, CHEMICAL AND MATERIAL ENGINEERING

DEPARTMENT OF MECHANICAL AND VEHICLE ENGINEERING

MSC.PROGRAMIN AUTOMOTIVE ENGINEERING

2. Questionnaire

2.1. Questionnaires to be filled by Trainers.

Questionnaire for trainees prepared in English language.

Dear respondent trainers:

The purpose of this questionnaire is to evaluate the objective of Road construction equipment operation training administered at Alemgena Machine Based Technology Training Center (AMBTTC) in Equipment operation Training Team. You have been answered this questionnaire. The information that you provide will be used only for the research purpose and it would be keep confidential. Your cooperation in filling the questionnaire contributes a lot to make the study more meaning full and complete, so please try to answer all the questions.

General Instructions:

1. Please don't write your name.

2. Sex: …………..

3. Age: ……………..

4. Title ………………………

5. Education Level: ………………………

Part one:- Please read each question very carefully. Make sure you understand what is being asked, and then answer the correct one.

1. Does Simulator-based training support actual machine training?

A) Yes B) No C) Medium

2. Are the trainees can easily operate the actual machine after simulator training?

A) Yes B) No C) Medium

3. Is the training time on actual machine decrease because of the trainee trained by simulator?

A) Yes B) No C) Medium

4. Does simulator training reduce failure on the actual machine?

A) Yes B) No C) Medium

5. Does simulator training decrease fuel consumption?

A) Yes B) No C) Medium

6. Does simulator training reduced accident during on the actual machine training?

A) Yes B) No C) Medium

7. Can the trainee's operate at dangerous working area in safe condition in simulator training?

A) Yes B) No C) Medium

8. Are the numbers of trainees and number of machines balance?

A) Yes B) No C) Medium

9. Is the training program enough to complete the training?

A) Yes B) No C) Medium

10. Is the simulator training schedule suitable for trainees?

A) Yes B) No C) Medium

11. Dose simulator training reduced tiredness of actual machine trainer?

A) Yes B) No C) Medium

12. Is there a difference between younger and older trainees in catching-up the training?

A) Yes B) No C) Medium

13. If yes for Q 12, explain?

    ………

    ……………………………………………………………………………….

Part two:- Please read each question very carefully. Make sure you understand what is being asked, and then write the answer clearly and shortly.

14. How do you observe the trainees interest in attending the simulator training?

    ……..

    ……

    ……………………………………………………………………………….

15. Do you observe any difference between conventional and simulator-based trainees?………………………………………………………………………………………………

    ……

    ……………………………………………………………………………….

16. Please write any limitation of simulator training?

    ……

    ……

    …………………………………………………………………………………

17. Please, forward your general suggestion and comment on the area you think to be improved the training?

    ……

    ……

    …………………………………………………………………………………

Thank you so much for your cooperation!