Analysis of Earthmoving Operation Using Discrete-Event Simulation

by

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SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

(CONSTRUCTION TECHNOLOGY AND MANAGEMENT STREAM)

ANALYSIS OF EARTHMOVING OPERATION USING DISCRETE-EVENT SIMULATION

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Declaration

I, the undersigned declare that this thesis entitled ***"Analysis of earthmoving Operation Using Discrete-Event Simulation"***is my original work and composed bymyself, with the guidance of my advisor, this thesis has not been presented to any otheruniversity and is not concurrently submitted in the candidature of any other degree. Further, Icertify that this work is free of plagiarism and all materials appearing in this thesis have beenproperly quoted andattributed.

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Abstract

Earthmoving operations are a sizable and heavy portion of most civil construction projects. It includes cyclic work, expensive fleet, and a large volume of works. Earthmoving operations are difficult to plan and operate because of their operation complexity, uncertainty in the operation process, and environment. Due to this fact, and as the earthmoving operation process is cyclic, i.e., the events (activities) occur in a discretized manner. Therefore, Discrete-Event Simulation (DES) is found to be the most effective approach to analyze and model their improvement strategies for their operational performance. The main objective of this thesis is thus to analyze the current earthmoving operation practice, develop the DES model, and develop improvement strategies for the earthmoving operation production system. In this thesis, 421 field data instances were collected through observation from the sample road construction project. Out of this, 345 of the data instances were collected from the earthmoving operation process of selected materials. Simphony CYCLONE simulation software was used as a simulation tool. A detailed earthmoving operation simulation model with various adaptation (or scenarios) based on the types of loading equipment (loader and Excavator) and types of material (selected and crushed unbounded) is developed. The simulation experimentation and sensitivity analysis were performed to optimize production rates and resources' utilization levels of the earthmoving operation processes. Accordingly, in the case of selected material operation, assigning ten trucks, single dozer (stockpiling), Excavator, and dozer (spreading) is more effective in production rate and resource utilization. Besides, there is no significant difference in production rate and utilization of the resource between the overall and excluding the embankment work of retaining wall and box culverts of selected material. Additionally, in crushed unbounded material operation, assigning 27 trucks, two loaders, and a single grader is more effective.

Keywords: Earthmoving, Simulation, Discrete-Event Simulation, Simphony-CYCLONE

Dedication

I dedicate this thesis to My Mother, **Tsige Berhe Gezehay**, My Father, **Gebrezihier Tekle Kinfu,** and All My **Families.** Their love, support, moral, and inspiration laid the foundation and discipline needed to complete this research work.

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List of Abbreviations

CDF	Cumulative distribution function
CIPROS	Construction integrated project and process planning simulation system
COOPS	Construction object-oriented process simulation system
COSYE	Construction synthetic environments
CPM	Critical path method
CSV	Comma-separated values
CU	Crushed unbounded
CYCLONE	Cyclic operations network
DES	Discrete-event simulation
DISCO	Dynamic interface for simulation of construction operation
FDRE	Federal democratic republic of Ethiopia
GIS	Geographical information system
GPS	General purpose of simulation
GPS	Global positioning system
GTP II	Growth and transformation plan II
INSIGHT	Interactive graphics for simulating construction operations
K-S	Kolmogorov-Smirnov
NGM	Natural granular material
PCT	Project Completion Time
PDF	Probability density function
PERT	Project evaluation and review techniques
RISim	Resource integrated simulation modeling
RMC	Ready-mix concrete
SPS	Special purpose of simulation

CHAPTER 1: INTRODUCTION

1.1. Background of the Study

Construction operation is a work process that contributes to the delivery of construction projects. Earthmoving operations are one of the most essential and equipment intensive construction operations. These operations include preparation (stockpiling), excavation, loading, hauling, and placing of materials. They commonly include repetitive work, expensive fleets, and huge volumes of work (Shawki, et al., 2015). Earthmoving operations are performed under conditions that may give rise to uncertainty, and this makes them difficult and complex to plan and operate. Therefore, using computer simulation is one of the best options to model uncertainties associated with earthmoving operations, and this minimizes the difficulties and makes it easier to understand its complexities during the planning and operating time. Discrete-event simulation (DES) is one of the most important techniques used for modeling and analyzing for cyclic and complex construction operations such as earthmoving operation.

Shawki, et al. (2015) and Martinez (1998) mentioned that the reason why planning the earthmoving operation at the beginning makes it difficult is its probable nature, and many decisions will be taken on-site according to evolving status. Mohamed & AbouRizk (2006) stated that simulation modeling is an effective approach for analyzing and improving the performance of construction operations due to complexity, uncertainty, and randomness of the operation. Shawki, et al. (2015) concluded that the use of simulation as a tool for precise planning and estimation of earthmoving operations is proved through different researches. Computer-based simulation is one of the techniques that has been used to model uncertainties associated with earthmoving operations (Marzouk & Moselihi, 2004).

According to Montaser, et al. (2014), DES serves as a powerful tool in examining and breaking down complex problems. Therefore, using DES to construction operation particularly to earthmoving operation more advantageous because of its repetitive cycle process (i.e., to minimize problems encounter during the operation, it needs to plan the operation process in operation activity level). Discrete-event simulation (DES) is the only earthmoving operation analysis technique that can explicitly incorporate the detailed but the significant aspects (e.g., equipment characteristics, haul road condition, load and dump area configuration, and dynamic context-based decisions) of the operation (Martinez, 1998).

1.2. Statement of the Problem

Nowadays, there are mega construction projects in Ethiopia and abroad. These construction projects include a large number of earthwork operations with repetitive work cycles, expensive fleet, and a large volume of work. Most of the earthmoving operation is performed in a highly uncertain environment, and this makes it difficult and complex to plan and operate. Optimizing this operation has seen the development of different models using different techniques. Incorporate the earthmoving operation with discrete-event simulation (DES) technologies is one of the simulation techniques used to minimize its difficulty and complexity and to optimize its cost and productivity. It must be completed in a smart and flexible paradigm that accepts various types of data, maintains a presentable view of the model operation and analysis, and produces accurate results. This research aims to build the methodology of creating earthmoving simulation models, based on the discrete-event simulation.

Even though the application of simulation in earthmoving remains a well-researched area in other countries, I can say there is no research done for the earth moving operation simulation model in our country. This paper presented the analysis of current earthmoving operation practices in Addis Ababa, particularly in Kality-Tullu Dimtu Round About Road Project. It introduced the Discrete-event simulation (DES) model for earthmoving operation in the sample project. It put the improvement strategies based on the analysis result that enhance the overall system production of current practice.

1.3. The Objective of the Research

1.3.1.General objective

The general objective of this thesis is to identifying and studying the earthmoving operation process, develop a discrete-event simulation model, carry out optimization analysis and recommend the best strategies that improve the overall system production of earthmoving operations.

1.3.2. Specific objective

The specific objective of this research can be stated as follow:

- To identify and study the earthmoving operation process (component, practices, and problem) in general.
- To analyze the current earthmoving operations practice in Addis Ababa city construction projects particularly in Kality-Tullu Dimtu round about Road Project;
- To develop a discrete-event simulation model describing earthmoving operation using Simphony-CYCLONE software;
- To optimize delivery time, resources and production rate of the system through comparing and experimenting with different models for earthmoving operations;
- To recommend improvement strategies that enhance the overall system production for the earth moving operations.

1.4. Research question

This research will answer the following questions:

- What is earthmoving operation's current practice in the construction industry?
- How can we establish the discrete-event simulation model for the current practice of earthmoving operation?
- How can we analyze the optimization and improve the strategies of the current practice?

1.5. Significance of the Study

In Ethiopia, the construction industry, in general, especially earthmoving operation, is not well researched, and this research helps the industry planners and managers in minimizing the difficulties and complexity during the planning and operating of earthmoving. Another significance of the study is to help future researchers as a foundation for their earthmoving operation research. Furthermore, the following are some significance of this research:

I. The analysis result of this research can be used as initial benchmark information for similar projects in the city.

II. The proposed model and its observation-based data collection format and the proposed model can be used in assessing and serving as a guide in the earthmoving operation process of other similar road projects.

III. It has identified critical activity in earthmoving operation with optimizing suggestions, and the finding is helpful for the improvement of earthmoving operation productivity and resource utilization.

1.6. Scope of the Study

The scope of this research is to study one case study (road construction project) only. The sample projects are a road project undergoing construction, namely Kality-Tullu Dimtu Round About Road Project (Kality Ring Road Square-Tullu Dimtu Square Road). The road project is located at Akaki-Kality sub-city from Kality Ring Road Square to Tullu Dimtu Square, and the quarry site (material production site) is located at Akaki-Kality sub-city in two different project sites. The selected material and sub-base/base-coarse are located around Kality St. Marry church and Akaki TVET college, respectively. The research work is limited to the earthmoving operations of road projects in Addis Ababa city administration. Also, the stockpiling and placing activities are part of the research, and their data were assumed based on the concept of caterpillar performance handbook calculation.

Besides, the data used in this research work data doesn't include the equipment breakdown, delivery period, weather condition, traffic jam, and hauling route type of earthmoving operations. Still, data is collected only from the cycle time (delivery of the material from the quarry site to the construction site) of the operations.

1.7. Limitation of the Study

The limitation of this research is mainly the lack of documented information on the subject of earthmoving operation and simulation software in the Ethiopian construction industry. The sampled project used to collect data is limited to one because of time and resource restriction. The research didn't include the data observed from the stockpiling and spreading (placing) activities; rather, it includes only the data found from the truck cycle (i.e., the delivery of the selected and crushed and unbounded materials). Generally, in earthmoving operation researches, data are collected by the help of the Global Positioning System (GPS) or Geographic Information System (GIS) and then transferred into the database automatically. But, in this research, the data collection (observation) is undertaken manually due to financial problems and the absence of GPS/GIS mounted trucks in the sampled project, and this may make it challenging to develop an appropriate simulation model for the operation.

Another limitation is concerning the implementation of the simulation and optimization framework for earthmoving operations developed in this thesis. At this stage, the work carried out is to examine the possibility of improving earthmoving operations, and the software development of this framework is not considered here.

1.8. Expected Output of the Study

The expected outputs of the research are:

1. Develop a DES model for current earthmoving operation practice.
2. Analyze the developed model for the current practice.
3. Establish better delivery time, resources, and production rate of the system by comparing and experimenting with different model scenarios for earthmoving operations.

1.9. Research Organization

The following chapters of the research are shaped around the concepts, details, implementation of the research tasks. This thesis is divided into five sections. These are:

Chapter 1: presents and gives a brief introduction to the issue of the earthmoving operation process in the construction industry, particularly in road construction projects. Besides, it shows the statement of the problem, research objective, research questions, research scope and limitation, and research significance and contribution to the construction industry.

Chapter 2: presents the detailed analysis, techniques, and practices of earthmoving operation, discrete-event simulation with the support of computer-aided software through literature review. Most of the materials presented in this chapter are previously published as technical paper and reports, Journals, books, and best practices. The material used as a reference for the document has been acknowledged.

Chapter 3: presents the research methodology and material by describing the sample project location (case study), data sample, data collection method, model development, model result analysis and discussion, and finally, conclusion and recommendation of the research.

Chapter 4: analyzes and discusses the earthmoving operation model input data and the parameters, developing and run the simulation model, output data analysis, result, and statistics report discussion and result from comparison for different earthmoving operation models in detail by graphical representation and tabulated form, and finally summarize the research findings.

Chapter 5: presents conclusions and suggestions based on the findings of the study and issues to be recommendations for action and further research.

CHAPTER 2: LITERATURE REVIEW

2.1. Introduction

Construction projects are dynamic, subject to randomness, and often complicated. They involve many operations and several interacting resources, including equipment, labor, and materials. They take place in a diverse physical environment. They also include a wide range of participants that do not generally use the same standards for data representation or common standards for information exchange. To develop a better understanding of the challenges associated with complex construction systems, it needs to analyze the application area of construction project bidding (AbouRizk & Hague, 2009). Construction projects, in general, are complex, and large construction projects, in particular, are broad in scope.

Ethiopia shows rapid development in the road construction sector, and there have been several road projects throughout the country. In Ethiopian GTP II, the total road length is planned to increase from 110,414 km in 2014/20115 to 220,000 km by 2019/2020. It is also expected to increase the ratio of asphalt (paved road) roads from 13% in 2014/15 to 16% by 2019/20. As clearly stated above, the country planned to double the road, and this has a significant contribution to the development of the country's economy (FDRE, National Planning Commission, 2016).

2.2. Earth Moving Operation

Earthwork projects involve moving specific amounts of earth from a set of source locations to a set of destinations (Rueda, 2011). Earthmoving operation commonly encountered in heavy and represent a sizable portion of infrastructure construction projects, such as dams, highways, and buildings with deep basements, frequently represent the sizable scope of work (Marzouk & Moselihi, 2004; Moselhi & Alshibani, 2009). Azar (2013), also stated that earthmoving is a major component of heavy-civil construction, such as highways, earth- and rock-fill dams, pipelines, land development, irrigation systems, and harbor construction projects. It may include site preparation, excavation, embankment construction, backfilling, preparing subgrade/ subbase/ base coarse, dredging, compaction, and road surfacing. Earthmoving is an essential part of major construction projects involving specially designed heavy equipment with significant purchasing/leasing prices, high operating, and maintenance costs (Fu, 2012). In earthmoving operations, project managers are under pressure to improve productivity, efficiency, and safety. Achieving these goals requires effective planning, tracking, and control system (Moselhi & Alshabani, 2007). Earthmoving operation includes four main activities, namely: loading, traveling, dumping, and returning (Pradhananga & Teizer, 2015; Fu, 2013; Shawki, et al., 2015). Earthmoving operations are also performed under conditions that may give rise to uncertainty. These conditions can include equipment breakdown, inclement weather, unexpected site conditions (Marzouk & Moselihi, 2004).

According to Fu (2013), the earthmoving operation has two methods. The first and most common method in earthmoving is employing several excavators, wheel loaders, and haulers to prepare, excavate, load, and transport soil. This method is more beneficial when the hauling distances and material quantities involved are relatively large. The second method is to use more independent equipment such as scrapers and wheel loaders to carry out the entire process, and this method is more appropriate when the transport distance is short. However, depending on the scope and working conditions of each project, anyone can select different operation methods and machine types to maximize the overall performance of the operation.

2.3. Earth Moving Process

The earthmoving process is the process of earthmoving operation from the inception up to the end of the work. Pena-Mora, et al. (2008) defined the earthmoving process as; iterations of moving soil and dumping it to an off-site location as part of the construction of a new highway. They summarized, in the earthmoving process, each iteration consists of subtasks named Load, Haul, Dump, and Return. Using available trucks and loaders, a certain amount of soil is loaded into a truck (Load), and the truck travels to a planned dumping site (Haul). The truck arrives at the site; it dumps the loaded soil (Dump) and returns to the loading site to be reloaded for the next iteration (Return). According to Fu (2013), the earthmoving operation includes four main parts; these are, loader/truck loading cycle, haulage of trucks to the disposal place, the deposition of the material, and the trucks' return trip to the loading station to start another load-and-haul cycle.

According to Voster & Bafna (1992), repetitive processes can be divided into two main categories: typical and no typical. Typical repetitive processes are characterized by having identical durations in all repetitions. On the other hand, no typical repetitive process doesn't have identical durations due to variations in the quantities of work and productivity. Moselhi & El-Rayes (1993), considering this categorization, the earthmoving process can be classified as a no typical repetitive construction process as all repetitions of the process do not have identical durations due to the increase in distance as the iterations progress.

The earthmoving process was selected for several reasons. First, the earthmoving process is an atypical (non-typical) repetitive process that usually requires construction managers to take management action, i.e., timely movement of resources to maintain work continuity (El-Rayes & Moselhi, 1998). Therefore, the earthmoving process could be a natural candidate to incorporate management actions into its modeling. Besides, the earthmoving process is one of the representative processes considered as indicators of the success or failure of many heavy construction projects as a whole (Smith, et al., 2000). Finally, based on this recognition, the earthmoving process has been used to determine the effectiveness of previous DES-based models, including (Martinez, et al., 1994; Smith, 1998; AbouRizk & Mather, 2000).

An earthmoving process has different steps, namely, preparation, cycle time (i.e., loading, hauling, unloading, and returning). Hereafter the earth moving process steps will be described in detail.

2.3.1.Preparation

Preparation is the setting of the earth to loading into haulers. It includes clearing the site, excavating, or ballasting the earth or rock according to the designing and planning of the project. Preparation can be done by Labor or equipment (E.gs. excavator, jackhammer, e.tc.) according to its volume, time, and difficulty of the work.

2.3.2.Cycle Time

According to Lineberry (1985), Cycle time is a time spent by any equipment to complete one cycle of operation. For a truck, cycle time includes the time to spot and load, travel to the dumpsite, maneuver, spotting, and dump and drive back to the loading point, also predictable delays, unpredictable, and wait times are included in the cycle.

Alhasan & White (2016) Conducted the cycle time analysis process involved defining the location of the Excavator and either the nearest stopping point of the hauling truck or the point with the lowest speed. The starting time of the stopping point defines the end of a cycle and the beginning of a new cycle. Accordingly, the cycle time is defined as the difference between the times of two loading points. Within a cycle, it was observed that there were several instances where the equipment stopped for a short period (e.g., two minutes) and then resumed travel.

According to Montaser & Moselhi (2014), and Rueda (2011), truck cycle time consists of four main components, which are loading, traveling/hauling, dumping, and return.

Loading time is the time spent by the truck inside the material stockpiled area. Loading is the process of transporting earth from the prepared pile into trucks. Wheel loaders and excavators are the most employed machinery for loading. Depending on the material state and ground space limitations, one type of equipment may be more applicable than the other (Fu, 2013).

Travel time is the time spent by the truck during transport of the loaded material from the quarry into construction (disposal) site. Hauling involves haul trucks traveling through roads with varying slopes and ground conditions as well as traffic intersections to transport earth to the deposit place. The earth is transferred from trucks into the spreading piles or crushers at the dumping station based on its final purpose.

Montaser & Moselhi (2014) defined dumping (unloading) time as; the time that spent by the truck inside the dumping area. Dumping is unloading the transported/hauled material into the prepared place of the earth materials. After dumping its load, the hauling units travel to the loading/stockpiled station to start another new cycle.

Return time is the time needed by truck to travel back from the unloading area to the loading area to start the new cycle (Montaser & Moselhi, 2014).

2.4. Computer-Aided Simulation and its Application in Construction Industry

2.4.1.Simulation and its technical term

The Oxford English dictionary describes simulation as: "The technique of imitating the behavior of some situation or system (economic, mechanical, etc.) utilizing an analogous model, situation, or apparatus, either to gain information more conveniently or to train personnel." Simulation is a quite general term, and there is plenty of room for misconceptions. Spreadsheet packages of today give the possibility to generate what-if scenarios quite easily. Simulation is the technique of building a model of a real or proposed system so that the behavior of the system under specific conditions may be studied. A simulation model may contain complex relationships between activities that specifically consider resource usage and uncertainties, such as variable weather conditions or random machine failure. The simulation model needs a lot of input data and produces even more result data. Simulation is an advanced technology based on a complex theory (Birgisson, 2009).

According to Birgisson (2009), simulation determines how an actual system functions; you would build a model of the system and see how the model functions**.** Simulation is an indispensable problem-solving methodology for the solution of many real-world problems. Simulation is used to describe and analyze the behavior of a system. It is especially useful to perform "what-if-scenarios." Both existing and conceptual systems can be modeled with simulations (Banks, 2000).

Simulations run in simulation time, an abstraction of real-time. As the simulation clock advances, the model determines if there have been changes, recalculates its values, and outputs the results. If the model is valid, the outputs of the simulation will be reflective of the performance or behavior of the real system (Birgisson, 2009)**.** The purpose for which a simulation model is built has a strong impact on which aspects of the methodology (or parts of the model in question) require the fullest rigor and which can be treated more flexibly. Quite often, a simulation model is used for purposes that are better served by other methods of analysis that require less effort to implement properly (e.g., a spreadsheet) (Martinez, 2010). Simulation is defined as the art and science of designing a model that acts in the same way as a real system does (Law & Kelton, 1991). Simulation provides a virtual world where decision-makers can better understand the complex nature of the problem by conducting experiments in a more controllable and low-cost environment (Wang & Halpin, 2004).

Computer simulation has been successfully used to analyze complex systems in operations research and the manufacturing industry. A successful simulation model results from the inseparable cooperation between domain experts and simulation engineers (Chua & Li, 2002). Simulation models are increasingly being used to solve problems and to aid in decision-making. The developers and users of these models, the decision-makers using information obtained from the results of these models, and the individuals affected by decisions based on such models are all rightly concerned with whether a model and its results are correct. (Sargent, 2011). Simulations are necessarily abstractions of the real world, and no one simulation design can meet the functional needs of the entire modeling and simulation community. However, in defining an overriding architecture, generic issues can be addressed. When doing so, such an architecture must encompass both differing computing environments and different classes of simulations.

2.4.2.Discrete-Event Simulation (DES)

Discrete-event simulation is a powerful method to imitate the behavior of a real-world system over time by modeling repetitive processes in which operations durations are stochastic, and many resources interact (Law & Kelton, 1991). The DES model is a system in which the state variables occur only at discretize points and by discrete steps (Shawki, et al., 2015). The objects in the system are distinct individuals, each possessing characteristics that determine what happens to that individual, and the activity durations are sampled for each individual from the probability distribution (Hao, 2012).

According to Rekapalli & Martinez (2011), discrete-event simulation (DES) are state-based systems, where the state of a simulation is a snapshot of current internal information such as the simulation time, the location of resources, activities that are currently in progress and their scheduled finish times, resource properties, and variables. During a simulation run, based on the current state of the model, the DES determines the future simulation time at which the DES model state will change and advances its simulation clock instantaneously to that time. Upon advancing the simulation clock, the new simulation state is determined based on the logic and structure of the simulation model. This process continues until a simulation state is reached where no further changes can occur or a simulation ending condition is reached.

Discrete-event modeling is an inherently complex activity that is both a science and an art. Describing the operation model in the language of a simulation modeling system (metal plan) is considered as art and operation of actually modeled is as science (Kamat & Martinez, 2001). DES is particularly beneficial for modeling complex dynamic systems that are intractable to other modeling approaches (Kamat & Martinez, 2001). DES has been found as a powerful technique for the quantitative study of operations and processes that take place during the life cycle of a constructed facility (Martinez, 2010). DES is then the only feasible way of analyzing the system at some level of detail. An event in the context of discrete-event simulation can be defined as an instant of time at which a significant state change occurs in the system (Randell, 2002)

Operations research-based DES systems are effectively used to model construction processes and to analyze their productivity at the operation level. On the other hand, DES-based scheduling systems also model the uncertainty of activity durations and effectively handle the variability of project completion times (PCTs) at the project level. However, these systems are not used extensively in practice because of various deficiencies that hamper their usability (Lee, et al., 2010)

According to Birgisson (2009), Discrete-event simulation is a method well suited to describe and simulate complex systems. It is especially appropriate for dealing with complex relationships between components, resources, and how they are used in the process. A method is now a standard tool in manufacturing industries, but it is so far limited to individual research projects in the construction industry. However, the recent developments in computer software, that support this technology open for an introduction of discrete-event simulation as an alternative planning method in construction projects.

The DES model results illustrate the advantages of flexible dispatching intervals provided by fixed-quantity inventory control policy, including maintaining continuous work and reducing waste. DES models have mainly dealt with operational issues without aggressively considering the project feedback structure and have focused on the efficiency of process logistics in terms of time, cost, and resource usage (Pena-Mora, et al., 2008).

When variables change discretely, the system is referred to as a DES system. A DES model depicts the operation of the system as a sequential order of events called the chronological list. In DES, a change in variable occurs as an event at a specific point in time, marking a change of state in the system. On the other hand, in continuous simulation models, variables change over a while and not instantaneously at specific points in the simulation run time. This change is performed using a set of mathematical equations.

DES models a system as a network or a flow diagram of a collection of queues and processes, where changes in the system occur at distinct points in time (Brailsford & Hilton, 2001). Overall, in DES, entities involved in the process being modeled are treated as passive objects. They can represent people, equipment, organizations, documents, tasks, messages, etc.

These entities travel through the DES flowchart, where they stay in queues, get processed, and then release resources (Borshchev & Filippov, 2004). An entity flows through a DES model, seizing resources to perform different tasks, and releasing these resources once the work task has been completed. But, if these resources are busy and unavailable when the entity requires them to complete the work task, the entity will pause and be delayed in a queue until the required resources become available again.

According to Martinez (2010) discussed steps which are appropriate for DES studies in construction engineering and management as follow:

- Determine the extent to which a DES model can lead to a better understanding of the system in question or to obtaining quantitative measures of performance for the problem of interest.
- Establish the scope of the model and the specific questions that the model should answer.
- Define the model for the operation, and this includes establishing the level of detail of the model, selecting the elements that will be used to represent the real system.
- Collect and synthesize data about the operation to suit the model. In addition to actual data collection, this includes determining whether basic probabilistic assumptions, fitting distributions, and testing for the goodness of fit.

- Verification and validation of the model and data ensure that it matches the modeler's understanding of the system and the real or imaginary, respectively.
- Analysis of simulation model output for a single running
- Design and execution of simulation experiments.
- Analyze the output of experiments to determine the performance of various system configurations or to select the best from among several alternatives.
- Result documentation and presentation.
- Use results for decision making.

2.4.3.Classification (Types), purpose and Application of Simulation

2.4.3.1. Classification/Types of Simulation

According to Chua & Li (2002), simulation modeling methods can be classified in terms of strategies (i.e., process-oriented simulation and resource-oriented simulation) or scope (i.e., general-purpose simulation and special-purpose simulation). The latter category elaborates as below:

Models created in general programming languages or general-purpose simulation tools can, in principle, represent almost any real-life process. They can be tailored to the very precise requirements of the model in question. However, usually, a tremendous amount of effort is also required, even in developing a very simple model. General-purpose simulation systems usually involve computer programming and are flexible enough to model very complicated operations (Chua & Li, 2002).

In contrast, special-purpose simulation modeling methods target a specific domain such as earthmoving, shield tunneling, and so on. Special-purpose simulation bridges the need for accurate modeling and the desire for a reduced level of effort and lower complexity. Rather than develop a general-purpose simulation framework requiring a high degree of abstraction, it may be more effective to develop a special-purpose tool for a specific sector of the industry. Special-purpose simulation tools are usually nonprogrammable and easy to learn, but May only be used to effectively model simulation operations. The special-purpose simulation tools should allow the user not only to select and customize the models from the model set to increase its flexibility but also to create his/her model (Chua & Li, 2002).

According to Banks, et al. (2014) and Law & Kelton (1991), Models can be generally classified along three dimensions as Static or dynamic, deterministic or stochastic, discrete, or continuous. These classifications will be elaborated as below:

A static simulation model is a representation of a system at a particular point in time. It does not contain the time factor (Shi, 1999). A dynamic simulation model represents a system over time, i.e., the system state, entity attributes, and the number of active entities, the contents of sets, and the activities and delays currently in progress are all functions of time. They are constantly changing over time, dynamic simulation evolves (Shi, 1999). Both static and dynamic simulation consists of two major phases, i.e., designing a mathematical, logical method of a real system and experimenting with this model on a computer (Pritsker, 1995).

Deterministic simulation models do not contain any probabilistic inputs, and the results are fully determined as long as the inputs are given (Law & Kelton, 1991; Shi, 1999). If a model contains no probabilistic components, it is deterministic, i.e., the result is always the same given the same input. The stochastic model contains variables defined by a random (probabilistic) distribution function. Stochastic models produce output that is itself random. Therefore, the inputs should reflect the characteristics of the real system (Law & Kelton, 1991; Shi, 1999). In a stochastic simulation model, the behavior is determined by stochastic variables. In the real world, most things are stochastic. Typical stochastic variables are cycle times, the time between failure and repair times.

A continuous system is one in which the state variables change continuously over time (Randell, 2002). Continuous simulation is used to model systems whose conditions and dependent variables change continuously concerning time (Pritsker, 1995), (Al-Sudairi, 2000), (Law & Kelton, 1991; Shi, 1999). A discrete system is one in which the state variables change at a discrete set of times (Randell, 2002). Discrete-event simulation is used to model systems whose conditions and dependent variables discretely change at specified points in time as a result of specific events (Pritsker, 1995), (Al-Sudairi, 2000), (Law & Kelton, 1991; Shi, 1999).

2.4.3.2. Purpose (Advantage and Disadvantage) of Simulation

According to Oloufa (1992) description, the purpose, and advantage of using simulation in any operational process as the following:

- Serve as an option to study systems that are complex to describe in an analytical model.
- Enables the investigator to study an existing or planned system when subjected to any set of operating conditions.
- Alternate solutions to a problem can be studied and compared.
- It gives the investigator an insight and enhances the comprehensibility of the system considered.

Additionally, Banks, et al. (2014) also listed some advantages of simulation. The following are among them:

- New policies, operating procedures, decision rules, information flows, organizational procedures, and so on can be explored without disrupting ongoing operations of the real system.
- New hardware designs, physical layouts, transportation systems, and so on can be tested without committing resources for their acquisition.
- Hypotheses about how or why certain phenomena occur can be tested for feasibility
- Time can be compressed or expanded to allow for a speed-up or slow-down of the phenomena under investigation.
- Insight can be obtained about the interaction of variables and the importance of variables to the performance of the system.

- Bottleneck analysis can be performed to discover where work in process, information, materials, and so on are being delayed excessively.
- A simulation study can help in understanding how the system operates rather than how individuals think the system works.
- "What if' questions can be answered.

According to Banks, et al. (2014), the following are some disadvantages of simulation.

- Model building requires specialized training, and it is an art that is learned over time and through experience.
- Simulation results can be challenging to interpret. Most simulation outputs are essentially random variables, so it can be hard to distinguish whether an observation is a result of system interrelationships or randomness.
- Simulation modeling and analysis can be time consuming and expensive.
- simulation is used in some 'cases when an analytical solution is possible, or even preferable

Oloufa (1992) mentioned, the disadvantages of using simulations as follow:

- Reliable simulation models are often expensive and time-consuming to develop.
- Simulation generally portrays the system's performance for a given set of conditions. A large number of simulation runs may be required.
- Simulation aids in selecting the best alternative from the standpoint of the model and its constraints, which is not necessarily the optimum one.
- A large amount of data produced after stimulation may give misleading information about the simulation model's performance and validity.

2.4.3.3. Application of Simulation

The application scope and simulation strategies determine the capability and flexibility of a simulation modeling method (Chua & Li, 2002). The simulation approach may be used to study almost any problem and provided that the simulation model identifies the elements involved in the simulation, along with the major attributes of the interactions between these elements. Each simulation on the model becomes an experiment on the system that can be observed and controlled (Oloufa, 1992). Furthermore, the main reason for simulations application popularity and makes it versatile and powerful tool is its ability to deal with very complicated models of a corresponding complicated system. Another reason for increasing simulation popularity is the obvious improvement in performance, flexibility, quick and valid decision-making tools (Kelton, et al., 2002).

Law & Kelton (1991) Stated that application areas for simulation are numerous and diverse. The following are a list of some particular kinds of problems for which simulation is a useful and powerful tool:

- Designing and analyzing manufacturing systems,
- Designing communications systems and message protocols for them,
- Designing and operating transportation facilities such as freeways, airports, subways, or ports,
- Determining ordering policies for an inventory system,
- Evaluating hardware and software requirements for a computer system,
- Evaluating a new military weapons system or tactic,
- Evaluating designs for service organizations such as hospitals, post offices, or fast-food restaurants.

According to Banks, et al. (2014), discussion simulation can be applied in different areas such as; manufacturing applications, semiconductor manufacturing, construction engineering and project management, military applications, logistics, supply chain, and distribution applications, transportation modes and traffic, and business process simulation.

Besides, AbouRizk, et al. (2016) stated that simulation could be applied in the construction industry in various ways. For example, during design: it can be used to analyze Risk, Value, Constructability reviews (scenario-based planning), Construction plan development, Budget development, and Estimating. During/post-construction: Planning and control, Continuous improvement, Claims, and dispute resolution. Etc.

2.4.4.Simulation in Construction Operation

Construction simulation is the science of developing and experimenting with computer-based representations of construction systems to understand their underlying behavior. Simulation modeling is important in predicting the productivity of construction operations and the performance of project schedules (Lee, et al., 2010). Computer simulation techniques are very effective in this domain at providing the tools required to design and analyze construction processes regardless of complexity or size (Hajjar & AbouRizk, 1999). Computer simulation ensures more realistic structuring and planning of construction operations as it allows for observing technological and logical dependencies and resource availability limits, and analyzing the impacts of potential variations on the total project performance (Polat & Buyuksaracogul, 2009).

Computer simulation allows for the modeling, analysis, and optimization of construction operations. It is a proven technology, and countless studies have been performed to demonstrate its applicability to the analysis of a wide range of construction operations, including aggregate production, earthmoving, mining, tunneling, and precast concrete manufacturing (Hajjar & AbouRizk, 2000). Construction simulation can be of great assistance to decision-makers in analyzing various construction operations and alternatives. Simulation of construction operations allows analysts and construction industry personnel to experiment with different construction technologies, and estimate the possible consequences and impacts on scheduling and costs (Ruwanpura, et al., 2001).

Simulation is a powerful objective function evaluator that is well suited for the design of construction processes. Simulation, as applied to construction operations planning and analysis, entails the creation of a model that represents how a construction operation will be performed. This model considers the different resources that are required to carry out the construction operation, the rules under which the different tasks that compose the operation are performed, the managerial decisions made during the operation, and the stochastic nature of events (Kamat & Martinez, 2001).

Simulation is one of the powerful techniques for supporting the decision-making process for construction management. Accurate modeling of a construction process can help the development of better alternatives and optimization of the involved resources. However, the use of simulation techniques in the construction industry is believed to be minimal. The complexity of simulation methodologies and lack of deep simulation knowledge among industry personnel are among the main causes of weak utilization of simulation in construction management (AbouRizk & Mohmed, 2000).

According to Packer (2002) and Shi & AbouRizk (1997) conclusion, at the research level, Construction simulation has proven to be an effective tool for planning and improving the performance of the construction process. Still, it has struggled to become fully accepted at the practical level.

2.5. Application of Discrete-Event Simulation to Earthmoving Operation.

Discrete-event simulation is an effective approach to analyze construction operations, and thus improve construction productivity. It concerns the modeling of a system as it evolves by a representation in which the state variables change instantaneously at separate points in time (Chua & Li, 2002).

According to Chua & Li (2002), how to apply discrete-event simulation in analyzing and designing construction operations has been doing researches for the past three decades. However, due to the uniqueness and relatively short life of construction projects, the capability of discrete-event simulation modeling has not been popularly recognized by site managers until recently.

Simulation studies are appropriate for the analysis of earthmoving operations for numerous reasons, including the repetition of given operations, dynamics of resource interactions, external factors that need to be included in the analysis, and the randomness associated with such systems

(Hajjar & AbouRizk, 1996). It allows construction professionals prediction and valuation of operational productivity. However, it is not simple to develop a simulation model because of its complex, resource-intensive, and probabilistic nature of the occurrence.

Discrete-event simulation (DES) is a modeling technique that has been used to analyze and design many construction operations. DES has been used for the planning and analysis of construction operations since the 1970s. It offers significantly greater power at modeling construction systems than the traditional scheduling and planning methods such as the critical path method (CPM) by providing for methods that consider the flow of resources in addition to activity precedence diagrams (Louis, et al., 2014).

DES models directly replicate construction processes so construction managers can easily analyze their logistics. As DES models can provide detailed information for execution, they have been mainly utilized to analyze operational issues like earthmoving or pipe installation (Pena-Mora, et al., 2008).

The probabilistic nature of the work and the dynamics of earthwork operations make them difficult to plan. They are typically planned using manual or traditional techniques, but mainly relying on the experience and insights of the planner. Discrete-event simulation is the only earthwork analysis method that can explicitly incorporate the detailed but significant aspects (e.g., equipment characteristics, haul road conditions, load and dump area configuration, and dynamic context-based decisions) of an operation. The preparation of a detailed and precise simulation model, however, typically requires the use of a general-purpose simulation programming language. These advanced tools require extensive training that is not generally available in the personnel responsible for planning (Martinez, 1998).

According to Perdomo (2001), DES is a very useful tool for the design and analysis of earthmoving operations because it can consider most of the uncertainties and logic associated with them. DES techniques are used to capture the interaction between resources and the randomness of the earthmoving activities.

2.6. Input Modeling and Output Analysis for Simulation of Earth Moving Operation

2.6.1.General Developing of the Simulation Model

According to Hillier & Lieberman (2001), a simulation model has several basic building blocks; 1) A definition of the state of the system, 2) Identify the possible state of the system that can occur, 3) Identify the possible events, 4) A provision for a simulation clock, 5) A method for randomly generating the events of the various kinds, and 6) A formula for identifying state transition that is generated by the various kinds of events.

Banks, et al. (2014), mentioned ten steps that use to build detail and sound simulation study. These are; Problem formulation, the setting of objectives and overall project plan, Model conceptualization, Data collection, Model translation, Model verification, and validation, Experimental design, production runs, and analysis, finally documentation and reporting. Similarly, Law (2015), stated ten steps that will compose a typical, sound simulation study as; Formulate problem and plan the study, Collect data and define a model, Construct a computer program and verify, Make pilot runs, Program model validation, Design experiments, Make production runs, Analyze output data, and Document, Present, and use results.

Hao (2012) used five general steps for developing the DES model of RMC delivery operation process; develop a model in the Any Logic environment, input data analysis, model validation, experiment design of two control policies implemented in the base model, and simulation results analysis. Smith (1998), also mentioned five steps involving in discrete-event simulation modeling development of concrete placing operation. These are the gathering of actual data, choice of the probability distribution for individual time component, generation of random samples (variants) from these distributions, simulation of concrete operations, and experimental analysis of concrete operations.

According to AbouRizk, et al. (2016) stated, the development of simulation models needs to follow a high-level approach systematic process to be fruitful.

- The formalism of the Problem Domain or Conceptual Modeling: this is the identification and abstraction of the problems and its overall process from the real world. The problem may comprise an entire real-world problem or a part of the system (e.g., operation). It culminates in the production of simulation model assumptions, requirements, and specifications. Each of these needs to be documented descriptively and graphically, resulting in the creation of conceptual models.

- Development Process: involves translating these concept models into working simulation models to require the simulationist to select an appropriate simulation on modeling paradigm, a simulation environment, knowledge of simulation principle (e.g., Discrete-event simulation), and know-how of the simulation environment chosen for deployment of the models. In this stage, the "Draft Model" has developed.

- Simulation Model Accreditation, Verification, and validation: after validation and verification of the drafted model, users of the model to build confidence in the model through the model accreditation process. It also can go jointly with documentation of the details of the model. These include model inputs, model implementation, and logic, and model validation and verification.

- Simulation Model Deployment: this is the final stage simulation model development and the final working of the computer simulation model.

A high-level approach that can be followed during the typical development process of the simulation model is given below in figure 2.1

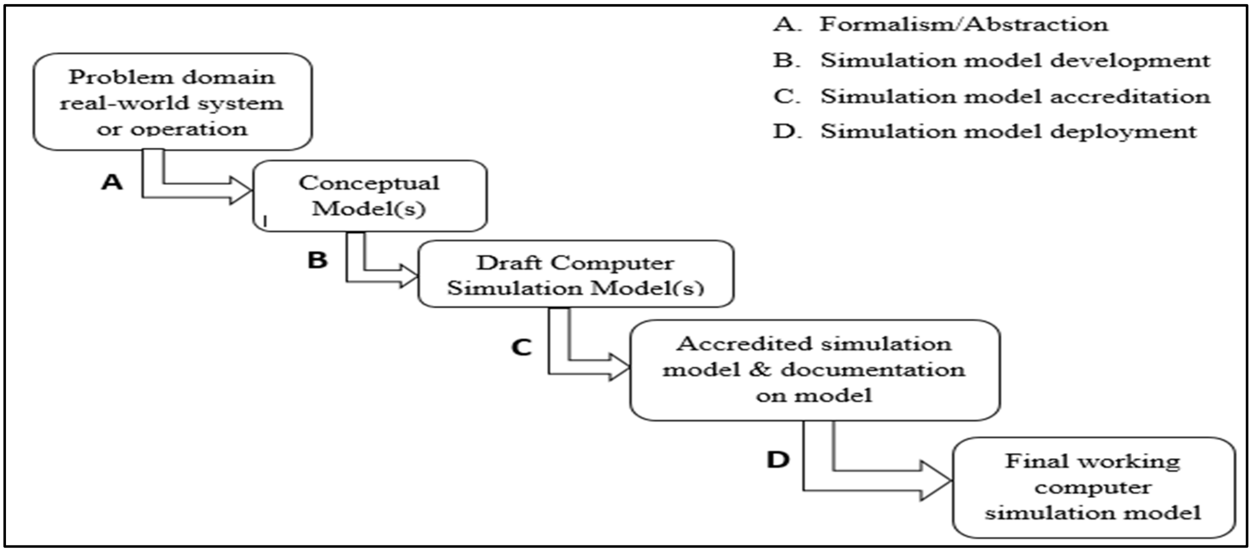


Figure 2. 1: A schematic layout of a typical simulation model development process (source: AbouRizk el at., 2016)

2.6.2.Input Modeling for Earthmoving Operation

AbouRizk, et al. (2016) mentioned three things that simulator should ensure to have fruitful simulation experiment as follow;

1. Proper input in the form of statistical models for work task duration and allocation of resources in the system, stopping rules for ending simulation;
2. Proper analysis of the output; and
3. Validation and verification of the model.

Law (2015) stated that to perform a simulation using random variable inputs such as interarrival times or demand sizes, we have to specify their probability distribution, and the simulation model follows these specific distributions. It proceeds through time by generating random values from these distributions. He mentioned three approaches to specify a distribution by using collected data on an input variable of interest. These are; (1) using the data values directly in the simulation, (2) using the data values to define an empirical distribution in some way, (3) standard techniques of statistical inference are used to fit a theoretical distribution form to the data and to perform hypothesis tests to determine the goodness of fit.

Hao (2012) discussed, traveling time, unloading time, the number of trucks, and the number of the pump as key(main) input and return time and loading time as minor or variable inputs in his simulation model development of delivery and placement of ready-mix-concrete operation.

AbouRizk, et al. (2016) stated, duration input (the most critical form of input in construction models) to a simulation experiment in construction is classically approached by fitting a statistical distribution to a collected sample of observations. A simulationist can fit any of the classical statistical distributions to the sample of observations.

A checking goodness-of-fit should be performed in any case by using statistical goodness-of-fit tests like Chi-square, Kolmogorov-Smirnov (K-S) test, Q-Q plots, and Visual inspection of the quality of the fit of the empirical and the fitted CDF or PDF and the histogram of the sample data (AbouRizk, et al., 2016). The steps usually followed in input modeling are shown below in figure 2.2

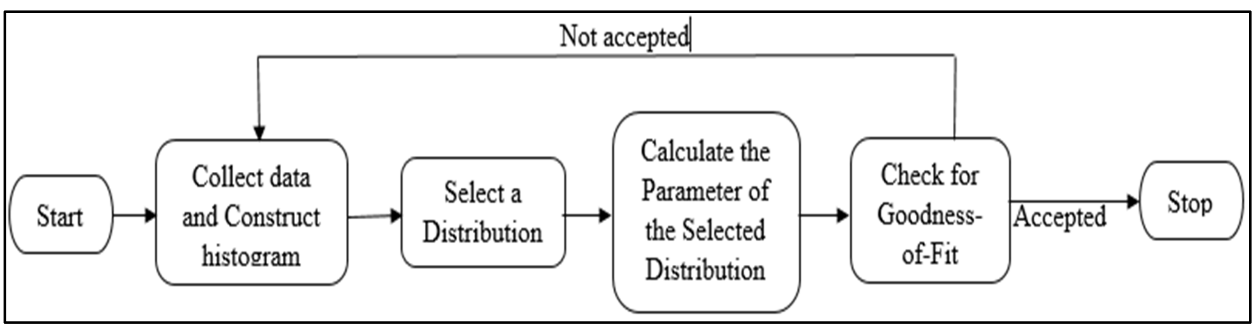


Figure 2. 2: Input Modeling Steps for a Simulation Experiment (source: AbouRizk el at., 2016)

2.6.3.Simulation Model Verification, Validation, and Accreditation

2.6.3.1. Simulation model verification

Model verification is ensuring and concerned with translating the conceptual model to computerized model representation that implements that conception. Its process involves determining that the computer model is instantly consistent and following the logic of the conceptual (Sargent, 2011; Banks, et al., 2014; Law, 2015). AbouRizk et al. (2016) confirmed that Simphony provides a feature for checking model integrity.

2.6.3.2. Simulation model validation

Sargent (2011) defined model validation as substantiation that a computerized model within its domain of applicability possesses a satisfactory range of accuracy consistent with the intended application of the model.

Verification and validation, although conceptually distinct, usually are conducted simultaneously by the modeler. Validation is the overall process of comparing the model and its behavior to the real system and its behavior (Banks, et al., 2014). Simulation model validation has to be done to guarantee the computer simulation model in providing a virtual environment that is the accurate and credible replica of the real-world (AbouRizk, et al., 2016).

Sargent (2011) discussed many simulation model validation techniques that should be done to check the validation of simulation models in a different stage of simulation model development (conceptual validation, input data validation, and operation validation). AbouRizk, et al. (2016) selected some validation techniques among the techniques discussed by which they found useful in construction engineering and management simulation modeling application, namely: face validation, comparison to other models, event validation, degenerate tests, and historical data validation.

1. **Face validity:** Individuals knowledgeable about the system are asked whether the model and/or its behavior are reasonable. Therefore, they can evaluate the model input-output for the correctness and can support in identify the model deficiency (Sargent, 2011; Banks, et al., 2014; Law, 2015). This type of validation is directly related to the logical, conceptual modeling, and model's input-output relationship (implementation).

2. **Comparison to other models:** includes the comparison of various results (e.g., output) of the simulation model is validated to known results of other analytical models or models that have been validated (Sargent, 2011; AbouRizk, et al., 2016).

3. **Event validity:** the events of occurrences of the simulation model are compared to those of the real system to determine if they are similar (Sargent, 2011; AbouRizk, et al., 2016). For example, compare the number of trucks available in real operation to the output result of the simulation model.

4. **Historical Data Validation:** if historical data exist (or if data are collected on a system for building or testing a model), part of the data is used to build the model, and the remaining data are used to determine (test) whether the model behaves as the system does (Sargent, 2011; AbouRizk, et al., 2016).

2.6.3.3. Simulation model accreditation

Sargent (2011), AbouRizk, et al. (2016) and Law (2015) mentioned that, the definition of accreditation by U.S.A Department of Defense (DoD) as the official certification that a model, simulation, or federation of models and simulations and its associated data are acceptable for the use of a specific application. DoD has moved to accrediting simulation models.

Model accreditation should typically be performed by a third party who determines how easy the model is to use for the intended user, the model's validity, and its reliability. The objective of model accreditation is to confirm that the simulation model and its accompanying documentation conform to all the modeling requirements (AbouRizk, et al., 2016).

2.6.4.Output Analysis for Simulation of Earth Moving Operation

According to Law (2015) and Banks, et al. (2014), output analysis is the examination of data generated by a simulation. Its purpose is either to predict the performance of the system or to compare the performance of two or more alternative system designs. A typical analysis of simulation output usually includes determination of whether the simulation is deterministic or stochastic, and it reflects a static, transient, or steady-state (AbouRizk, et al., 2016).

Mohsen, et al. (2008) examined the simulation model of the on-site assembly aspect of the modular construction process using the Simphony general-purpose simulation (GPS) template. Accordingly, the simulation output from the simulation was provided CDF for project duration, production statistics, and crew (workforce, equipment) and laydown space utilization.

2.7. Simulation Software Used in Construction Operation

According to AbouRizk & Hague (2009), traditionally discrete-event process interaction process is the dominant approach for simulation construction operations. With this approach, a simulationist creates a model of a construction operation using specific modeling constructs. It is an inherently complex undertaking in which the simulationist has to describe, in a given simulation language, the production process under consideration. Much advancement has taken place to facilitate the application of discrete-event process interaction simulation in construction.

Some researchers developed several simulation software to simulate construction operation process; Hajjar & AbouRizk (1997) developed AP2-Earth, a special purpose simulation-based system for the analysis of large earthmoving projects, Hajjar & AbouRizk (1998) also developed CRUISER for modeling aggregate production plans, Hajjar et al. (1998) developed for the optimization of construction site dewatering operations, Hajjar & AbouRizk (1999) developed a DES system called SIMPHONY, Shi (1999) introduced ABC (Activity-Based Construction) which uses a single element for modeling general construction processes, Chua & Li (2002) developed RISim for simulation modeling construction operation, Lu, et al. (2003) developed *HKCONSIM* for modeling ready mix concrete production operation, AbouRizk & Hague (2009) developed a virtual environment that capture all features, resources, and processes required to design, build and maintain a facility in COSYE, (Siadat & Ruwanpura, 2013) developed EarthSim for modeling earthmoving projects, Shawki, et al. (2015), used ARENA to develop a simulation model of earthmoving operation.

DES-based systems at the operation and project levels are independently used to improve operational productivity and scheduling performance. These systems are well accepted in a wide range of applications in practice (Lee, et al., 2010). INSIGHT (Paulson 1978), UM-CYCLONE (Ioannou, 1990), Micro CYCLONE (Halpin and Riggs 1992), CIPROS (Tommelein et al. 1994), COOPS (Liu, 1995), DISCO (Huang and Halpin, 1995), STROBOSCOPE (Martinez, 1996), ABC (Shi, 1999), and SIMPHONEY (Hajjar & AbouRizk, 1999) are among the several custom developed simulation packages specially designed for construction projects based on CYCLic Operation NEtwork developed by Halpin (1977) (Zahran & Nassar, 2013; Jabri, 2014).

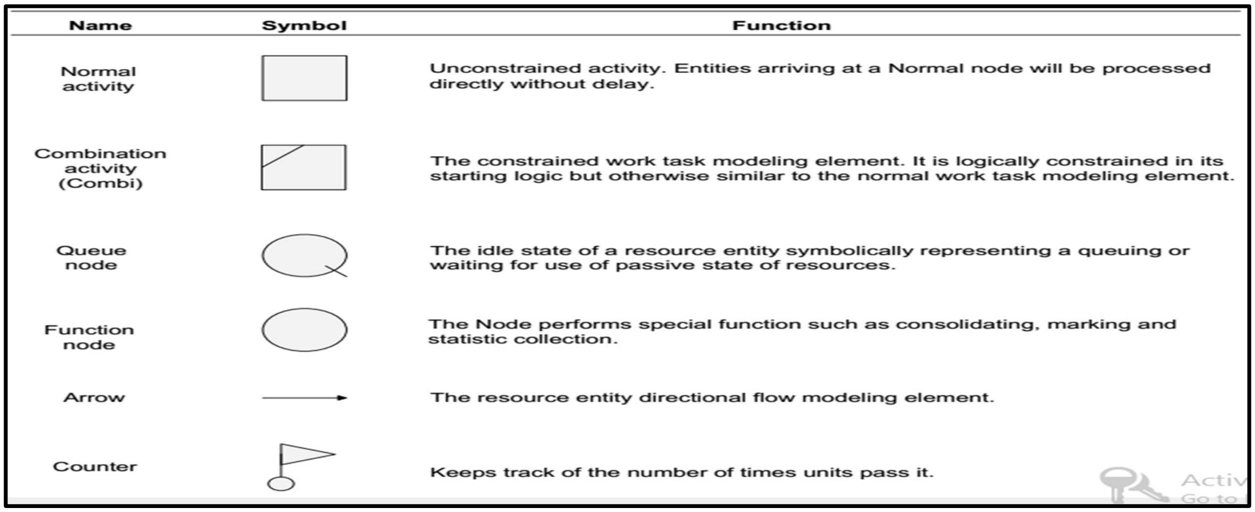
Several simulation software and planning optimization techniques have been developed and used in construction operation, as described in the above literature. However, the most popular simulation is listed and discussed as the following.

2.7.1.CYCLONE/Micro-CYCLONE/UM-CYCLONE

CYCLONE (CYCLic Operations Network) was developed by Halpin (1977). CYCLONE is a modeling technique that allows the graphical representation and simulation of discrete systems that deal with deterministic or stochastic variables. CYCLONE creates simple simulation model processing and makes it accessible to construction practitioners with limited experience in simulation (Purdue University, 2020). CYCLONE is among the first simulation languages developed for use in construction operation, and it mainly focuses on the modeling construction process rather than the system. In CYCLONE construction process is abstracted and represented in the form of operation and processes that are composed of tasks and queues. (AbouRizk, et al., 2016). It also has powerful modeling capabilities that are based on a very small, comprehensive set of primitives (Tommelein, et al., 1994).

CYCLONE uses the following four steps to perform project-level simulation (Sawehney, et al., 1998): (1) identify all the processes that are to be modeled for the project under consideration; (2) identify and define the resource required for the processes identified in step 1; (3) develop process models using the CYCLONE modeling element; and (4) perform simulation of the processes using the common resource pool.

CYCLONE Provides a systematic way of planning, organizing, analyzing, and controlling construction operations. It consists of a network simulation language that suits operations of cyclic (repetitive) nature, such as highway, construction, concrete poring, earthmoving, and piping. CYCLONE consists of six essential elements used to model construction operation. These are NORMAL, COMBI, QUEUE, FUNCTION, COUNTER, and ARROW. The list, symbol, and function of the six-element elements are shown below in figure 2.3 (Alzraiee, 2013).



Name	Symbol	Function
Normal activity		Unconstrained activity. Entities arriving at a Normal node will be processed directly without delay.
Combination activity (Combi)		The constrained work task modeling element. It is logically constrained in its starting logic but otherwise similar to the normal work task modeling element.
Queue node		The idle state of a resource entity symbolically representing a queuing or waiting for use of passive state of resources.
Function node		The Node performs special function such as consolidating, marking and statistic collection.
Arrow		The resource entity directional flow modeling element.
Counter		Keeps track of the number of times units pass it.

Figure 2. 3: Basic CYCLONE modeling elements (source Zayed & Halpin, 2001)

Micro-CYCLONE is a microcomputer-based simulation designed especially for modeling and analyzing site-level processes that are cyclic. It uses the modeling concepts of CYCLONE. Generally, it can be used to model construction operation, which involves the interaction of tasks with their related duration, and the resource unit flow routes through the work tasks are the basic rationale for the modeling of construction operations (Purdue University, 2020).

UM-CYCLONE is a discrete event simulation system made up of a collection of programs that work together to provide an integrated modeling environment. A UM-CYCLONE simulation model is a network of interconnected nodes: Activities, Queues, and Consolidation Nodes (Ioannou, 1990).

2.7.2.STROBOSCOPE

STROBOSCOPE (STate and ResOurce Based Simulation of COnstruction ProcEsses) (Martinez, et al., 1994; Martinez & Ioannou, 1994) is a programming language specially designed to model construction operation. Stroboscope models are based on a network of interconnected modeling elements and on a series of programming statements that give the elements unique behavior and control the simulation (Marzouk & Moselhi, 2003).

According to Mohamed & AbouRizk (2006), Stroboscope provides the user with the ability to dynamically access the state of the simulation and the properties of the resources involved in the operation. Stroboscope modeling elements have attributes define through programming statements that define how they behave throughout a simulation (Jabri, 2014; Martinez, et al., 1994).

Stroboscope can be used to develop simulation models for different construction operations such as the Airplane Service center (Martinez & Ioannou, 1994); operation of the quarry (Martinez & Ioannou, 1995), and earthmoving operation of dam construction (Ioannou & Martinez, 1996).

Stroboscope can be extended via add-ons written according to its add-on interface with conventional compiled language such as C, C++, PASCAL, and FORTRAN (Martinez, 1996). For example, Martinez & Ioannou (1997) developed a simulation model of probabilistic CPM scheduling for food-outlet construction operation by using the CPM Add-on program to Stroboscope. Ioannou & Martinez (1998) also used the same Add-on for the highway project.

2.7.3.SIMPHONY

Hajjar & AbouRizk (1999) developed SIMPHONY; it is a Microsoft Windows-based computer system developed to provide a standard, consistent, and intelligent environment for both the development as wells the utilization of construction SPS tools. Tool developers can use Simphony to implement highly flexible simulation tools that support graphical, hierarchical, modular, and integrated modeling with great ease. But tool users can access only to a single program that allows them to build simulation models in an intuitive and user-friendly manner.

Hajjar & AbouRizk (2002) developed Simphony based on unified modeling methodology and redeveloped templates for earthmoving and aggregate production simulation tools. Simphony allows for the creation of new SPS tools in the form of modeling element templates. Some templates are tunnel construction operation template (Ruwanpura, et al., 2001), crushing plant and earthmoving operation template-based CYCLONE methodology template (Hajjar, et al., 2000), industrial fabrication template (Sadeghi & Fayek, 2008), supply chain simulation toolkit (Ebrahimy, et al., 2011).

Simphony provides a highly flexible, yet user-friendly, environment for the simulation modeling process, including support for (Hajjar & AbouRizk, 2002):

1. Modular and hierarchical modeling for the representation of complex and large construction projects;
2. Developing models using standard templates including PERT simulation, Range Estimation, CYCLONE, General purpose modeling as well as special-purpose simulation including earthmoving, utility tunneling, aggregate production, and others;
3. Extension of specialized SPS tools through the construction of models, which includes more than one templates;
4. Generation of custom output results in the form of tables and graphs;
5. Automated generation of externally accessible project planning data in a standard format;
6. Script-based modeling for the accommodation of advanced users wishing to bypass the graphical user interface;
7. Storage and retrieval of commonly used simulation model structures in the user model library; and
8. Integrated development environment (IDE) style interface for tool development.

According to AbouRizk, et al. (2014) discussion, the features that make Simphony unique is its ability to create SPS tools (templates); its ability to modify behaviors of various modeling templates; the integrated calendars for scheduling work, DES, and continuous simulation; and several templates in the public domain to enable general-purpose modeling and special-purpose modeling.

2.8. Construction Simulation in Ethiopia

In Ethiopia, construction simulations and models are at its infant stage at the university research level, and it has not started at a practical level in the construction operation. Some researches related to modeling and simulation of the construction industry in Ethiopian are: Getachew (2016) conducted the role of building information modeling (BIM) in improving building design process, Matheas (2009) and Alemayehu (2014) developed Multiple Linear Regression model (MLR) to analyze, design, and cost-effectiveness of pre-cast beam slab system and to estimate the cost of road construction projects respectively using Multiple Linear Regression model (MLR), Kassahun (2018) and Taye (2019) developed Monte Carlo Simulation model for cashflow forecasting for building construction projects and cost overrun in construction projects respectively. These researches are related to the design process and financial for road and building construction operations.

Besides, there is also some another simulation modeling research related such as A factor model to predict the construction labor productivity in building projects using Multiple linear Regression model (MLR) (Arnaud, 2019), a simulation model for optimization of tower crane location in high-rise building projects using Particle Swarm Optimization (PSO) (Ketema, 2019), and simulation model for planning of ready-mix concrete (RMC) site delivery using Simphony-CYCLONE (Sileshi, 2018). But there is no simulation related to earthmoving operations at research and practical level.

CHAPTER 3: RESEARCH METHODOLOGY

3.1. Research Design

3.1.1.Description of Sample Project

The Construction industry is an important sector that contributes a significant role in economic growth, and the activities of the industry are also vital to the achievement of socio-economic development goals of providing shelter, infrastructure, and employment. The road transport industry is the backbone of strong economies and dynamic societies. AbouRizk & Hague (2009) stated characteristics of construction projects as dynamic, subject to randomness, often complex, involve many operations, and several interacting resources. They take place in a diverse physical environment and involve a wide range of participant that does not generally use the same standard for data representation or common standards for information exchange.

To have a better understanding of the challenges associated with complex construction operations, identify the implementation area of the construction project, type of construction, the volume of the work, and the difficulty of the construction is essential. Accordingly, several heavy, capital, and equipment intensive construction projects, especially road projects, are appearing in Addis Ababa city. This research has sampled one of the difficult, capital and equipment intensive, and more amount of material demanding road project. It allows the researcher to study the component, the problem, and the practice of the earthmoving process (i.e., the delivery process of selected and crushed unbounded materials). Finally, to achieve the research objective and significantly contribute to the construction industry, especially earthmoving operation, by developing efficient and effective earthmoving operation methodology for heavy and complex construction projects.

To achieve the objective of this research, select a sample project (case study) is important. The sample project is a road project under construction, namely Kality-Tullu Dimtu Round About Road Project (Kality Ring Road Square-Tullu Dimtu Square Road). The road project is located at Akaki-Kality sub-city from Kality Ring Road Square to Tullu Dimtu Square, and the quarry site (material production site) is located at Akaki-Kality sub-city in two different sites. The selected material and sub-base/base-coarse are located around Kality St. Marry church and Akaki TVET college, respectively. The material delivery process of the sampled project has two alternative paths (Path-1 and Path-2, as shown in figure 3.1) in case of crushed unbounded aggregate and only single path in case of natural granular (selected) material. The project also has two overfly bridges.

The project was selected among the other three road construction projects which were under construction during the sample selection period by comparing their status obtained from their project managers of the sites. Accordingly, the Kality-Tullu Dimtu roundabout road project was better to collect the data needed by this research. The main reasons to justify why it is important to select the Kality-Tulu Dimtu road project as a sample project (case study) for this research are:

I. The project was more active than the other projects, and this helps to obtain enough data needed by the research during the given period.

II. The project also has embankment works for retaining walls and box culverts. Therefore, this activity helps to have a different variety of data, which may help to have a better simulation model.

III. The project is one of the large road projects in Addis Ababa city with a total length of 11.0 km, total road width of 50.0m, 13.50m width of the carriageway, and 5.0m width of the walkway. It also requires a significantly large amount of materials and a large number of fleets;

IV. To study the component, the problem, and the practice of earthmoving operation process in one of the areas where high traffic amount of city and to solve problems with techniques that help to optimize production and number of the fleet.

V. The best option to develop a simulation model due to site found (the construction and quarry sites) with different quarry site, access roads, road grade, and traffic amount;

VI. The experience learned from this sample project and the modeling approach can be used for similar projects. There are many planned and undergoing road projects in Addis Ababa, and the developed simulation model will also be useful for those projects.

The following figure 3.1 shows the location of both sites (the construction and quarry site/production plant) and the access road to deliver the materials used by the road project from the quarry site with their distance.

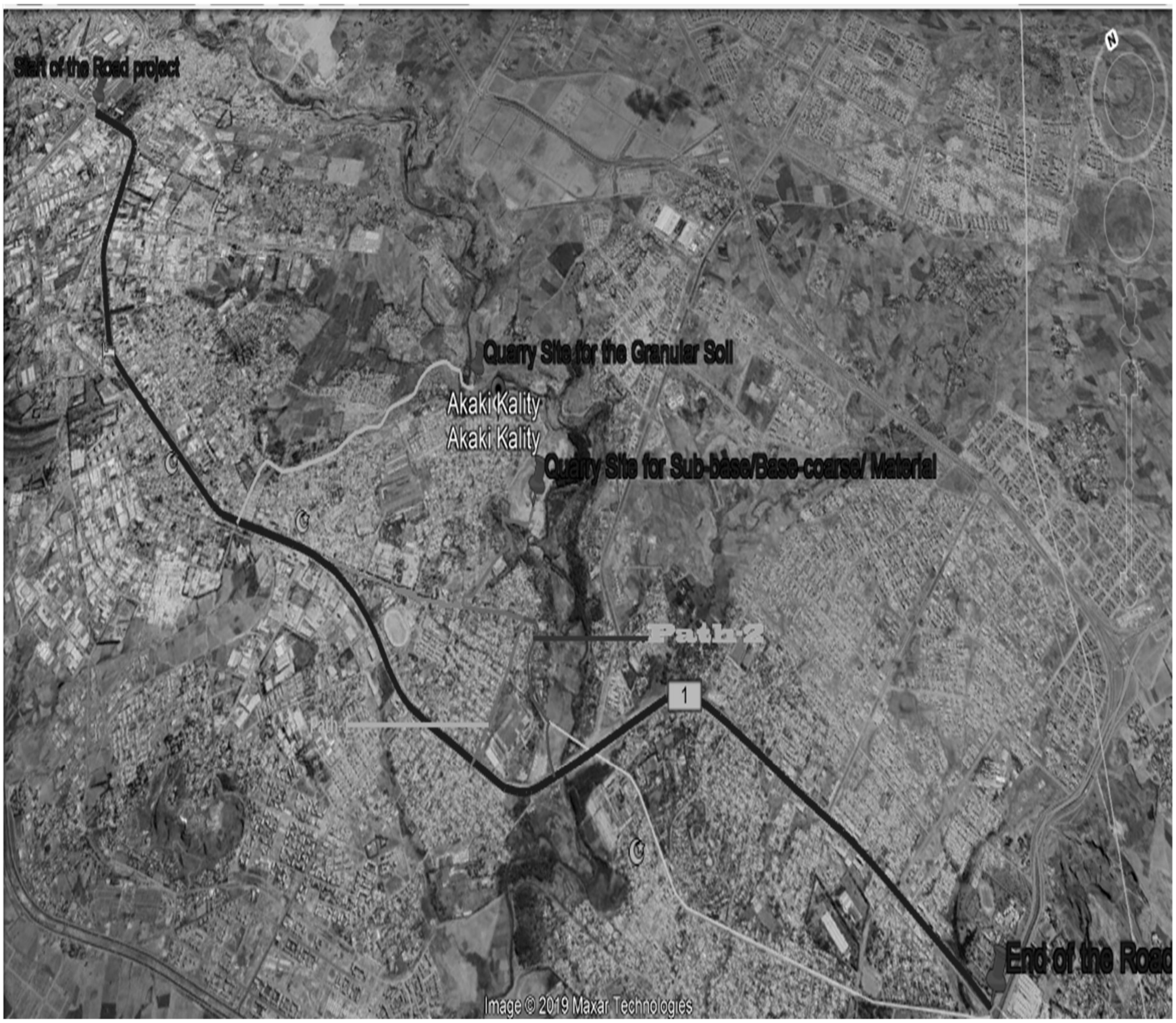


Figure 3. 1: Sample project location, quarry site, delivery site and Paths

3.1.2.Research Design and Organization

The main purpose of this research is to identify the process of earthmoving operation, to develop a discrete-event simulation model, to carry out optimization analysis, and to develop improvement strategies that improve the overall system production of earthmoving operations. Thus, it is required to analyze to what extent the operation is difficult, complex, and whether practices and tools of earthmoving operation using discrete-event simulation and computer-aided simulation software are being implemented by the construction industry to solve the problem.

Earthmoving is an important major part of construction projects involving heavy and expensive equipment that interacts in a complex way, high operating and maintenance costs, performed in an environment fraught with uncertainties. For this reason, it is necessary to develop a simulation model to ensure effective management of earthmoving projects to guide the planners and estimators in the planning and construction phase and to maximize project productivity and several fleets used. It also used to forecast activities durations to achieve optimum cost and project duration.

The earthmoving operation (different cycle times) for this paper, the system has a single (one) loading station and one delivery site (dumping stations). Still, the quarry sites are two according to the type of material, i.e., one for natural granular (selected material) and the other crushed unbounded (sub-base/base-coarse) materials. Dozer has been used in stockpiling and placing (spreading) of the selected material. Grader for placing (spreading) of sub-base (base-coarse) materials, Excavator and Loader for loading of selected and crushed unbounded (sub-base/base-coarse) materials, respectively, and dump truck for hauling purposes, which are the popular method for earthmoving operations. To achieve the objective of this research required to pass through the following research processes.

1. Statement of the problem and problem identification,
    a) To identify the significance of the research.
    b) To identify an operation problem happens during the earthmoving operation process.
2. Starting general and specific objectives,
    a) To establish a framework of what and how was studied and what was found?
3. Literature review,

a) To identify the operation process (component and practice) to be included in the development of simulation modeling.

b) To identify the study mechanism, i.e., what and how studied in the subject area.

c) To study and identify the state-of-art, significance, and way of simulation model implementation in construction operation in general and earthmoving operation in specific.

4. Case study (sample project),

a) To model and analyze the existing earthmoving operation using discrete-event simulation.

b) To develop better earthmoving operation using discrete-event simulation through computer-aided simulation software.

5. Data Collection Process

a) Data has been collected through observation from the sample project to develop and model the earthmoving operation.

6. Data analysis and discussion

a) To analyze the collected data using the selected simulation by computer software and spreadsheet tools.

b) To determine the significance of the simulation model in the earthmoving operation.

c) To experiment and examine the effects of different simulation models in the earthmoving operation production and utilization of the resources (especially equipment).

d) To develop an effective decision-making tool that used to maximizing production and optimizing the number of fleets in earthmoving operation.

7. Finally, using the developed model efficiency analysis, the conclusion and recommendation have developed.

The below figure shows the flow chart of the research methodology (design and organization).

Figure 3. 2: Flow chart of the research methodology

3.2. Methods

3.2.1.Data Sampling and Collection.

This research is an exploratory study, where quantitative data are used and put together to get a rich understanding of the earthmoving operation process, especially the delivery material used in the case study (road construction project) in Addis Ababa city. The study is used both primary (field data) and secondary (documented data) in studying the problems.

3.2.1. Primary Data (Observation)

The main source of data for this research, the collected data through observation technique is reliable since the data are recorded by observation from the construction project (i.e., dumping and spreading activities) and quarry site (i.e., selected and sub-base/base-coarse production site) through different days. However, it may need training for the persons to participate during the collection process to minimize errors created by the observer. In this research, one trial week was used to minimize errors created by the observer's bias and other problems. During the first week of the collecting data period, data were collected for seeking training, and the data were not included in this research.

The observation data collection format contains the following main important information. (For detail refer Appendix A.)

- Truck queueing length and waiting time at quarry site (loading station),
- Truck loading duration in time
- Truck departure time, (from quarry site)
- Hauling distance and route used,
- Truck arrival time, (to the construction site)
- Truck queueing length and waiting time in the delivery site,
- Loading equipment at the quarry site
- Truck dump dumping time (at the construction site).
- Truck capacity (in M^3)

3.2.2. Secondary Data (Literature Review)

Secondary data which involves information from published text such as books, academics periodicals, research journals, proceeding and conference report, government publications, dictionaries, past dissertations, best practice records, and internet resources are used to complement the primary data.

3.3. The Methodology of Data analysis and Modeling strategy

All the data collected on the incorporation problems are organized and analyzed by using an Excel-based spreadsheet and Simphony-CYCLONE software tools to develop a discrete-event simulation model and identify the bottleneck problem on the earthmoving operation.

The main advantage of construction simulation is allowing to evaluate and experiment with different scenarios and problems which are happened in the real construction operation. This section presents the process and modeling strategy of an Earthmoving Operation Using Discrete-Event Simulation. The approach of the strategy classified into the following main objectives:

I. The first objective of the modeling strategy is to identify and study the real-world earthmoving operation process (component, problem, and practice) and to develop a conceptual and logical discrete-event simulation model of the operation to facilitate the simulation framework and to establish input data parameters. (Discussed in section 4.2).

II. The second objective of the modeling strategy is to demonstrate the input data analysis process, real input data collection process. It discussed the methods of how to input data modeling is performed within Simphony CYCLONE software, how to select proper statistical distribution, and goodness-of-fit to sample data. (Discussed in section 4.3).

III. The third objective of the simulation modeling strategy is running the discrete-event simulation model using SIMPHONY-CYCLONE software through considering some important checking and testing criteria of the simulation modeling approaches such as simulation model verification, validation, and accreditation. (Discussed in section 4.4)

IV. The fourth stage of the modeling strategy is to discuss simulation model output results, simulation model output analyzing process should be studied, experimented, and tested to achieve optimum performance. This strategy is performed through establishing different simulation scenario, such as developing a model for the overall model of earthmoving operation of works that use selected (natural granular) material with and without including embankment works, overall model of earthmoving operation of works that use crushed unbounded material and by varying the available resource model to develop the model. In the final stage of this strategy, discussion of results has been done based on the comparison result of those established scenarios to the satisfaction of defined parameters such as; higher production, minimum delivery cycle time, and lowest idleness of resources. (Discussed in section 4.5).

V. The final objective of modeling strategy is to discuss the general finding of the research depending on the result of the simulation experiment accomplished in the previous strategy. (Discussed in section 4.6.).

CHAPTER 4: ANALYSIS AND DISCUSSION

4.1. Introduction

Based on the method presented in the methodology section and literature reviews, this chapter provides the overall discussion and analysis of the research results. It includes the earthmoving operation process and designing a simulation model development process for earthmoving operation in the first part. In the second part, it covers data collection and input data analysis of the simulation model, identifying proper simulation model input parameters and developing a Simphony input data analyzer. In the third part, it presents the developing and running simulation model using Simphony CYCLONE software. Fourth, it presents simulation modeling output data resulted from simulation acquired. Finally, it discusses and analyzes with a different scenario, and establishing the key research findings is discussed.

4.2. Earthmoving Operation and Simulation Modeling

4.2.1.Earthmoving operation process

To develop the DES model of the earthmoving operation process, it requires to study and investigate the component, practice, and problems of earthmoving operation from the case study of the real-operation of the selected sample project in detail. In this research, a case study was done on the real operation of the earthmoving process of the sample project (road construction site) by collecting data through observation.

Accordingly, 345 data (cycle time) were collected from the operation process of selected (natural granular) material (i.e., the sub-grade (roadway) work and embankment work of retaining wall and box-culvert) of the sampled project. In addition, 76 data (cycle time) from the operation process of crushed unbounded aggregate (i.e., sub-base and base-coarse works) of the sample (road construction) project have been studied through observation. However, based on the different kinds of literature, the earthmoving process has three general steps, which are preparation (stockpiling), cycle time (i.e., loading, hauling, dumping, spreading, returning, and waiting), and spreading (placing). In this research, data collected only from the cycle time step, and it has six components that are loading, hauling, waiting to dump, dumping, returning, and waiting to load.

Data used in the stockpiling and spreading activities were assumed based on the concept of the caterpillar performance handbook calculation.

The practice of the earthmoving operation for the specific sample project is that:

- According to the master schedule of the project, the construction engineer or site engineer identify the type work (embankment of retaining wall or box culvert, sub-grade or sub-base/base-coarse) and material (selected (i.e., natural granular) or sub-base/base coarse material (i.e., crushed unbounded)) to be worked, then communicate with quarry site owners (material suppliers) to prepare the material and instruct to the foreman of the site to prepare the labor and equipment at the site which are necessary for the identified work.
- The facility officer orders the rental dump trucks and ready for the material delivery process.
- The material engineer checks the quality of the delivered material and proper compaction of the spread (placed) material before the supervisor checks it. If there is a problem with quality and compaction, the material engineer (field test officer) instructs the foreman to take corrective measures.
- Finally, the supervisor takes the field as well as laboratory tests to check the quality of material and compaction requirements.

The studied sample project has confronted different kinds of earthmoving operation process problems. However, during the study of the earthmoving operation process, the following problems have been observed:

- The project has no proper and detailed material delivery schedule (when and how much material to be delivered), and we cannot know when is the specific material delivered and how many trucks are needed. This makes it difficult to predict the number of trucks and other equipment needed and the productivity of the project.
- There is a problem with the equipment management (controlling system) in the sample project.
- Traffic jam Problems for the trucks and this is due to improper scheduling the delivery time.

- Imbalance of trucks and their need; This is happened due to the poor equipment management system (i.e., since the trucks are rental, it needs a serious controlling system because the owner of the rental truck usually available according to the suitability of the work, and this makes it difficult to predict the productivity of the delivery process).

4.2.2.Design the model in sequence and logical manner

Designing an earthmoving operation process model in a work sequence and logical manner starts with the identification of the problems and abstraction of the overall operation process that occurred in the real-world, which required an art of visualizing the entire operation of the process from starting to the end. AbouRizk et al. (2016) stated, when a model is created, one should be able to describe the general workflow of the real construction process by simply following the journey of the entity within the model which means describe the life-cycle of the entity as it navigates from one modeling element to the next in the model as shown below in figure 4.1 & 4.2.

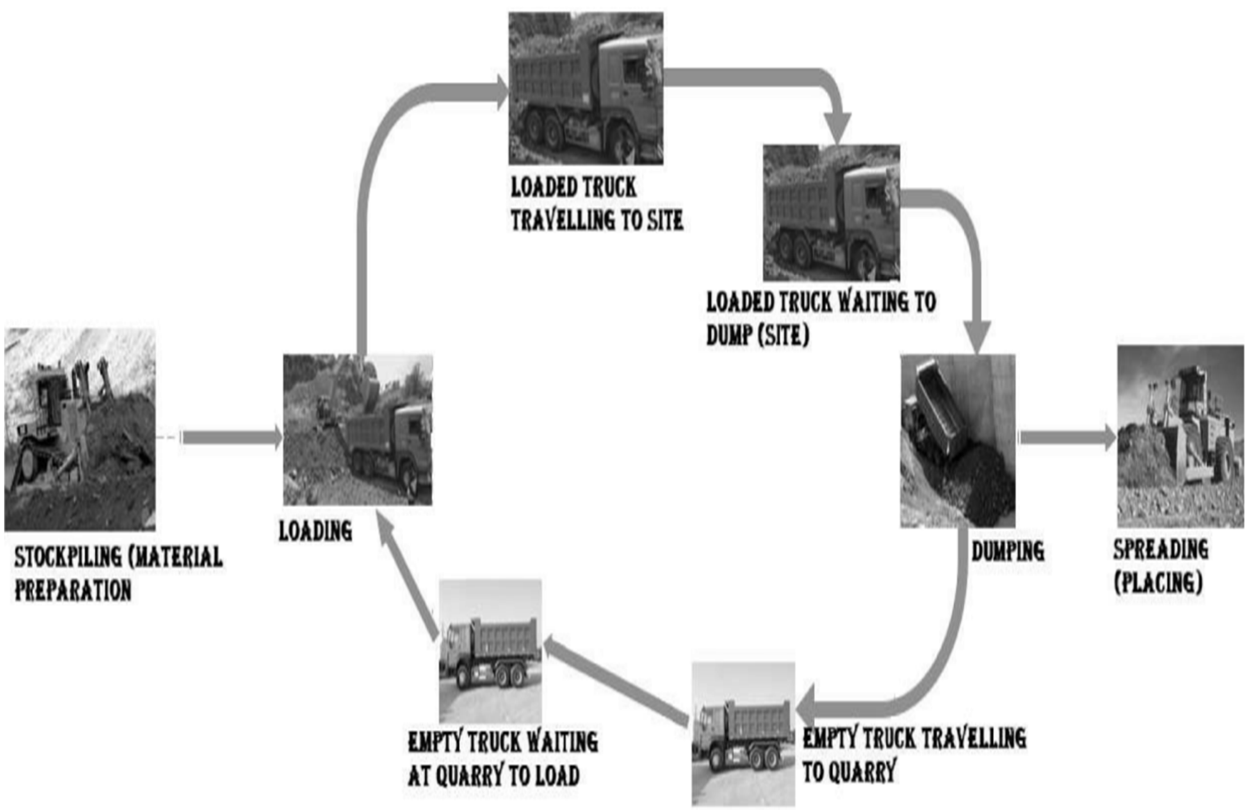


Figure 4. 1: Schematic of the earthmoving operation (for selected material)

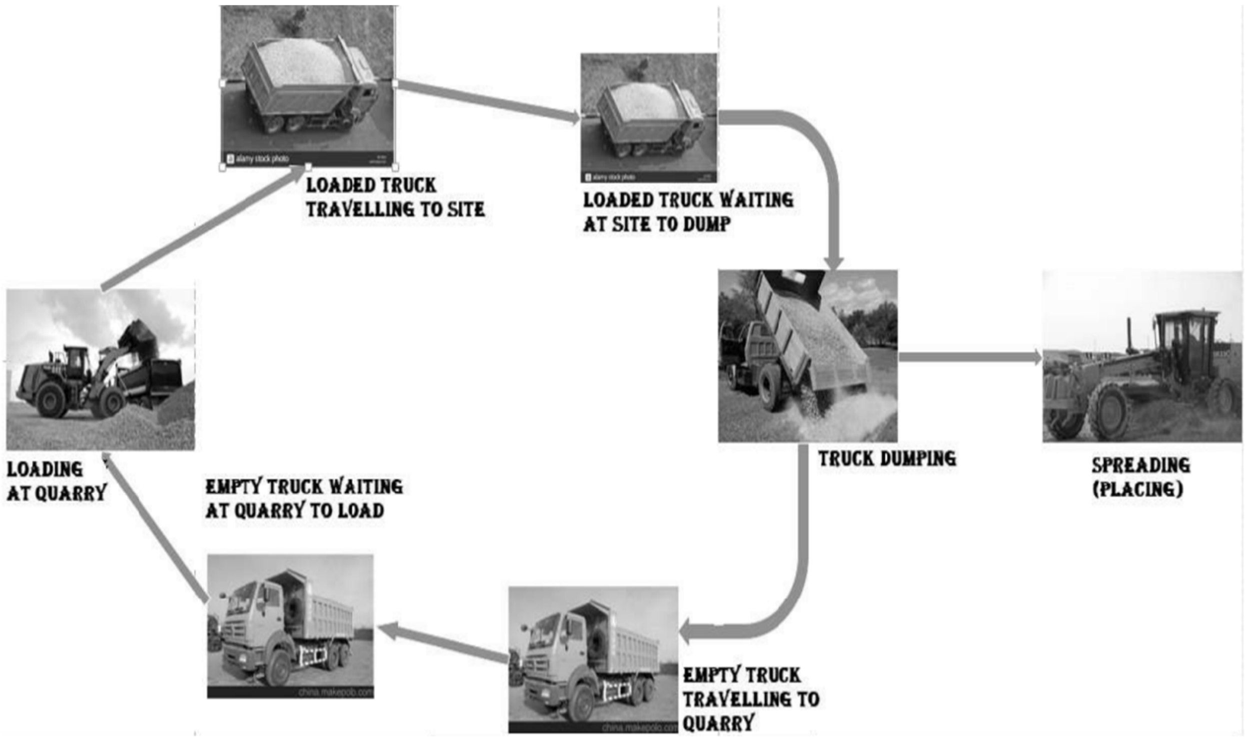


Figure 4. 2: Schematic of the earthmoving operation (sub-base/base-coarse)

Figure 4.1 & 4.2 demonstrates the entire schematic of the earthmoving operation process (for the selected material (sub-grade and embankment material) and sub-base /base-coarse material) and describing each cycle from start to finish. The process for the production of sub-grade (selected material) starts with dozer preparing the selected materials at the quarry site (stockpiling). Then the excavator is loading the selected material to a truck (Loading). The loaded truck travels to the construction site (hauling), and after arriving at the construction site and waiting to dump (queue at dump station), it dumps the selected material (dumping). Finally, the truck travels back to the quarry site (returning) and waits for another loading (queue at the loading station). The process for the production of sub-base/base-coarse material may also include the same as the production of the selected material except for preparation of material (stockpiling), in this case, the material production is not considered in the study.

Earthmoving operation commonly encounters heavy and represents a sizable portion of infrastructure construction projects because of its repetitive work cycle, expensive fleet, and the large volume of work, probable nature of the operation. Another attribute of earthmoving operation is that it involves multiple interactions between resources and cycles. As shown in figure 4.1 &

4.2, each of the cycles is characterized by uncertainties such as duration. The earthmoving operation is one that had been extensively analyzed using simulation because of its repetitive nature and simplicity. Modeling and simulating the logical sequence, the dynamic, and uncertainties of such operation, first, it needs to understand and to abstract the important elements, then represent those elements in some graphical symbols that have to be familiar with simulation software language using a computer.

Besides, to represent the elements graphically, the development of the simulation model requires a description of inputs and output parameters that should be collected from construction (road construction) site described as input requirement parameters and information that collected from simulation described as simulation experiment result output.

The below table 4.1. presented the complete description of the input and output parameters of the study.

Table 4. 1: Description of input and output parameters

No.	Parameters	descriptions
1	Input Data (collected from the case study)	▪ What is the distance between the job and the material production site? ▪ Are there any alternative routes available? ▪ What is the amount of the material to be delivered? ▪ What is the type of (selected or sub-base/base-coarse) material to be delivered? ▪ What is the inter-arrival time between each delivery cycle? ▪ What is the actual time duration to finish each cycle (loading, hauling, dumping, and returning)? ▪ What is the mean and standard deviation of each cycle time (loading, hauling, dumping, and returning)? ▪ What are the type of loading equipment and the number of equipment to be used? ▪ What type of earthwork in the construction site (embankment of retaining/box culvert, sub-grade, and sub-base/base course)?
2	Simulation result Output	▪ What is the utilization rate of each equipment (dozer, excavator, loader, grader, and dump truck) used in the earthmoving operation? ▪ What is the productivity rate of each equipment listed above and used in the earthmoving operation? ▪ What is the idleness time of each equipment list above and involved in the earthmoving operation? ▪ What type of earthwork activities (embankment, sub-grade, and sub-base/base-coarse) have maximum productivity rate?

In this research, the graphical model of the earthmoving operation is developed and presented in Figures 4.3 & 4.4. The development process has to be simulated with suitable software, which is the modeling task typically involves abstraction and implementation of parts and the entire operation process on a computer. The proper software (simulation model tool) that is selected to model the process of earthmoving operation is SIMPHONY. Simphony is chosen for this research because (Hajjar & AbouRizk, 1999; Hajjar & AbouRizk, 2002; AbouRizk & Mohmed, 2000; Alzraiee, 2013; AbouRizk, et al., 2014) confirmed that Simphony provides:

- DES-based simulations;
- Incorporate CYCLONE template;
- Highly flexible, user-friendly, and graphical user interface;
- Standard, consistent, and intelligent environment for developing simulation models;
- General and special purpose simulation templates;
- Statistical analysis (provide support for the collection and analysis of observations data, standard statistical results);
- Relationship between the modeling environment is used to define the logic of the simulation model and flow paths of entities;
- Tracing this service internally to informally the user in case a run-time error is detected in the developer's code;

Additionally, Simphony is free licensing and available for educational purposes, relatively recent simulation software. It uses different entities/abstract elements that graphically symbolize certain operations and arrows that connect elements and dictate the direction of the operation process.

The above figure 4.1 (Selected material), the model has five cycle time, namely: stockpiling cycle, loading cycle, truck hauling/returning cycle, spotter cycle, and spreading cycle. In Figure 4.2 (Sub-base/Base-coarse material), the model layout also has four cycle time, namely: loading cycle, truck hauling/returning cycle, spotter cycle, and spreading cycle. Each of the cycles is graphically symbolized and abstracted to represent the operation process, and those symbols (elements) are discussed in table 4.2 below.

At this stage, it is important to develop the discrete-event simulation model of the earthmoving operation process by using SIMPHONY-CYCLONE simulation modeling languages through a schematic diagram.

The stockpiling process is the creation or start of the whole operation process in case of the selected materials, the dozer stockpiles the selected material from the natural ground at the selected quarry (material production) sites. Loading cycle is the loading process of material needed by the project, excavator (embankment or sub-grade work), loader (in case of sub-base/base-coarse work), and truck should be a queue at the quarry site. They enter the stockpiled material to load, as the area is free or ready to load. Immediately as the loading process completed, the quarry will release the truck to the travel construction (road project) site using the available routes.

The Spotter cycle is the process of dumping the hauled material at the job site. It starts with the arrival of loaded trucks at the job site and dumps the material according to the spotter's instruction, but if another truck is unloading at the time of arriving, the newly arrived truck waited until the dumping truck leaves the spot). After the dumping process is completed, the truck returns to the quarry site for another cycle. The dozer (embankment or sub-grade work) or grader (in case of sub-base/base-coarse work) spread the delivered materials in the construction site; this is the spreading cycle.

However, to develop a symbolized simulation model with computer simulation first, the simulationist should be familiar with those graphical simulation languages. The below table 4.2, described and discussed those languages. Besides, figure 4.3 also demonstrates the overall earthmoving operation process simulation model, which is developed using SIMPHONY-CYCLONE simulation software.

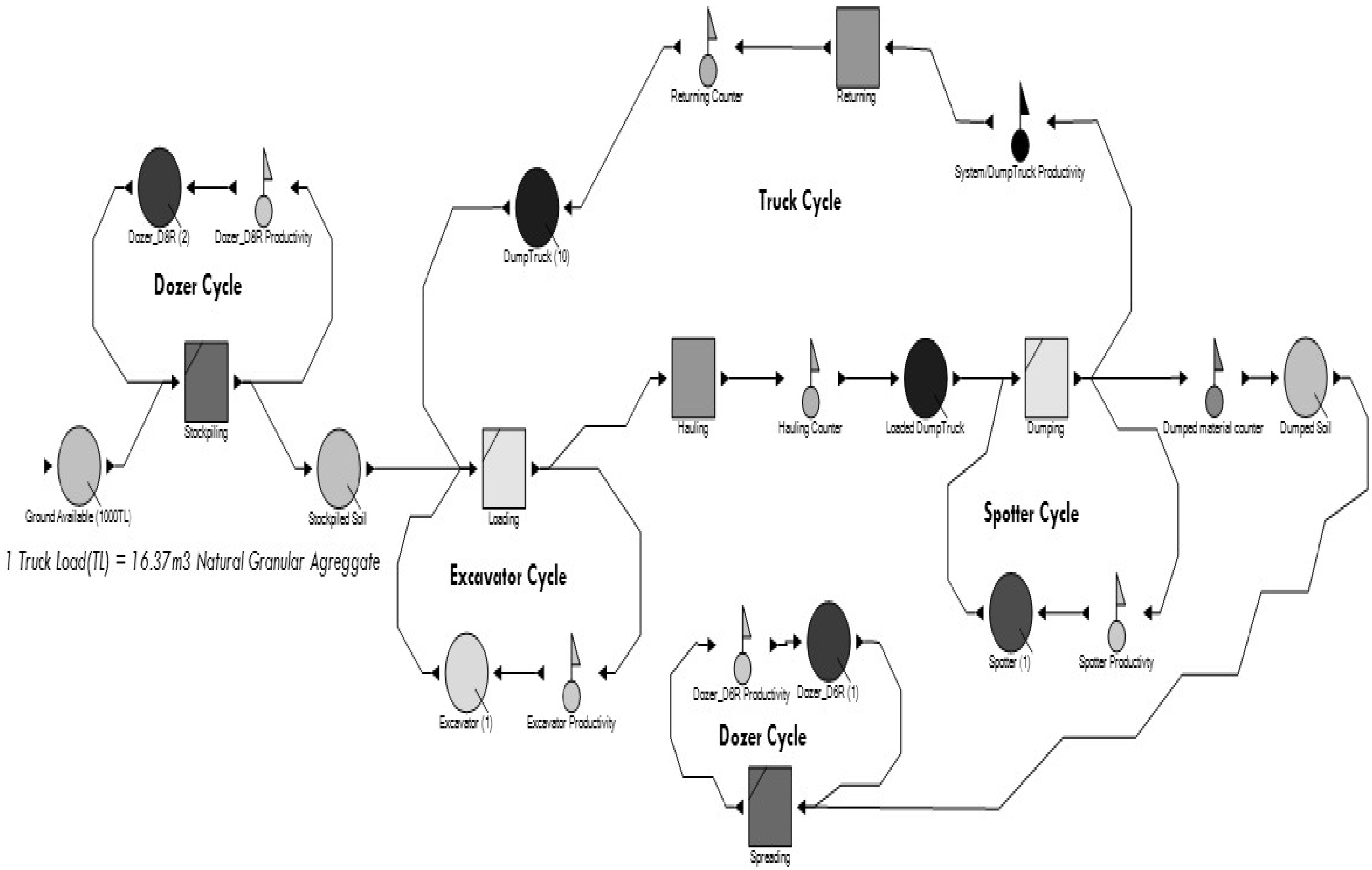
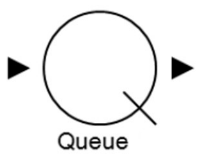
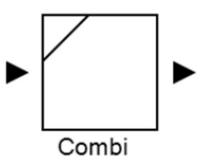


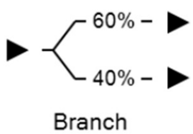
Figure 4. 3: Overall Earthmoving operation process model developed by Simphony-CYCLONE

Table 4. 2: Graphical symbols of elements used to develop a simulation model using SIMPHONY-CYCLONE

No.	Entities/Graphical symbols	Entities Description	Input Data scope	Output Data scope	Abstract/Entity representation	Remark
1		**Queue/Create Element** ▪ It initializes entities within the model at the beginning of the simulation (create entities and introducing them into the model). ▪ The input of combi connected to any type of element except a queue. ▪ The output point of a queue element may only be connected to combi elements. ▪ It is a place where entities are waiting for service.	▪ The total number of entities. ▪ The number of entities waiting for service.	▪ Several entities at the end of the simulation model. ▪ Statistical report (waiting time and percentage of waiting).	▪ At the begining of the model. ▪ Waiting to stockpile the material. ▪ Waiting to load the truck. ▪ The number of trucks waiting for loading. ▪ The number of a truck waiting for dumping. ▪ Waiting to spread the dumping material.	
2		**Combi/Task Element** ▪ The combi element represents a constraint.	▪ The duration of the activities (time).	▪ The statistical report (entity	▪ The Stockpiling cycle (in case of selected material)	

		▪ During the simulation, entities can flow into the combi from proceeding queues. ▪ The input point connected to queue elements. ▪ The output point connected to any type of element except a combi. ▪ It is responsible for modeling any activities.	▪ The number of servers available to the activities. ▪ A priority of the system.	inter-arrival report).	▪ The Loading cycles ▪ The Spotter cycles ▪ Spreading cycle	
3		**Normal/Task Element** ▪ The normal element can process an infinite number of entities simultaneously, so it represents an unconstrained task. ▪ The input connected to any type of element except a queue.	▪ The duration of the task (time)	▪ Statistical report (entity inter-arrival time)	▪ The loaded truck hauling construction site (hauling). ▪ The empty truck return to the quarry site (material production site)	

		▪ The output point may be connected to any type of element except combi.				
4		**Counter Element** ▪ Measure the productivity of the entities by recording the time an entity passes through it. ▪ The input point may be connected to any type of element except a queue. ▪ The output point may be connected to any type of element except a combi.	▪ The amount the counter should be incremented with each passing entity (entity capacity). ▪ The count value at which simulation will be terminated. ▪ The count amount at which the simulation will be terminated.	▪ Number of the entity that passes through the counter during simulation, ▪ Simulation time at which the pass observed ▪ Statistical report (entity inter-arrival time, production, and production rate).		

5		**The Branch (Probabilistic) Element** ▪ It is used to model uncertainties associated with events in the system being modeled. ▪ The input point of the branch element may be connected to any type of element except a queue. ▪ Output points may be connected to any type of element except a combi.	▪ The probability that an arrival entity will be routed through the topmost branch. This value must be between 0 and 1.		▪ The truck traveling routes (paths). ▪ The truck returning route (paths). ▪ This shows which route is used mostly path 1 or path 2 (in case of selected material).	
6	 Arrow	**Arrow Element** ▪ Responsible for showing the direction of the work sequence in the model.			▪ Indicate the direction of the delivery process.	

4.2.3.Developing model input data and parameter

Developing a simulation model is not only limited to describing and representing the entire operation process in graphical and symbols. It involves properly collecting and modeling input data to the model for each cycle time from the real-world operation, with clearly defined parameters. The development of model input data and their parameters are describing those important factors that affect the earthmoving operation process, and it identified as uncertainty. Generally, we can classify this as process-oriented and performance-oriented. The discussion of this part is based on observation of real operation.

4.2.3.1 Earthmoving operation process-oriented

These factors affecting the earthmoving operation process by identifying the duration time to be required to execute the full cycle times of the operation (E.g., loading, hauling, dumping, and returning times).

Stockpiling (preparation) time: is the production of material earthmoving material required for the construction project. The duration of the stockpiling material has affected the process of operation time. It considered as input data for the model of the selected material operation process. This process also identified during the observation as a fixed length of time because the research focuses mainly on the cycle time of the delivery processes.

Loading and maneuver time: this is the time (duration) that the truck spent in spotting for loading and loading by the loading equipment. It is one input data during the development of the simulation model in the research. This process identified during the observation process as the variable unit time recorded. The variability of the loading time varies due to operator efficiency, type of material, type of equipment (excavator or loader), the performance of the loading equipment (i.e., either the bucket of the equipment is full or not), and capacity of the truck.

Traveling (hauling) time: this the duration in which the earthmoving operation truck travels from the quarry (material production) site to the construction site using the different routes of the path. Traveling duration is identified through the observation, and it appears and recorded with different variables length of time. The variation time may occur due to operator (driver) efficiency, truck performance, traffic jam, route length and gradient, and loading capacity of the truck.

Dumping Time: this time is the duration that the truck dumps the delivered material at the construction site. The duration of dumping is observed as variable time, and this variation occurred due to dumping areas (either embankment of retaining and box-culvert or roadway), operator (driver) efficiency, truck performance, spotter efficiency, the loading capacity of the truck.

Returning time: is the duration that the truck travels from the construction site after dumped its load to the quarry (material production) site for another delivery cycle. This process has the same property as the traveling time.

Spreading (placing) time: is the duration that the placing equipment (grader or dozer) consumes to spread (place) the delivered material on the roadway or embankment part of the construction. This process is considered a constant variable during the observation.

4.2.3.2 Earthmoving operation performance-oriented

This type of process is significant to identify the input data and parameters of the earthmoving process based on the performance of equipment involved in the operation. It includes a truck number, truck capacity (m^3), the total amount of material (selected and Sub-base/base-coarse) to be delivered, traveling distance (Km), material type to be delivered (selected or sub-base/base-coarse), type of work activities (embankment or roadway). The happening of interruption events such as equipment break-down and anything that interrupts the performance of earthmoving operation processes is the main factor that affects the performance of the operation.

4.3. Development of Modeling Input Data Analysis

In analyzing any real-world problems, the analyzer is often faced with the challenge of having collected and model data. Several key factors can affect the efficiency of the construction process in the real world, including the uncertainty, dynamics, and transient nature of most construction projects.

AbouRizk, et al. (2016) strengthen this idea; the real world is not static or deterministic; rather, many events are unpredictable, and many processes appear to occur randomly.

Banks, et al. (2014) suggested four-step in developing useful model input data for any kind of simulation software, namely: collect input data from the real operation, identify appropriate data distribution, estimate distribution parameters, and test for goodness of fit data.

4.3.1.Input data collecting process

The input data collection process is one of the biggest, most significant, and difficult tasks in developing the simulation model and solving real-world problems. It often requires significant time and resource commitment. However, it is mandatory to collect real input data from a sample project for each component (cycle time of the earthmoving operation) with different duration to create a similar working environment with a real-world operation in the simulation model. Wang, et al. (2001) strengthen this idea, to produce a valid model, the nature of the real system must be investigated first, and this was done based on the data observed from the construction site.

The observed data is discrete (state of variable changes at an only a discrete set of points in time), even different time scale has been recorded in a similar operation. The observation process took over time intervals from initial to the finishing of the operation process. The data collection has been done by separate the cycle time (loading, hauling, dumping, returning, and waiting) for three (3) months (March 01, 2019-May 24, 2019) through consideration of different shifts, morning time (7:30-12:30) and afternoon time (13:30-18:00). It is done on purpose to record a variety of data (due to period, loading equipment, and type of material to be delivered) and happening interruption events through different periods (rainy and dry). Considering those constraints will allow constructing a more realistic simulation model of the earthmoving operation.

Generally, quantitative sample data has been collected through observation from the road construction site and quarry (material production) site in diverse condition with a total number of 421 (Four hundred twenty-one) cycle times; 345 (three hundred forty-five) selected (natural granular) and 76 (seventy-six) Sub-base/base coarse (crushed unbounded aggregate) materials of earthmoving operation. Below table 4.3 and 4.4 shows part of the collected data and summary of input data, respectively. Additionally, Appendix B & C show the overall collected input data.

Table 4. 3: Data collection sheet

Project Name:Kality-Tullu Dimtu Round About Road Project

Consultant: Enginer Zewude Consulting Engineers

Project Location: Addis Ababa, Akaki kality Sub-city

Contractor: IFH Engineering (China Communications Construction Company)

Client: Addis Ababa City Administration Road Authority (AACRA)

Su-Contractor Contractor: ASER Construction Plc

Working Time: Morning (7:30-12:30) and Afternoon (13:00-17:3

Type of Material : Wastage(soil/Rock) [ ] Natural (Gravel /Granullar) soil [X] Crushed Stone (unbound) [ ]

Date	Cycle No.	Truck Code	Truck Vol.(M^3)	Distance (Km)	Loading		Travel/Hauling			Dumping		Queue			Returning			Queue			Time Record		Idle time (Min)	Reason	Loading Equipment				Reason	Type of work/Task	
					Start	Finish	Start	Finish	Path	Start	Finish	Start	Finish	No.	Start	Finish	Path	Start	Finish	No.	Functional	Waiting			Excavator	Loader	No	Idle Time		Road Way	Embankment
03/05/19(25/08/11 E	1	70680	16.70	8.00	9.19	9.22	9.22	10.05	1	10.05	10.07				10.07	10.39	1	10.39	10.43	1					X		1			X	
	2	70680	16.70	8.00	10.43	10.48	10.48	11.24	1	11.24	11.26				11.26	11.58	1								X		1			X	
	Lunch TIME																														
	3	70680	16.70	8.00	13.23	13.27	13.27	13.57	1	13.57	13.59				13.59	14.28	1	14.28	14.30	1					X		1			X	
	4	70680	16.70	8.00	14.30	14.36	14.36	15.07	1	15.07	15.09				15.09	15.34	1								X		1			X	
	5	70680	16.70	8.00	15.34	15.38	15.38	16.10	1	16.10	16.12				16.12	16.46	1	16.46	16.49	1					X		1			X	
	6	70680	16.70	8.00	16.49	16.53	16.53	17.26	1	17.26	17.28				17.28	17.57	1								X		1			X	
06/05/19(28/08/2011 E.C)	1	58646	16.70	8.00	9.35	9.39	9.39	10.15	1	10.15	10.17				10.17	10.45	1								X		1			X	
	2	48127	15.50	8.00	10.14	10.23	10.23	11.05	1	11.05	11.07				11.07	11.33	1	11.33	11.35	1					X		1			X	
	3	71425	16.70	8.00	10.23	10.30	10.30	11.06	1	11.06	11.08				11.08	11.36	1	11.36	11.39	1					X		1			X	
	4	52358	15.80	8.00	10.30	10.37	10.37	11.12	1	11.12	11.15				11.15	11.40	1	11.40	11.44	1					X		1			X	
	5	82397	16.70	8.00	10.37	10.43	10.30	11.13	1	11.13	11.17				11.17	11.40	1	11.40	11.49	2					X		1			X	
	6	47521	15.00	8.00	10.52	10.57	10.57	11.30	1	11.30	11.33				11.33	12.05	1								X		1			X	
	7	64868	16.70	8.00	11.07	11.13	11.13	11.55	1	11.55	11.57				11.57	12.28	1								X		1			X	
	8	89772	16.70	8.00	11.17	11.22	11.22	12.00	1	12.00	12.01				12.01	12.32	1								X		1			X	
	9	51434	16.70	8.00	11.31	11.35	11.35	12.03	1	12.03	12.06				12.06	12.34	1								X		1			X	
	10	48127	15.50	8.00	11.35	11.39	11.39	12.07	1	12.07	12.10				12.10	12.39	1								X		1			X	
	11	71425	16.70	8.00	11.39	11.44	11.44	12.15	1	12.15	12.18				12.18	12.54	1								X		1			X	
	12	52358	15.80	8.00	11.44	11.49	11.49	12.30	1	12.28	12.31				12.31	12.59	1								X		1			X	
	13	82397	16.70	8.00	11.49	11.54	11.54	12.25	1	12.25	12.27				12.27	12.57	1								X		1			X	
	Lunch TIME																														
	14	58646	16.70	8.00	13.41	13.50	13.50	14.25	1	14.25	14.26				14.26	14.53	1								X		1			X	
	15	64868	16.70	8.00	13.57	14.01	14.01	14.27	1	14.27	14.30				14.30	14.55	1								X		1			X	
	16	89772	16.70	8.00	14.24	14.29	14.29	14.56	1	14.56	14.58				14.58	15.30	1								X		1			X	
	17	82397	16.70	8.00	14.33	14.37	14.37	15.03	1	15.03	15.04				15.04	15.32	1	15.32	15.35	1					X		1			X	
	18	52358	15.80	8.00	14.29	14.33	14.33	15.06	1	15.06	15.08				15.08	15.32	1	15.32	15.41	2					X		1			X	
	19	48127	15.50	8.00	14.37	14.43	14.43	15.13	1	15.13	15.16				15.16	15.42	1	15.42	15.49	1					X		1			X	

Table 4. 4: Summary of the overall collected input data

Total delivery cycle observed	Observed data collected for basic four cycle								Total deliver amount of Soil and			
	Loading time in No.		Traveling time in No.		Placing time in No.		Return time in No.		Grannualr Soil		Crushed Unbounded	
	Grannular	Crushed	Grannular	Crushed	Grannular	Crushed	Grannular	Crushed	In (M^3)	In Cycle	In M^3	In Cycle
421	345	76	345	76	345	76	345	76	5647.70	345.00	1193.96	76

Deliver time record data

Type of Material	Delivery Count and Quantity		Type of Activities to be done	Delivered amount Material		Delivery Route used (Path 1 /path 2)						Loading Equipment	Delivery Count and Quantity	
						Traveling			Return					
	In Cycle	In (M^3)		In Cycle	In (M^3)	Path	Cycle	%age	Path	Cycle	%age		In Cycle	In (M^3)
Natural Granular Soil	345	5648.70	Normal Road(Sub-Grade)	287	4699.6	1	287	100%	1	287	100%	Excavator	345	5648.70
						2	0	0	2	0	0%			
			Embankment of Retaining/Box	58	949.1	1	58	100%	1	58	100%			
						2	0	0	2	0	0%			
Crushed Unbounded Aggregate	76	1193.85	Normal (Sub-Base)	76	1193.85	1	24	32%	1	33	43%	Loader	76	1193.85
						2	52	68%	2	43	57%			
Allover	421	6842.55	Normal Road(Sub-Grade or Base	363	5893.45							Both	421	6842.55
			Embankment of Retaining/Box	58	949.1									

4.3.2.Identified an appropriate data distribution

According to Banks, et al. (2014) and AbouRizk, et al. (2016), identifying a probability distribution begins when sample data are available. A frequency distribution or histogram is one of the techniques that can be used to identify the shape of the underlying distributions.

Banks et al. (2014) stated the purpose of preparing a histogram is to gather a known PDF (probability density function). A family of distribution is selected based on what might arise in the context being investigated along with the shape of the histogram. AbouRizk, et al. (2016), the strength of this idea, as the most basic way of selecting a statistical distribution as a model for a set of data, is to relate the sample obtained to the shape (or shape for the family of distribution) of theoretical distribution. A histogram formed from the sample is analogous to the PDF (probability density function) of the theoretical distribution since both reflect the weight each of the sample intervals (or sample points) should receive in terms of probability occurrence. This is to relate the shape of the histogram of the sample to the shape of the known distribution.

4.3.3.Estimating distribution parameters

Numerical estimation of the parameters is needed to reduce the family of distributions to a specific distribution and to test the resulting hypothesis. An estimator is a numerical function of the data (Banks, et al., 2014). There are many ways to specify the form of an estimator for a particular parameter of a given distribution and many alternative ways to evaluate the quality of an estimator (Law, 2015)

According to AbouRizk, et al. (2016), estimation of the parameters of a particular distribution is controlled by data availability. When data are available, we can use different techniques such as moment matching, percentile matching, maximum likelihood, least-square, etc. to arrive at estimates for the parameter of the underlying distribution. Since different techniques often give different parameter estimates, it is suggested that the simulationist use all fitting methods available within the software being used and select the parameters that produce the best fit.

4.3.4.Test for goodness-of-fit

Goodness-of-fit tests represent a statistical hypothesis test used to assess if the input data is an independent sample from a particular distribution function (Maio & Schexnayder, 1999; Law, 2015). Banks, et al. (2014) and AbouRizk, et al. (2016) stated, goodness-of-fit tests provide helpful guidance for evaluating the suitability of a potential input model; one should check for the goodness of fit by comparing the fitted distribution to the empirical distribution and assessing the quality of the fit obtained. Usually, one would perform the goodness of fit test by using statistical tests such as the Chi-square test, or Kolmogorov-Smirnov (K-S) test, or by visual assessing the quality of the fit.

4.3.4.1 Chi-square test

The chi-square test is based on the measurement of the discrepancy between the histogram of the sample and the fitted probability density function (PDF). When the discrepancy is large enough, the tests reject the fitted model; if it is small, the fit is good (AbouRizk, et al., 2016). Besides, Banks, et al. (2014) stated, the chi-square test formalizes the intuitive idea of comparing the histogram of the data to the shape of the candidate density or mass function. The test is valid for large sample sizes and both discrete and continuous distributional assumptions when parameters are estimated by maximum likelihood. Maio, et al. (2000) stated the strength of chi-square as, it can be used with any type of input data (sample, density, or cumulative) and any type of distribution function (discrete or continuous).

4.3.4.2 The Kolmogorov-Smirnov (K-S) test

The K-S test is based on measuring the largest discrepancy between empirical distribution function defined by the samples and the fitted cumulative distribution function (CDF) (AbouRizk, et al., 2016). K-S test is particularly useful when sample sizes are small, and when no parameters have been estimated from the data (Banks, et al., 2014). K-S test does not depend on the number of intervals, which makes it more powerful than the chi-square (Maio, et al., 2000).

4.3.4.3 Visually assess the quality of the fit.

According to AbouRizk et al. (2016), visual of the quality of the fit is among the most widely used techniques in measuring the goodness-of-fit of a theoretical distribution to an empirical one. The visual assessment of the quality of fit is usually conducted in conjunction with the statistical tests as an assurance of the test results. The method is simply to plot both the empirical and fitted CDFs one plot and compare how well the fitted CDF tracks the empirical one. Alternatively, we can also compare how well the shape of the sample histogram compares to that of the theoretical PDF. When CDF is available, it is always better to use in your comparison because histograms can be easily distorted and can attain any desired shape.

Based on the discussion above (4.3.1-4.3.3), it is necessary to pass through the four steps during the development of models input data. The last step in the process, which is the goodness-of-fit test, is recommended by different researchers to use input data analyzer software.

Accordingly, AbouRizk et al. (2016) stated, testing for goodness-of-test using the statistical test is made easier when statistical tests are incorporated into the fitting software. Fitting a distribution to the data sample is both an art and a science. Banks et al. (2014) also recommended that the researcher must use simulation software at the stage of testing for the goodness-of-fit.

4.3.5.SIMPHONY input data analyzer

The difficulty of collecting and analyzing data faces many researchers when trying to model real-world activities. However, many simulations and input data analyzer software were developed by various researchers. Maio & Schexnayder (1999) mentioned, computer software programs have been developed that automatically assess the goodness-of-fit of the sample data to distribution functions.

AbouRizk, et al. (2016) state duration input data (the most critical form of input in construction models) to a simulation experiment in construction is classically approached by fitting a statistical distribution to a collected sample of observations. The most suitable method for this fitting would be to use the sample directly from raw data, observed data, and find out the probability distribution (Wang, et al., 2001). Fitting a statistical distribution to sample data by the manual method is often boring. Therefore, it's better when one uses computer software to do the fitting.

AbouRizk et al. (2016) Confirmed that SIMPHONY provides and facilitates the best fitting distribution selection to sample data based on different criteria. It is capable of analyzing and selecting best-fit distribution to sample observation input data by checking the statistical goodness-of-fit data to the empirical cumulative density function (CDF) and the fitted (theoretical) CDF. Simphony uses Four different techniques (moment matching, maximum likelihood, least-square, and Nonparametric) to fit the distribution to sample observations. Besides, Simphony is also testing for goodness-of-fit by performing the Chi-square and Kolmogorov-Smirnov tests. Then, an appropriate distribution can be selected. A simulator can fit any of the classical statistical distributions to the sample of the observations.

4.3.6.SIMPHONY input data analyzer best fitting results

Simphony's input modeling services are used to fit the appropriate statistical distributions. Given that the input modeling process is performed within the same environment as that in which the simulation model will be developed and executed, the concerns of selecting statistical distributions that are supported by the simulation environment in which the final model is to be built (AbouRizk, et al., 2016).

According to AbouRizk et al. (2016) discussion, Simphony supports two file formats for importing data to be used in input modeling. These include text files such as notepad and comma-separated values (CSV) files. In both cases, all the data needs to be assembled within one column. Two important issues need to be looked into when performing input modeling. The first relates to the selection of an appropriate method for estimating the parameters of statistical distributions to be fit to the data. The other relates to the selection of a goodness-of-fit test that will guide in the choice of the best statistical distribution from the fitted options.

It is critical to establish criteria for selecting an appropriate parameter of statistical distribution and criteria of ranking best goodness-of-fit. Accordingly, for sample data collected from the earthmoving operation process of embankment and sub-grade works maximum likelihood statistical distribution method has been selected and for the sample data collected from the earthmoving operation process of sub-base and base-coarse works least-square statistic distribution has been selected. The selection criteria are based on random selection. The other important criterion in selecting the best goodness-of-fit. In line with this, the study has used both Kolmogorov-Smirnov (K-S) and chi-squared test methods of testing goodness-of fitted for all types of sample data. It is critical to establish criteria for selecting an appropriate parameter of statistical distribution and criteria of ranking best goodness-of-fit.

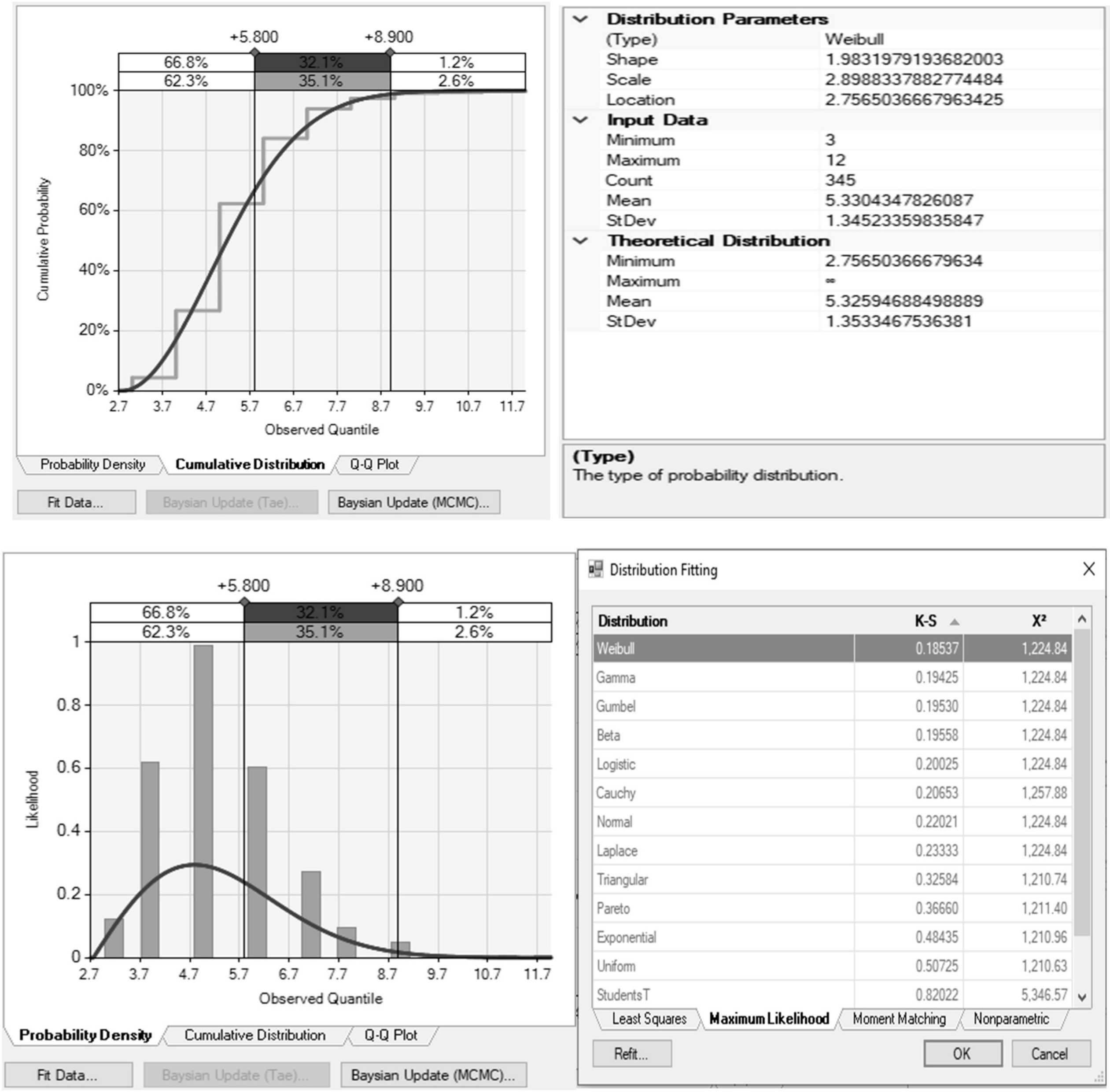


Figure 4. 4: Weibull distribution fittings for the data collected from the operation process of selected material

The above figure 4.4 shows the statistical distribution automatically fitted and selected result of the loading time (duration) of the excavator for the earthmoving operation process of works that use selected (natural granular) material. Similarly, for overall collected sample data (cycle times) entered into Simphony input data analyzer and automatically fitted result selected as is summarized in table 4.5 & 4.6 below. Table 4.5 shows the result obtained from the earthmoving operation process of the works which use selected material, and table 4.6 shows the result obtained from the earthmoving operation process of the works which use crushed unbounded (sub-base and base-coarse) material.

Table 4. 5: Summary of statistical fitting distribution for earthmoving operation process (for Embankment and Sub-grade work)

Selected (Natural Granular) Material												
Delivery Cycle	Estimation Method	Distribution Fittings		Input data Results					Goodness of Fit Test			Remark
		Distribution Types	Distribution Parameters	Count	Min	Max	Mean	StDev	K-S values	X2 Values	Fitting Criteria	
Loading Cycle	Least Square	Uniform(low, high)	Uniform(2.928, 6.464)	345	3.00	12.00	5.33	1.35	0.319	1,303.48		Kolmogorov-Simirnov test
		Exponential(mean)	Exponential(5.339)						0.484	1,210.96		
	Maximum Likelihood	Weibull(shape, Scale, loacation)	Weibull(1.983, 2.899, 2.757)						0.185	1,224.84	auto fit	
		Uniform(low, high)	Uniform(3, 12)						0.507	1,210.63		
	Moment Matching	Gamma (Shape, Scale)	Gamma (15.701, 0.339)						0.189	1,224.84		
		Exponential(mean)	Exponential(5.330)						0.484	1,210.96		
Traveling Cycle	Least Square	Logistics(Loacation, Scale)	Logistics(17.214, 1.443)	345	21.00	90.00	35.17	6.80	0.080	82.31		Kolmogorov-Simirnov test
		LogNormal(Loacation, Shape)	LogNormal(2.843, 0.139)						0.084	73.17		
	Maximum Likelihood	Gumbel(loacation, Scale)	Gumbel(32.269, 5.109)						0.060	67.00	auto fit	
		Normal(mean, StDev)	Normal(2.658,0.674)						0.098	37.70		
	Moment Matching	Gamma (Shape, Scale)	Gamma (29.879, 0.754)						0.073	37.70		
		Gamma (Shape, Scale)	Gamma (29.879, 0.754)						0.073	37.70		
DumpingCycle	Least Square	ChiSquare(freedom)	ChiSquare(2)	345	1.00	12.00	2.30	1.18	0.415	1,650.22		Kolmogorov-Simirnov test
		ChiSquare(freedom)	ChiSquare(2)						0.415	1,650.22		
	Maximum Likelihood	Gamma (Shape, Scale)	Gamma (4.665, 0.494)						0.226	1,654.63	auto fit	
		Triangular(low, high, mode)	Triangular(0.999, 12.153, 0.999)						0.558	1,649.67		
	Moment Matching	Gumbel(loacation, Scale)	Gumbel(1.774, 0.919)						0.240	1,654.63		
		Exponential(mean)	Exponential(2.304)						0.363	1,649.78		
Returning Cycle	Least Square	Beta(alpha, beta, low, high)	Beta(5.019, 24.624, 17, 96)	345	17.00	96.00	31.83	8.64	0.081	107.97		Kolmogorov-Simirnov test
		LogNormal(Loacation, Shape)	LogNormal(3.395, 0.178)						0.081	93.87		
	Maximum Likelihood	Gumbel(loacation, Scale)	Gumbel(28.661, 5.176)						0.080	83.08	auto fit	
		Gamma (Shape, Scale)	Gamma (18.935, 1.681)						0.121	73.94		
	Moment Matching	Gumbel(loacation, Scale)	Gumbel(27.939, 6.739)						0.126	119.54		
		Gumbel(loacation, Scale)	Gumbel(27.939, 6.739)						0.126	119.54		

Table 4. 6: Summary of statistical fitting distribution for earthmoving operation process (for sub-base and base-coarse works)

Overall Crushed Unbound Aggregate (Sub-base/base-coarse) Material													
Delivery Cycle		Estimation Method	Distribution Fittings		Input data Results					Goodness of Fit Test			Remark
			Distribution Types	Distribution Parameters	Count	Min	Max	Mean	StDev	K-S values	X2 Values	Fitting Criteria	
Loading Cycle		Least Square	Cauchy (Location, Scale)1	Cauchy (2.148, 0.346)	76	1.00	4.47	2.66	0.67	0.389	210.58		Chi-square test
			Gamma (Shape, Scale)	Gamma (10.063, 0.224)						0.359	188.74		
		Maximum Likelihood	Beta(alpha, beta, low, high)	Beta(2.686,2.935,1,4.47)						0.222	185.05		
			Weibull(shape, Scle, loacation)	Weibull(2.989,2.098,0.73)						0.231	184.79		
		Moment Matching	Beta(alpha, beta, low, high)	Beta(2.686,2.935,1,4.47)						0.222	185.05		
			Normal(mean, StDev)	Normal(2.658,0.674)						0.244	184.79		
Traveling Cycle	Path-1	Least Square	Uniform(low, high)	Uniform(17.509, 24.663)	24	17.00	36.00	22.55	4.13	0.211	4.33		Chi-square test
			Uniform(low, high)	Uniform(17.509, 24.663)						0.211	4.33	auto fit	
		Maximum Likelihood	Weibull(shape, Scale, loacation)	Weibull(1.449, 6.331, 16.812)						0.181	3.08		
			Gumbel(loacation, Scale)	Gumbel(20.827, 2.795)						0.190	1.83		
		Moment Matching	Beta(alpha, beta, low, high)	Beta(0.989,2.397,17.36,22.55)						0.185	6.42		
			Gamma (Shape, Scale)	Gamma (29.879, 0.754)						0.238	1.83		
	Path 2	Least Square	Uniform(low, high)	Uniform(17.509, 27.663)	52	18.00	37.00	23.26	3.46	0.140	13.77		Chi-square test
			Weibull(shape, Scle, loacation)	Weibull(3.489, 10.279, 13.301)						0.164	12.38	aautofit	
		Maximum Likelihood	Logistics(Loacation, Scale)	Logistics(23.068, 1.861)						0.103	6.85		
			Laplace(Loacation, Scale)	Laplace(23.000, 2.591)						0.141	6.50		
		Moment Matching	Gamma (Shape, Scale)	Gamma (45.092, 0.516)						0.108	6.85		
			Gamma (Shape, Scale)	Gamma (45.092, 0.516)						0.108	6.85		
DumpingCycle		Least Square	Weibull(shape, Scale, loacation)	Weibull(0.977, 0.746, 1.268)	76	1.00	4.57	2.02	0.74	0.071	9.26		Chi-square test
			Weibull(shape, Scale, loacation)	Weibull(0.977, 0.746, 1.268)						0.071	9.26	auto fit	
		Maximum Likelihood	Weibull(shape, Scale, loacation)	Weibull(1.487, 1.172, 0.964)						0.104	15.84		
			Gumbel(loacation, Scale)	Gumbel(1.704, 0.511)						0.109	11.89		
		Moment Matching	Gumbel(loacation, Scale)	Gumbel(1.689, 0.576)						0.100	14.26		
			Gumbel(loacation, Scale)	Gumbel(1.689, 0.576)						0.100	14.26		
Returning Cycle	Path-1	Least Square	Uniform(low, high)	Uniform(14.122, 20.348)	28	13.00	34.00	18.29	3.73	0.217	5.13		Chi-square test
			Uniform(low, high)	Uniform(14.122, 20.348)						0.217	5.13	auto fit	
		Maximum Likelihood	Logistics(Loacation, Scale)	Logistics(17.826, 1.667)						0.119	0.71		
			Logistics(Loacation, Scale)	Logistics(17.826, 1.667)						0.119	0.71		
		Moment Matching	Gumbel(loacation, Scale)	Gumbel(16.607, 2.909)						0.141	9.29		
			Laplace(Loacation, Scale)	Laplace(18.286, 2.638)						0.194	3.71		
	Path 2	Least Square	Normal(mean, StDev)	Normal(17.748, 2.685)	48	13.00	50.00	18.92	5.21	0.161	10.67		Chi-square test
			Normal(mean, StDev)	Normal(17.748, 2.685)						0.16	9.09	autofit	
		Maximum Likelihood	Cauchy (Location, Scale)	Cauchy (18.097, 1.505)						0.109	13.33		
			Logistics(Loacation, Scale)	Logistics(18.313, 1.891)						0.123	3.33		
		Moment Matching	Laplace(Loacation, Scale)	Laplace(18.917, 3.682)						0.201	15.33		
			Laplace(Loacation, Scale)	Laplace(18.917, 3.682)						0.201	15.33		

4.4. Run Simulation Model (SIMPHONY-CYCLONE)

After proper input data analysis performed and best for goodness-of-fit statistic distribution selected for the sample data, the next important step to do is running a simulation model, but before and during simulation running, it is necessary to check the simulation modeling approach, such as simulation model accreditation, verification, and validation. Banks et al. (2014) stated that one of the most difficult problems confronting a simulation analyst is that of trying to determine whether a simulation model is an accurate representation of the actual system being studied, i.e., whether the model is valid.

Conceptual validation, input data validation, computerized verification, and operational validation are the simulation model verification and validation approaches that can be used at different stages of the simulation model development process. (Sargent, 2011; Banks, et al., 2014) A checking simulation model with different criterion is helping to proof that:

- Is the model defining properly with involved entities and resources?
- Are the work sequence and logical framework stated as real-world operations?
- Are proper input data developed and fitted, are the simulation model by itself accredited?

4.4.1.Simulation model verification

Simphony-CYCLONE simulation software provides a check and tracing option to verify the model input data statistical probability distribution fit to sample data, and the logical work sequence is located according to real-world operation process and report any errors that happen in the model, and the modeler can take action. It reports logical errors and data errors that can be identified during the simulation model running.

In general, simulation model verification asks the following questions:

- Is the model implemented correctly in the simulation software (i.e., is the conceptual model developed according to the real-world operation with the integration of simulation model requirements)?
- Are the input parameters and logical structure of the model represented correctly (i.e., properly distributed input data to the sample data according to the requirement of the statistical distribution of best fit data)?

Accordingly, in this research, the simulation model is developed according to the real operation of the sampled project (i.e., stockpiling, loading, hauling, dumping, returning, spreading, and trip counter). The simulation has been checked by running so many time, and their result is almost the same. For example, in the case of the selected material operation simulation model, the interarrival time of the system/truck using ten trucks was the same in running a number of times.

4.4.2.Simulation model validation

In Simphony-CYCLONE, the conceptual model and the input data modeling has been checked through the built-in tools. In this research, it is also checked the validation of the conceptual and logical sequence diagram of earth-moving operation (i.e., cycle time of the operation) simulation model developed by SIMPHONY-CYCLONE using face validity by presenting it to the project manager and construction head of the sample project.

4.4.3.Simulation model accreditation

The earthmoving operation process model was developed base on selected sample projects, and each cycle, resource, and event are recorded from the actual site operation and modeled accordingly; also, this can prove that the developed model was exactly the representation of the real-world operation.

4.5. Simulation Model Output Analysis

Output analysis is the examination of data generated by a simulation. Its purpose is either to predict the performance of a system or to compare the performance of two or more alternative system designs (Banks, et al., 2014).

AbouRizk, et al. (2016) stated that a typical analysis of output usually includes determination of whether the simulation is deterministic or stochastic, and whether it reflects a static, transient, or steady-state. Most simulation-software vendors have developed output analysis capabilities within their packages for performing the very extensive analysis (Banks, 2000).

4.5.1.Developing a strategy for model output analysis

In order to provide a comprehensive simulation model results, the simulation model data output analysis strategy has been developed. Therefore, different testing and checking techniques used to verify the validation and correctness of the simulation model and its input/output result. Accordingly, the modeler has developed checking and testing criteria to analyze the outcome of model output data by establishing a framework for simulation model run and output result comparison.

In this research, simulation model techniques and scenarios were developed for different events as follow:

I. Perform the simulation model run multiple times: after formulating a detailed simulation model, many long computer runs may be needed to obtain good estimates of how well all the alternative designs of the system would perform (Hillier & Lieberman, 2001). AbouRizk et al. (2016) strengthen this idea as, the larger the number of runs, the more accurate the results. Accordingly, in this research, for every run of the simulation experiment, 1000 (one thousand) runs have been done using the multiple-run feature of Simphony-CYCLONE.

II. Establish a simulation model scenario: the simulation model is running with different scenarios based on the actual sample observed data. After running the simulation, the output data analyzer system provides a more comprehensive and realistic simulation model result. In this research, a different scenario has been considered during the simulation model development as follow:

   a) A simulation model for the overall delivery (operation process) of the selected material used on the embankment of retaining wall and box culvert, sub-grade, and other filling works.

   b) A simulation model for the delivery (operation process) of the selected material used on the sub-grade, and other filling works (i.e., except the embankment of the retaining wall and box culvert work).

   c) A simulation model for the overall delivery (operation process) of the sub-base/base-coarse material (crushed unbounded aggregate).

III. Compare the simulation model result: the above three results of the simulation models from the different scenarios have been tested by comparing their results to each other by changing the number of different resources (e.g., trucks). Sensitivity analysis has been performed to study the behavior and characteristics of each model (e.g., to find optimum results, i.e., maximize the production rate and minimize the number of fleets) and to identify the bottleneck of the operation. Finally, the result of the model helps to recommend the optimum earthmoving operation process.

1. Analysis of the simulation model for the overall data collected from embankment and subgrade work (selected material)

This section demonstrates the process of the simulation modeling of the overall operation process of the selected (natural granular) material or operation process of the embankment of the retaining wall and box culvert, sub-grade works, and another fill works of the sampled project, which includes graphical modeling of the operation, preparation of the input data for every cycle in the process, running simulation model and generates a statistical report with Simphony-CYCLONE simulation. The overall model represents all data collected from the embankment work of retaining wall and box culverts through observation during the earthmoving operation process of the sampled project. The data merged without considering the types of work (activities) to be constructed. A hierarchical conceptual model developed based on a real-world operation of the earthmoving processes. In this section, the simulation model uses the excavator as loading equipment and dozer as spreading (placing equipment).

Table 4.7 below shows the assumptions that are used as simulation model input data and including in the simulation models.

Table 4. 7: Simulation model Input data assumption for the equipment

Type of equipment	Dozer	Dozer	Grader
Model	D8R-Series II	D6R-Series III	140K
Formula	Production (Lm3/hr.) = (Maximum Production) x (Correction Factor)	Production (Lm3/hr.) = (Maximum Production) x (Correction Factor)	$A(m^2) = S*(L_e-Lo)*1000*E$
Given (based on Cat Performance book and Actual site performance assumption)	▪ Uncorrected Maximum Production = 300 Lm3/h ▪ Applicable Correction Factors: • Hard to drift; "dead (dry) material……... = 0.8 • Grade correction (from graph). . ……... . .=1.25 • Slot dozing ……………….…………..= 1.20 • Average operator . . . .= 0.75 • Job efficiency (40 min/hr.) . . . .= 0.67 • Weight correction . . . .(1389/1750) = 0.79	▪ Uncorrected Maximum Production = 295 Lm3/h ▪ Applicable Correction Factors: • Loose stockpile……………………..…. = 1.20 • Grade correction (from graph). ………... . .=1.13 • Slot dozing ……………………………= 1.20 • Average operator . . . .= 0.75 • Job efficiency (50 min/hr.) . . . .= 0.83 • Weight correction . . . .(1389/1750) = 0.79	▪ Moldboard for the given model = 3.7 m ▪ Angle of blade = 30° ▪ Effective width of blade (L_e) (30°) = 3.17 m ▪ Width of overlap (L_o)=0.60m ▪ Job efficiency (E) = 0.80 ▪ Operating speed (for finishing grade) (S) =4 km/hr.
Production rate (M^3/hr)	119.09 m^3/hr = 1.98m^3/min	236.06 m^3/hr = 3.93 m^3/min	8224 m^2 (for 15cm thickness 1233.60m^3)
Model Input data (min/truck load)	8.27 min	4.17 min	0.76min

The earthwork operation process works which use selected (natural granular) material (i.e., embankment of retaining wall and box culvert, sub-grade works and another fill) started at quarry (material production) site by making the dozer ready for stockpiling and stockpiling the selected (natural granular) material (produce the material to be used by the project) the material at quarry site (i.e., Dozer cycle) → the excavator and dump-truck ready and queue at the quarry site for loading, and loading the selected (natural granular) material (i.e., Excavator cycle) → the loaded truck traveled to the construction site → the truck arrives at the construction site, queue to dump, and dumping the material (i.e., Spotter cycle) → the empty truck return to the quarry site → the truck arrives at the quarry site and queue to start another cycle. Another dozer also ready and queue at the construction site to spread the delivered material and place (spreading) it (i.e., Dozer cycle).

Figure 4.5 shows the overall simulation model of the earthmoving operation process (embankment of retaining wall and box culvert, sub-grade, and another fill works), table 4.8 shows the summary of the input data for a simulation model of the earthmoving operation process (embankment of retaining wall and box culvert, sub-grade, and another fill works), and figure 4.6 shows simulation model output statistical report and it is also similar to figure 4.3.

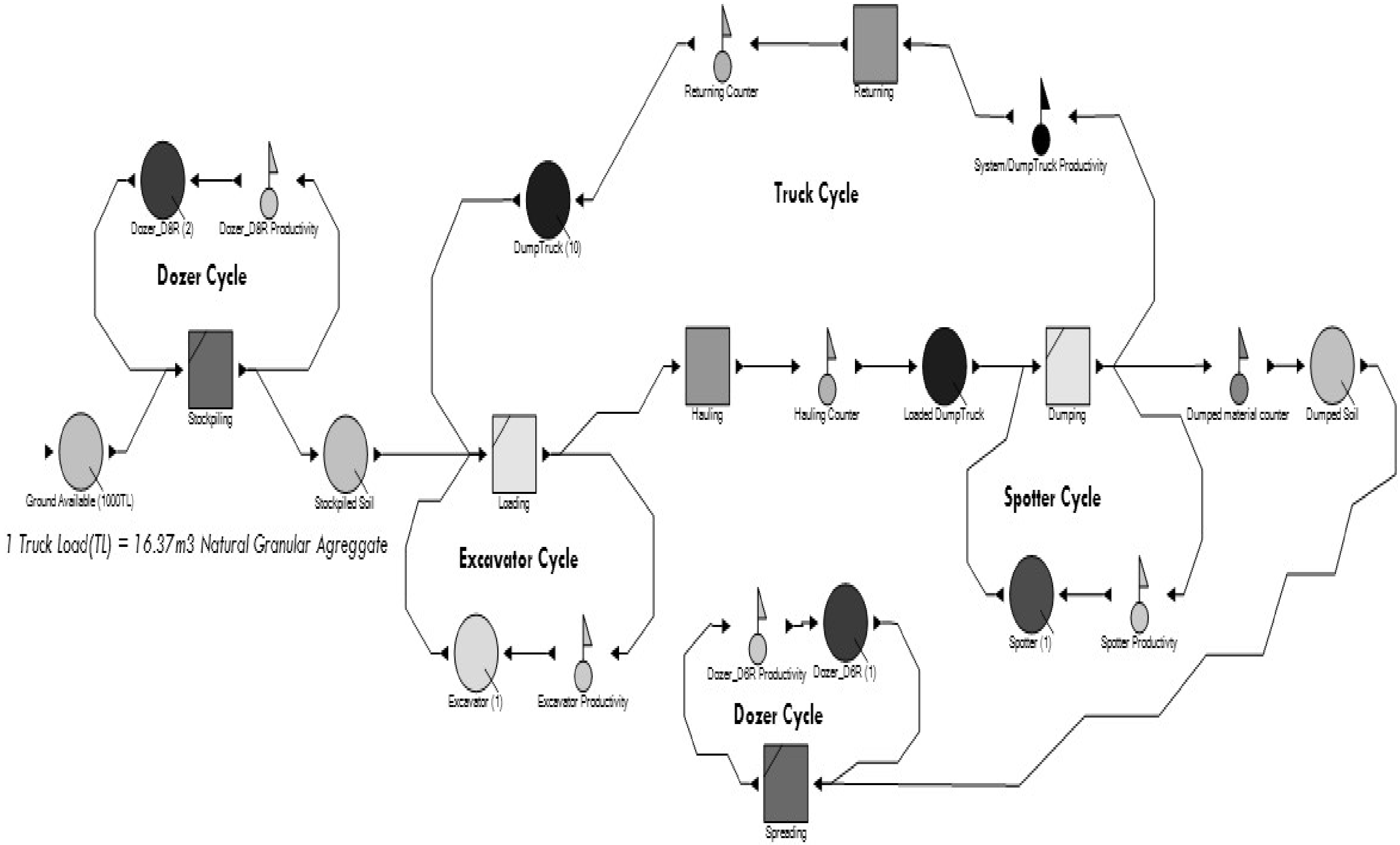


Figure 4. 5: Overall earthmoving operation process for selected material (NGM) delivery

During the data collection period, 345 sample data has been collected from the overall earthmoving operation process of an embankment of the retaining wall, and box culvert, sub-grade works, and another fill works through observation then entered the data to the simulation software tool according to Simphony-CYCLONE input data analyzer requirement and the output result of the modeling input data analyzer report performed with the built-in estimating fit distribution and auto-fit goodness-of-fit. Once the proper input data is developed, then additional assumption input data like the amount of material to be delivered, the unit measurement for the input data (e.g., truckload in number and amount of earth material in cubic meter), and the number of available resources, which helps in the development of the simulation model have been developed.

The production of the stockpiling and spreading (placing) equipment that was involved in the sample construction site during observation is shown in the above table 4.7. Those equipment are: Dozer (model D8R) for stockpiling (material production), Dozer (model D6R) for placing (spreading) of selected material, and motor Grader (model 140K) for placing (spreading) of sub-base or base-coarse; and the calculation and values are taken from cat performance book and the actual sample construction site. 1000TL cycles and 5-15 dump trucks are assumed for this simulation model input data.

Table 4. 8: Input data summary for overall earthmoving operation process (selected material)

Overall Selected Material (Natural Granular Soil)-Best Fitting										
Delivery Cycle		Input data Results					Distribution fittings			Test Method
		Count	Min	Max	Mean	StDev	Distribution Type	Parameter	Best fit	
Loading Cycle		345	3.00	12.00	5.33	1.35	Maximum Likelihood	Weibull	auto fit	K-S Test
Traveling Cycle		345	21.00	90.00	35.17	6.80	Maximum Likelihood	Gumbel	auto fit	K-S Test
DumpingCycle		345	1.00	12.00	2.30	1.18	Maximum Likelihood	Gamma	auto fit	K-S Test
Returning Cycle		345	17.00	96.00	31.83	8.64	Maximum Likelihood	Gumbel	auto fit	K-S Test
Amount of Grannular Material		Truck capacity (m3)			Resource (No.)					Remark
Truck load	m3	Max	Min	Aver.	Truck	Excavator	Dozer/D8R	Dozer/D6R	Spotter	
1,000	16,370	16.70	15.00	16.37	10.00	1.00	1.00	1.00	1.00	

The above table 4.8 shows the simulation model input data and assumption of the overall input data analysis for the earthmoving operation process (embankment of retaining wall and box culvert, sub-grade works, and other fill works) which are used only the natural granular (selected) materials.

The generated statistical output data report from the input data and the assumption of the characteristics of the earthmoving operation process of the embankment (in retaining wall and box culvert), sub-grade, and another fill works, shows that it is possible to estimate the total simulation time to finish the operation (number of runs), equipment (another resource) production rate, truck queue lengths, average waiting time in the queue, truck interarrival time, number of truck (another resource) used, productivity rate of the system. Figure 4.6 shows those points in detail.

Statistics Report

Date: 2020-01-31
Project: Model
Scenario: EMO-Model: Including the Embankment data
Run: All Runs (of 1000)

Note: When summarized across all runs, the mean value reported for a statistic is the mean of the means of each run; the minimum value reported is the minimum of the means of each run; the maximum value reported is the maximum of the means of each run; and so forth.

Non-Intrinsic Statistics

Element Name	Mean Value	Standard Deviation	Observation Count	Minimum Value	Maximum Value
EMO-Model: Including the Embankment data (Termination Time)	8,348.929	8.715	1,000.000	8,326.957	8,384.232

Intrinsic Statistics

Element Name	Mean Value	Standard Deviation	Minimum Value	Maximum Value	Current Value
Dozer_D6R (1) (PercentNonEmpty)	0.501	0.001	0.499	0.503	0.501
Dozer_D8R (1) (PercentNonEmpty)	0.009	0.001	0.007	0.014	0.009
DumpTruck (10) (PercentNonEmpty)	0.686	0.021	0.615	0.746	0.714
Excavator (1) (PercentNonEmpty)	0.362	0.005	0.343	0.378	0.364

Counters

Element Name	Final Count	Production Rate	Average Interarrival	First Arrival	Last Arrival
Dozer_D6R Productivity	1,000.000	0.117	8.274	54.349	8,319.787
Dozer_D8R Productivity	1,000.000	0.121	8.270	8.270	8,270.000
Excavator Productivity	1,000.000	0.120	8.271	13.652	8,276.062
System/DumpTruck Productivity	1,000.000	0.118	8.273	50.179	8,315.034

Waiting Files

Element Name	Average Length	Standard Deviation	Maximum Length	Current Length	Average Wait Time
Dozer_D6R (1)	0.501	0.001	0.503	0.501	4.150
Dozer_D8R (1)	0.009	0.001	0.014	0.009	0.000
DumpTruck (10)	1.024	0.039	1.145	1.050	8.151
Excavator (1)	0.362	0.005	0.378	0.364	2.950

Figure 4. 6: Statistics report of Simphony CYCLONE Simulation for the overall model of the selected material delivery process

According to the figure 4.6 above, by assigning ten trucks, one dozer at the quarry site, one excavator, and one dozer at the construction site: the simulation model is resulting, time that it took to complete the total simulation run was 8,348.929 min. or 139.15 hrs. The production rate of the overall system was 0.118TL/min (truckload per min) or 115.90 M3/hr. The average interarrival time of the truck takes 8.273min between 10 trucks at the dumping station. Regarding the resource idleness in the simulation model, the trucks waited approximately 68.60% of the time, the dozer (D6R) waited approximately 50.10% of the time, the dozer (D8R) waited approximately 0.9% of the time, and the excavator also waited approximately 36.20% of the time. This result shows that the truck was idle more than two-third of its time.

2. Analysis of the simulation model for the sub-grade work (selected material)

This section demonstrates the process of simulation modeling for the overall works that use selected (natural granular) material except for the embankment work of the retaining wall and box culverts (i.e., sub-grade and another fill works of the construction site). It includes the conceptual modeling of the operation process, preparation of simulation input data for each cycle time in the operation process, running the simulation model, and finally, generate reports for the statistical simulation model output result with Simphony-CYCLONE. This model represents the data collected from the earthmoving operation process works (activities) that use selected material (sub-grade and another fill works) during the observation period. In this section, the simulation model uses the excavator as loading equipment and dozer as spreading (placing equipment).

A hierarchical conceptual model developed based on the real-world operation of the earthmoving operation process. The operation process started at quarry (material production) site by making the dozer ready for stockpiling and stockpiling the selected (natural granular) material (produce the material to be used by the project) the material at quarry site (i.e., Dozer cycle) → the excavator and dump-truck ready and queue at the quarry site for loading, and loading the selected (natural granular) material (i.e., Excavator cycle) → the loaded truck traveled to the construction site → the truck arrives at the construction site, queue to dump, and dumping the material (i.e., Spotter cycle) → the empty truck return to the quarry site → the truck arrives at the quarry site and queue to start another cycle. Another dozer also ready and queue at the construction site to spread the delivered material and place (spreading) it (i.e., Dozer cycle). Figure 4.7 shows the overall simulation model of the earthmoving operation process except for the embankment work (sub-grade and another fill activities), table 4.9 shows the summary of the input data for a simulation model of the earthmoving operation process except for the embankment work of the retaining and box culverts (sub-grade and another fill works), and figure 4.8 shows simulation model output statistical report, and it is also similar to figure 4.3 & 4.6.

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In this section of the simulation model, a total of 287 sample data has been collected and entered into simulation software according to the Simphony CYCLONE input data analyzer requirement, and the result of the analyzer collected with the auto fit and selected the best result of distribution and goodness-of-fit. Another input data assumption is required to manipulate the simulation. The assumptions took in this section are the same as the previous section.

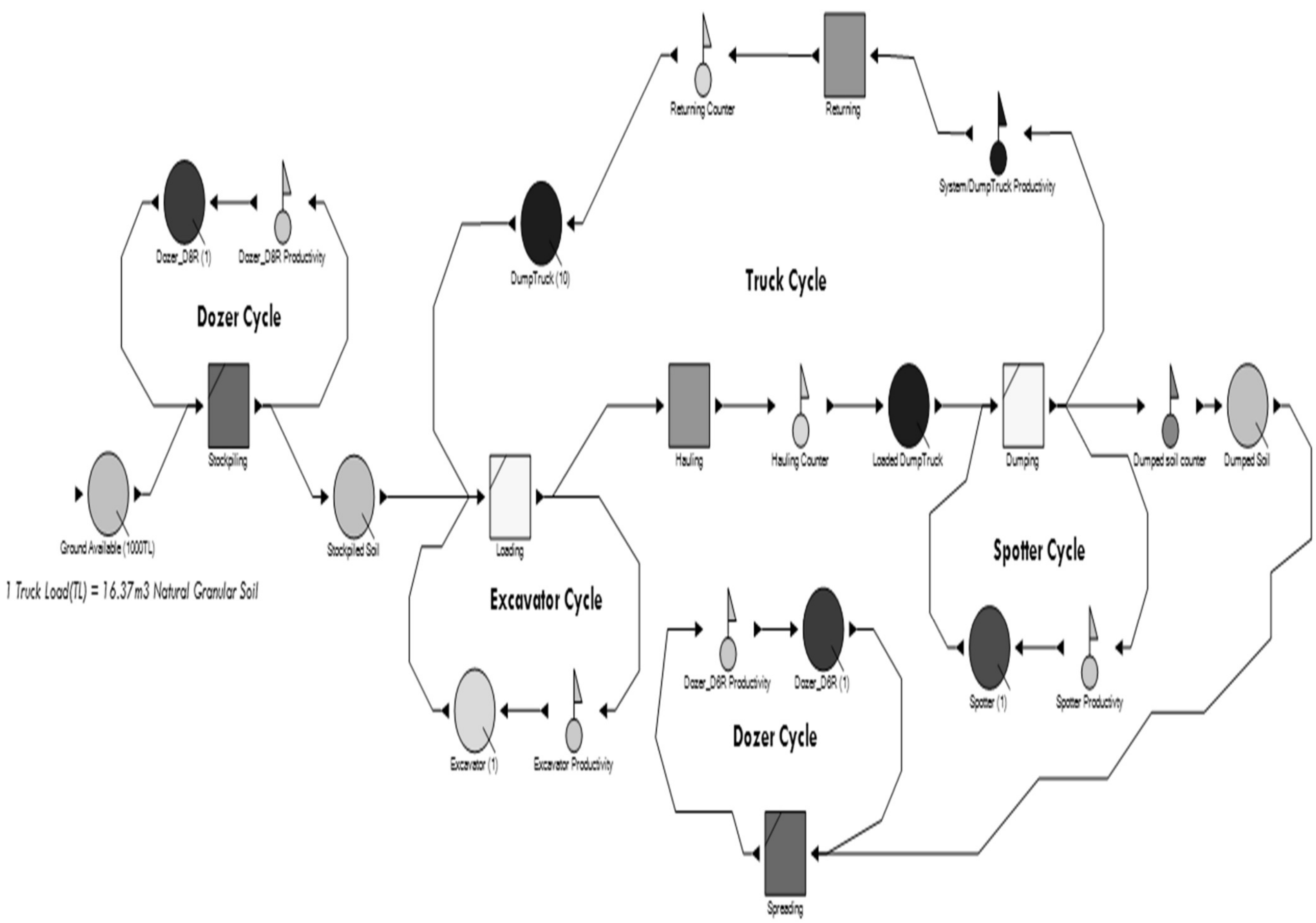


Figure 4. 7: Overall earthmoving operation process for selected material (NGM) delivery except for the embankment work

Table 4.9 below shows the simulation model input data and assumption of the overall input data analysis for the earthmoving operation process except for the embankment works of retaining wall and box culvert (sub-grade works and other fills), which are used only the natural granular (selected) materials.

Table 4. 9: Input data summary for overall earthmoving operation process except for embankment (uses selected material)

Selected Material (Natural Granular Soil) excluding Embankment Work-Best Fitting									
Delivery Cycle	Input data Results					Distribution fittings			Test Method
	Count	Min	Max	Mean	StDev	Distribution Type	Parameter	Best fit	
Loading Cycle	287	3.00	12.00	5.33	1.41	Maximum Likelihood	Weibull	auto fit	K-S Test
Traveling Cycle	287	21.00	62.00	35.01	6.11	Maximum Likelihood	Weibull	auto fit	K-S Test
DumpingCycle	287	1.00	12.00	2.17	1.09	Maximum Likelihood	Gamma	auto fit	K-S Test
Returning Cycle	287	19.00	84.00	31.22	7.72	Maximum Likelihood	Gumbel	auto fit	K-S Test

Amount of		Truck capacity (m3)			Resource (No.)					Remark
Truck load	m3	Max	Min	Aver.	Truck	Excavator	Dozer/D8R	Dozer/D6R	Spotter	
1,000	16,370	16.70	15.00	16.37	10.00	1.00	1.00	1.00	1.00	

The generated statistical output data report from the input data and the assumption of the characteristics of the earthmoving operation process of the sub-grade and another fill works except for embankment of the retaining wall and box culvert work shows that it is possible to estimate the total simulation time to finish the operation (number of the run), equipment (another resource) production rate, truck queue lengths, average waiting time in the queue, truck interarrival time, number of truck (another resource) used productivity rate of the system. Figure 4.8 shows those points in detail.

Statistics Report

Date: 2020-02-01

Project: Model

Scenario: EMO-Model: Excluding the Embankment data

Run: All Runs (of 1000)

Note: When summarized across all runs, the mean value reported for a statistic is the mean of the means of each run; the minimum value reported is the minimum of the means of each run; the maximum value reported is the maximum of the means of each run; and so forth.

Non-Intrinsic Statistics

Element Name	Mean Value	Standard Deviation	Observation Count	Minimum Value	Maximum Value
EMO-Model: Excluding the Embankment data (Termination Time)	8,345.763	7.851	1,000.000	8,327.063	8,392.015

Intrinsic Statistics

Element Name	Mean Value	Standard Deviation	Minimum Value	Maximum Value	Current Value
Dozer_D6R (1) (PercentNonEmpty)	0.500	0.000	0.499	0.503	0.500
Dozer_D8R (1) (PercentNonEmpty)	0.009	0.001	0.007	0.015	0.009
DumpTruck (10) (PercentNonEmpty)	0.765	0.017	0.715	0.823	0.750
Excavator (1) (PercentNonEmpty)	0.362	0.006	0.341	0.379	0.352

Counters

Element Name	Final Count	Production Rate	Average Interarrival	First Arrival	Last Arrival
Dozer_D6R Productivity	1,000.000	0.117	8.273	53.822	8,318.691
Dozer_D8R Productivity	1,000.000	0.121	8.270	8.270	8,270.000
Dumped soil counter	1,000.000	0.118	8.272	49.652	8,313.843
Excavator Productivity	1,000.000	0.120	8.270	13.533	8,275.651
System/DumpTruck Productivity	1,000.000	0.118	8.272	49.652	8,313.843

Waiting Files

Element Name	Average Length	Standard Deviation	Maximum Length	Current Length	Average Wait Time
Dozer_D6R (1)	0.500	0.000	0.503	0.500	4.149
Dozer_D8R (1)	0.009	0.001	0.015	0.009	0.000
DumpTruck (10)	1.158	0.033	1.255	1.123	9.275
Excavator (1)	0.362	0.006	0.379	0.352	2.949

Figure 4. 8: Statistics report of Simphony CYCLONE Simulation for the overall model of the selected material delivery process except for the embankment work

According to the figure 4.8 above, by assigning ten trucks, one dozer at the quarry site, one excavator, and one dozer at the construction site: the simulation model is resulting, time that it took to complete the total simulation run was 8,345.7638min. or 139.10hrs. The production rate of the overall system was 0.118TL/min (truckload per min) or 115.90 M3/hr. The average *interarrival time of the truck takes 8.27min between 10 trucks at the dumping station. Regarding the resource idleness in the simulation model, the trucks waited approximately 76.50% of the time, the dozer (D6R) waited approximately 50.00% of the time, the dozer (D8R) waited approximately 0.9% of the time, and the excavator also waited approximately 36.20% of the time. This result shows that the truck was idle more than three-fourth of its time.*

3. Analysis of the simulation model for the overall of the sub-base and base-coarse works

This section demonstrates the process of the simulation modeling for the overall earthmoving operation (crushed unbounded material delivery) process of sub-base and base-coarse works. It includes conceptual modeling of the operation, preparation of the simulation modeling input data for each cycle time in the operation process, running the simulation model, and finally, generate statistical reports for the simulation model output results with Simphony-CYCLONE. The overall model represents all data collected from the crushed unbounded material delivery process of the sub-base and base-coarse works of the sample construction site during the data collection period through the observation method. In this section, the simulation model uses a loader as loading equipment and grader as spreading (placing equipment).

A hierarchical conceptual model developed based on the real-world operation of the earthmoving operation process. The operation process started at quarry (material production) site by making the Loader and dump-truck ready and queue at the quarry site for loading, and loading the crushed unbounded (sub-base and base-coarse) material (i.e., Loader cycle) → the loaded truck traveled to the construction site → the truck arrive at the construction site, queue to dump, and dumping the material (i.e., Spotter cycle) → the empty truck return to the quarry site → the truck arrive at the quarry site and queue to start another cycle. A Grader also ready and queue at the construction site to spread the delivered material and place (spreading) it (i.e., Grader cycle). Figure 4.8 shows the overall simulation model of the earthmoving operation process of sub-base and base-coarse works of the construction (road) site, table 4.6 shows the summary of the input data for a simulation model of the earthmoving operation process of sub-base and base-coarse works of the construction (road) site, and figure 4.9 shows simulation model output statistical report.

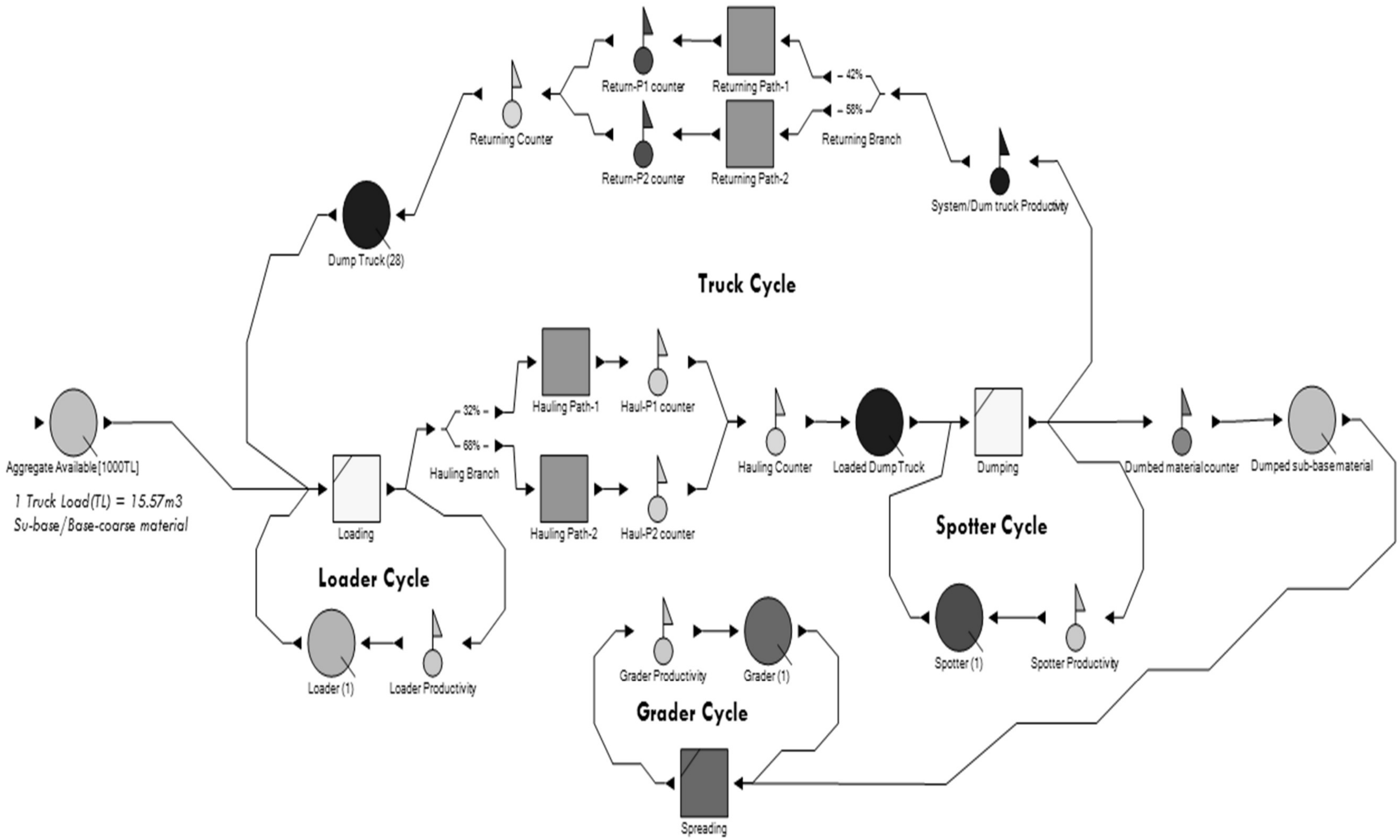


Figure 4. 9: Overall earthmoving operation process for crushed unbounded material delivery (Loader as loading equipment)

In this section of the simulation model, a total of 76 sample data has been collected and entered into simulation software according to the Simphony CYCLONE input data analyzer requirement, and the result of the analyzer collected with the auto fit and selected the best result of distribution and goodness-of-fit. Another input data assumption is required to manipulate the simulation, such as truckload (TL), number of the grader and dump truck, number of spotters, amount of the material to be delivered, and another the same to previous sections.

Table 4.10 below shows the simulation model input data and assumption of the overall input data analysis for the earthmoving operation process sub-base and base-coarse works, which are used only the crushed unbounded (sub-base/base-coarse) materials.

Table 4. 10: Input data summary for overall earthmoving operation process of the sub-base and base-coarse

Overall Crushed Unbound Aggregate (Sub-base/base-coarse) Material-Best Fitting										
Delivery Cycle		Input data Results					Distribution fittings			Test Method
		Count	Min	Max	Mean	StDev	Distribution Type	Parameter	Best fit	
ading Cycle		76	1.00	4.47	2.66	0.67	Least Square	Gamma	auto fit	Chi-square test
Traveling Cycle	Path-1	24	17.00	36.00	22.55	4.13	Least Square	Uniform	auto fit	Chi-square test
	Path 2	52	18.00	37.00	23.26	3.46	Least Square	Weibull	auto fit	Chi-square test
DumpingCycle		76	1.00	4.57	2.02	0.74	Least Square	Weibull	auto fit	Chi-square test
Returning Cycle	Path-1	28	13.00	34.00	18.29	3.73	Least Square	Uniform	auto fit	Chi-square test
	Path 2	48	13.00	50.00	18.92	5.21	Least Square	Normal	auto fit	Chi-square test
Amount of Crushed Material		Truck capacity (m3)			Resource (No.)				Remark	
Truck load	m3	Max	Min	Aver.	Truck	Loader	Grader	Spoter		
1,000	15,710	17.03	14.00	15.71	28.00	1.00	1.00	1.00		

The generated statistical output data report from the input data and the assumption of the characteristics of the earthmoving operation process of the sub-base and base-coarse works using the only loader as loading equipment show that it is possible to estimate the total simulation time to finish the operation (number of runs), equipment (another resource) production rate, truck queue lengths, average waiting time in the queue, truck interarrival time, the number of truck (another resource) used productivity rate of the system. Figure 4.9 shows those points in detail.

Statistics Report

Date: 2020-02-01
Project: Model
Scenario: EMO Model for the Crushed Unbounded Material delivery
Run: All Runs (of 1000)

Note: When summarized across all runs, the mean value reported for a statistic is the mean of the means of each run; the minimum value reported is the minimum of the means of each run; the maximum value reported is the maximum of the means of each run; and so forth.

Non-Intrinsic Statistics

Element Name	Mean Value	Standard Deviation	Observation Count	Minimum Value	Maximum Value
EMO Model for the Crushed Unbounded Material delivery (Termination Time)	2,298.642	21.767	1,000.000	2,224.848	2,374.165

Intrinsic Statistics

Element Name	Mean Value	Standard Deviation	Minimum Value	Maximum Value	Current Value
Dump Truck (28) (PercentNonEmpty)	0.990	0.009	0.927	1.000	0.969
Grader (1) (PercentNonEmpty)	0.669	0.003	0.658	0.680	0.667
Loader (1) (PercentNonEmpty)	0.022	0.002	0.017	0.031	0.030

Counters

Element Name	Final Count	Production Rate	Average Interarrival	First Arrival	Last Arrival
Grader Productivity	1,000.000	0.425	2.257	26.309	2,281.336
Haul-P1 counter	316.037	0.136	7.130	28.264	2,269.535
Haul-P2 counter	683.963	0.296	3.296	25.054	2,275.330
Loader Productivity	1,000.000	0.453	2.253	2.237	2,252.999
Return-P1 counter	421.583	0.170	5.353	46.376	2,294.712
Return-P2 counter	578.417	0.246	3.902	45.421	2,296.993
System/Dum truck Productivity	1,000.000	0.426	2.257	25.549	2,280.576

Waiting Files

Element Name	Average Length	Standard Deviation	Maximum Length	Current Length	Average Wait Time
Dump Truck (28)	5.601	0.304	6.467	5.232	12.119
Grader (1)	0.669	0.003	0.680	0.667	1.521
Loader (1)	0.022	0.002	0.031	0.030	0.004

Figure 4. 10: Statistics report of Simphony CYCLONE Simulation for the overall model of the crushed unbounded material delivery process

According to the figure 4.10 below, by assigning 28 trucks, one loader at the quarry (material production) site, one spotter at the construction site, and one grader at the construction site: the simulation model is resulting, time that it took to complete the total simulation run was 2,298.642min. or 38.31hrs. The production rate of the overall system was 0.426TL/min (truckload per min) or 401.548M^3/hr. The average interarrival time of the truck takes 2.257min between 28 trucks at the dumping station. Regarding the resource idleness in the simulation model, the trucks waited approximately 99.00% of the time, the grader waited approximately 66.90% of the time, and the loader also waited approximately 2.20% of the time. This report shows that only a few of the trucks are working, and the other (99%) of them did not work (i.e., they are almost idle).

4. Analysis of the simulation model for the overall data collected from the sub-base and base-coarse works (Excavator and Loader as loading equipment)

This section demonstrates the process of the simulation modeling for the overall earthmoving operation (crushed unbounded material delivery) process of sub-base and base-coarse works. In this simulation model demonstration, we use both excavator and loader as loading equipment (i.e., they load at the same time). It includes conceptual modeling of the operation, preparation of the simulation modeling input data for each cycle time in the operation process, running the simulation model, and finally, generate statistical reports for the simulation model output results with Simphony-CYCLONE. The overall model represents all data collected from the crushed unbounded material delivery process of the sub-base and base-coarse works of the sample construction site during the data collection period through the observation method. In this section, the simulation model uses a loader as loading equipment and grader as spreading (placing equipment).

A hierarchical conceptual model developed based on the real-world operation of the earthmoving operation process. The operation process started at quarry (material production) site by making the Excavator, Loader and dump-truck ready and queue at the quarry site for loading, and loading the crushed unbounded (sub-base and base-coarse) material (i.e., Excavator and Loader cycle) → the loaded truck traveled to the construction site → the truck arrive at the construction site, queue to dump, and dumping the material (i.e., Spotter cycle) → the empty truck return to the quarry site → the truck arrive at the quarry site and queue to start another cycle. A Grader also ready and queue at the construction site to spread the delivered material and place (spreading) it (i.e., Grader cycle). Figure 4.8 shows the overall simulation model of the earthmoving operation process of sub-base and base-coarse works of the construction (road) site, table 4.6 shows the summary of the input data for a simulation model of the earthmoving operation process of sub-base and base-coarse works of the construction (road) site, and figure 4.12 shows simulation model output statistical report.

In this section of the simulation model, a total of 76 sample data has been collected except the data used for the loading of an excavator which is 121 and entered the overall data to simulation software according to Simphony CYCLONE input data analyzer requirement, and the result of the analyzer collected with the auto fit and selected the best result of distribution and goodness-of-fit. Another input data assumption is required to manipulate the simulation, such as truckload (TL), number of the grader and dump truck, number of spotters, amount of the material to be delivered, and another the same to previous sections.

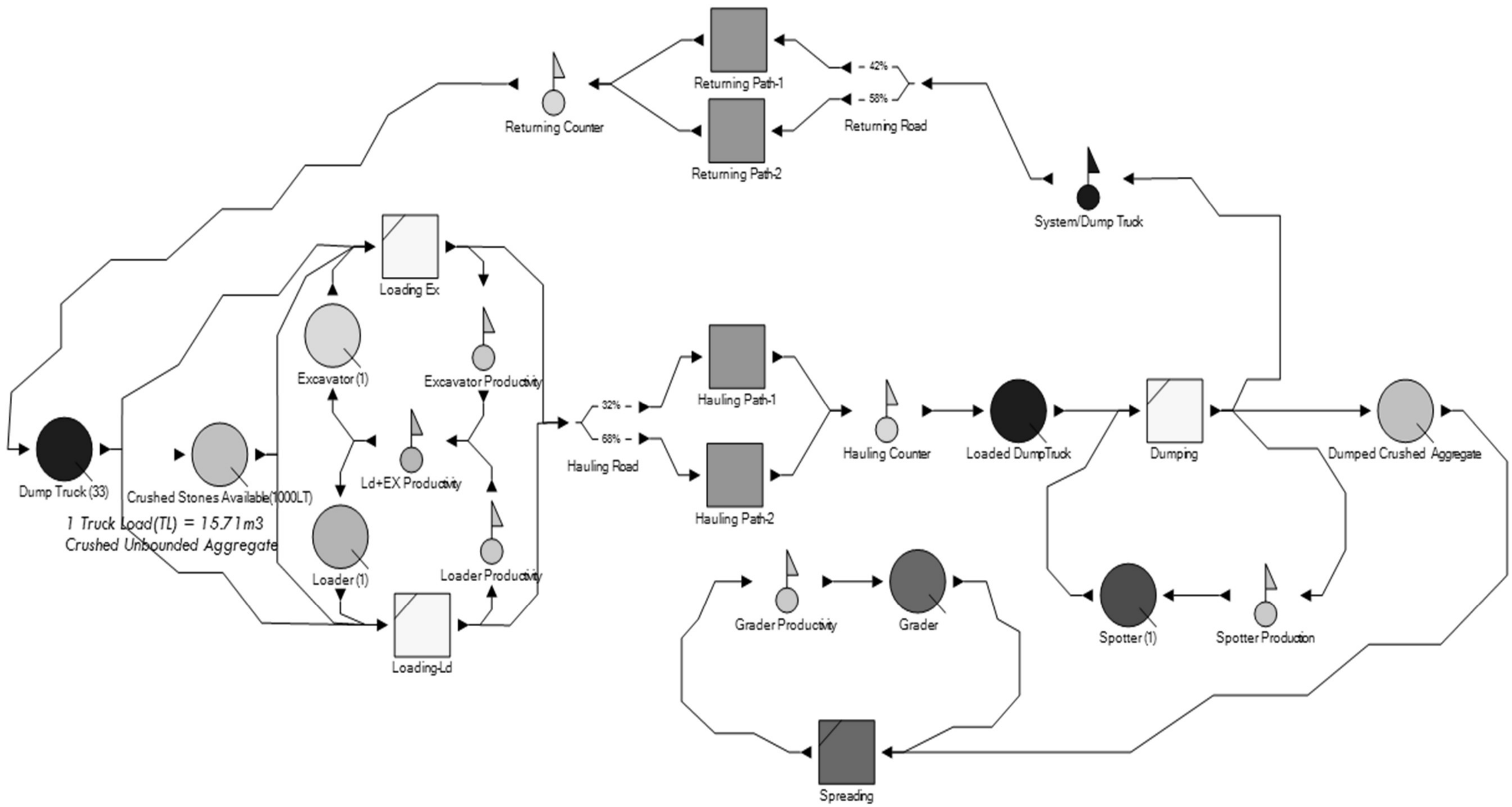


Figure 4. 11: Overall earthmoving operation process for crushed unbounded material delivery (Excavator and Loader as loading equipment)

Table 4.11 below shows the simulation model input data and assumption of the overall input data analysis for the earthmoving operation process sub-base and base-coarse works, which are used only the crushed unbounded (sub-base/base-coarse) materials. It also shows the excavator and loader as loading equipment and their loading time (duration).

Table 4. 11: Input data summary for overall earthmoving operation process of the sub-base and base-coarse works (Excavator and Loader as loading equipment)

Overall Crushed Unbound Aggregate (Sub-base/base-coarse) Material (Excavator and Loader as Loading Equipment)-Best Fitting										
Delivery Cycle		Input data Results					Distribution fittings			Test Method
		Count	Min	Max	Mean	StDev	Distribution Type	Parameter	Best fit	
Loading Cycle	Excavator	121	2.03	5.08	2.99	0.54	Least Square	Gumble	auto fit	Chi-square test
	Loader	76	1.00	4.47	2.66	0.67	Least Square	Gamma	auto fit	Chi-square test
Traveling Cycle	Path-1	24	17.00	36.00	22.55	4.13	Least Square	Uniform	auto fit	Chi-square test
	Path 2	52	18.00	37.00	23.26	3.46	Least Square	Weibull	auto fit	Chi-square test
DumpingCycle		76	1.00	4.57	2.02	0.74	Least Square	Weibull	auto fit	Chi-square test
Returning Cycle	Path-1	28	13.00	34.00	18.29	3.73	Least Square	Uniform	auto fit	Chi-square test
	Path 2	48	13.00	50.00	18.92	5.21	Least Square	Normal	auto fit	Chi-square test
Amount of Crushed Material		Truck capacity (m3)			Resource (No.)					Remark
Truck load	m3	Max	Min	Aver.	Truck	Loader	Excavator	Grader	Spoter	
1,000	15,710	17.03	14.00	15.71	33.00	1.00	1.00	1.00	1.00	

The generated statistical output data report from the input data and the assumption of the characteristics of the earthmoving operation process of the sub-base and base-coarse works using both excavator and loader as loading equipment shows that it is possible to estimate the total simulation time to finish the operation (number of runs), equipment (other resources) production rate, truck queue lengths, average waiting time in the queue, truck interarrival time, number of truck (other resources) used, productivity rate of the system. Figure 4.12 shows those points in detail.

Statistics Report

Date: 2020-02-03
Project: Model
Scenario: EMO-Model: Loading with LD+EX
Run: All Runs (of 1000)

Note: When summarized across all runs, the mean value reported for a statistic is the mean of the means of each run; the minimum value reported is the minimum of the means of each run; the maximum value reported is the maximum of the means of each run; and so forth.

Non-Intrinsic Statistics

Element Name	Mean Value	Standard Deviation	Observation Count	Minimum Value	Maximum Value
EMO-Model: Loading with LD+EX (Termination Time)	2,063.120	24.514	1,000.000	1,985.501	2,152.119

Intrinsic Statistics

Element Name	Mean Value	Standard Deviation	Minimum Value	Maximum Value	Current Value
Dump Truck (33) (PercentNonEmpty)	0.036	0.002	0.030	0.044	0.037
Excavator (1) (PercentNonEmpty)	0.996	0.000	0.995	0.997	0.996
Grader (PercentNonEmpty)	0.632	0.004	0.617	0.647	0.629
Loader (1) (PercentNonEmpty)	0.995	0.000	0.994	0.997	0.996

Counters

Element Name	Final Count	Production Rate	Average Interarrival	First Arrival	Last Arrival
Excavator Productivity	16.000	0.835	0.608	2.959	12.078
Grader Productivity	1,000.000	0.477	2.022	25.155	2,045.552
Ld+EX Productivity	1,000.000	0.568	1.998	2.159	1,998.030
Loader Productivity	984.000	0.503	2.030	2.265	1,998.030
System/Dump Truck	1,000.000	0.478	2.022	24.395	2,044.792

Waiting Files

Element Name	Average Length	Standard Deviation	Maximum Length	Current Length	Average Wait Time
Dump Truck (33)	0.626	0.051	0.802	0.604	0.201
Excavator (1)	506.174	3.434	515.933	509.392	0.000
Grader	0.632	0.004	0.647	0.629	1.286
Loader (1)	15.858	0.019	15.918	15.840	31.844

Figure 4. 12: Statistics report of Simphony CYCLONE Simulation for the overall model of the crushed unbounded material delivery process (Loader and Excavator as loading equipment)

According to the figure 4.12 above, by assigning 33 trucks, one loader and one excavator at the quarry (material production) site, one spotter at the construction site, and one grader at the construction site: the simulation model is resulting, time that it took to complete the total simulation run was 2063.120min. or 34.39hrs. The production rate of the overall system was

0.478TL/min (truckload per min) or 7.44M3/hr. The average interarrival time of the truck takes 2.022min between 33 trucks at the dumping station. Regarding the resource idleness in the simulation model, the trucks waited approximately 3.60% of the time, the grader waited approximately 63.20% of the time, the excavator waited approximately 99.6% of the time, and the loader also waited approximately 99.5% of the time. This report shows that the excavator and loader equipment are working little time (i.e., they are almost idle).

4.5.2. Sensitivity analysis of the simulation models/comparison of the model results from

The sensitivity analysis of simulation models quantifies the change in the simulation model output as simulation model input changes. In this research, the sensitivity analysis of the critical resources of the earthmoving operation process was performed by changing the input resources (number of equipment) to obtain the optimum simulation model results. For doing sensitivity analysis, different scenarios related to different resource combinations were defined and modeled in Simphony-CYCLONE to predict the earthmoving operation productivity and the number of resources used. Sensitivity analysis was then conducted to find the best combination that has the best productivity and number of resources used.

The above sections from 4.5.2 to 4.5.5 presents and discusses the result of the different simulation model without performing the comparison of the results, therefore in this section the sensitivity analysis of the simulation model results of the different model scenarios of the earthmoving operation process is conducted to:

- Estimate the effects of the resource combination (e.g., number of the truck, stockpiling, or loading equipment) on the earthmoving operation process and
- Find the optimum production rate and the number of fleets of the earthmoving operation process.

This allows decision-makers to develop an effective and efficient earthmoving operation process based on result comparison parameters and decision support tools. The main objective of comparing result is to identify and recommend the best operation process simulation model which resulting optimized production rate of the system by evaluating and comparing usage of resources available (minimum number of equipment), less idleness time of resources, lowest interarrival time of truck and choose the best combination of the equipment.

If so, it is critically required to define result comparison parameters that affect the production rate of the earthmoving operation process. The parameters that have been believed which affect the production rate of the delivery are assigned the number of truck and capacity, type of work to be done (i.e., type of material to be delivered), number and type of loading equipment used, type of stockpiling equipment used, and type of material to be delivered. This is discussed as the following:

1. Assign truck number and capacity: according to (Pradhananga & Teizer, 2015) findings, the number of trucks is the primary resource in the earthmoving process that needs focusing. For example, having many trucks at the site may not increase the production rate; rather, it may increase the idleness and cost of the trucks in operation. Therefore, the criteria for assigning a number of the trucks should be less idleness and optimum production rate.
2. Type of work to be done (embankment of retaining wall & box culvert; sub-grade): this affects the production rate of the system. During the observation, it has been identified dumping at the retaining wall, and large box culverts are more difficult than sub-grade (dumping at the roadway) due to the suitability of the space for spotting for dump and dumping of the truck.
3. Type of delivered material (natural granular /selected/ material; crushed unbounded material): type of material to be delivered in the earthmoving operation affects the production rate of the system. During the data collection, it has been recognized that the delivery of natural granular material is more difficult than the crushed one.
4. Type and assigning the number of loading equipment (loader or excavator): loading equipment type also affects the production rate of the system. During the data observed from the delivery of the crushed unbounded material, loading with loader is takes less loading duration (time) than an excavator.

After the parameters are defined, to select the optimum production rate and best resource combination of the system, the next step is identifying the result comparison procedure for each simulation model, and the following sections discuss the sensitivity analysis (result comparison) in detail.

4.5.2.1.Sensitivity analysis (output result comparison) for the overall operation process of the natural granular (selected) material:

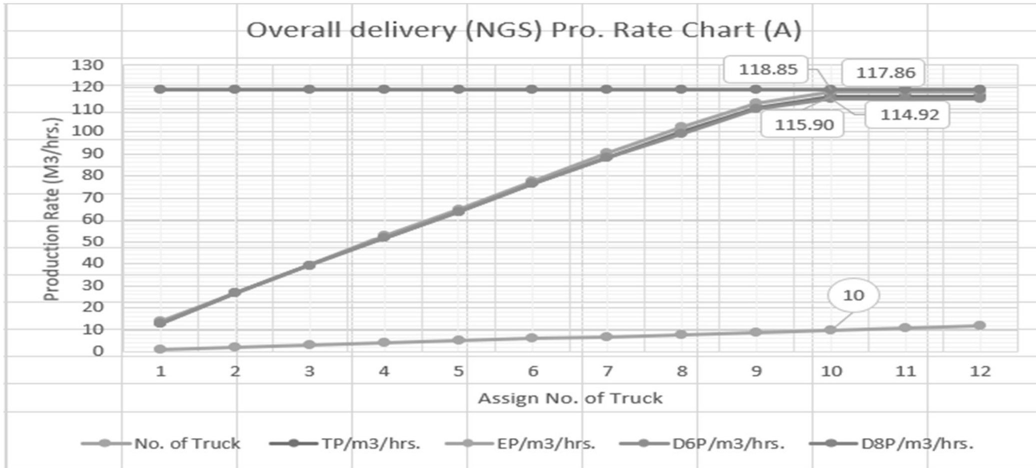
This section presents the discussion and results from a comparison of the simulation model of the data observed from the delivery of the selected (natural granular) material based on the assigned number of the trucks, minimum interval time, and optimum production rate of the system. The following procedure has been defined:

Step 1: develop the overall delivery of the natural granular (selected) material and report simulation results in tabulated form and discuss the specific model:

As discussed in section 4.5.2, similar simulation modeling input data and graphical representation are used to develop the simulation model scenarios of the overall selected material delivery process. Table 4.12 below shows a summary of the simulation model result from the overall selected (natural granular) material delivery operation.

Table 4. 12: The overall earthmoving operation process of the embankment and subgrade work (delivery of selected material)

Overall Summary Model Result Report (1000 Count) for The Delivery of Natural granular Material																		
No. of Truck	Production Rate								Idleness (Waiting)								Truck Inter arrival	Termination time (mean)
	Truck		Excavator		Dozer_D6R		Dozer_D8R		Truck		Excavator		Dozer_D6R		Dozer_D8R			
	TL/Minute	TP/m3/hrs.	EL/Minute	EP/m3/hrs.	D6L/Minute	D6P/m3/hrs.	D8L/Minute	D8P/m3/hrs.	length	TI %age	length	EI %age	length	D6I %ag	length	D8I %age		
1	0.013	12.77	0.014	13.75	0.013	12.77	0.121	118.85	-	0.00%	0.929	92.90%	0.944	94.40%	0.889	88.90%	74.66	74,672.01
2	0.027	26.52	0.027	26.52	0.027	26.52	0.121	118.85	0.007	0.70%	0.858	85.80%	0.889	88.90%	0.779	77.90%	37.45	37,490.10
3	0.040	39.29	0.040	39.29	0.040	39.29	0.121	118.85	0.022	1.90%	0.788	78.80%	0.834	83.40%	0.671	67.10%	25.05	25,103.13
4	0.053	52.06	0.054	53.04	0.053	52.06	0.121	118.85	0.046	3.80%	0.719	71.90%	0.780	78.00%	0.563	56.30%	18.85	18,916.98
5	0.065	63.84	0.066	64.83	0.065	63.84	0.121	118.85	0.080	6.40%	0.650	65.00%	0.726	72.60%	0.456	45.60%	15.15	15,215.16
6	0.078	76.61	0.079	77.59	0.078	76.61	0.121	118.85	0.127	9.60%	0.582	58.20%	0.673	67.30%	0.352	35.20%	12.68	12,753.24
7	0.090	88.40	0.092	90.36	0.090	88.40	0.121	118.85	0.188	13.60%	0.516	51.60%	0.621	62.10%	0.248	24.80%	10.93	10,999.12
8	0.102	100.18	0.104	102.15	0.101	99.20	0.121	118.85	0.265	18.40%	0.450	45.00%	0.570	57.00%	0.147	14.70%	9.62	9,691.46
9	0.113	110.99	0.115	112.95	0.112	110.01	0.121	118.85	0.364	24.20%	0.387	38.70%	0.520	52.00%	0.048	4.80%	8.61	8,685.80
10	**0.118**	**115.90**	**0.120**	**117.86**	**0.117**	**114.92**	**0.121**	**118.85**	**1.023**	**68.60%**	**0.362**	**36.20%**	**0.501**	**50.10%**	**0.009**	**0.90%**	**8.27**	**8,349.20**
11	0.118	115.90	0.120	117.86	0.117	114.92	0.121	118.85	2.024	95.70%	0.362	36.20%	0.501	50.10%	0.009	0.90%	8.27	8,348.67
12	0.118	115.90	0.120	117.86	0.117	114.92	0.121	118.85	3.023	99.80%	0.362	36.20%	0.500	50.00%	0.009	0.90%	8.27	8,348.06
Legend	TP=Truck Prod. Rate		D8P=Dozer D8R Prod. Rate		D6P=Dozer_D6R Prod. Rate		EP=Excavator Prod. Rate		TI=Truck Idleness		D8I=Dozer D8R Idleness		D6I=Dozer D6R Idleness		EI=Excavator Idleness		TL=Truck Load	



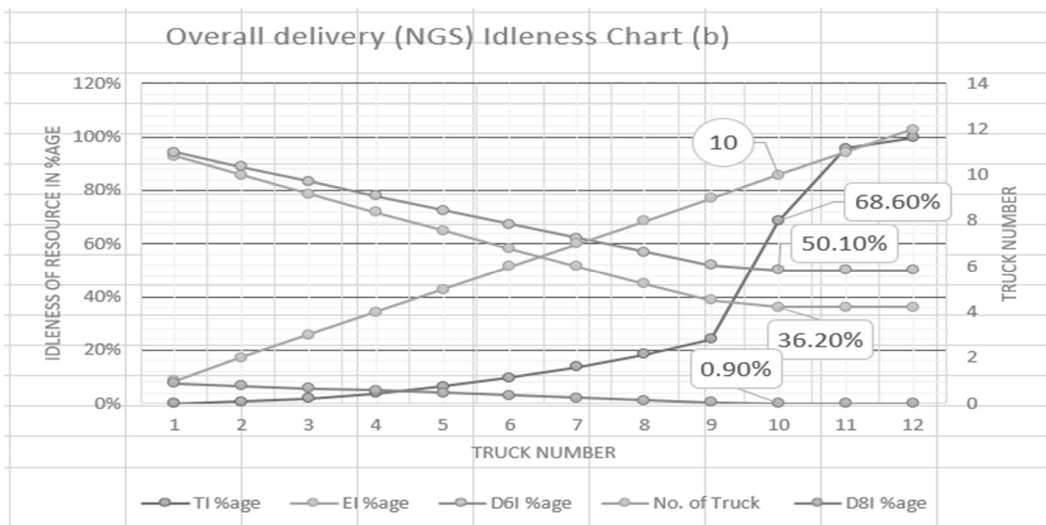


Figure 4. 13: The overall delivery of the selected material (Chart Form)

Table 4.12 and figure 4.13 show that; the optimum production rate of the system has been recorded on assigned truck number ten; a detail discussion presented here below:

- *Assigning ten trucks and the other remains the same: is resulting, the total time that it took to complete the total simulation run was 8,349.20min. or 139.15 hrs. The production rate of the overall system was 0.118TL/min (truckload per min) or 115.90 M3/hr. The average interarrival time of the truck takes 8.273min between 10 trucks at the dumping station. Regarding the resource idleness in the simulation model, the trucks waited approximately 68.60% of the time, the dozer (D6R) waited approximately 50.10% of the time, the dozer*

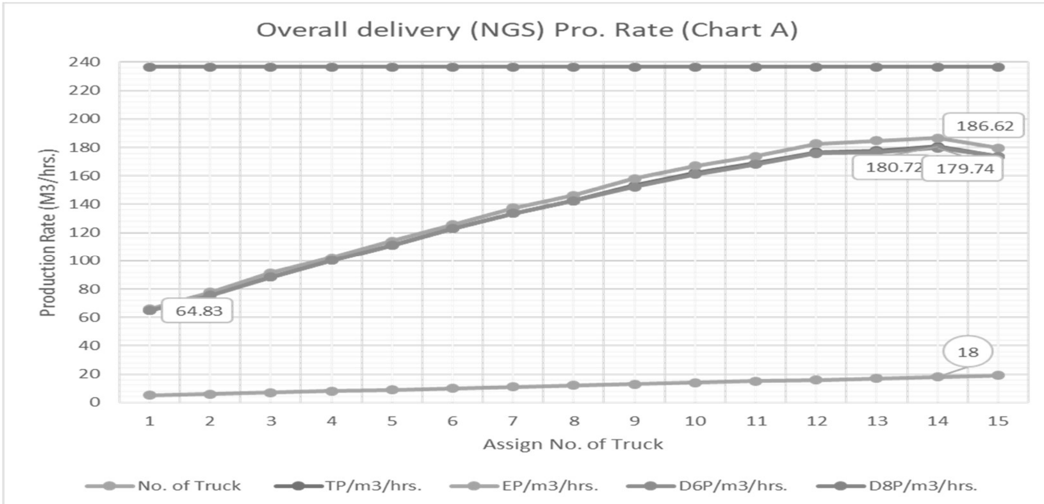
(D8R) waited approximately 0.9% of the time, and the excavator also waited approximately 36.20% of the time.

Step 2: develop the overall delivery of the natural granular (selected) material by changing the number of stockpiling equipment and report simulation result in tabulated form and discuss the specific model:

The same procedure as step 1 above, but except the number of dozers of the material stockpiling (preparation) into two at the quarry site. Table 4.13 below shows the summary of the simulation model result of the selected material delivery used works except for the embankment work of the retaining wall and box culvert**.**

Table 4. 13: The overall earthmoving operation process of the embankment and subgrade work (using Two Dozers in case of stockpiling)

Overall Summary Model Result Report (1000 Count) for The Delivery of Natural granular Material (using two dozers at the stockiling cycle)																		
No. of Truck	Production Rate								Idleness (Waiting)								Truck Inter arrival	Termination time (mean)
	Truck (5-18)		Excavator (1)		Dozer_D6R (1)		Dozer_D8R (2)		Truck		Excavator		Dozer_D6R		Dozer_D8R			
	TL/Minute	TP/m3/hrs.	EL/Minute	EP/m3/hrs.	D6L/Minute	D6P/m3/hrs.	D8L/Minute	D8P/m3/hrs.	length	TI %age	length	EI %age	length	D6I %age	length	D8I %age		
5	0.066	64.83	0.067	65.81	0.066	64.83	0.241	236.71	0.079	6.30%	0.650	65.00%	0.726	72.60%	1.456	72.80%	15.139	15,206.61
6	0.078	76.61	0.079	77.59	0.077	75.63	0.241	236.71	0.124	9.50%	0.582	58.20%	0.673	67.30%	1.351	67.50%	12.671	12,742.83
7	0.090	88.40	0.093	91.34	0.090	88.40	0.241	236.71	0.183	13.50%	0.515	51.50%	0.621	62.10%	1.248	62.40%	10.920	10,992.15
8	0.102	100.18	0.104	102.15	0.102	100.18	0.241	236.71	0.258	18.20%	0.450	45.00%	0.569	56.90%	1.146	57.30%	9.610	9,683.40
9	0.113	110.99	0.116	113.94	0.113	110.99	0.241	236.71	0.352	23.80%	0.386	38.60%	0.519	51.90%	1.047	52.30%	8.599	8,673.73
10	0.125	122.78	0.128	125.72	0.125	122.78	0.241	236.71	0.468	30.20%	0.324	32.40%	0.470	47.00%	0.950	47.50%	7.797	7,872.74
11	0.136	133.58	0.140	137.51	0.136	133.58	0.241	236.71	0.610	37.60%	0.263	26.30%	0.423	42.30%	0.856	42.80%	7.152	7,227.97
12	0.145	142.42	0.149	146.35	0.145	142.42	0.241	236.71	0.787	46.00%	0.205	20.50%	0.378	37.80%	0.766	38.30%	6.624	6,701.20
13	0.156	153.22	0.161	158.13	0.155	152.24	0.241	236.71	1.013	55.60%	0.150	15.00%	0.335	33.50%	0.681	34.10%	8.610	8,685.80
14	0.165	162.06	0.170	166.97	0.164	161.08	0.241	236.71	1.309	66.60%	0.101	10.10%	0.296	29.60%	0.604	30.20%	5.847	5,925.59
15	0.172	168.94	0.177	173.85	0.171	167.96	0.241	236.71	1.727	78.40%	0.061	6.10%	0.265	26.50%	0.542	0.27%	5.593	5,671.14
16	0.180	176.80	0.186	182.69	0.179	175.81	0.241	236.71	2.332	89.50%	0.033	3.30%	0.243	24.30%	0.498	24.90%	5.429	5,507.31
17	0.181	177.78	0.188	184.65	0.180	176.80	0.241	236.71	3.140	96.50%	0.020	2.00%	0.232	23.20%	0.478	23.90%	5.354	5,432.17
18	**0.184**	**180.72**	**0.190**	**186.62**	**0.183**	**179.74**	**0.241**	**236.71**	**4.087**	**99.30%**	**0.016**	**1.60%**	**0.230**	**23.00%**	**0.472**	**23.60%**	**5.335**	**5,413.25**
19	0.177	173.85	0.183	179.74	0.177	173.85	0.241	236.71	5.082	99.90%	0.015	1.50%	0.229	22.90%	0.472	23.60%	5.333	5,411.17
Legend	TP=Truck Prod. Rate		D8P=Dozer D8R Prod. Rate		D6P=Dozer_D6R Prod. Rate		EP=Excavator Prod. Rate		TI=Truck Idleness		D8I=Dozer D8R Idleness		D6I=Dozer D6R Idleness		EI=Excavator Idleness		TL=Truck Load	



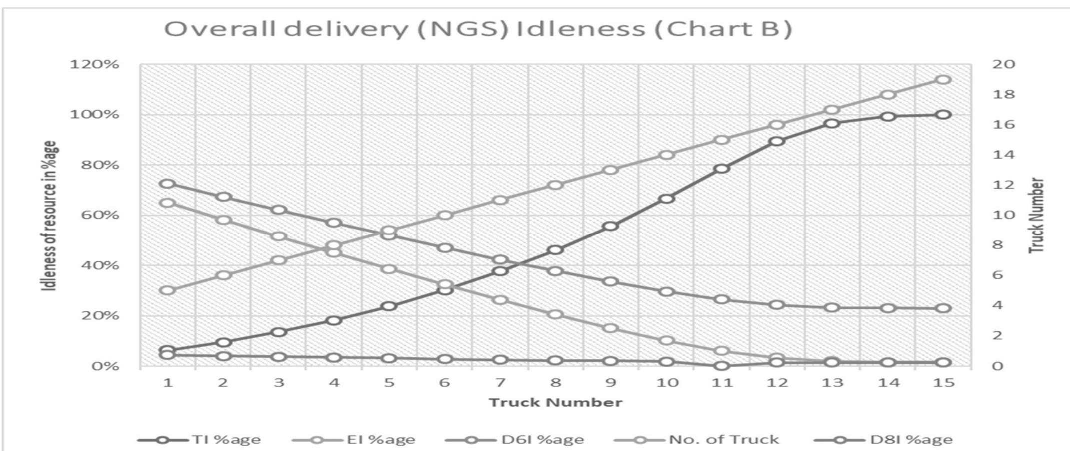


Figure 4. 14: The overall delivery of the selected material (A. productivity rate and B. Idleness of the resource in %age) using two dozers in the stockpiling (Chart Form)

Table 4.13 and figure 4.14 show that; the optimum production rate of the system has been recorded on assigned truck number 18, and the number of dozers in the stockpiling is two, a detail discussion presented here below:

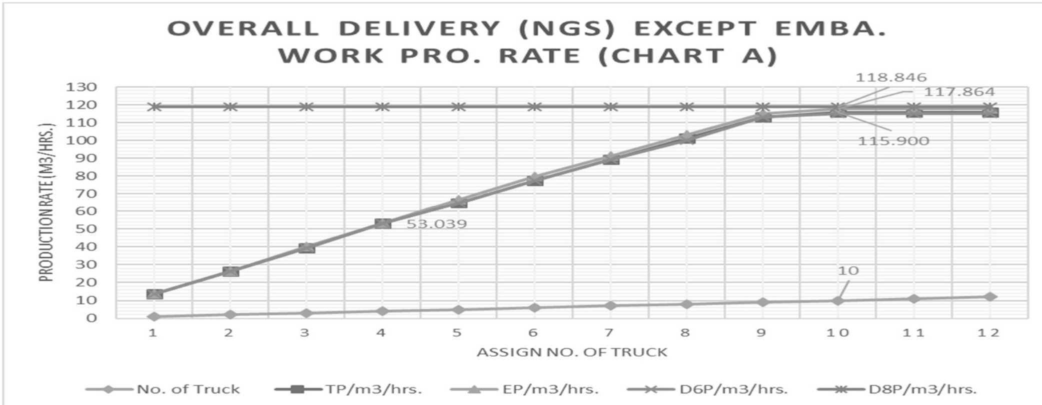
- *Assigning 18 trucks, stockpiling equipment (dozer) 2, and the other remains the same: is resulting, the total time that it took to complete the total simulation run was 5413.25min. or 90.22 hrs. The production rate of the overall system was 0.184TL/min (truckload per min) or 180.72M3/hr. The average interarrival time of the truck takes 5.335min between 18 trucks at the dumping station. Regarding the resource idleness in the simulation model,* *the trucks waited approximately 99.3% of the time, the dozer (D6R) waited approximately 23% of the time, the dozer (D8R) waited approximately 23.6% of the time, and the excavator also waited approximately 1.6% of the time.*

Step 3: develop the simulation model only for the delivery of earthmoving operation of sub-grade (without including the embankment of retaining and box culvert).

The same procedure followed with section 4.5.3, simulation modeling input data, and graphical representation is used to model the earthmoving operation process of the sub-grade work (i.e., the delivery of the selected (natural granular) material) except the embankment work of retaining wall and box culvert. Table 4.14 below shows the summary of the simulation model result of the selected material delivery used works except for the embankment work of the retaining wall and box culvert.

Table 4. 14: the earthmoving operation process of the sub-grade work (selected material delivery)

Summary Model Result Report (1000 Count) for The Delivery of Natural granular Material (without including the Embankment work)																		
No. of Truck	Production Rate								Idleness (Waiting)								Truck Inter arrival	Termination time (mean)
	Truck		Excavator		Dozer_D6R		Dozer_D8R		Truck		Excavator		Dozer_D6R		Dozer_D8R			
	TL/Minute	TP/m3/hrs.	EL/Minute	EP/m3/hrs.	D6L/Minute	D6P/m3/hrs.	D8L/Minute	D8P/m3/hrs.	length	TI %age	length	EI %age	length	D6I %age	length	D8I %age		
1	0.014	13.751	0.014	13.751	0.014	13.751	0.121	118.846	-	0.00%	0.928	92.80%	0.943	94.30%	0.888	88.80%	73.55	73,556.84
2	0.027	26.519	0.027	26.519	0.027	26.519	0.121	118.846	0.007	0.70%	0.858	85.80%	0.887	88.70%	0.776	77.60%	36.89	36,932.04
3	0.040	39.288	0.041	40.270	0.040	39.288	0.121	118.846	0.022	1.90%	0.784	78.40%	0.831	83.10%	0.665	66.50%	24.66	24,717.17
4	0.054	53.039	0.054	53.039	0.054	53.039	0.121	118.846	0.046	3.90%	0.714	71.40%	0.776	77.60%	0.556	55.60%	18.56	18,626.79
5	0.066	64.825	0.068	66.790	0.066	64.825	0.121	118.846	0.081	6.40%	0.650	65.00%	0.722	72.20%	0.448	44.80%	14.91	14,979.47
6	0.079	77.594	0.081	79.558	0.079	77.594	0.121	118.846	0.128	9.80%	0.576	57.60%	0.668	66.80%	0.341	34.10%	12.49	12,556.19
7	0.091	89.380	0.093	91.345	0.091	89.380	0.121	118.846	0.189	13.80%	0.508	50.80%	0.615	61.50%	0.236	23.60%	10.76	10,831.28
8	0.103	101.167	0.105	103.131	0.102	100.184	0.121	118.846	0.267	18.60%	0.442	44.20%	0.563	56.30%	0.134	13.40%	9.47	9,545.42
9	0.115	112.953	0.117	114.917	0.115	112.953	0.121	118.846	0.368	24.70%	0.377	37.70%	0.513	51.30%	0.033	3.30%	8.48	8,554.51
10	**0.118**	**115.900**	**0.120**	**117.864**	**0.117**	**114.917**	**0.121**	**118.846**	**1.161**	**76.60%**	**0.362**	**36.20%**	**0.500**	**50.00%**	**0.009**	**0.90%**	**8.27**	**8,346.48**
11	0.118	115.900	0.120	117.864	0.117	114.917	0.121	118.846	2.159	97.80%	0.362	36.20%	0.500	50.00%	0.009	0.90%	8.27	8,345.81
12	0.118	115.900	0.120	117.864	0.117	114.917	0.121	118.846	3.158	99.90%	0.362	36.20%	0.500	50.00%	0.009	0.90%	8.27	8,345.68
Legend	TP=Truck Prod. Rate		D8P=Dozer D8R Prod. Rate		D6P=Dozer_D6R Prod. Rate		EP=Excavator Prod. Rate		TI=Truck Idleness		D8I=Dozer D8R Idleness		D6I=Dozer D6R Idleness		EI=Excavator Idleness		TL=Truck Load	



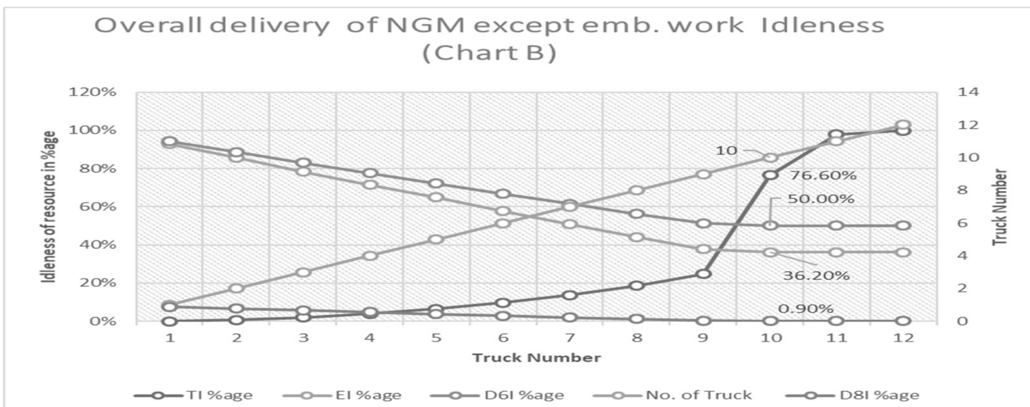


Figure 4. 15: The delivery of the selected material operation process (A. productivity rate and B. Idleness of the resource in %age) of subgrade work (Chart Form)

Table 4.14 and figure 4.15 show that; the optimum production rate of the system has been recorded on assigned truck number ten; a detail discussion presented here below:

- *Assigning ten trucks and the other remains the same: is resulting, the total time that it took to complete the total simulation run was 8,346.48min. or 139.108hrs. The production rate of the overall system was 0.118TL/min (truckload per min) or 115.90 M3/hr. The average interarrival time of the truck takes 8.273min between 10 trucks at the dumping station. Regarding the resource idleness in the simulation model, the trucks waited approximately 76.60% of the time, the dozer (D6R) waited approximately 50.00% of the time, the dozer (D8R) waited approximately 0.9% of the time, and the excavator also waited approximately 36.20% of the time.*

Step 4: Perform result comparison and discuss the comparison result in detail.

Based on the discussion in the above three steps, there are three models developed which are: overall, overall (but assign two dozers in the stockpiling), overall except embankment (i.e., excluding the earthmoving operation of embankment work of retaining wall and box culvert) of the selected (natural granular) material operation process simulation model and the result have been reported accordingly. These steps will present the comparison of those three model results at the point of the optimum production rate of the system recorded. The main objective of the comparison is to identify and recommend the best earthmoving operation model, which results in the optimum production rate of the system by evaluating and comparing the best combination of resources, less idleness of resources, and lower interarrival time of the trucks.

Table 4. 15: Production rate summary of overall, overall (except embankment work), and overall (but assign two dozers) of the earthmoving operation (in case selected material)

Simulation Model Type	Number of Resources				Production Rate of the System (M^3/hrs.)	Idleness of resources (%)				Termination time
	Truck	Excavator	Dozer (D6R)	Dozer (D8R)		Truck	Excavator	Dozer (D6R)	Dozer (D8R)	
Overall	10	1	1	1	115.90	68.60	36.20	50.10	0.90	8349.20
Overall	18	1	1	2	180.72	99.30	1.60	23.00	23.60	5413.25
Overall except embankment	10	1	1	1	115.90	76.60	36.20	50.00	0.90	8346.48

Nevertheless,

- The first simulation model confirms that the optimum production rate is recorded on assigned truck number 10, which is 115.90m^3/hrs. This indicates the minimum number of trucks required to deliver the 1000 truckloads (16,370 m^3) of selected (natural granular) material. The other factor that affects production is the idleness of the resources. In this case, the truck waited for 68.60% or utilized 31.40% of its time, and this result shows the truck is free more than two-thirds (2/3) of its time (i.e., more time spend on queue); the excavator waited for 36.20% or utilized 63.80% of its time, the dozer (D6R) of the spreading activity waited for 50.10% or utilized 49.90% of its time, and this result shows the dozer is spent half of its time without work (i.e., waiting for material to dump); the dozer (D8R) of the stockpiling activity waited for only 0.90% or utilized 99.10% of its time, and this indicates it spent almost all its time at stockpiling (preparing) the material.

- The second simulation model represents the same as the first step except the number of the dozers changed into two (i.e., earthmoving operation process which uses selected material): in this simulation model, the optimum production rate of the system is recorded on assigned truck number 18 which is 180.72 m^3 /hrs., and this indicates the minimum truck required to deliver 1000 truckload (16,370 m^3) selected material. The other factor that affects production is the idleness of the resources (utilization of the resources). In this case, the truck waited for 99.30% or utilized only 0.70% of its time. This indicates that the trucks are almost free, or only a few trucks are worked. The excavator waited for 1.60% or utilized 98.40% of its time. This shows that the excavator is spending almost all its time on serving the 18 trucks. The dozer (D6R) of spreading activity waited for 23% or utilized 77% of its time. The dozer (D8R) of stockpiling activity waited for 23.60% or utilized 76.40% of its time.
- The third simulation model represents overall the earthmoving operation, which uses selected material except for the embankment of the retaining wall and box culvert. In this simulation model, the optimum production rate of the system is recorded on assigned truck number 10, which is 115.90 m^3 /hrs., and this indicates the minimum truck required to deliver 1000 truckloads (16,370 m^3) selected material. The other factor that affects production is the idleness of the resources (utilization of the resources). In this case, the truck waited for 76.60% or utilized only 23.40% of its time. This indicates that the trucks are not utilized for about three-fourth of their time. The excavator waited for 36.20% or utilized 98.40% of its time. The dozer (D6R) of spreading activity waited for 50% or utilized 50% of its time. This shows that the dozer does not utilize half of its time. The dozer (D8R) of stockpiling activity waited for only 0.90% or utilized 99.10% of its time, and this indicates it spent almost all its time at stockpiling the materials.

Generally, the above discussion presents the three simulation models with a different type of works and resource combinations and their results. In the case of resource combination, the overall earthmoving operation uses selected material by assign a different number of dozers (D8R) of the stockpiling activity. The result indicates that as the number of the dozer is increased from 1 to 2 (doubled), it increases the truck number from 10 to 18, and other resources remain the same, the optimum production increase from 115.90 to 180.72m^3/hrs. Even if the optimum production is increased as the increase in the number of trucks and dozer, it increases the idleness of the trucks (the truck doesn't work almost all of their time, or only a few trucks are served). This may result in inefficient and ineffective use of resources (trucks) and may increase the cost of the project. In case of the types of work (with or without including the earthmoving operation of embankment work of retaining wall and box culvert), the operation (delivery of selected material) archives the optimum production rate both with truck number 10. But the truck is idler in the overall earthmoving operation without including the embankment work of retaining wall and box culvert than the overall earthmoving operation, including the embankment work. This idleness may create due to the truck spent more time in spotting for the dump at the embankment area (retaining wall and box culvert) than the roadway (subgrade) area because of space.

4.5.2.2. Sensitivity analysis (output result comparison) for the overall operation process of the crushed unbounded (Sub-base/base-coarse) material:

comparison and discussion of the overall data observed from crushed unbounded materials operations of the earthmoving operation simulation model. These works are sub-base and base-coarse of the asphalt work of the sample project. The experiment in this section presents the operation process of crushed unbounded (sub-base and base-coarse) material and compares the simulation result from the different types (loader and excavator) and the number of loading equipment (assign number of the loader). This helps planners or project managers to choose the type of loading and number of loading equipment during planning and construction to maximize the production of their project.

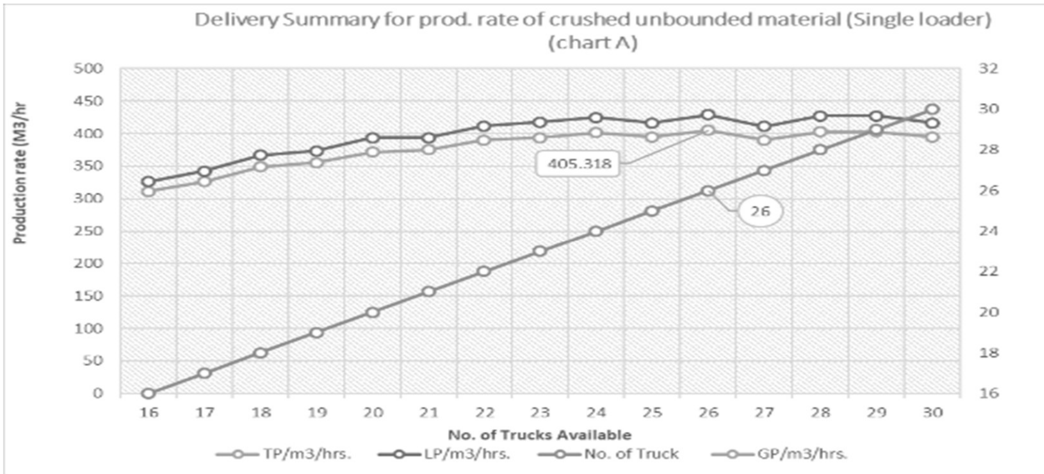
Accordingly, three different models have been developed and experimented with it. The models are the overall model for the earthmoving operation of sub-base and base-coarse works using a single loader as loading equipment, two loaders, and using both excavator and loader as loading equipment at a time. The main objective of the experiment is and comparing their result is to achieve the maximum production rate of the system and choose the best combination of the resources. The process starts by assigning the number of trucks from 16-31, and selection criteria for the best result are through minimum truck interarrival time, lowest idleness of resources, and resulting optimum production rate of the system. The following important procedures have been defined and examined step by step:

Step 1: the overall model for the earthmoving operation of sub-base and base-coarse works (assign single loader as loading equipment), report simulation model result in tabulated form, and discuss the result.

As discussed in section 4.5.4, similar simulation modeling input data and graphical simulation models are used to model the overall delivery of crushed unbounded material (i.e., the earthmoving operation process of the sub-base and base-coarse works). The model described and shown in figure 4.9. Table 4.16 and figure 4.16 below show the summary of the simulation model result from the overall earthmoving operation of sub-base and base-coarse work (crushed unbounded material delivery operation).

Table 4. 16: the earthmoving operation process of the sub-base and base-coarse work (crushed unbounded material delivery)

Overall Delivery Summary Report (1000 Count) for Cruched Unbounded Material (Loading Equip. = Loader)														
No. of Truck	Production Rate						Idleness (Waiting)						Truck Inter arrival	Termination time (mean)
	Truck (16-30)		Loader (1)		Grader (1)		Truck		Loader		Grader			
	TL/Minute	TP/m3/hrs.	LL/Minute	LP/m3/hrs.	GL/Minute	GP/m3/hrs.	length	TI %age	length	LI %age	length	GI %age		
16	0.330	311.058	0.346	326.140	0.330	311.058	0.763	41.30%	0.240	24.00%	0.743	74.30%	2.920	2,960.20
17	0.346	326.140	0.363	342.164	0.346	326.140	0.915	47.50%	0.200	20.00%	0.730	73.00%	2.772	2,813.18
18	0.370	348.762	0.389	366.671	0.369	347.819	1.098	54.40%	0.162	16.20%	0.717	71.70%	2.646	2,686.55
19	0.377	355.360	0.396	373.270	0.376	354.418	1.320	61.80%	0.128	12.80%	0.705	70.50%	2.538	2,579.17
20	0.394	371.384	0.418	394.007	0.394	371.384	1.603	69.70%	0.097	9.70%	0.695	69.50%	2.449	2,490.41
21	0.398	375.155	0.418	394.007	0.397	374.212	1.976	77.90%	0.070	7.00%	0.686	68.60%	2.379	2,420.40
22	0.414	390.236	0.437	411.916	0.413	389.294	2.452	85.10%	0.050	5.00%	0.679	67.90%	2.326	236.70
23	0.418	394.007	0.443	417.572	0.417	393.064	3.084	91.40%	0.036	3.60%	0.674	67.40%	2.292	2,333.54
24	0.426	401.548	0.451	425.113	0.425	400.605	3.817	95.30%	0.028	2.80%	0.671	67.10%	2.271	2,312.94
25	0.419	394.949	0.442	416.629	0.419	394.949	4.706	97.90%	0.023	2.30%	0.670	67.00%	2.263	2,304.33
26	0.430	405.318	0.455	428.883	0.429	404.375	5.612	99.00%	0.022	2.20%	0.669	66.90%	2.257	2,298.54
27	0.414	390.236	0.436	410.974	0.414	390.236	6.551	99.50%	0.021	2.10%	0.669	66.90%	2.255	2,296.14
28	0.427	402.490	0.453	426.998	0.427	402.490	7.540	99.80%	0.020	2.00%	0.669	66.90%	2.255	2,296.02
29	0.427	402.490	0.453	426.998	0.427	402.490	8.518	99.90%	0.002	0.20%	0.669	66.90%	2.253	2,294.19
30	0.419	394.949	0.442	416.629	0.418	394.007	9.537	100.00%	0.002	0.20%	0.669	66.90%	2.255	2,296.38
Legend	TL= Truck Load		GL= Grader Prod.		LL=Loader Prod. Rate		TI=Truck Idleness		GI= Grader Idleness		LoaderI=Loader Idleness		TL=Truck Load	
	TP=Truck Prod. Rate		GP= Grader Prod. Rate		LP=Loader Prod. Rate									



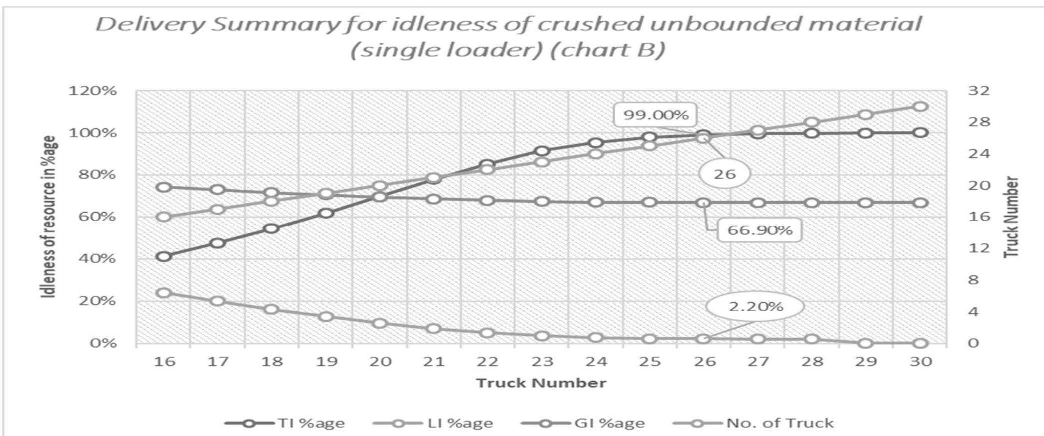


Figure 4. 16: The overall delivery of the crushed unbounded material (A. productivity rate and B. Idleness of the resource in %age) using the single loader (Chart Form)

Table 4.16 and figure 4.16 show that; the optimum production rate of the system has been recorded on assigned truck number 26; a detail discussion presented here below:

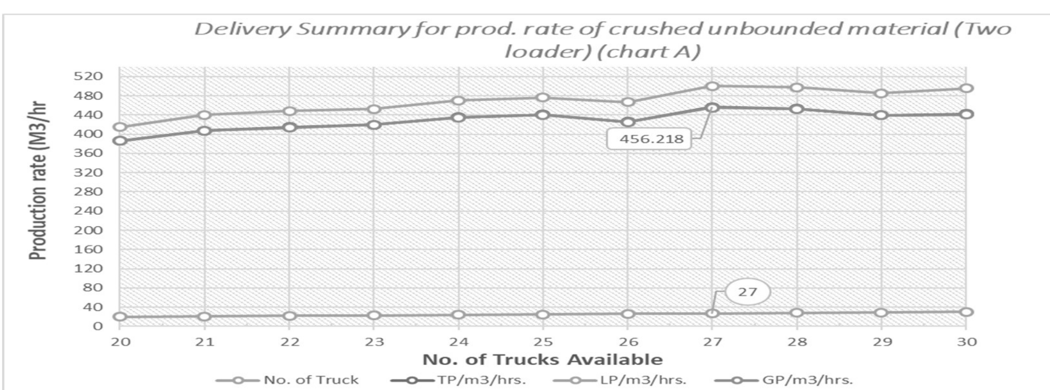
- *Assigning 26 trucks and the other remains the same: is resulting, the total time that it took to complete the total simulation run was 2,298.54min. or 38.309hrs. The production rate of the overall system was 0.430TL/min (truckload per min) or 405.32M3/hr. The average interarrival time of the truck takes 2.257min between 26 trucks at the dumping station. Regarding the resource idleness in the simulation model, the trucks waited approximately 99% of the time, the grader waited approximately 66.90% of the time, and the Loader also waited approximately 2.20% of the time.*

Step 2: the overall model for the earthmoving operation of sub-base and base-coarse works (assign two loaders as loading equipment), report simulation model result in tabulated form, and discuss the result.

The same procedure as step 1 above except the increasing the number of loaders into two at the quarry site (loading activity). Table 4.17 and figure 4.17 below show the summary of the simulation model result of the overall earthmoving operation of sub-base and base-coarse work (crushed unbounded material delivery operation) and using two loaders at the loading station.

Table 4. 17: the earthmoving operation process of the sub-base and base-coarse work (crushed unbounded material delivery)

Overall Delivery Summary Report (1000 Count) for Cruched Unbounded Material (Loading Equip. = Loader)														
No. of Truck	Production Rate						Idleness (Waiting)						Truck Cycle time (Inter	Termination time (mean)
	Truck (20-30)		Loader (2)		Grader (1)		Truck		Loader		Grader			
	TL/Minute	TP/m3/hrs.	LL/Minute	LP/m3/hrs.	GL/Minute	GP/m3/hrs.	length	TI %age	length	LI %age	length	GI %age		
20	0.410	386.466	0.440	414.744	0.410	386.466	0.352	9.00%	1.051	72.40%	0.680	68.00%	2.33	2,371.99
21	0.432	407.203	0.467	440.194	0.432	407.203	0.393	9.90%	1.016	70.50%	0.667	66.70%	2.24	2,284.24
22	0.440	414.744	0.476	448.678	0.439	413.801	0.437	10.80%	0.983	68.80%	0.656	65.60%	2.17	2,211.33
23	0.445	419.457	0.480	452.448	0.445	419.457	0.480	11.60%	0.955	67.20%	0.647	64.70%	2.11	2,153.24
24	0.462	435.481	0.499	470.357	0.461	434.539	0.521	12.30%	0.933	66.00%	0.640	64.00%	2.07	2,110.11
25	0.468	441.137	0.505	476.013	0.467	440.194	0.566	12.90%	0.919	65.20%	0.635	63.50%	2.04	2,082.86
26	0.452	426.055	0.495	466.587	0.451	425.113	0.608	13.20%	0.913	64.80%	0.633	63.30%	2.03	2,068.52
27	0.484	456.218	0.531	500.521	0.483	455.276	0.649	13.50%	0.910	64.60%	0.632	63.20%	2.03	2,065.11
28	0.481	453.391	0.528	497.693	0.480	452.448	0.691	13.60%	0.909	64.60%	0.632	63.20%	2.02	2,063.02
29	0.466	439.252	0.515	485.439	0.466	439.252	0.733	13.80%	0.909	64.50%	0.632	63.20%	2.02	2,063.25
30	0.469	442.079	0.526	495.808	0.468	441.137	0.778	13.90%	0.909	64.50%	0.632	63.20%	2.02	2,062.09
Legend	TL= Truck Load		GL= Grader Prod.		LL=Loader Prod. Rate		TI=Truck Idleness		GI= Grader Idleness		LoaderI=Loader Idleness		TL=Truck Load	
	TP=Truck Prod. Rate		GP= Grader Prod. Rate		LP=Loader Prod. Rate									



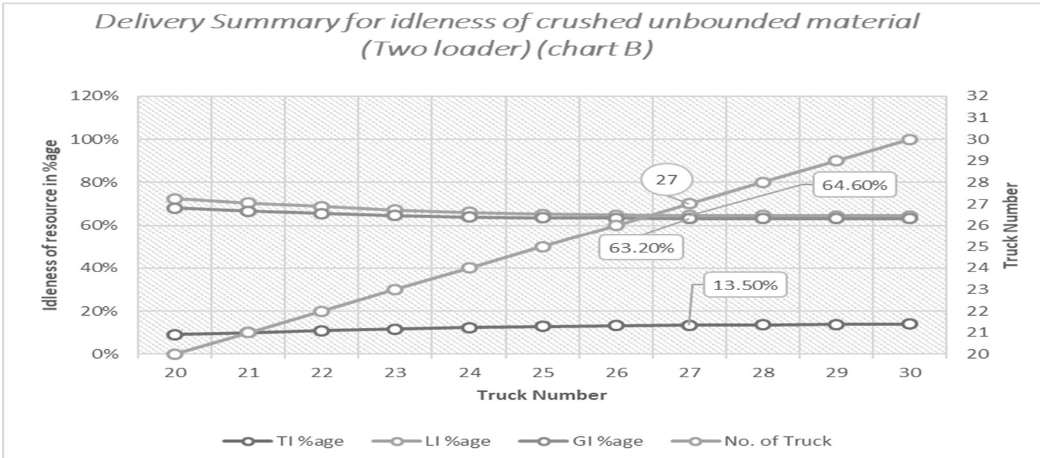


Figure 4. 17: The overall delivery of the crushed unbounded material (A. productivity rate B. Idleness of resource in %age) using two loaders (Chart Form)

Table 4.17 and figure 4.17 show that; the optimum production rate of the system has been recorded on assigned truck number 27; a detail discussion presented here below:

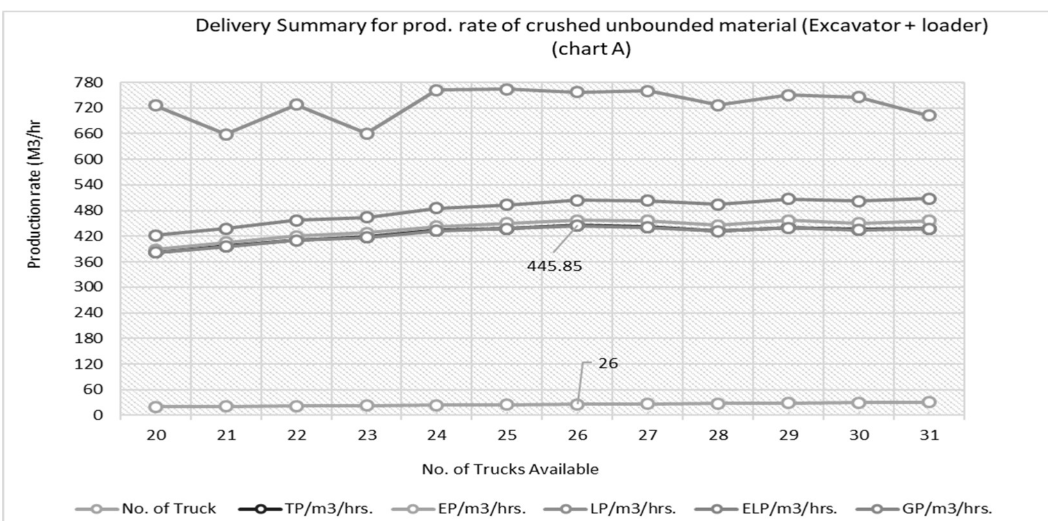
- *Assigning 27 trucks, two loaders, and the other remains the same: is resulting, the total time that it took to complete the total simulation run was 2,065.11min. or 34.419hrs. The production rate of the overall system was 0.484TL/min (truckload per min) or 456.218M3/hr. The average interarrival time of the truck takes 2.025min between 27 trucks at the dumping station. Regarding the resource idleness in the simulation model, the trucks waited approximately 13.50% of the time, the grader waited approximately 63.20% of the time, and the Loader also waited approximately 64.60% of the time.*

Step 3: the overall model for the earthmoving operation of sub-base and base-coarse works (assign excavator and loader as loading equipment), report simulation model result in tabulated form and discuss the result.

The same procedure as step 1 above except the using excavator and loader as loading equipment at a time. Table 4.18 and figure 4.18 below show the summary of the simulation model result of the overall earthmoving operation of sub-base and base-coarse work (crushed unbounded material delivery operation) and using excavator and loader at a time at the loading station.

Table 4. 18: the earthmoving operation process of the sub-base and base-coarse work (crushed unbounded material delivery)

Overall Delivery Summary Report (1000 Count) for Cruched Unbounded Material (Loading Equip. = Loader +Excavator)																				
	Production Rate										Idleness (Waiting)								Truck	
No. of	Truck (20-31))		Excavator (1)		Loader (1)		Excavator +Loader		Grader (1)		Truck		Excavator		Loader (1)		Grader (1)		Inter	Termination
Truck	TL/Minute	TP/m3/hrs.	EL/Minute	EP/m3/hrs.	LL/Minute	LP/m3/hrs.	ELL/Minute	ELP/m3/hrs.	GL/Minute	GP/m3/hrs.	length	TI %age	length	EI %age	length	LI %age	length	GI %age	arrival	time (mean)
20	0.405	381.75	0.413	389.29	0.770	725.80	0.448	422.28	0.405	381.75	0.235	2.20%	9.755	99.70%	501.593	99.70%	0.683	68.30%	2.356	2,396.26
21	0.421	396.83	0.430	405.32	0.699	658.88	0.465	438.31	0.420	395.89	0.258	2.30%	9.705	99.70%	501.985	99.70%	0.670	67.00%	2.265	2,305.20
22	0.437	411.92	0.446	420.40	0.772	727.69	0.485	457.16	0.436	410.97	0.284	2.40%	10.658	99.00%	501.484	99.60%	0.659	65.90%	2.188	2,227.98
23	0.444	418.51	0.454	427.94	0.701	660.76	0.492	463.76	0.443	417.57	0.311	2.60%	10.620	99.60%	501.995	99.60%	0.649	64.90%	2.126	2,166.42
24	0.460	433.60	0.470	443.02	0.808	761.62	0.515	485.44	0.459	432.65	0.337	2.70%	11.585	99.60%	501.805	99.60%	0.641	64.10%	2.079	2,119.18
25	0.465	438.31	0.478	450.56	0.810	763.51	0.524	493.92	0.464	437.37	0.366	2.80%	11.564	99.60%	502.222	99.60%	0.636	63.60%	2.048	2,088.17
26	**0.473**	**445.85**	**0.485**	**457.16**	**0.803**	**756.91**	**0.535**	**504.29**	**0.472**	**444.91**	**0.396**	**2.90%**	**502.141**	**99.60%**	**12.548**	**99.60%**	**0.633**	**63.30%**	**2.030**	**2,070.54**
27	0.469	442.08	0.484	456.22	0.806	759.74	0.534	503.35	0.468	441.14	0.424	3.00%	503.086	99.60%	12.545	99.60%	0.632	63.20%	2.025	2,065.53
28	0.459	432.65	0.473	445.85	0.771	726.74	0.525	494.87	0.458	431.71	0.457	3.10%	503.203	99.60%	13.540	99.60%	0.632	63.20%	2.022	2,063.03
29	0.468	441.14	0.485	457.16	0.796	750.31	0.538	507.12	0.467	440.19	0.488	3.20%	503.908	99.60%	13.539	99.60%	0.631	63.10%	2.022	2,062.68
30	0.462	435.48	0.478	450.56	0.791	745.60	0.533	502.41	0.461	434.54	0.518	3.30%	503.806	99.60%	14.535	99.60%	0.632	63.20%	2.023	2,063.15
31	0.465	438.31	0.484	456.22	0.745	702.24	0.539	508.06	0.464	437.37	0.555	3.40%	504.809	99.60%	14.535	99.60%	0.632	63.20%	2.021	2,062.07
Legend	TP=Truck Prod. Rate		LP=Loader Prod. Rate		GP= Grader Prod. Rate		ELP=Excavator +Loader Prod. Rate		EP=Excavator Prod. Rate		TI=Truck Idleness		LI = Loader Idleness		GI = Grader Idleness		EI=Excavator Idleness		TL=Truck Load	



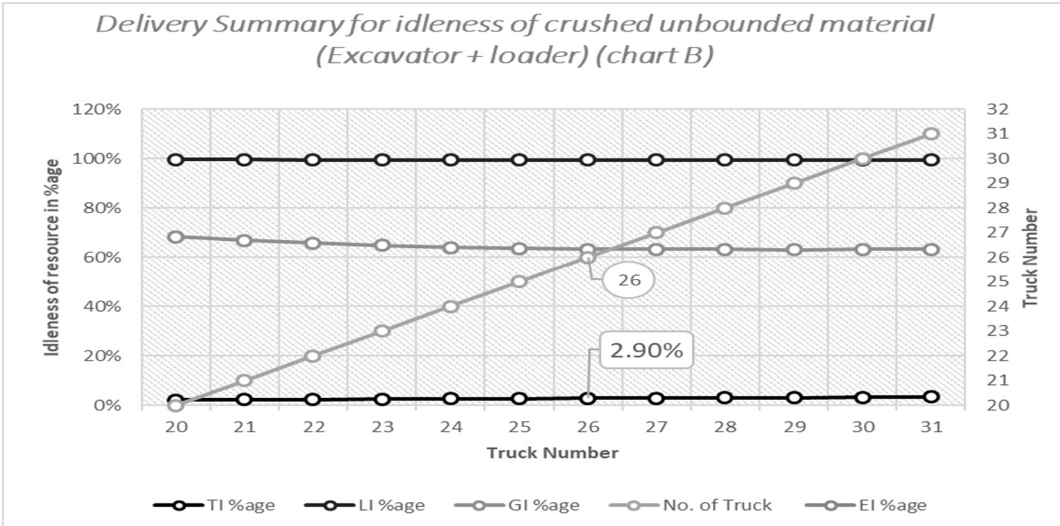


Figure 4. 18: The overall delivery of the crushed unbounded material (A. production rate B. Idleness of equipment in %age) (using Excavator + loader) (Chart Form)

Table 4.18 and figure 4.18 show that; the optimum production rate of the system has been recorded on assigned truck number 26; a detail discussion presented here below:

- *Assigning 26 trucks, two loaders, and the other remains the same: is resulting, the total time that it took to complete the total simulation run was 2,070.54min. or 34.509hrs. The production rate of the overall system was 0.473TL/min (truckload per min) or 445.85M3/hr. The average interarrival time of the truck takes 2.030min between 26 trucks at the dumping station. Regarding the resource idleness in the simulation model, the trucks waited approximately 2.90% of the time, the excavator waited 99.60% of its time, the Loader also waited approximately 99.60% of the time, and the grader waited approximately 63.30% of the time.*

Step 4: Perform result comparison and discuss the comparison result in detail.

Based on the discussion in the above three steps, there are three models developed which are: overall, overall (but assign two loaders in the loading station), overall (but assign excavator and loaders in the loading station) of earthmoving operation of sub-base and base-coarse work simulation model and the result have been reported accordingly. These steps will present the comparison of those three model results at the point of the optimum production rate of the system recorded. The main objective of the comparison is to identify and recommend the best earthmoving operation model, which results in the optimum production rate of the system by evaluating and comparing the best combination of resources, less idleness of resources, and lower interarrival time of the trucks.

Table 4. 19: Production rate for the operation process of crushed unbounded material

Simulation model Type	No. of Resources				Production Rate	Idleness of resources (%)				Termination time (mean)
	Truck	Excavator	Loader	Grader		Truck	Excavator	Loader	Grader	
OVERALL	26	-	1	1	405.318	99.00%	-	2.20%	66.90%	2,298.54
OVERALL (Two Loaders)	27	-	2	1	456.218	13.50%	-	64.60%	63.20%	2,065.11
OVERALL (Excavator and Loader)	26	-	1	1	445.85	2.90%	99.60%	99.60%	63.30%	2,070.54

However,

- The first simulation model confirms that the optimum production rate is recorded on assigned truck number 26, which is 405.318m^3/hrs., this indicates the minimum number of trucks required to deliver the 1000 truckloads (15,710 m^3) of crushed unbounded (sub-base and base-coarse) material. The other factor that affects production is the idleness of the resources. In this case, the truck waited for 99.00% or utilized 1.00% of its time, and this result shows the truck is free almost all of its time or only a few trucks are active at work; the loader waited for 2.20% or utilized 97.80% of its time, and this indicates that the loader used almost all its time to serve the trucks, the grader waited for 66.90% or utilized 33.10% of its time, and this result shows the grader is spent three-fourth of its time without work.
- The second simulation model represents the same as the first step except for the number of the loaders changed into two (i.e., earthmoving operation process which uses crushed unbounded or sub-base and base-coarse material): in this simulation model, the optimum production rate of the system is recorded on assigned truck number 27 which is 456.218m^3 /hrs, and this indicates the minimum truck required to deliver 1000 truckload (15710 m^3) crushed unbounded (sub-base and base-coarse) material. The other factor that affects production is the idleness of the resources (utilization of the resources). In this case, the

truck waited for 13.50% or utilized only 86.50% of its time. This indicates that the trucks spend most of their time at work. The loader waited for 64.60% or utilized 35.40% of its time. This shows that the loader spends nearly three-fourth of its time without work. The grader waited for 63.20% or utilized 36.80% of its time.

- The third simulation model represents the same as the first step except using excavator and loader at loading station at a time (i.e., earthmoving operation process which uses crushed unbounded or sub-base and base-coarse material). In this simulation model, the optimum production rate of the system is recorded on assigned truck number 26, which is 445.85m^3 /hrs, and this indicates the minimum truck required to deliver 1000 truckload (15710m^3) crushed unbounded (sub-base and base-coarse) material. The other factor that affects production is the idleness of the resources (utilization of the resources). In this case, the truck waited for 2.90% or utilized 97.10% of its time. This indicates that the trucks are utilized fully to deliver the material. The excavator and loader waited for 99.60% or utilized 0.40% of their time. This indicates the excavator and loader are spent almost all of their time waiting to serve the 26 trucks. The grader waited for 63.30% or utilized 36.70% of its time.

Generally, the above discussion presents the three simulation models with a different type of resource combinations and their results. In the case of resource combination, the overall earthmoving operation which uses crushed unbounded (sub-base and base-coarse) material by assign different number of loaders or both loader and excavator at a time of the loading activity. The result indicates that as the number of loaders is increased from 1 to 2 (doubled), it increases the truck number from 26 to 27, and other resources remain the same, the optimum production increase from 405.318 to 456.218m3/hrs. This result shows that as the number of loaders increases from 1 to 2, the optimum production rate increases significantly without changing the other resources. Even if this increases the idleness of the loader (2.20% to 64.60%), it decreases the idleness of the trucks significantly (99% to 13.50%). Therefore, increasing only the number of loaders makes us economical because it increases the optimum productivity of the system and efficiency of trucks (i.e., when the efficiency of the truck increases, it increases the optimum production rate of the system). In the case of using different types of loading equipment (excavator and loader) at a time, the operation (delivery and construction of sub-base and base-coarse materials) archives the optimum production rate with truck number 26. in this model, the trucks utilized their time fully to deliver the crushed unbounded material, but the excavator and loader are spent almost all their time without working. Since this model is less in optimum production rate and more in truck utilization than the second, its trade-off their difference, therefore, it needs further investigation to choose the best combination (i.e., two loaders or single loader and single excavator) for example, the rental cost of the equipment and idleness of the loading equipment.

4.6. Research Finding

The main objective of this thesis research was to analyze and develop an effective improvement strategy of earthmoving operation using discrete-event simulation in Addis Ababa city. The additional specific objective was set to analyze the existing practice of earthmoving operation; to study each component of the earthmoving operations; to study application and state-of-the-art of the simulation in the construction industry; to develop an effective earthmoving operation simulation model which represent the real-world operation; and the model that could be used to experiment different operation scenario to optimize production rate, time and resource of the operation system, Furthermore, the research was focus on modeling earthmoving operation which represents real-world operation, and finally the developed operation model result was examined and compared to different operating model scenarios. Thus, in this regard, the research result has found the following major findings.

I. The literature review section approved, an earthmoving operation commonly encountered in heavy and represent a sizable portion of infrastructure construction projects, such as dams, highways, and buildings with deep basements, frequently represent the sizable scope of work. Simulation is the imitation of a real-world operation over time, and it is one of the most powerful techniques and tools for supporting the managers and decision-makers. The simulation approach may be used to study almost any problem, and it is applicable in different industries such as manufacturing, construction, military, logistic, supply, transportation, and business process. Consequently, construction simulation is a very powerful, popular, and widely used engineering management tool, and the result of the simulation is greatly assisting the designers, the managers, and the decision-makers by allowing them to experiment with different construction technologies, alternatives, and optimization of the involved resources appropriate for the analysis of earthmoving operations because of its repetition of given operations, dynamics of resource interactions, external factors that need to be included in the analysis and the randomness associated with such systems. Accordingly, discrete-event simulation is the only earthwork analysis method that can explicitly incorporate the detailed but significant aspects of an operation. Generally, the application of simulation in construction operations has been identified as the main reason to use simulation during project identification and planning, to identifying bottlenecks in operations, to examining productivity improvements and optimizing resource utilization and quick comparison of alternative construction scenarios.

II. Computer simulation is a proven, powerful, and widely used technique and tools for decision-making and planning purposes to the construction industry by representing the real-world operation process. Accordingly, simulation software called "Simphony CYCLONE" has been used to analyze and develop an effective and efficient earthmoving operation. As a result, different earthmoving operation process models have been developed with defined scenarios and parameters to experiment, evaluate, and select the best model result. Most of the experimented models confirm to express which resource in the system highly valuable and requires optimization, which type of earthmoving operation activity and resource combination is advanced to achieve a higher production rate with the minimum number of resources and which type of material is suitable to achieve higher production rate. However, the developed model result and their finding discussed as the following:

1) OVERALL simulation model, this represents an earthmoving operation that uses selected (natural granular) material (i.e., sub-grade and embankment of retaining wall and box culvert works) without considering their type. Under the OVERALL model additional two earthmoving operation models (the model that excludes the embankment work and uses two Dozers in the stockpiling activity) were developed and examined to experiment with the operation process effect on production rate and resource utilization.

Table 4. 20: Overall model (operation of selected material) result from conclusion

Model	No. of Truck	Production Rate	Idleness of resources (%)				Truck Interarrival	Termination time (mean)
			Truck	Excavator	Dozer_D6R	Dozer_D8R		
OVERALL	10	115.90	68.60%	36.20%	50.10%	0.90%	8.27	8,349.20
OVERALL (Two Dozer (D8R))	18	180.72	99.30%	1.60%	23.00%	23.60%	5.335	5,413.25
OVERALL (Except Embankment work)	10	115.90	76.60%	36.20%	50.00%	0.90%	8.27	8,346.48

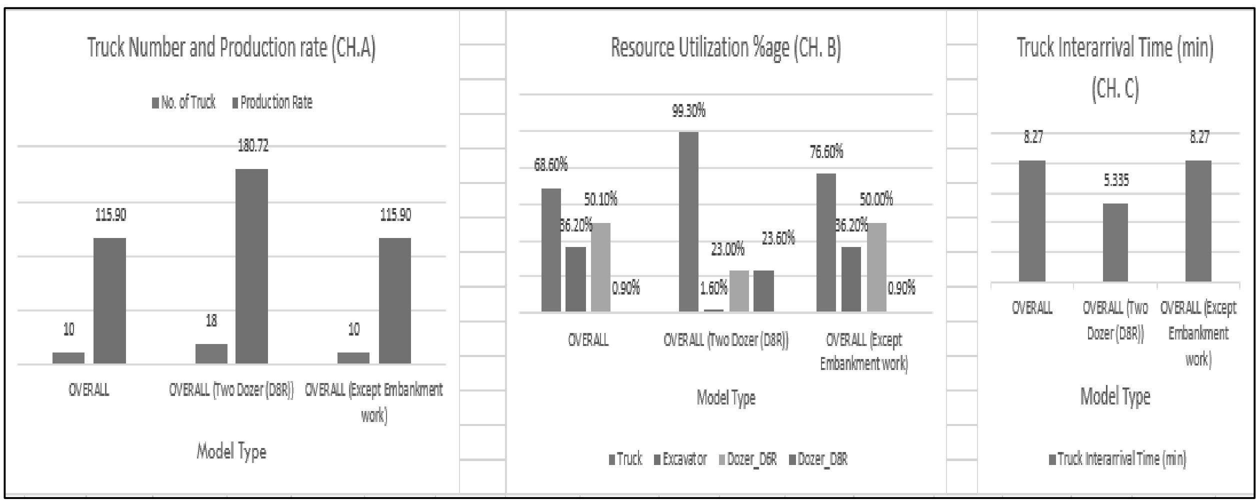


Figure 4. 19: Overall model (operation of selected material) result conclusion (Chart Form)

1.1) The Overall simulation model of the earthmoving operation of works that use selected (natural granular) material takes to finish the operation about 8,349.20min having ten trucks with an optimum production rate of 115.90m^3/hr., regarding the resource utilization the model trucks 31.40%, excavator 63.80%, dozer (spreading activity) 49.90%, and dozer (stockpiling activity) 99.10% of their time utilized. The interarrival truck time is 8.273min between 10 trucks.

1.2) The Overall (using two Dozers in the stockpiling activity) simulation model of the earthmoving operation of works that use selected (natural granular) material takes to finish the operation about 5413.25min having 18 trucks with an optimum production rate of 180.72m^3/hr., regarding the resource utilization the model trucks

0.70%%, excavator 98.40%, dozer (spreading activity) 77.00%, and dozer (stockpiling activity) 76.40% of their time utilized. The interarrival truck time is 5.335min between 18 trucks.

1.3) The Overall simulation model of the earthmoving operation of works that use selected (natural granular) material except for the embankment of retaining wall and box culvert works takes to finish the operation about 8346.48min having ten trucks with an optimum production rate of 115.90m3/hr., regarding the resource utilization the model trucks 23.40%%, excavator 63.80%, dozer (spreading activity) 50.00%, and dozer (stockpiling activity) 99.10% of their time utilized. The interarrival truck time is 8.273min between 10 trucks.

Generally, the overall simulation model result comparison finds that:

- When the overall model re-simulates by optimizing the number of dozer from 1 to 2 and assign the number of trucks from 5-19, the optimum production rate increases from 115.90 to 180.72m^3/hr., and the truck utilization down to below 1% (0.70%). In addition to the truck, the dozer utilization also decreases from almost full of its time to 76.40%. Since the production rate of the system depends on the utilization of the truck, it not recommended to optimize the number of dozers at the stockpiling from 1 to 2.
- There is no change in the optimum production rate between the overall and overall (excluding embankment work), and also no significant difference in terms of resource utilization. Therefore, the optimum production rate of this model is not significantly changing due to the different types of works that use selected material (during the operation of selected material).

2) OVERALL simulation model, this represents an earthmoving operation that uses crushed unbounded material (i.e., sub-base and base-coarse works) without considering the resource number and combination. Under the OVERALL model additional two earthmoving operation models (use two loaders or Excavator and loader at a time in the loading station) were developed and examined to experiment with the operation process effect on production rate and resource utilization.

Table 4. 21: Overall model (operation of Crushed material) result from conclusion

Model	No. of Truck	Production Rate	Idleness of resources (%)				Truck Interarrival Time (min)	Termination time (mean)
			Truck	Excavator	Loader	Grader		
OVERALL	**26**	**405.32**	**99.00%**	**-**	**2.20%**	**66.90%**	**2.26**	**2,298.54**
OVERALL (Two Loaders)	**27**	**456.22**	**13.50%**	**-**	**64.60%**	**63.20%**	**2.025**	**2,065.11**
OVERALL (Excavator and Loader)	**26**	**445.85**	**2.90%**	**99.60%**	**99.60%**	**63.30%**	**2.03**	**2,070.54**

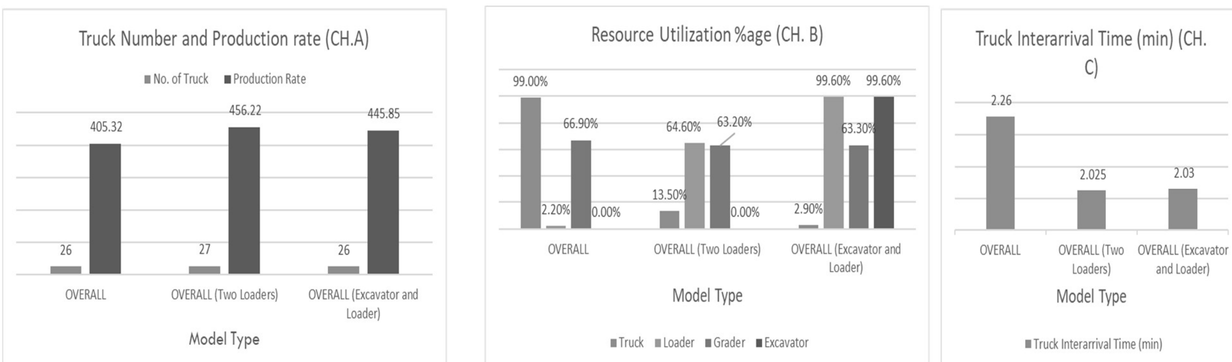


Figure 4. 20: Overall model (operation of crushed unbounded material) result conclusion (Chart Form)

2.1) The Overall simulation model of the earthmoving operation of works that use crushed unbounded (sub-base and base-coarse) material takes to finish the – operation about 2,298.54min having 26 trucks with the optimum production rate of 405.318m3/hr., regarding the resource utilization the model trucks 1.00%, loader 97.80%, and grader 33.10% of their time utilized. The interarrival truck time is 2.257min between 26 trucks.

2.2) The Overall (using two loaders at the loading station) simulation model of the earthmoving operation of works that use crushed unbounded (sub-base and base-coarse) material takes to finish the operation about 2065.11min having 27 trucks with the optimum production rate of 456.218m^3/hr., regarding the resource utilization the model trucks 86.50%%, loader 35.40%, and grader 36.80% of their time utilized. The interarrival truck time is 2.025min between 27 trucks.

2.3) The Overall simulation model of the earthmoving operations that use selected (natural granular) material except for data observed from the embankment work of retaining wall and box culvert takes to finish the operation about 2,070.54min having 26 trucks with an optimum production rate of 445.85m^3/hr., regarding the resource utilization the model trucks 97.10%%, excavator 0.40%, loader 0.40%, and grader 36.70% of their time utilized. The interarrival truck time is 2.030min between 26 trucks.

Generally, the overall simulation model result comparison finds that:

- When the overall model re-simulates by optimizing the number of the loading equipment (loader) from 1 to 2 and assign the number of trucks to remain almost the same, the optimum production rate increases from 405.32 to 456.22m^3/hr, and truck utilization increases significantly from 1.00% to 86.50% of their time. Therefore, optimizing a number of the loader from 1 to 2 increases both optimum production rate and utilization of the trucks by adding only one truck.
- In the case of using excavator and loader at the loading station, the optimum production rate more than using a single loader, but less than using two loaders. The utilization of the trucks is increased to almost fully utilized better than both cases (using single and double loader), but it decreases the utilization of the loader to almost zero utilization (i.e., the excavator and loader are utilized 0.40% of their time) and this may cause to increase the operation cost. Therefore, it is better to use the double loader instead of a single loader or both excavator and loader at a time.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1. Conclusion

In the previous chapter, the results attained from analysis of developing and comparing the result of different models being discussed, and based on the findings from the same. The following major conclusions have been summarized:

I. Studying, modeling, and analyzing earthmoving operation using discrete-event simulation based on the existing earthmoving operation process allows us to identify and analyze three important things. These are; 1) components of the earthmoving operation process (stockpiling →waiting to load → loading → traveling → waiting to dump, and dumping → returning), 2) practice the experience of the earthmoving operation process, and 3) the problem of the earthmoving operation process (traffic jam, type of route, delivery of unsuitable material, and weak equipment management) of the project. Assigning extra or low number of trucks, weather conditions, equipment failure, etc.

II. The simulation approach may be used to analyze almost any problem, and it is applicable in different industries such as manufacturing, construction, military, logistic, supply, and transportation. Consequently, construction simulation is a very powerful, popular, and widely used engineering management tool, and the result of the simulation is greatly assisting the designers, managers, and decision-makers easily to experiment with different construction technologies, alternatives, and optimization of resources.

III. Generally, different earthmoving operation process simulation models were developed and experienced. Accordingly, the developed model is efficient, effective, and flexible to identify bottlenecks entities in earthmoving operations, to examining the production rate improvements and optimizing resource utilization and combination, and the comparison of alternative earthmoving operation process scenarios.

IV. Four earthmoving operation simulation models were developed and analyzed to identify the effect of work type (with or without the embankment work) and type loading equipment used (single loader or loader + excavator at a time) on production rate and utilization of the fleets. Accordingly, in case of types of work, the overall earthmoving operation process of works that use selected (natural granular) materials (both with and without including the embankment of retaining wall and box culvert works) simulation model requires ten (10) trucks to produce 115.90m3/hrs. this result shows that the changing in dumping area (i.e., only dumping time doesn't affect the whole production rate of the system) don't change in the production rate of the system (earthmoving operation process). In case of the type of loading equipment in the crushed unbounded material (sub-base and base-coarse works) of the earthmoving operation process model, it requires twenty-seven (27) trucks to produce 456.22m3/hrs.

V. Besides, sensitivity analysis (comparison) was done on the earthmoving operation process of works that use selected (natural granular) material by assigning a different number of stockpiling equipment to check and examine whether production rate of the system affects by the material production rate or not and to optimize the production rate and the number of fleets in the system. Accordingly, even if assigning two dozers in the stockpiling (material production) is more productive than using a single dozer with a difference of $64.82m^3$/hrs., it requires additional assigning 8 number of trucks and decreases the utilization of the trucks from 31.40% to 0.70% of the trucks time. This result shows that assigning single excavator and ten trucks are the more efficient and effective combination of fleets (resources).

VI. In line with the above, sensitivity analysis (comparison) was also done for the earthmoving operation process of works that use crushed unbounded (sub-base and base-coarse) material by assigning a single loader, two loaders, and loader and excavator at a time in the loading activity. Accordingly, assigning two loaders at the loading station is more productive and effective than a single loader or loader and excavator with a production rate of $456.22m^3$/hrs., and this is $50.90m^3$/hrs more than assigning a single loader and 10.40 m^3/hrs more than assigning loader and excavator at a time. It is also better in the utilization of over the resources than the other two options.

5.2. Recommendation

Construction operation, in general, earthmoving operation in particular, deals with complex and difficulty, especially in its implementation. Due to it provides the number of heavy equipment and huge capital and manpower, it needs the best planning and implementation techniques with highly experienced professionals for its operation process. The planner can develop models with advancements in computer software to minimize the risk that happens during the implementation and simplify decision making. Simulation is one of the powerful techniques for supporting the decision-making process in construction management. In this regard, this research recommends the following specific actions to be undertaken.

I. The literature review shows that construction simulation is an effective tool for planning and improving the performance of construction operations at the research level and accepted at a practical level, especially in developed countries. However, the practice in Ethiopian in research as well as in practical level using construction simulation software doesn't practice yet. This implies more research needs to be conducted and introduce it to the construction industry as a planning and performance improvement tool.

II. The study carried out developed models for different tasks of earthmoving operation processes with a different type of material and resource combinations, and all models result identified that stockpiling is critical as activity and dozer as a resource in the operation of selected material and loading activity is critical in the crushed unbounded material. Therefore, planners and contractors should focus on these two activities and resources used in the theme to optimize the production rate, number, and utilization of the fleets used in the earthmoving operation process. For example, in the selected material operation by either stockpiling enough material early before the loading start or increase the number of dozers. But the later may decrease the utilization of the dozer and increase the cost of the stockpiling activity.

III. Finally, the study has tried to assess and explore the use, practice, and state-of-the-art simulation software as a simulation modeling tool for earthmoving operation. Further, the research has provided benchmark data and models for earthmoving operation processes (focus only on truck cycles or delivery) for use in a continuous assessment of future improvement efforts.

IV. Moreover, the provided models allow developing an effective earthmoving operation with achieving optimum production rate and effective resource utilization. The developed models can also be used by planners, contractors, and researchers to solve the problem they desired. However, the study is meant only a starting work towards a long way to use and implement discrete-event simulation to analyze and solve the problem that exists in real-world operations in the Ethiopian construction industry.

5.3. Recommendation for Further Research

This research focused on the analysis using discrete-event simulation, and it also tried to develop a simulation model of the operation using simulation software. It is starting on construction simulation in Ethiopia and needs be followed by the number of researchers to investigate scopes which are not considered in this research and to refine the concepts raised and further enhance our understanding, and contribute to the consideration of using simulation software as analyzing tools in the construction operation. Thus, this research recommends the following for further research and investigation:

1. Conduct further research to refine the model, the models, and the data collection format by incorporating modern tools such as GPS, detail events, and production unit cost to every assigned resource in the model.
2. This research focused only on a single road. Therefore, conduct similar research for different road projects and other earthmoving operations such as dam and Highrise building.
3. Conduct different researches using simulation software as planning tools, e.g., risk analysis, design alternatives, scheduling, etc.

Appendices

Appendix A: Data collection Format and collected Data

Project Name:Kality-Tullu Dimtu Round About Road Project
Project Location: Addis Ababa, Akaki kality Sub-city
Client: Addis Ababa City Administration Road Authority (AACRA)

Consultant: Enginer Zewude Consulting Engineers
Contractor: IFH Engineering (China Communications Construction Company)
Su-Contractor Contractor: ASER Construction Plc
Working Time: Morning (7:30-12:30) and Afternoon (13:00-17:30)

Date	Cycle No.	Truck Code	Truck Vol.(M^3)	Distance (Km)	Loading		Travel/Hauling			Dumping		Queue			Returning			Queue			Time Record		Idle time (Min)	Reason	Loading Equipment			Type of Material		Type of work/Task	
					Start	Finish	Start	Finish	Path	Start	Finish	Start	Finish	No.	Start	Finish	Path	Start	Finish	No.	Functional	Waiting			Excavator	Loader	No	NGS	CUS/Agg.	Road Way	Embankment

Project Name:Kality-Tullu Dimtu Round About Road Project
Consultant: Enginer Zewude Consulting Engineers
Project Location: Addis Ababa, Akaki kality Sub-city
Contractor: IFH Engineering (China Communications Construction Company)
Client: Addis Ababa City Administration Road Authority (AACRA)
Su-Contractor Contractor: ASER Construction Plc
Working Time: Morning (7:30-12:30) and Afternoon (13:00-17:30)

Date	Cycle No.	Truck Code	Truck Vol.(M^3)	Distance (Km)	Loading		Travel/Hauling			Dumping		Queue			Returning			Queue			Time Record		Idle time (Min)	Reason	Loading Equipment			Type of Material		Type of work/Task	
					Start	Finish	Start	Finish	Path	Start	Finish	Start	Finish	No.	Start	Finish	Path	Start	Finish	No.	Functional	Waiting			Excavator	Loader	No	NGS	CUS/Agg.	Road Way	Embankment
03/05/19(25/08/11 E	1	70680	16.70	8.00	9.19	9.22	9.22	10.05	1	10.05	10.07				10.07	10.39	1	10.39	10.43	1					X		1	X		X	
	2	70680	16.70	8.00	10.43	10.48	10.48	11.24	1	11.24	11.26				11.26	11.58	1								X		1	X		X	
																Lunch TIME															
	3	70680	16.70	8.00	13.23	13.27	13.27	13.57	1	13.57	13.59				13.59	14.28	1	14.28	14.30	1					X		1	X		X	
	4	70680	16.70	8.00	14.30	14.36	14.36	15.07	1	15.07	15.09				15.09	15.34	1								X		1	X		X	
	5	70680	16.70	8.00	15.34	15.38	15.38	16.10	1	16.10	16.12				16.12	16.46	1	16.46	16.49	1					X		1	X		X	
	6	70680	16.70	8.00	16.49	16.53	16.53	17.26	1	17.26	17.28				17.28	17.57	1								X		1	X		X	
06/05/19(28/08/2011 E.C)	1	58646	16.70	8.00	9.35	9.39	9.39	10.15	1	10.15	10.17				10.17	10.45	1								X		1	X		X	
	2	48127	15.50	8.00	10.14	10.23	10.23	11.05	1	11.05	11.07				11.07	11.33	1	11.33	11.35	1					X		1	X		X	
	3	71425	16.70	8.00	10.23	10.30	10.30	11.06	1	11.06	11.08				11.08	11.36	1	11.36	11.39	1					X		1	X		X	
	4	52358	15.80	8.00	10.30	10.37	10.37	11.12	1	11.12	11.15				11.15	11.40	1	11.40	11.44	1					X		1	X		X	
	5	82397	16.70	8.00	10.37	10.43	10.30	11.13	1	11.13	11.17				11.17	11.40	1	11.40	11.49	2					X		1	X		X	
	6	47521	15.00	8.00	10.52	10.57	10.57	11.30	1	11.30	11.33				11.33	12.05	1								X		1	X		X	
	7	64868	16.70	8.00	11.07	11.13	11.13	11.55	1	11.55	11.57				11.57	12.28	1								X		1	X		X	
	8	89772	16.70	8.00	11.17	11.22	11.22	12.00	1	12.00	12.01				12.01	12.32	1								X		1	X		X	
	9	51434	16.70	8.00	11.31	11.35	11.35	12.03	1	12.03	12.06				12.06	12.34	1								X		1	X		X	
	10	48127	15.50	8.00	11.35	11.39	11.39	12.07	1	12.07	12.10				12.10	12.39	1								X		1	X		X	
	11	71425	16.70	8.00	11.39	11.44	11.44	12.15	1	12.15	12.18				12.18	12.54	1								X		1	X		X	
	12	52358	15.80	8.00	11.44	11.49	11.49	12.30	1	12.28	12.31				12.31	12.59	1								X		1	X		X	
	13	82397	16.70	8.00	11.49	11.54	11.54	12.25	1	12.25	12.27				12.27	12.57	1								X		1	X		X	
																Lunch TIME															
	14	58646	16.70	8.00	13.41	13.50	13.50	14.25	1	14.25	14.26				14.26	14.53	1								X		1	X		X	
	15	64868	16.70	8.00	13.57	14.01	14.01	14.27	1	14.27	14.30				14.30	14.55	1								X		1	X		X	
	16	89772	16.70	8.00	14.24	14.29	14.29	14.56	1	14.56	14.58				14.58	15.30	1								X		1	X		X	
	17	82397	16.70	8.00	14.33	14.37	14.37	15.03	1	15.03	15.04				15.04	15.32	1	15.32	15.35	1					X		1	X		X	
	18	52358	15.80	8.00	14.29	14.33	14.33	15.06	1	15.06	15.08				15.08	15.32	1	15.32	15.41	2					X		1	X		X	
	19	48127	15.50	8.00	14.37	14.43	14.43	15.13	1	15.13	15.16				15.16	15.42	1	15.42	15.49	1					X		1	X		X	
	20	51434	16.70	8.00	14.43	14.50	14.50	15.16	1	15.16	15.18				15.18	15.46	1	15.46	15.54	2					X		1	X		X	
	21	71425	16.70	8.00	15.18	15.25	15.25	16.02	1	16.02	16.04				16.04	16.34	1								X		1	X		X	
	22	89772	16.70	8.00	15.30	15.35	15.35	16.07	1	16.07	16.10				16.10	16.40	1								X		1	X		X	
	23	82397	16.70	8.00	15.35	15.41	15.41	16.10	1	16.10	16.11				16.11	16.45	1	16.45	16.47	1					X		1	X		X	
	24	52358	15.80	8.00	15.41	15.48	15.48	16.20	1	16.20	16.21				16.21	16.51	1								X		1	X		X	
	25	48127	15.50	8.00	15.48	15.54	15.54	16.29	1	16.29	16.31				16.31	17.08	1								X		1	X		X	
	26	51434	16.70	8.00	15.54	15.58	15.58	16.24	1	16.24	16.25				16.25	16.50	1								X		1	X		X	
	27	71425	16.70	8.00	16.34	16.40	16.40	17.21	1	17.21	17.22				17.22	17.52	1								X		1	X		X	
	28	89772	16.70	8.00	16.40	16.47	16.47	17.19	1	17.19	17.20				17.20	17.49	1								X		1	X		X	
	29	82397	16.70	8.00	16.47	16.52	16.52	17.22		17.22	17.24				17.24	17.56									X		1	X		X	
07/05/19(29/08/2011 E.C)	1	82397	16.70	8.50	8.00	8.06	8.06	8.47	1	8.47	8.48				8.48	9.22	1								X		1	X		X	
	2	58646	16.70	8.50	8.34	8.39	8.39	9.19	1	9.19	9.22				9.22	9.49	1								X		1	X		X	
	3	71425	16.70	8.50	8.53	8.58	8.58	9.38	1	9.38	9.40				9.40	10.59	1						47	Fuel	X		1	X		X	
	4	70680	16.70	8.50	9.01	9.05	9.05	9.45	1	9.45	9.46				9.46	10.17	1								X		1	X		X	
	5	52358	15.80	8.50	9.18	9.24	9.24	9.57	1	9.57	9.59				9.59	11.08	1						69	Fuel	X		1	X		X	
	6	82397	16.70	8.50	9.22	9.28	9.28	10.06	1	10.06	10.08				10.08	10.48	1	10.48	10.51	1					X		1	X		X	
	7	58646	16.70	8.50	9.49	9.54	9.54	10.24	1	10.24	10.25				10.25	10.48	1								X		1	X		X	
	8	70680	16.70	8.50	10.17	10.21	10.21	10.58	1	10.58	10.59				10.59	11.32	1								X		1	X		X	
	9	89772	16.70	8.50	10.42	10.45	10.45	11.23	1	11.23	11.25				11.25	11.52	1								X		1	X		X	
	10	58646	16.70	8.50	10.48	10.51	10.51	11.27	1	11.27	11.28				11.28	12.03	1								X		1	X		X	
	11	82397	16.70	8.50	10.51	10.55	10.55	11.23	1	11.23	11.25				11.25	11.54	1	11.54	11.56	1					X		1	X		X	
	12	71425	16.70	8.50	10.59	11.04	11.04	11.42	1	11.42	11.45				11.45	12.14	1								X		1	X		X	
	13	52358	15.80	8.50	11.08	11.13	11.13	11.45	1	11.45	11.46				11.46	12.19	1								X		1	X		X	
	14	48127	15.50	8.50	11.24	11.29	11.29	12.06	1	12.06	12.08				12.08	12.38	1								X		1	X		X	
	15	51434	16.70	8.50	11.32	11.38	11.38	12.09	1	12.09	12.13				12.13	12.39	1								X		1	X		X	
	16	89772	16.70	8.50	11.52	11.56	11.56	12.36	1	12.36	12.39				12.39	13.16	1								X		1	X		X	
																Lunch TIME															

	18	52358	15.80	8.50	13.27	13.32	13.32	14.13	1	14.13	14.18				14.18	14.45	1								X		1	X		X	
	19	51434	16.70	8.50	13.32	13.35	13.35	14.15	1	14.15	14.20				14.20	14.46	1								X		1	X		X	
	20	89772	16.70	8.50	13.45	13.50	13.50	14.29	1	14.29	14.31				14.31	15.04	1								X		1	X		X	
	21	70680	16.70	8.50	14.25	14.29	14.29	14.58	1	14.58	15.01				15.01	15.31	1								X		1	X		X	
	22	82397	16.70	8.50	14.35	14.38	14.38	15.15	1	15.15	15.16				15.16	15.43	1								X		1	X		X	
	23	89772	16.70	8.50	15.05	15.09	15.09	15.35	1	15.35	15.36				15.16	15.48	1								X		1	X		X	
	24	70680	16.70	8.50	15.31	15.38	15.38	16.04	1	16.06	16.08				16.08	16.45	1								X		1	X		X	
	25	82397	16.70	8.50	15.43	15.48	15.48	16.20	1	16.20	16.21				12.21	17.00	1								X		1	X		X	
08/05/19(30/08/2011 E.C)	1	89772	16.70	8.50	7.34	7.40	7.40	8.08	1	8.08	8.11				8.11	8.40	1								X		1	X		X	
	2	88941	16.70	8.50	7.56	8.01	8.01	8.35	1	8.35	8.38				8.38	9.08	1								X		1	X		X	
	3	48127	15.50	8.50	8.02	8.08	8.08	8.38	1	8.38	8.40				8.40	9.10	1	9.10	9.12	1					X		1	X		X	
	4	82397	16.70	8.50	8.33	8.38	8.38	9.09	1	9.09	9.11				9.11	9.43	1								X		1	X		X	
	5	89772	16.70	8.50	8.40	8.46	8.46	9.18	1	9.18	9.20				9.20	9.55	1								X		1	X		X	
	6	88941	16.70	8.50	9.08	9.12	9.12	9.46	1	9.46	9.51				9.51	10.21	1								X		1	X		X	
	7	48127	15.50	8.50	9.12	9.17	9.17	9.52	1	9.52	9.54				9.54	10.23	1	10.23	10.24	1					X		1	X		X	
	8	52358	15.80	8.50	9.26	9.30	9.30	10.10	1	10.10	10.14				10.14	10.51	1								X		1	X		X	
	9	82397	16.70	8.50	9.43	9.48	9.48	10.11	1	10.11	10.13				10.13	10.37	1								X		1	X		X	
	10	47521	15.00	8.50	9.39	9.42	9.42	10.19	1	10.19	10.21				10.21	10.59	1								X		1	X		X	
	11	89772	16.70	8.50	9.55	9.59	9.59	10.37	1	10.37	10.40				10.40	11.10	1	11.10	11.11	1					X		1	X		X	
	12	71425	16.70	8.50	10.08	10.11	10.11	10.54	1	10.54	10.57				10.57	11.34	1	11.34	11.39	1					X		1	X		X	
	13	88941	16.70	8.50	10.21	10.24	10.24	10.57	1	10.57	11.01				11.01	11.27	1								X		1	X		X	
	14	48127	15.50	8.50	10.24	10.30	10.30	11.05	1	11.05	11.08				11.08	11.36	1								X		1	X		X	
	15	82397	16.70	8.50	10.37	10.40	10.40	11.10	1	11.10	11.11				11.11	11.46	1								X		1	X		X	
	16	52358	15.80	8.50	10.51	10.56	10.56	11.41	1	11.41	11.46				11.46	12.10	1								X		1	X		X	
	17	47521	15.00	8.50	10.59	11.04	11.04	11.43	1	11.43	11.47				11.47	12.18	1								X		1	X		X	
	18	58646	16.70	8.50	11.05	11.10	11.10	11.52	1	11.52	11.54				11.54	12.19	1								X		1	X		X	
	19	89772	16.70	8.50	11.27	11.30	11.30	12.01	1	12.01	12.04				12.04	12.41	1								X		1	X		X	
	20	48127	15.50	8.50	11.37	11.41	11.41	12.04	1	12.04	12.08				12.08	12.33	1								X		1	X		X	
	21	82397	16.70	8.50	11.41	11.47	11.47	12.28	1	12.28	12.30				12.30	13.08	1								X		1	X		X	
	Lunch TIME																														
	22	88941	16.70	7.50	12.54	13.00	13.00	13.26	1	13.26	13.29				13.29	13.58	1								X		1	X		X	
	23	89772	16.70	7.50	13.00	13.07	13.07	13.38	1	13.38	13.39				13.39	14.03	1								X		1	X		X	
	24	82397	16.70	7.50	13.07	13.10	13.10	13.39	1	13.39	13.42				13.42	14.11	1								X		1	X		X	
	25	48127	15.50	7.50	13.10	13.18	13.18	13.46	1	13.46	13.48				13.48	14.22	1								X		1	X		X	
	26	58646	16.70	7.50	13.18	13.24	13.24	14.03	1	14.03	14.05				14.05	14.31	1								X		1	X		X	
	27	47521	15.00	7.50	13.27	13.36	13.36	14.10	1	14.10	14.14				14.14	14.44	1								X		1	X		X	
	28	88941	16.70	7.50	13.58	14.03	14.03	14.29	1	14.29	14.32				14.32	14.59	1								X		1	X		X	
	29	89772	16.70	7.50	14.03	14.11	14.11	14.45	1	14.45	15.47				14.47	15.21	1								X		1	X		X	
	30	82397	16.70	7.50	14.11	14.16	14.16	14.43	1	14.43	14.46				14.46	15.05	1								X		1	X		X	
	31	48127	15.50	7.50	14.22	14.26	14.26	14.57	1	14.57	14.59				14.59	15.31	1								X		1	X		X	
	32	71425	16.70	7.50	14.26	14.34	14.34	15.07	1	15.07	15.09				15.09	15.35	1								X		1	X		X	
	33	88941	16.70	7.50	14.59	15.05	15.05	15.41	1	15.41	15.44				15.44	16.08	1	16.08	16.12	1					X		1	X		X	
	34	82397	16.70	7.50	15.05	15.10	15.10	15.35	1	15.35	15.38				15.38	16.05	1								X		1	X		X	
	35	89772	16.70	7.50	15.21	15.25	15.25	16.03	1	16.03	16.05				16.05	16.31	1								X		1	X		X	
	36	48127	15.50	7.50	15.31	15.35	15.35	16.06	1	16.06	16.08				16.08	16.44	1								X		1	X		X	
	37	71425	16.70	7.50	15.35	15.43	15.43	16.11	1	16.11	16.13				16.13	16.43	1								X		1	X		X	
	38	82397	16.70	7.50	16.05	16.12	16.12	16.43	1	16.43	16.48				16.48	17.30	1								X		1	X		X	
	39	88941	16.70	7.50	16.12	16.18	16.18	16.43	1	16.43	16.45				16.45	17.17	1								X		1	X		X	

09/05/19(01/09/2011 E.C)	1	48127	15.50	7.50	7.30	7.37	7.37	8.13	1	8.13	8.14				8.14	8.41	1								X		1	X		X	
	2	89772	16.70	7.50	7.37	7.43	7.43	8.23	1	8.23	8.24				8.24	8.52	1								X		1	X		X	
	3	52358	15.80	7.50	7.43	7.49	7.49	8.22	1	8.22	8.25				8.25	8.48	1								X		1	X		X	
	4	88941	16.70	7.50	7.50	7.57	7.57	8.30	1	8.30	8.33				8.33	8.59	1								X		1	X		X	
	5	52261	16.20	7.50	8.09	8.15	8.15	8.53	1	8.53	8.58				8.58	9.24	1	9.24	9.29	1					X		1	X		X	
	6	71425	16.70	7.50	8.16	8.24	8.24	8.55	1	8.55	8.57				8.57	9.22	1								X		1	X		X	
	7	82397	16.70	7.50	8.27	8.31	8.31	9.02	1	9.02	9.04				9.04	9.34	1								X		1	X		X	
	8	48127	15.50	7.50	8.41	8.46	8.46	9.16	1	9.16	9.18				9.18	9.54	1								X		1	X		X	
	9	52358	15.80	7.50	8.48	8.52	8.52	9.50	1	9.50	9.52				9.52	10.20	1								X		1	X		X	
	10	89772	16.70	7.50	8.52	8.59	8.59	9.43	1	9.43	9.46				9.46	10.12	1								X		1	X		X	
	11	88941	16.70	7.50	8.59	9.07	9.07	9.54	1	9.54	9.57				9.57	10.20	1	10.20	10.24	1					X		1	X		X	
	12	71425	16.70	7.50	9.22	9.29	9.29	10.08	1	10.08	10.10				10.10	10.34	1	10.34	10.39	1					X		1	X		X	
	13	52261	16.20	7.50	9.29	9.34	9.34	10.03	1	10.03	10.05				10.05	10.34	1								X		1	X		X	
	14	82397	16.70	7.50	9.34	9.39	9.39	10.00	1	10.00	10.04				10.04	10.28	1								X		1	X		X	
	15	48127	15.50	7.50	9.54	9.59	9.59	10.43	1	10.43	10.45				10.45	11.10	1								X		1	X		X	
	16	47521	15.00	7.50	10.00	10.06	10.06	10.38	1	10.38	10.40				10.40	11.09	1								X		1	X		X	
	17	89772	16.70	7.50	10.12	10.20	10.20	10.47	1	10.47	10.50				10.50	11.14	1								X		1	X		X	
	18	52358	15.80	7.50	10.20	10.24	10.24	11.05	1	11.05	11.06				11.06	11.32	1								X		1	X		X	
	19	88941	16.70	7.50	10.24	10.28	10.28	11.13	1	11.13	11.13				11.13	11.50	1								X		1	X		X	
	20	82397	16.70	7.50	10.28	10.34	10.34	11.04	1	11.04	11.05				11.05	11.25	1								X		1	X		X	
	21	52261	16.20	7.50	10.34	10.39	10.39	11.16	1	11.16	11.18				11.18	11.43	1								X		1	X		X	
	22	71425	16.70	7.50	10.39	10.45	10.45	11.18	1	11.18	11.19				11.19	11.47	1								X		1	X		X	
	23	58646	16.70	7.50	10.57	11.02	11.02	11.36	1	11.36	11.38				11.38	12.08	1								X		1	X		X	
	24	48127	15.50	7.50	11.10	11.13	11.13	11.50	1	11.50	11.51				11.51	12.22	1								X		1	X		X	
	25	89772	16.70	7.50	11.14	11.19	11.19	11.57	1	11.57	11.59				11.59	12.26	1								X		1	X		X	
	26	82397	16.70	7.50	11.25	11.30	11.30	11.58	1	11.58	12.01				12.01	12.28	1								X		1	X		X	
	Lunch TIME																														
	27	52358	15.80	8.50	13.29	13.33	13.33	14.19	1	14.19	14.21				14.21	14.57	1								X		1	X		X	
	28	71425	16.70	8.50	13.33	13.38	13.38	14.15	1	14.15	14.17				14.17	14.46	1	14.46	14.48	1					X		1	X		X	
	29	82397	16.70	8.50	14.03	14.10	14.10	14.44	1	14.44	14.46				14.46	15.14	1	15.14	15.17	1					X		1	X		X	
	30	89772	16.70	8.50	14.10	14.16	14.16	14.53	1	14.53	14.55				14.55	15.21	1	15.21	15.28	2					X		1	X		X	
	31	48127	15.50	8.50	14.25	14.30	14.30	15.13	1	15.13	15.15				15.15	15.44	1								X		1	X		X	
	32	52261	16.20	8.50	14.30	14.35	14.35	15.17	1	15.17	15.20				15.20	15.46	1								X		1	X		X	
	33	88941	16.70	8.50	14.42	14.47	14.47	15.25	1	15.25	15.26				15.26	15.55	1								X		1	X		X	
	34	71425	16.70	8.50	14.48	14.56	14.56	15.45	1	15.45	15.47				15.47	16.39	1								X		1	X		X	
	35	52358	15.80	8.50	14.57	15.02	15.02	15.47	1	15.47	15.48				15.48	16.23	1								X		1	X		X	
	36	64868	16.70	8.50	15.11	15.16	15.16	15.55	1	15.55	15.57				15.57	16.27	1								X		1	X		X	
	37	82397	16.70	8.50	15.17	15.23	15.23	15.57	1	15.57	15.59				15.59	16.23	1	16.23	16.29	1					X		1	X		X	
	38	70680	16.70	8.50	15.24	15.28	15.28	16.13	1	16.13	16.14				16.14	16.44	1								X		1	X		X	
	39	89772	16.70	8.50	15.28	15.34	15.34	16.26	1	16.26	16.27				16.27	17.00	1								X		1	X		X	
	40	48127	15.50	8.50	15.44	15.49	15.49	16.51	1	16.51	16.53				16.53	17.21	1								X		1	X		X	
	41	88941	16.70	8.50	15.55	16.00	16.00	16.37	1	16.37	16.40				16.40	17.04	1								X		1	X		X	
	42	52358	15.80	8.50	16.23	16.28	16.28	17.10	1	17.10	17.13				17.13	17.51	1								X		1	X		X	
	43	82397	16.70	8.50	16.29	16.33	16.33	17.14	1	17.14	17.15				17.15	17.38	1								X		1	X		X	
	44	64868	16.70	8.50	16.34	16.44	16.44	17.13	1	17.13	17.14				17.14	17.44	1								X		1	X		X	
	1	70680	16.70	8.50	10.38	10.42	10.42	11.10	1	11.10	11.12				11.12	11.38	1								X		1			X	
	2	71425	16.70	8.50	10.43	10.47	10.47	11.20	1	11.20	11.24				11.24	11.48	1								X		1	X		X	
	3	89772	16.70	8.50	10.56	11.01	11.01	11.30	1	11.30	11.33				11.33	11.55	1								X		1	X		X	
	4	64868	16.70	8.50	11.01	11.06	11.06	11.40	1	11.40	11.41				11.41	12.10	1								X		1	X		X	
	5	88941	16.70	8.50	11.09	11.14	11.14	11.55	1	11.55	11.57				11.57	12.28	1								X		1	X		X	
	6	52261	16.20	8.50	11.15	11.19	11.19	11.58	1	11.58	12.01				12.01	12.25	1								X		1	X		X	
	Lunch TIME																														

14/05/19(06/09/2011 E.C)	7	71425	16.70	11.00	13.57	14.02	14.02	14.40	1	14.40	14.43				14.43	15.20	1								X		1	X		X	
	8	52358	15.80	11.00	14.10	14.14	14.14	15.00	1	15.00	15.01				15.01	15.46	1								X		1	X		X	
	9	52261	16.20	11.00	14.14	14.19	14.19	14.50	1	14.50	14.52				14.52	15.31	1	15.31	15.32	1					X		1	X		X	
	10	88941	16.70	11.00	14.23	14.27	14.27	15.00	1	15.00	15.01				15.01	15.46	1	15.46	15.50	1					X		1	X		X	
	11	47521	15.00	11.00	14.27	14.32	14.32	15.15	1	15.15	15.17				15.17	16.22	1	16.22	16.32	2					X		1	X		X	
	12	86432	16.40	11.00	14.32	14.37	14.37	15.15	1	15.05	15.17				15.17	16.03	1	16.03	16.11	2					X		1	X		X	
	13	64868	16.70	11.00	14.38	14.42	14.42	15.20	1	15.20	15.23				15.23	16.01	1								X		1	X		X	
	14	89772	16.70	11.00	14.43	14.47	14.47	15.33	1	15.33	15.35				15.35	16.02	1	16.02	16.06	1					X		1	X		X	
	15	70680	16.70	11.00	14.52	14.56	14.56	15.30	1	15.30	15.32				15.32	16.14	1	16.14	16.16	1					X		1	X		X	
	16	82397	16.70	11.00	14.59	15.04	15.04	15.40	1	15.40	15.42				15.42	16.16	1	16.16	16.20	1					X		1	X		X	
	17	72377	16.10	11.00	15.06	15.10	15.10	16.00	1	16.00	16.01				16.01	16.42	1								X		1	X		X	
	18	62858		11.00	15.10	15.14	15.14	16.01	1	16.01	16.02				16.02	16.43	1	16.43	16.47	1					X		1	X		X	
	19	81671		11.00	15.15	15.19	15.19	16.05	1	16.05	16.08				16.08	16.45	1	16.45	16.51	2					X		1	X		X	
	20	71425	16.70	11.00	15.20	15.26	15.26	16.17	1	16.17	16.18				16.18	16.52	1								X		1	X		X	
	21	58646	16.70	11.00	15.26	15.31	15.31	16.10	1	16.10	16.11				16.11	16.53	1	16.53	16.56	1					X		1	X		X	
	22	52261	16.20	11.00	15.32	15.37	15.37	16.20	1	16.20	16.22				16.22	16.49	1	16.49	17.02	2					X		1	X		X	
	23	52358	15.80	11.00	15.46	15.50	15.50	16.32	1	16.32	16.33				16.33	16.58	1	16.58	17.07	2					X		1	X		X	
	24	88941	16.70	11.00	15.50	15.56	15.56	16.40	1	16.40	16.41				16.41	17.09	1	17.09	17.13	1					X		1	X		X	
	25	64868	16.70	11.00	16.01	16.06	16.06	16.50	1	16.50	16.51				16.51	17.21	1	17.21	17.27	1					X		1	X		X	
	26	89772	16.70	11.00	16.06	16.10	16.10	16.45	1	16.45	16.47				16.47	17.19	1	17.19	17.21	1					X		1	X		X	
	27	86432	16.40	11.00	16.11	16.15	16.15	16.47	1	16.47	16.49				16.49	17.21	1	17.21	17.31	2					X		1	X		X	
	28	70680	16.70	11.00	16.16	16.20	16.20	16.55	1	16.55	16.56				16.56	17.30	1	17.30	17.31	1					X		1	X		X	
15/05/19(07/09/2011 E.C)	1	62857		8.50	9.46	9.51	9.51	10.27	1	10.27	10.30				10.30	11.07	1								X		1	X		X	
	2	52261	16.20	8.50	9.56	10.00	10.00	10.40	1	10.40	10.42				10.42	11.17	1	11.17	11.26	3					X		1	X		X	
	3	68686	16.70	8.50	10.00	10.05	10.05	10.42	1	10.42	10.44				10.44	11.12	1	11.12	11.16	1					X		1	X		X	
	4	71425	16.70	8.50	10.05	10.09	10.09	10.45	1	10.45	10.47				10.47	11.15	1	11.15	11.22	2					X		1	X		X	
	5	88941	16.70	8.50	10.09	10.14	10.14	10.47	1	10.47	10.49				10.49	11.19	1	11.19	11.35	4					X		1	X		X	
	6	82397	16.70	8.50	10.14	10.19	10.19	10.47	1	10.49	10.50	10:47	10:49	1	10.50	11.18	1	11.18	11.31	3					X		1	X		X	
	7	58646	16.70	8.50	10.19	10.25	10.25	10.54	1	10.54	10.56				10.56	11.27	1	11.27	11.44	4					X		1	X		X	
	8	81671		8.50	10.25	10.29	10.29	11.03	1	11.03	11.05				11.05	11.43	1								X		1	X		X	
	9	86432	16.40	8.50	10.29	10.35	10.35	11.12	1	11.12	11.15				11.15	11.49	1	11.49	12.03	3					X		1	X		X	
	10	52358	15.80	8.50	10.35	10.40	10.40	11.15	1	11.15	11.17				11.17	11.50	1								X		1	X		X	
	11	58941	16.00	8.50	10.40	10.43	10.43	11.16	1	11.16	11.18				11.18	11.45	1	11.45	11.58	3					X		1	X		X	
	12	62858		8.50	10.43	10.48	10.48	11.25	1	11.25	11.27				11.27	11.54	1								X		1	X		X	
	13	70680	16.70	8.50	10.48	10.53	10.53	11.33	1	11.33	11.34				11.34	12.01	1								X		1	X		X	
	14	89772	16.70	8.50	10.53	10.57	10.57	11.38	1	11.38	11.40				11.40	12.00	1								X		1	X		X	
	15	72377	16.10	8.50	11.02	11.06	11.06	11.40	1	11.40	11.42				11.42	12.10	1								X		1	X		X	
	16	62857		8.50	11.07	11.11	11.11	11.40	1	10.42	10.46	10:40	10:42	1	10.46	12.10	1								X		1	X		X	
	17	50784	16.10	8.50	11.11	11.16	11.16	11.55	1	11.55	11.58				11.58	12.33	1								X		1	X		X	
	18	68686	16.70	8.50	11.16	11.22	11.22	11.56	1	11.56	11.59				11.59	12.22	1								X		1	X		X	
	19	71425	16.70	8.50	11.22	11.26	11.26	12.00	1	12.00	12.03				12.03	12.35	1								X		1	X		X	
	20	52261	16.20	8.50	11.26	11.31	11.31	12.03	1	12.03	12.07				12.07	12.41	1								X		1	X		X	
	21	82397	16.70	8.50	11.31	11.35	11.35	12.05	1	12.05	12.07				12.07	12.45	1								X		1	X		X	
	22	88941	16.70	8.50	11.35	11.41	11.41	12.13	1	12.13	12.14				12.14	12.40	1								X		1	X		X	
	23	47521	15.00	8.50	11.41	11.44	11.44	12.22	1	12.22	12.23				12.23	12.54	1								X		1	X		X	
	24	58646	16.70	8.50	11.44	11.49	11.49	12.28	1	12.28	12.30				12.30	13.00	1								X		1	X		X	
	25	64868	16.70	8.50	11.49	11.58	11.58	12.36	1	12.36	12.37				12.37	13.13	1								X		1	X		X	
	26	58941	16.00	8.50	11.58	12.03	12.03	12.37	1	12.37	12.41				12.41	13.13	1								X		1	X		X	
	27	86432	16.40	8.50	12.03	12.09	12.09	12.41	1	12.41	12.44				12.44	13.09	1								X		1	X		X	

16/05/19(08/09/2011 E.C)	1	89772	16.70	8.50	8.53	8.58	8.58	9.32	1	9.32	9.35				9.35	10.04	1	10.04	10.10	1					X		1	X			X
	2	48127	15.50	8.50	8.58	9.04	9.04	9.39	1	9.39	9.43				9.43	10.09	1	10.09	10.14	1					X		1	X			X
	3	62857		8.50	9.08	9.13	9.13	9.48	1	9.48	9.51				9.51	10.41	1								X		1	X			X
	4	71425	16.70	8.50	9.14	9.19	9.19	9.52	1	9.52	9.54				9.54	10.33	1						11	fuel	X		1	X			X
	5	64868	16.70	8.50	9.19	9.23	9.23	9.55	1	9.55	9.57				9.57	10.47	1						22	fuel	X		1	X			X
	6	86432	16.40	8.50	9.23	9.29	9.29	10.02	1	10.02	10.05				10.05	11.06	1						25	fuel	X		1	X			X
	7	65993		8.50	9.34	9.39	9.39	10.09	1	10.09	10.13				10.13	10.52	1	10.52	10.56	1					X		1	X			X
	8	72377	16.10	8.50	9.39	9.43	9.43	10.17	1	10.17	10.20				10.20	10.51	1	10.51	10.52	1					X		1	X			X
	9	62858		8.50	9.43	9.48	9.48	10.30	1	10.30	10.32				10.32	10.57	1								X		1	X			X
	10	81671	16.70	8.50	9.48	9.53	9.53	10.21	1	10.21	10.24				10.24	10.53	1								X		1	X			X
	11	52261	16.70	8.50	9.53	9.59	9.59	10.35	1	10.38	10.42	10:35	10:38	1	10.42	11.17	1								X		1	X			X
	12	58646	15.80	8.50	9.59	10.03	10.03	10.34	1	10.34	10.38				10.38	11.09	1	11.09	11.12	1					X		1	X			X
	13	70680	15.50	8.50	10.04	10.10	10.10	10.42	1	10.42	10.45				10.45	11.16	1								X		1	X			X
	14	89772	16.70	8.50	10.10	10.14	10.14	10.46	1	10.46	10.50				10.50	11.15	1	11.15	11.16	2					X		1	X			X
	15	48127	15.50	8.50	10.14	10.19	10.19	10.50	1	10.50	10.54				10.54	11.30	1								X		1	X			X
	16	71425	16.70	8.50	10.33	10.38	10.38	11.10	1	11.10	11.14				11.14	11.40	1								X		1	X			X
	17	62857	15.80	8.50	10.41	10.46	10.46	11.31	1	11.31	11.33				11.33	12.02	1								X		1	X			X
	18	64868	16.70	8.50	10.47	10.52	10.52	11.28	1	11.28	11.31				11.31	12.08	1								X		1	X			X
	19	72377	16.70	8.50	10.52	10.56	10.56	11.36	1	11.36	11.39				11.39	12.17	1	12.17	12.20	1					X		1	X			X
	20	65939	16.70	8.50	10.57	11.01	11.01	11.42	1	11.42	11.46				11.46	12.15	1								X		1	X			X
	21	86432	16.70	8.50	11.06	11.11	11.11	11.46	1	11.46	11.48				11.48	12.27	1								X		1	X			X
	22	58646	15.80	8.50	11.12	11.16	11.16	11.48	1	11.48	11.51				11.51	12.29	1	12.29	12.32	1								X			
	23	89772	16.70	8.50	11.16	11.20	11.20	11.51	1	11.51	11.54				11.54	12.23	1	12.23	12.26	1					X		1	X			X
17/05/19(09/09/2011 E.C)	1	48127	15.50	8.00	8.42	8.48	8.48	9.22	1	9.22	9.24				9.24	9.55	1	9.55	10.01	1					X		1	X			X
	2	89772	16.70	8.00	8.48	8.53	8.53	9.24	1	9.24	9.25				9.25	9.49	1	9.49	9.56	2					X		1	X			X
	3	52358	15.80	8.00	8.53	8.57	8.57	9.35	1	9.35	9.36				9.36	10.14	1								X		1	X			X
	4	64868	16.70	8.00	8.57	9.02	9.02	9.37	1	9.37	9.39				9.39	10.15	1	10.15	10.19	1					X		1	X			X
	5	62857		8.00	9.02	9.09	9.09	9.44	1	9.44	9.47				9.47	10.22	1	10.22	10.28	2					X		1	X			X
	6	86432	16.40	8.00	9.09	9.14	9.14	9.45	1	9.47	9.53	9:45	9:47	1	9.53	10.21	1	10.21	10.23	1					X		1	X			X
	7	88941	16.70	8.00	9.14	9.19	9.19	9.48	1	9.53	9.56	9:48	9:53	1	9.56	10.23	1	10.23	10.33	2					X		1	X			X
	8	65939	16.40	8.00	9.19	9.24	8.24	9.54	1	9.56	10.01	9:54	9:56	1	10.01	10.31	1	10.31	10.40	2					X		1	X			X
	9	62858		8.50	9.22	9.27	9.27	10.23	1	10.23	10.25				10.25	10.58	1								X		1	X		X	
	10	70680	16.70	8.50	9.46	9.50	9.50	10.18	1	10.18	10.20				10.20	10.48	1	10.48	10.49	1					X		1	X		X	
	11	71425	16.70	8.50	9.50	9.54	9.54	10.35	1	10.35	10.37				10.37	11.04	1	11.04	11.09	1					X		1	X		X	
	12	89772	16.70	8.50	9.56	10.01	10.01	10.32	1	10.32	10.33				10.33	11.00	1								X		1	X		X	
	13	48127	15.50	8.50	10.02	10.07	10.07	10.37	1	10.37	10.39				10.39	11.05	1	11.05	11.13	1					X		1	X		X	
	14	52358	15.80	8.50	10.14	10.19	10.19	10.46	1	10.46	11.49				10.49	11.19	1								X		1	X		X	
	15	64868	16.70	8.50	10.19	10.23	10.23	10.58	1	10.58	11.01				11.01	11.32	1								X		1	X		X	
	16	86432	16.40	8.50	10.23	10.28	10.28	11.04	1	11.04	11.07				11.07	11.43	1								X		1	X		X	
	17	62857		8.50	10.28	10.33	10.33	11.03	1	11.03	11.06				11.06	11.38	1	11.38	11.39	1					X		1	X		X	
	18	88941	16.70	8.50	10.33	10.40	10.40	11.12	1	11.12	11.14				11.14	11.49	1								X		1	X		X	
	19	65939	16.40	8.50	10.40	10.45	10.45	11.24	1	11.24	11.25				11.25	11.57	1	11.57	12.00	1					X		1	X		X	
	20	58646	16.70	8.50	10.45	10.49	10.49	11.28	1	11.28	11.31				11.31	12.00	1								X		1	X		X	
	21	70680	16.70	8.50	10.49	10.54	10.54	11.23	1	11.23	11.25				11.25	11.56	1								X		1	X		X	
	23	71425	16.70	8.50	11.09	11.13	11.13	11.48	1	11.48	11.52				11.52	12.21	1								X		1	X		X	
	24	48127	15.50	8.50	11.13	11.17	11.17	11.51	1	11.51	11.53				11.53	12.25	1								X		1	X		X	
	25	52358	15.80	8.50	11.19	11.23	11.23	12.01	1	12.01	12.04				12.04	12.42	1								X		1	X		X	
	26	64868	16.70	8.50	11.32	11.39	11.39	12.05	1	12.05	12.07				12.07	12.44	1								X		1	X		X	
	27	62857		8.50	11.39	11.43	11.43	12.14	1	12.14	12.16				12.16	12.43	1								X		1	X		X	
	28	86432	16.40	8.50	11.43	11.48	11.48	12.26	1	12.26	12.27				12.27	12.57	1								X		1	X		X	
	29	88941	16.70	8.50	11.49	11.54	11.54	12.27	1	12.27	12.30				12.30	12.58	1								X		1	X		X	
																Lunch TIME															
	30	86432	16.40	8.00	13.42	13.46	13.46	14.24	1	14.24	14.26				14.26	14.57	1								X		1	X		X	
	31	88941	16.70	8.00	13.45	13.50	13.50	14.24	1	14.24	14.26				14.26	14.58	1								X		1	X		X	
	32	52358	15.80	8.00	13.50	13.57	13.57	14.28	1	14.28	14.30				14.30	15.08	1								X		1	X		X	
	33	64868	16.70	8.00	13.57	14.05	14.05	14.34	1	14.34	14.36				14.36	15.09	1								X		1	X		X	
	34	65939	16.40	8.00	14.05	14.11	14.11	14.43	1	14.43	14.45				14.45	15.18	1								X		1	X		X	
	35	58646	16.70	8.00	14.11	14.17	14.17	14.48	1	14.48	14.50				14.50	15.26	1								X		1	X		X	
	36	48127	15.50	8.00	14.17	14.24	14.24	15.01	1	15.01	15.03				15.03	15.34	1								X		1	X		X	
	37	62858		8.00	14.25	14.32	14.32	15.02	1	15.02	15.04				15.04	15.30	1								X		1	X		X	
	38	62857		8.00	14.35	14.40	14.40	15.08	1	15.08	15.10				15.36	16.03	1								X		1	X		X	

	39	89772	16.70	8.00	14.48	14.53	14.53	15.20	1	15.20	15.21				15.21	16.37	1								X		1	X		X	
	40	70680	16.70	8.00	14.53	14.56	14.56	15.21	1	15.21	15.22				15.22	15.46	1	15.46	15.52	1					X		1	X		X	
	41	86432	16.40	8.00	14.57	15.03	15.03	15.39	1	15.39	15.40				15.40	16.17	1								X		1	X		X	
	42	88941	16.70	8.50	15.03	15.10	15.10	15.48	1	15.48	15.51				15.51	16.20	1	16.20	16.22	1					X		1	X		X	
	43	64868	16.70	8.50	15.10	15.16	15.16	15.49	1	15.49	15.51				15.51	16.24	1	16.24	16.28	1					X		1	X		X	
	44	52358	15.80	8.00	15.16	15.21	15.21	16.08	1	16.08	16.10				16.10	16.37	1								X		1	X		X	
	45	65939	16.40	8.50	15.21	15.26	15.26	16.05	1	16.05	16.10				16.10	16.41	1	16.41	16.57	3					X		1	X		X	
	46	58646	16.70	8.50	15.26	15.31	15.31	16.05	1	16.05	16.07				16.07	16.39	1	16.39	16.42	1					X		1	X		X	
	47	48127	15.50	8.00	15.37	15.41	15.41	16.12	1	16.12	16.15				16.15	16.40	1	16.40	16.50	2					X		1	X			X
	48	62858		8.00	15.46	15.52	15.52	16.27	1	16.27	16.29				16.29	17.00	1	17.00	17.09	2					X		1	X			X
	49	70680	16.70	8.00	15.52	15.57	15.57	16.23	1	16.23	16.24				16.24	16.49	1	16.49	17.03	3					X		1	X			X
	50	62857		8.00	16.03	16.08	16.08	16.34	1	16.34	16.38				16.38	17.13	1								X		1	X			X
	51	86432	16.40	8.00	16.17	16.22	16.22	17.10	1	17.10	17.12				17.12	17.42	1								X		1	X		X	
	52	88941	16.70	8.00	16.22	16.28	16.28	17.01	1	17.01	17.03				17.03	17.20	1								X		1	X			X
	53	64868	16.70	8.00	16.28	16.34	16.34	17.00	1	17.00	17.02				17.02	17.30	1								X		1	X			X
	54	89772	16.70	8.00	16.37	16.42	16.42	17.14	1	17.14	17.16				17.16	17.41	1								X		1	X		X	
18/05/19(10/09/2011 E.C)	1	48127	15.50	8.00	7.50	7.54	7.54	8.29	1	8.29	8.30				8.30	8.56	1	8.56	8.58	1					X		1	X		X	
	2	52358	15.80	8.00	7.54	8.01	8.01	8.31	1	8.31	8.32				8.32	9.02	1	9.02	9.04	1					X		1	X		X	
	3	64868	16.70	8.00	8.15	8.21	8.21	8.53	1	8.53	8.55				8.55	9.23	1	9.23	9.31	2					X		1	X		X	
	4	88941	16.70	8.00	8.27	8.33	8.33	9.01	1	9.01	9.04				9.04	9.40	1								X		1	X		X	
	5	52261	16.20	8.00	8.21	8.27	8.27	9.01	1	9.04	9.06	9:01	9:04	1	9.06	9.37	1								X		1	X		X	
	6	47521	15.00	8.00	8.33	8.38	8.38	9.06	1	9.06	9.08				9.08	9.42	1								X		1	X		X	
	7	65939	16.40	8.00	8.38	8.45	8.45	9.13	1	9.13	9.16				9.16	9.49	1								X		1	X		X	
	8	71425	16.70	8.00	8.38	8.44	8.44	9.20	1	9.20	9.23				9.03	9.52	1	9.52	9.53	1					X		1	X		X	
	9	62858		8.00	8.44	8.51	8.51	9.31	1	9.31	9.33				9.33	10.06	1								X		1	X		X	
	10	89772	16.70	8.00	8.51	8.58	8.58	9.31	1	9.31	9.32				9.32	10.01	1								X		1	X		X	
	11	48127	15.50	8.00	8.58	9.04	9.04	9.36	1	9.36	9.39				9.39	10.11	1	10.11	10.13	1					X		1	X		X	
	12	52358	15.80	8.00	9.04	9.08	9.08	9.41	1	9.41	9.43				9.43	10.24	1	10.24	10.33	2					X		1	X		X	
	13	62857		8.00	9.08	9.15	9.15	9.52	1	9.52	9.53				9.53	10.22	1								X		1	X		X	
	14	70680	16.70	8.00	9.15	9.26	9.26	9.52	1	9.52	9.54				9.54	10.23	1	10.23	10.28	1					X		1	X		X	
	15	86432	16.40	8.00	9.26	9.31	9.31	10.14	1	10.14	10.16				10.16	10.50	1	10.50	10.55	1					X		1	X		X	
	16	64868	16.70	8.00	9.31	9.37	9.37	10.17	1	10.17	10.19				10.19	10.48	1								X		1	X		X	
	17	52261	16.20	8.00	9.37	9.45	9.45	10.21	1	10.21	10.24				10.24	11.08	1	11.08	11.18	3					X		1	X		X	
	18	65939	16.40	8.00	9.49	9.53	9.53	10.33	1	10.33	10.36				10.36	11.06	1	11.06	11.13	2					X		1	X		X	
	19	71425	16.70	8.00	9.53	10.00	10.00	10.36	1	10.36	10.38				10.38	11.04	1	11.04	11.08	1					X		1	X		X	
	20	89772	16.70	8.00	10.01	10.05	10.05	10.35	1	10.35	10.36				10.36	11.01	1	11.01	11.02	1					X		1	X		X	
	21	62858		8.00	10.06	10.13	10.13	10.53	1	10.53	10.55				10.55	11.31	1								X		1	X		X	
	22	48127	15.50	8.00	10.13	10.22	10.22	10.56	1	10.56	10.57				10.57	11.26	1								X		1	X		X	
	23	62857		8.00	10.22	10.28	10.28	10.57	1	10.57	11.01				11.01	11.31	1	11.31	11.37	1					X		1	X		X	
	24	70680	16.70	8.00	10.28	10.33	10.33	10.59	1	10.59	11.01				11.01	11.28	1								X		1	X		X	
	25	52358	15.80	8.00	10.33	10.40	10.40	11.12	1	11.45	11.47				11.47	12.15	1						33	test	X		1	X		X	
	26	64868	16.70	8.00	10.48	10.55	10.55	11.28	1	11.28	11.30				11.30	11.57	1								X		1	X		X	
	27	86432	16.40	8.00	10.55	11.02	11.02	11.38	1	11.38	11.40				11.40	12.08	1								X		1	X		X	
	28	89772	16.70	8.00	11.02	11.08	11.08	11.37	1	11.37	11.39				11.49	12.19	1								X		1	X		X	
	29	71425	16.70	8.00	11.08	11.13	11.13	11.46	1	11.46	11.48				11.48	12.23	1								X		1	X		X	
	30	65939	16.40	8.00	11.13	11.18	11.18	11.49	1	11.49	11.51				11.51	12.21	1								X		1	X		X	
	31	52261	16.20	8.00	11.18	11.24	11.24	11.53	1	11.53	11.54				11.54	12.20	1								X		1	X		X	

21/05/19(13/09/2011 E.C)	1	58646	16.70	8.00	13.07	13.12	13.12	13.44	1	13.44	13.46				13.46	14.10	1								X		1	X			X
	2	64868	16.70	8.00	13.12	13.18	13.18	13.51	1	13.51	13.52				13.52	14.25	1								X		1	X			X
	3	70680	16.70	8.00	13.18	13.23	13.23	13.55	1	13.55	13.57				13.57	14.17	1								X		1	X			X
	4	81993		8.00	13.33	13.39	13.39	14.14	1	14.14	14.16				14.16	14.49	1								X		1	X			X
	5	89772	16.70	8.00	13.39	13.44	13.44	14.17	1	14.17	14.18				14.18	14.45	1								X		1	X			X
	6	52358	15.80	8.00	13.44	13.51	13.51	14.22	1	14.22	14.24				14.24	15.24	1	15.24	15.29	1			32	tyre	X		1	X			X
	7	71425	16.70	8.00	13.57	14.03	14.03	14.36	1	14.36	14.38				14.38	15.16	1	15.16	15.18	1					X		1	X			X
	8	58646	16.70	7.50	14.10	14.16	14.16	14.48	1	14.48	14.49				14.49	15.17	1	15.17	15.23	2					X		1	X		X	
	9	70680	16.70	7.50	14.17	14.23	14.23	14.51	1	14.51	14.53				14.53	15.28	1	15.28	15.35	2					X		1	X		X	
	10	64868	16.70	7.50	14.25	14.30	14.30	15.03	1	15.03	15.04				15.04	15.34	1	15.34	15.41	2					X		1	X		X	
	11	74879	16.40	8.00	14.35	14.40	14.40	15.14	1	15.14	15.15				15.15	15.51	1								X		1	X		X	
	12	89772	16.70	7.50	14.45	14.49	14.49	15.24	1	15.24	15.25				15.25	15.52	1	15.52	16.00	1					X		1	X		X	
	13	81993		8.00	14.49	14.55	14.55	15.28	1	15.28	15.29				15.29	16.05	1	16.05	16.06	1					X		1	X		X	
	14	88941	16.70	7.50	15.03	15.08	15.08	15.45	1	15.45	15.47				15.47	16.10	1	16.10	16.12	1					X		1	X		X	
	15	65939	16.40	7.50	15.12	15.18	15.18	16.02	1	16.02	16.04				16.04	16.32	1	16.32	16.34	1					X		1	X		X	
	16	71425	16.70	7.50	15.18	15.23	15.23	15.58	1	15.58	15.59				15.59	16.22	1								X		1	X		X	
	17	58646	16.70	7.50	15.23	15.29	13.29	16.01	1	16.01	16.02				16.02	16.29	1								X		1	X		X	
	18	52358	15.80	7.50	15.29	15.35	15.35	16.05	1	16.05	16.06				16.06	16.43	1								X		1	X		X	
	19	70680	16.70	7.50	15.35	15.41	15.41	16.13	1	16.13	16.15				16.15	16.48	1								X		1	X		X	
	20	64868	16.70	7.50	15.41	15.47	15.47	16.21	1	16.21	16.23				16.23	16.53	1								X		1	X		X	
	21	74879	16.40	7.50	15.51	16.00	16.00	16.32	1	16.32	16.33				16.33	17.10	1								X		1	X		X	
	22	89772	16.70	7.50	16.00	16.06	16.06	16.43	1	16.43	16.45				16.45	17.17	1								X		1	X		X	
	23	81993		7.50	16.06	16.12	16.12	16.50	1	16.50	16.52				16.52	17.17	1								X		1	X		X	
	24	88941	16.70	7.50	16.12	16.17	16.17	16.48	1	16.48	16.49				16.49	17.13	1								X		1	X		X	
	25	71425	16.70	7.50	16.22	16.28	16.28	16.59	1	16.59	17.01				17.01	17.28	1								X		1	X		X	
	26	58646	16.70	7.50	16.29	16.34	16.34	17.04	1	17.04	17.06				17.06	17.39	1								X		1	X		X	
24/05/19(16/09/2011 E.C)	1	89772	16.70	8.50	8.26	8.33	8.33	9.03	1	9.03	9.05				9.05	9.35	1								X		1	X			X
	2	70680	16.70	8.50	8.33	8.38	8.38	9.13	1	9.13	9.15				9.15	9.51	1								X		1	X			X
	3	88941	16.70	8.50	8.38	8.43	8.43	9.28	1	9.35	9.39	9:28	9:35	1	9.39	10.15	1	10.15	10.16	1					X		1	X			X
	4	65939	16.40	8.50	8.43	8.48	8.48	9.28	1	9.28	9.34				9.34	10.10	1								X		1	X			X
	5	71425	16.70	8.50	8.54	8.59	8.59	9.38	1	9.45	9.47	9:38	9:45	1	9.47	10.21	1	10.21	10.22	1					X		1	X			X
	6	52358	15.80	8.50	8.59	9.07	9.07	9.54	1	9.54	9.58				9.58	10.46	1								X		1	X			X
	7	81993		8.50	8.48	8.54	8.54	10.00	1	10.09	10.14				10.14	10.47	1	10.47	10.50	1			9	dozer work	X		1	X			X
	8	89772	16.70	8.50	9.35	9.40	9.40	10.17	1	10.17	10.20				10.20	10.51	1	10.51	10.58	1					X		1	X			X
	9	70680	16.70	8.50	9.51	9.57	10.03	10.31	1	10.31	10.33				10.33	12.09	1	12.09	12.11	1					X		1	X			X
	10	65939	16.40	8.50	10.10	10.16	10.16	10.53	1	10.53	10.57				10.57	11.51	1	11.51	11.56	1			13	due to oper	X		1	X			X
	11	88941	16.70	8.50	10.16	10.22	10.22	11.05	1	11.05	11.13				11.13	11.50	1								X		1	X			X
	12	71425	16.70	8.50	10.22	10.29	10.29	11.10	1	11.14	11.16	11:10	11:14	1	11.28	12.07	1						12	fuel	X		1	X			X
	13	81993		8.50	10.50	10.58	10.58	11.39	1	11.43	11.48	11:39	11:43	1	11.48	12.20	1								X		1	X			X
	14	89772	16.70	8.50	10.58	11.03	11.03	11.42	1	11.50	11.53	11:42	11:50	1	11.53	12.26	1								X		1	X			X
20/11/18(11/03/11 E.C)	1	88510	17.03		10.42	10.45	10.45	11.08	2	11.08	11.09				11.09	11.31	1									X	1		X	X	
	2	71425	16.7		10.46	10.50	10.50	11.10	1	11.10	11.11				11.11	11.32	2														
																Lunch TIME															
	3	71425	16.70		13.18	13.20	13.20	13.42	2	13.42	13.43				13.43	14.05	2	14.05	14.06	1						X	1		X	X	
	4	94335	16.00		13.24	13.26	13.26	13.47	2	13.47	13.48				13.48	14.09	2									X	1		X	X	
	5	43448	14.00		13.29	13.31	13.31	13.54	1	13.54	13.56				13.56	14.16	1									X	1		X	X	
	6	88510	17.03		13.33	13.36	13.36	14.00	2	14.00	14.03				14.03	14.20	1									X	1		X	X	
	7	43447	14.00		13.37	13.39	13.39	14.00	1	14.00	14.01				14.01	14.23	1									X	1		X	X	
	8	65648	14.00		13.41	13.43	13.43	14.07	2	14.07	14.08				14.08	14.30	2									X	1		X	X	
	9	65645	14.00		13.45	13.47	13.47	14.11	2	14.11	14.12				14.12	14.36	2	14.36	14.38	1						X	1		X	X	
	10	96623	16.70		13.49	13.51	13.51	14.13	1	14.13	14.15				14.15	14.32	1	14.32	14.35	1						X	1		X	X	
	11	89772	16.70		13.53	13.55	13.55	14.16	2	14.16	14.17				14.17	14.38	2	14.38	14.41	1						X	1		X	X	
	12	82461	16.70		13.58	14.01	14.01	14.24	1	14.24	14.26				14.26	15.00	1									X	1		X	X	
	13	65647	14.00		14.02	14.04	14.04	14.24	2	14.24	14.28				14.28	14.43	2	14.43	14.47	1						X	1		X	X	
	14	49079	16.00		14.04	14.06	14.06	14.42	2	14.42	14.44				14.44	15.04	2									X	1		X	X	
	15	70680	16.70		14.06	14.08	14.08	14.33	1	14.33	14.35				14.35	14.53	1									X	1		X	X	

	16	71425	16.70		14.06	14.07	14.07	14.38	2	14.38	14.39				14.39	14.57	2									X	1		X	X	
	17	94335	16.00		14.09	14.12	14.12	14.42	1	14.42	14.45				14.45	15.03	1									X	1		X	X	
	18	43448	14.00		14.16	14.18	14.18	14.44	2	14.44	14.48				14.48	15.06	2									X	1		X	X	
	19	88510	17.03		14.20	14.23	14.23	14.48	1	14.48	14.49				14.49	15.06	1	15.06	15.10	1						X	1		X	X	
	20	43447	14.00		14.23	14.25	14.25	14.49	2	14.49	14.51				14.51	15.10	2	15.10	15.13	1						X	1		X	X	
	21	65648	14.00		14.30	14.33	14.33	14.57	2	14.57	15.00				15.00	15.21	2									X	1		X	X	
	22	94327	16.00		14.33	14.36	14.36	15.04	1	15.04	15.06				15.06	15.24	1									X	1		X	X	
	23	96623	16.70		14.35	14.38	14.38	14.57	2	14.57	14.58				14.58	15.17	2									X	1		X	X	
	24	65645	14.00		14.38	14.41	14.41	15.08	2	15.08	15.09				15.09	15.35	2									X	1		X	X	
	25	89772	16.70		14.43	14.47	14.47	15.07	1	15.07	15.08				15.08	15.31	1									X	1		X	X	
	26	65647	14.00		14.47	14.49	14.49	15.10	1	15.10	15.11				15.11	15.32	1	15.32	15.33	1						X	1		X	X	
	27	70680	16.70		14.53	14.57	14.57	15.16	2	15.16	15.18				15.18	15.37	2									X	1		X	X	
	28	71425	16.70		14.57	15.01	15.01	15.20	1	15.20	15.21				15.21	15.37	1									X	1		X	X	
	29	82461	16.70		15.00	15.03	15.03	15.26	2	15.26	15.28				15.28	16.18	2									X	1		X	X	
	30	94335	16.00		15.03	15.06	15.06	15.28	2	15.28	15.29				15.29	15.49	1									X	1		X	X	
	31	43448	14.00		15.06	15.10	15.10	15.35	1	15.35	15.38				15.38	16.00	1									X	1		X	X	
	32	88510	17.03		15.10	15.13	15.13	15.38	1	15.38	15.40				15.40	15.59	1									X	1		X	X	
	33	43447	14.00		15.13	15.16	15.16	15.40	2	15.40	15.42				15.42	16.02	2									X	1		X	X	
	34	96623	16.70		15.17	15.20	15.20	15.44	2	15.44	15.46				15.46	16.04	2									X	1		X	X	
	35	65648	14.00		15.21	15.24	15.24	15.48	2	15.48	15.50				15.50	16.10	2									X	1		X	X	
	36	94327	16.00		15.24	15.26	15.26	15.50	1	15.50	15.52				15.52	16.10	1									X	1		X	X	
	37	65647	14.00		15.33	15.36	15.36	16.00	1	16.00	16.03				16.03	16.20	1									X	1		X	X	
	38	89772	16.70		15.31	15.34	15.34	16.00	2	16.00	16.02				16.02	16.20	2									X	1		X	X	
	39	65645	14.00		15.35	15.37	15.37	16.04	1	16.04	16.06				16.06	16.25	1									X	1		X	X	
	40	70680	16.70		15.37	15.40	15.40	16.02	2	16.02	16.05				16.05	16.21	2									X	1		X	X	
	41	71425	16.70		15.37	15.39	15.39	16.05	2	16.05	16.07				16.07	16.27	2									X	1		X	X	
	42	94335	16.00		15.49	15.52	15.52	16.19	2	16.19	16.20				16.20	16.40	2									X	1		X	X	
	43	43448	14.00		16.00	16.02	16.02	16.24	2	16.24	16.28				16.28	16.46	2									X	1		X	X	
	44	88510	17.03		15.59	16.02	16.02	16.29	1	16.29	16.31				16.31	16.46	1									X	1		X	X	
	45	43447	14.00		16.02	16.04	16.04	16.33	2	16.33	16.35				16.35	16.52	2									X	1		X	X	
	46	94327	16.00		16.10	16.13	16.13	16.39	2	16.39	16.41				16.41	16.59	2									X	1		X	X	
	47	96623	16.70		16.04	16.06	16.06	16.43	2	16.43	16.45				16.45	17.03	2									X	1		X	X	
	48	89772	16.70		16.20	16.23	16.23	16.45	1	16.45	16.46				16.46	17.00	1									X	1		X	X	
21/11/18(12/03/11 E.C)	1	69319	16.00		9.43	9.47	9.47	10.06	2	10.06	10.06				10.06	10.26	2									X	1		X	X	
	2	70680	16.70		9.47	9.50	9.50	10.09	2	10.09	10.09				10.09	10.26	2	10.26	10.28	1						X	1		X	X	
	3	63911	14.00		9.48	9.51	9.51	10.12	2	10.12	10.13				10.13	10.34	1									X	1		X	X	
	4	50241	16.00		9.51	9.54	9.54	10.16	1	10.16	10.17				10.17	10.34	1									X	1		X	X	
	5	68686	14.00		9.54	9.57	9.57	10.19	2	10.19	10.20				10.20	10.37	2									X	1		X	X	
	6	87783	16.70		10.00	10.03	10.03	10.25	2	10.25	10.26				10.26	10.43	2									X	1		X	X	
	7	58941	15.00		10.10	10.12	10.12	10.37	1	10.37	10.37				10.37	10.56	1									X	1		X	X	
	8	89772	16.70		10.15	10.17	10.17	10.34	2	10.34	10.35				10.35	10.52	2									X	1		X	X	
	9	96623	16.70		10.18	10.20	10.20	10.38	2	10.38	10.38				10.38	10.56	2	10.56	10.59	1						X	1		X	X	
	10	69319	16.00		10.26	10.28	10.28	10.50	2	10.50	10.51				10.51	11.09	2									X	1		X	X	
	11	70680	16.70		10.28	10.31	10.31	10.49	1	10.49	10.50				10.50	11.05	1									X	1		X	X	
	12	63911	14.00		10.34	10.36	10.36	10.58	2	10.58	10.59				10.59	11.15	2									X	1		X	X	
	13	50241	16.00		10.34	10.37	10.37	11.01	2	11.01	11.02				11.02	11.16	2	11.16	11.18	1						X	1		X	X	
	14	68686	14.00		10.37	10.39	10.39	11.02	1	11.02	11.03				11.03	11.19	1	11.19	11.20	1						X	1		X	X	
	15	87783	16.70		10.43	10.46	10.46	11.08	1	11.08	11.10				11.10	11.27	1									X	1		X	X	
	16	89772	16.70		10.52	10.55	10.55	11.16	2	11.16	11.17				11.17	11.32	2									X	1		X	X	
	17	58941	15.00		10.56	10.59	10.59	11.18	2	11.18	11.19				11.19	11.36	2									X	1		X	X	
	18	96623	16.70		10.59	11.02	11.02	11.21	1	11.21	11.22				11.22	11.38	1									X	1		X	X	
	19	70680	16.70		11.05	11.07	11.07	11.33	2	11.33	11.34				11.34	11.47	2									X	1		X	X	
	20	69319	16.00		11.09	11.12	11.12	11.32	1	11.32	11.33				11.33	11.51	1									X	1		X	X	
	21	63911	14.00		11.15	11.17	11.17	11.37	2	11.37	11.39				11.39	11.59	1									X	1		X	X	
	22	50241	16.00		11.18	11.20	11.20	11.41	2	11.41	11.42				11.42	11.57	2									X	1		X	X	
	23	68686	14.00		11.20	11.23	11.23	11.44	2	11.44	11.44				11.44	12.02	2									X	1		X	X	
	24	87783	16.70		11.27	11.29	11.29	11.50	1	11.50	11.51				11.51	12.10	1									X	1		X	X	
	25	89772	16.70		11.32	11.36	11.36	11.55	2	11.55	11.56				11.56	12.14	2									X	1		X	X	
	26	58941	15.00		11.36	11.38	11.38	11.57	2	11.57	11.59				11.59	12.20	2									X	1		X	X	
	27	96623	16.70		11.38	11.40	11.40	12.02	1	12.02	12.03				12.03	12.21	1									X	1		X	X	
	28	70680	16.70		11.47	11.49	11.49	12.14	2	12.14	12.14				12.14	12.34	2									X	1		X	X	

Project Name:Kality-Tullu Dimtu Round About Road Project

Project Location: Addis Ababa, Akaki kality Sub-city

Client: Addis Ababa City Administration Road Authority (AACRA)

Consultant: Enginer Zewude

Contractor: IFH Engineering

Su-Contractor Contractor: ASER Construction Plc

Working Time: Morning (7:30-12:30) and Afternoon (13:00-17:30)

Type of Material : Wastage(soil/Rock) [ ] Natural (Gravel /Granullar) soil [X] Crushed Stone (unbound) [ ]

Data No.	Truck Code	Distance (Km)	All Data in Time (t) Minutes									Delivered (M^3)	Queue Length at Quarry (No.)	Queue Length at Site (No.)	Idle time (Min)	Reason	Loading Equipment			Type of Material		Type of work/Task	
			Loading	Hauling	Path	Dumping	Waiting	Returning	Path	Waiting	Total Time						Excavator	Loader	No	NGS	CUS/ Agg.	**Road Way**	**Embankment**
1	15	8	3	43	1	2	0	32	1	4	84	16.7	0	1	0		X		1	X		X	
2	15	8	5	36	1	2	0	32	1	0	75	16.7	0	0	0		X		1	X		X	
3	15	8	4	30	1	2	0	29	1	2	67	16.7	0	1	0		X		1	X		X	
4	15	8	6	31	1	2	0	25	1	0	64	16.7	0	0	0		X		1	X		X	
5	15	8	4	32	1	2	0	34	1	3	75	16.7	0	1	0		X		1	X		X	
6	15	8	4	33	1	2	0	29	1	0	68	16.7	0	0	0		X		1	X		X	
7	7	8	4	36	1	2	0	28	1	0	70	16.7	0	0	0		X		1	X		X	
8	2	8	9	42	1	2	0	26	1	2	81	15.5	0	1	0		X		1	X		X	
9	16	8	7	36	1	2	0	28	1	3	76	16.7	0	1	0		X		1	X		X	
10	6	8	7	35	1	3	0	25	1	4	74	15.8	0	1	0		X		1	X		X	
11	21	8	6	43	1	4	0	23	1	9	85	16.7	0	2	0		X		1	X		X	
12	1	8	5	33	1	3	0	32	1	0	73	15	0	0	0		X		1	X		X	
13	11	8	6	42	1	2	0	31	1	0	81	16.7	0	0	0		X		1	X		X	
14	24	8	5	38	1	1	0	31	1	0	75	16.7	0	0	0		X		1	X		X	
15	4	8	4	28	1	3	0	28	1	0	63	16.7	0	0	0		X		1	X		X	
16	2	8	4	28	1	3	0	29	1	0	64	15.5	0	0	0		X		1	X		X	
17	16	8	5	31	1	3	0	36	1	0	75	16.7	0	0	0		X		1	X		X	
18	6	8	5	41	1	3	0	28	1	0	77	15.8	0	0	0		X		1	X		X	
19	21	8	5	31	1	2	0	30	1	0	68	16.7	0	0	0		X		1	X		X	
20	7	8	9	35	1	1	0	27	1	0	72	16.7	0	0	0		X		1	X		X	
21	11	8	4	26	1	3	0	25	1	0	58	16.7	0	0	0		X		1	X		X	
22	24	8	5	27	1	2	0	32	1	0	66	16.7	0	0	0		X		1	X		X	
23	21	8	4	26	1	1	0	28	1	3	62	16.7	0	1	0		X		1	X		X	
24	6	8	4	33	1	2	0	24	1	9	72	15.8	0	2	0		X		1	X		X	
25	2	8	6	30	1	3	0	26	1	7	72	15.5	0	1	0		X		1	X		X	
26	4	8	7	26	1	2	0	28	1	8	71	16.7	0	2	0		X		1	X		X	
27	16	8	7	37	1	2	0	30	1	0	76	16.7	0	0	0		X		1	X		X	
28	24	8	5	32	1	3	0	30	1	0	70	16.7	0	0	0		X		1	X		X	
29	21	8	6	29	1	1	0	34	1	2	72	16.7	0	1	0		X		1	X		X	
30	6	8	7	32	1	1	0	30	1	0	70	15.8	0	0	0		X		1	X		X	
31	2	8	6	35	1	2	0	37	1	0	80	15.5	0	0	0		X		1	X		X	
32	4	8	4	26	1	1	0	25	1	0	56	16.7	0	0	0		X		1	X		X	
33	16	8	6	41	1	1	0	30	1	0	78	16.7	0	0	0		X		1	X		X	
34	24	8	7	32	1	1	0	29	1	0	69	16.7	0	0	0		X		1	X		X	
35	21	8	5	30	1	2	0	32	1	0	69	16.7	0	0	0		X		1	X		X	
36	21	8.5	6	41	1	1	0	34	1	0	82	16.7	0	0	0		X		1	X		X	
37	7	8.5	5	40	1	3	0	27	1	0	75	16.7	0	0	0		X		1	X		X	
38	16	8.5	5	40	1	2	0	79	1	0	126	16.7	0	0	46	Fuel	X		1	X		X	
39	15	8.5	4	40	1	1	0	31	1	0	76	16.7	0	0	0		X		1	X		X	
40	6	8.5	6	33	1	2	0	69	1	0	110	15.8	0	0	69	Fuel	X		1	X		X	
41	21	8.5	6	38	1	2	0	40	1	3	89	16.7	0	1	0		X		1	X		X	
42	7	8.5	5	30	1	1	0	23	1	0	59	16.7	0	0	0		X		1	X		X	
43	15	8.5	4	37	1	1	0	33	1	0	75	16.7	0	0	0		X		1	X		X	
44	24	8.5	3	38	1	2	0	27	1	0	70	16.7	0	0	0		X		1	X		X	
45	7	8.5	3	36	1	1	0	35	1	0	75	16.7	0	0	0		X		1	X		X	

46	21	8.5	4	28	1	2	0	29	1	2	65	16.7	0	1	0		X		1	X		X	
47	16	8.5	5	38	1	3	0	29	1	0	75	16.7	0	0	0		X		1	X		X	
48	6	8.5	5	32	1	1	0	33	1	0	71	15.8	0	0	0		X		1	X		X	
49	2	8.5	5	37	1	2	0	30	1	0	74	15.5	0	0	0		X		1	X		X	
50	4	8.5	6	31	1	4	0	26	1	0	67	16.7	0	0	0		X		1	X		X	
51	24	8.5	4	40	1	3	0	37	1	0	84	16.7	0	0	0		X		1	X		X	
52	6	8.5	5	41	1	5	0	27	1	0	78	15.8	0	0	0		X		1	X		X	
53	4	8.5	3	40	1	5	0	26	1	0	74	16.7	0	0	0		X		1	X		X	
54	24	8.5	5	39	1	2	0	33	1	0	79	16.7	0	0	0		X		1	X		X	
55	15	8.5	4	29	1	3	0	30	1	0	66	16.7	0	0	0		X		1	X		X	
56	21	8.5	3	37	1	1	0	27	1	0	68	16.7	0	0	0		X		1	X		X	
57	24	8.5	4	26	1	1	0	32	1	0	63	16.7	0	0	0		X		1	X		X	
58	15	8.5	7	26	1	2	0	37	1	0	72	16.7	0	0	0		X		1	X		X	
59	21	8.5	5	32	1	1	0	39	1	0	77	16.7	0	0	0		X		1	X		X	
60	24	8.5	6	28	1	3	0	29	1	0	66	16.7	0	0	0		X		1	X		X	
61	23	8.5	5	34	1	3	0	30	1	0	72	16.7	0	0	0		X		1	X		X	
62	2	8.5	6	30	1	2	0	30	1	2	70	15.5	0	1	0		X		1	X		X	
63	21	8.5	5	31	1	2	0	32	1	0	70	16.7	0	0	0		X		1	X		X	
64	24	8.5	6	32	1	2	0	35	1	0	75	16.7	0	0	0		X		1	X		X	
65	23	8.5	4	34	1	5	0	30	1	0	73	16.7	0	0	0		X		1	X		X	
66	2	8.5	5	35	1	2	0	29	1	1	72	15.5	0	1	0		X		1	X		X	
67	6	8.5	4	40	1	4	0	37	1	0	85	15.8	0	0	0		X		1	X		X	
68	21	8.5	5	23	1	2	0	24	1	0	54	16.7	0	0	0		X		1	X		X	
69	1	8.5	3	37	1	2	0	38	1	0	80	15	0	0	0		X		1	X		X	
70	24	8.5	4	38	1	3	0	30	1	1	76	16.7	0	1	0		X		1	X		X	
71	16	8.5	3	43	1	3	0	37	1	5	91	16.7	0	1	0		X		1	X		X	
72	23	8.5	3	33	1	4	0	26	1	0	66	16.7	0	0	0		X		1	X		X	
73	2	8.5	6	35	1	3	0	28	1	0	72	15.5	0	0	0		X		1	X		X	
74	21	8.5	3	30	1	1	0	35	1	0	69	16.7	0	0	0		X		1	X		X	
75	6	8.5	5	45	1	5	0	24	1	0	79	15.8	0	0	0		X		1	X		X	
76	1	8.5	5	39	1	4	0	31	1	0	79	15	0	0	0		X		1	X		X	
77	7	8.5	5	42	1	2	0	25	1	0	74	16.7	0	0	0		X		1	X		X	
78	24	8.5	3	31	1	3	0	37	1	0	74	16.7	0	0	0		X		1	X		X	
79	2	8.5	4	23	1	4	0	25	1	0	56	15.5	0	0	0		X		1	X		X	
80	21	8.5	6	41	1	2	0	38	1	0	87	16.7	0	0	0		X		1	X		X	
81	23	7.5	6	26	1	3	0	29	1	0	64	16.7	0	0	0		X		1	X		X	
82	24	7.5	7	31	1	1	0	24	1	0	63	16.7	0	0	0		X		1	X		X	
83	21	7.5	3	29	1	3	0	29	1	0	64	16.7	0	0	0		X		1	X		X	
84	2	7.5	8	28	1	2	0	34	1	0	72	15.5	0	0	0		X		1	X		X	
85	7	7.5	6	39	1	2	0	26	1	0	73	16.7	0	0	0		X		1	X		X	
86	1	7.5	9	34	1	4	0	30	1	0	77	15	0	0	0		X		1	X		X	
87	23	7.5	5	26	1	3	0	27	1	0	61	16.7	0	0	0		X		1	X		X	
88	24	7.5	8	34	1	2	0	34	1	0	78	16.7	0	0	0		X		1	X		X	
89	21	7.5	5	27	1	3	0	19	1	0	54	16.7	0	0	0		X		1	X		X	
90	2	7.5	4	31	1	2	0	32	1	0	69	15.5	0	0	0		X		1	X		X	
91	16	7.5	8	33	1	2	0	26	1	0	69	16.7	0	0	0		X		1	X		X	
92	23	7.5	6	36	1	3	0	24	1	4	73	16.7	0	1	0		X		1	X		X	
93	21	7.5	5	25	1	3	0	27	1	0	60	16.7	0	0	0		X		1	X		X	
94	24	7.5	4	38	1	2	0	26	1	0	70	16.7	0	0	0		X		1	X		X	
95	2	7.5	4	31	1	2	0	36	1	0	73	15.5	0	0	0		X		1	X		X	
96	16	7.5	8	28	1	2	0	30	1	0	68	16.7	0	0	0		X		1	X		X	
97	21	7.5	7	31	1	5	0	42	1	0	85	16.7	0	0	0		X		1	X		X	
98	23	7.5	6	25	1	2	0	32	1	0	65	16.7	0	0	0		X		1	X		X	
99	2	7.5	7	36	1	1	0	27	1	0	71	15.5	0	0	0		X		1	X		X	
100	24	7.5	6	40	1	1	0	28	1	0	75	16.7	0	0	0		X		1	X		X	
101	6	7.5	6	33	1	3	0	23	1	0	65	15.8	0	0	0		X		1	X		X	
102	23	7.5	7	33	1	3	0	26	1	0	69	16.7	0	0	0		X		1	X		X	

103	5	7.5	6	38	1	5	0	26	1	5	80	16.2	0	1	0		X		1	X		X	
104	16	7.5	8	31	1	2	0	25	1	0	66	16.7	0	0	0		X		1	X		X	
105	21	7.5	4	31	1	2	0	30	1	0	67	16.7	0	0	0		X		1	X		X	
106	2	7.5	5	30	1	2	0	36	1	0	73	15.5	0	0	0		X		1	X		X	
107	6	7.5	4	58	1	2	0	28	1	0	92	15.8	0	0	0		X		1	X		X	
108	24	7.5	7	44	1	3	0	26	1	0	80	16.7	0	0	0		X		1	X		X	
109	23	7.5	8	47	1	3	0	23	1	4	85	16.7	0	1	0		X		1	X		X	
110	16	7.5	7	39	1	2	0	24	1	5	77	16.7	0	1	0		X		1	X		X	
111	5	7.5	5	29	1	2	0	29	1	0	65	16.2	0	0	0		X		1	X		X	
112	21	7.5	5	21	1	4	0	24	1	0	54	16.7	0	0	0		X		1	X		X	
113	2	7.5	5	44	1	2	0	25	1	0	76	15.5	0	0	0		X		1	X		X	
114	1	7.5	6	32	1	2	0	29	1	0	69	15	0	0	0		X		1	X		X	
115	24	7.5	8	27	1	3	0	24	1	0	62	16.7	0	0	0		X		1	X		X	
116	6	7.5	4	41	1	1	0	26	1	0	72	15.8	0	0	0		X		1	X		X	
117	23	7.5	4	45	1	2	0	35	1	0	86	16.7	0	0	0		X		1	X		X	
118	21	7.5	6	30	1	1	0	20	1	0	57	16.7	0	0	0		X		1	X		X	
119	5	7.5	5	37	1	2	0	25	1	0	69	16.2	0	0	0		X		1	X		X	
120	16	7.5	6	33	1	1	0	28	1	0	68	16.7	0	0	0		X		1	X		X	
121	7	7.5	5	34	1	2	0	30	1	0	71	16.7	0	0	0		X		1	X		X	
122	2	7.5	3	37	1	1	0	31	1	0	72	15.5	0	0	0		X		1	X		X	
123	24	7.5	5	38	1	2	0	27	1	0	72	16.7	0	0	0		X		1	X		X	
124	21	7.5	5	28	1	3	0	27	1	0	63	16.7	0	0	0		X		1	X		X	
125	6	8.5	4	46	1	2	0	36	1	0	88	15.8	0	0	0		X		1	X		X	
126	16	8.5	5	37	1	2	0	29	1	2	75	16.7	0	1	0		X		1	X		X	
127	21	8.5	7	34	1	2	0	28	1	3	74	16.7	0	1	0		X		1	X		X	
128	24	8.5	6	37	1	2	0	26	1	7	78	16.7	0	2	0		X		1	X		X	
129	2	8.5	5	43	1	2	0	29	1	0	79	15.5	0	0	0		X		1	X		X	
130	5	8.5	5	42	1	3	0	26	1	0	76	16.2	0	0	0		X		1	X		X	
131	23	8.5	5	38	1	1	0	29	1	0	73	16.7	0	0	0		X		1	X		X	
132	16	8.5	8	49	1	2	0	52	1	0	111	16.7	0	0	0		X		1	X		X	
133	6	8.5	5	45	1	1	0	35	1	0	86	15.8	0	0	0		X		1	X		X	
134	11	8.5	5	39	1	2	0	30	1	0	76	16.7	0	0	0		X		1	X		X	
135	21	8.5	6	34	1	2	0	24	1	6	72	16.7	0	1	0		X		1	X		X	
136	15	8.5	4	45	1	1	0	30	1	0	80	16.7	0	0	0		X		1	X		X	
137	24	8.5	6	52	1	1	0	33	1	0	92	16.7	0	0	0		X		1	X		X	
138	2	8.5	5	62	1	2	0	28	1	0	97	15.5	0	0	0		X		1	X		X	
139	23	8.5	5	37	1	3	0	24	1	0	69	16.7	0	0	0		X		1	X		X	
140	6	8.5	5	42	1	3	0	38	1	0	88	15.8	0	0	0		X		1	X		X	
141	21	8.5	4	41	1	1	0	23	1	0	69	16.7	0	0	0		X		1	X		X	
142	11	8.5	10	29	1	1	0	30	1	0	70	16.7	0	0	0		X		1	X		X	
143	15	8.5	4	28	1	2	0	26	1	0	60	16.7	0	0	0		X		1	X		X	
144	16	8.5	4	33	1	4	0	24	1	0	65	16.7	0	0	0		X		1	X		X	
145	24	8.5	5	29	1	3	0	22	1	0	59	16.7	0	0	0		X		1	X		X	
146	11	8.5	5	34	1	1	0	29	1	0	69	16.7	0	0	0		X		1	X		X	
147	23	8.5	5	41	1	2	0	31	1	0	79	16.7	0	0	0		X		1	X		X	
148	5	8.5	4	39	1	3	0	24	1	0	70	16.2	0	0	0		X		1	X		X	
149	16	11	5	38	1	3	0	37	1	0	83	16.7	0	0	0		X		1	X		X	
150	6	11	4	46	1	1	0	45	1	0	96	15.8	0	0	0		X		1	X		X	
151	5	11	5	31	1	2	0	39	1	1	78	16.2	0	1	0		X		1	X		X	
152	23	11	4	33	1	1	0	45	1	4	87	16.7	0	1	0		X		1	X		X	
153	1	11	5	43	1	2	0	65	1	10	125	15	0	2	0		X		1	X		X	
154	22	11	5	38	1	12	0	46	1	8	109	16.4	0	2	0		X		1	X		X	
155	11	11	4	38	1	3	0	38	1	0	83	16.7	0	0	0		X		1	X		X	
156	24	11	4	46	1	2	0	27	1	4	83	16.7	0	1	0		X		1	X		X	
157	15	11	4	34	1	2	0	42	1	2	84	16.7	0	1	0		X		1	X		X	
158	21	11	5	36	1	2	0	34	1	4	81	16.7	0	1	0		X		1	X		X	
159	17	11	4	50	1	1	0	41	1	0	96	16.1	0	0	0		X		1	X		X	

160	10	11	4	47	1	1	0	41	1	4	97	15.8	0	1	0		X		1	X		X	
161	19	11	4	46	1	3	0	37	1	6	96	16.7	0	2	0		X		1	X		X	
162	16	11	6	51	1	1	0	34	1	0	92	16.7	0	0	0		X		1	X		X	
163	7	11	5	39	1	1	0	42	1	3	90	16.7	0	1	0		X		1	X		X	
164	5	11	5	43	1	2	0	27	1	13	90	16.2	0	2	0		X		1	X		X	
165	6	11	4	42	1	1	0	25	1	9	81	15.8	0	2	0		X		1	X		X	
166	23	11	6	44	1	1	0	28	1	4	83	16.7	0	1	0		X		1	X		X	
167	11	11	5	44	1	1	0	30	1	6	86	16.7	0	1	0		X		1	X		X	
168	24	11	4	35	1	2	0	32	1	2	75	16.7	0	1	0		X		1	X		X	
169	22	11	4	32	1	2	0	32	1	10	80	16.4	0	2	0		X		1	X		X	
170	15	11	4	35	1	1	0	34	1	1	75	16.7	0	1	0		X		1	X		X	
171	9	8.5	5	36	1	3	0	37	1	0	81	15.8	0	0	0		X		1	X		X	
172	5	8.5	4	40	1	2	0	35	1	9	90	16.2	0	3	0		X		1	X		X	
173	14	8.5	5	37	1	2	0	28	1	4	76	16.7	0	1	0		X		1	X		X	
174	16	8.5	4	36	1	2	0	28	1	7	77	16.7	0	2	0		X		1	X		X	
175	23	8.5	5	33	1	2	0	30	1	16	86	16.7	0	4	0		X		1	X		X	
176	21	8.5	5	28	1	1	0	28	1	13	75	16.7	0	3	0		X		1	X		X	
177	7	8.5	6	29	1	2	0	31	1	17	85	16.7	0	4	0		X		1	X		X	
178	19	8.5	4	34	1	2	0	38	1	0	78	16.7	0	0	0		X		1	X		X	
179	22	8.5	6	37	1	3	0	34	1	14	94	16.4	0	3	0		X		1	X		X	
180	6	8.5	5	35	1	2	0	33	1	0	75	15.8	0	0	0		X		1	X		X	
181	8	8.5	3	33	1	2	0	27	1	13	78	16	0	3	0		X		1	X		X	
182	10	8.5	5	37	1	2	0	27	1	0	71	15.8	0	0	0		X		1	X		X	
183	15	8.5	5	40	1	1	0	27	1	0	73	16.7	0	0	0		X		1	X		X	
184	24	8.5	4	41	1	2	0	20	1	0	67	16.7	0	0	0		X		1	X		X	
185	17	8.5	4	34	1	2	0	28	1	0	68	16.1	0	0	0		X		1	X		X	
186	9	8.5	4	29	1	4	2	84	1	0	123	15.8	1	0	0		X		1	X		X	
187	3	8.5	5	39	1	3	0	35	1	0	82	16.1	0	0	0		X		1	X		X	
188	14	8.5	6	34	1	3	0	23	1	0	66	16.7	0	0	0		X		1	X		X	
189	16	8.5	4	34	1	3	0	32	1	0	73	16.7	0	0	0		X		1	X		X	
190	5	8.5	5	32	1	4	0	34	1	0	75	16.2	0	0	0		X		1	X		X	
191	21	8.5	4	30	1	2	0	38	1	0	74	16.7	0	0	0		X		1	X		X	
192	23	8.5	6	32	1	1	0	26	1	0	65	16.7	0	0	0		X		1	X		X	
193	1	8.5	3	38	1	1	0	31	1	0	73	15	0	0	0		X		1	X		X	
194	7	8.5	5	39	1	2	0	30	1	0	76	16.7	0	0	0		X		1	X		X	
195	11	8.5	9	38	1	1	0	36	1	0	84	16.7	0	0	0		X		1	X		X	
196	8	8.5	5	34	1	4	0	32	1	0	75	16	0	0	0		X		1	X		X	
197	22	8.5	6	32	1	3	0	25	1	0	66	16.4	0	0	0		X		1	X		X	
198	24	8.5	5	34	1	3	0	29	1	6	77	16.7	0	1	0		X		1	X			X
199	2	8.5	6	35	1	4	0	26	1	5	76	15.5	0	1	0		X		1	X			X
200	9	8.5	5	35	1	3	0	50	1	0	93	15.8	0	0	0		X		1	X			X
201	16	8.5	5	33	1	2	0	39	1	0	79	16.7	0	0	11	fuel	X		1	X			X
202	11	8.5	4	32	1	2	0	50	1	0	88	16.7	0	0	22	fuel	X		1	X			X
203	22	8.5	6	33	1	3	0	61	1	0	103	16.4	0	0	25	fuel	X		1	X			X
204	13	8.5	5	30	1	4	0	39	1	4	82	16.1	0	1	0		X		1	X			X
205	17	8.5	4	34	1	3	0	31	1	1	73	16.1	0	1	0		X		1	X			X
206	10	8.5	5	42	1	2	0	25	1	0	74	15.8	0	0	0		X		1	X			X
207	19	8.5	5	28	1	3	0	29	1	0	65	16.7	0	0	0		X		1	X			X
208	5	8.5	6	36	1	4	3	35	1	0	84	16.7	1	0	0		X		1	X			X
209	7	8.5	4	31	1	4	0	31	1	3	73	15.8	0	1	0		X		1	X			X
210	15	8.5	6	32	1	3	0	31	1	0	72	15.5	0	0	0		X		1	X			X
211	24	8.5	4	32	1	4	0	25	1	1	66	16.7	0	2	0		X		1	X			X
212	2	8.5	5	31	1	4	0	36	1	0	76	15.5	0	0	0		X		1	X			X
213	16	8.5	5	32	1	4	0	26	1	0	67	16.7	0	0	0		X		1	X			X
214	9	8.5	5	45	1	2	0	29	1	0	81	15.8	0	0	0		X		1	X			X
215	11	8.5	5	36	1	3	0	37	1	0	81	16.7	0	0	0		X		1	X			X
216	17	8.5	4	40	1	3	0	38	1	3	88	16.7	0	1	0		X		1	X			X

217	12	8.5	4	41	1	4	0	29	1	0	78	16.7	0	0	0		X		1	X			X
218	22	8.5	5	35	1	2	0	39	1	0	81	16.7	0	0	0		X		1	X			X
219	7	8.5	4	32	1	3	0	38	1	3	80	15.8	0	1	0				1	X			X
220	24	8.5	4	31	1	3	0	29	1	3	70	16.7	0	1	0		X		1	X			X
221	2	8	6	34	1	2	0	31	1	6	79	15.5	0	1	0		X		1	X			X
222	24	8	5	31	1	1	0	24	1	7	68	16.7	0	2	0		X		1	X			X
223	6	8	4	38	1	1	0	38	1	0	81	15.8	0	0	0		X		1	X			X
224	11	8	5	35	1	2	0	36	1	4	82	16.7	0	1	0		X		1	X			X
225	9	8	7	35	1	3	0	35	1	6	86	15.8	0	2	0		X		1	X			X
226	22	8	5	31	1	6	2	28	1	2	74	16.4	1	1	0		X		1	X			X
227	23	8	5	29	1	3	5	27	1	10	79	16.7	1	2	0		X		1	X			X
228	12	8	5	90	1	5	2	30	1	9	141	16.4	1	2	0		X		1	X			X
229	10	8.5	5	56	1	2	0	33	1	0	96	15.8	0	0	0		X		1	X		X	
230	15	8.5	4	28	1	2	0	28	1	1	63	16.7	0	1	0		X		1	X		X	
231	16	8.5	4	41	1	2	0	27	1	5	79	16.7	0	1	0		X		1	X		X	
232	24	8.5	5	31	1	1	0	27	1	0	64	16.7	0	0	0		X		1	X		X	
233	2	8.5	5	30	1	2	0	26	1	8	71	15.5	0	1	0		X		1	X		X	
234	6	8.5	5	27	1	3	0	30	1	0	65	15.8	0	0	0		X		1	X		X	
235	11	8.5	4	35	1	3	0	31	1	0	73	16.7	0	0	0		X		1	X		X	
236	22	8.5	5	36	1	3	0	36	1	0	80	16.4	0	0	0		X		1	X		X	
237	9	8.5	5	30	1	3	0	32	1	1	71	15.8	0	1	0		X		1	X		X	
238	23	8.5	7	32	1	2	0	35	1	0	76	16.7	0	0	0		X		1	X		X	
239	12	8.5	5	39	1	1	0	32	1	3	80	16.4	0	1	0		X		1	X		X	
240	7	8.5	4	39	1	3	0	29	1	0	75	16.7	0	0	0		X		1	X		X	
241	15	8.5	5	29	1	2	0	31	1	0	67	16.7	0	0	0		X		1	X		X	
242	24	8.5	9	28	1	2	0	26	1	0	65	16.7	0	0	0		X		1	X		X	
243	16	8.5	4	35	1	4	0	29	1	0	72	16.7	0	0	0		X		1	X		X	
244	2	8.5	4	34	1	2	0	32	1	0	72	15.5	0	0	0		X		1	X		X	
245	6	8.5	4	38	1	3	0	38	1	0	83	15.8	0	0	0		X		1	X		X	
246	11	8.5	7	26	1	2	0	37	1	0	72	16.7	0	0	0		X		1	X		X	
247	9	8.5	4	31	1	2	0	27	1	0	64	15.8	0	0	0		X		1	X		X	
248	22	8.5	5	38	1	1	0	30	1	0	74	16.4	0	0	0		X		1	X		X	
249	23	8.5	5	33	1	3	0	28	1	0	69	16.7	0	0	0		X		1	X		X	
250	22	8	4	38	1	2	0	31	1	0	75	16.4	0	0	0		X		1	X		X	
251	23	8	5	34	1	2	0	32	1	0	73	16.7	0	0	0		X		1	X		X	
252	6	8	7	31	1	2	0	38	1	0	78	15.8	0	0	0		X		1	X		X	
253	11	8	8	29	1	2	0	33	1	0	72	16.7	0	0	0		X		1	X		X	
254	12	8	6	32	1	2	0	33	1	0	73	16.4	0	0	0		X		1	X		X	
255	7	8	6	31	1	2	0	36	1	0	75	16.7	0	0	0		X		1	X		X	
256	2	8	7	37	1	2	0	31	1	0	77	15.5	0	0	0		X		1	X		X	
257	10	8	7	30	1	2	0	26	1	0	65	15.8	0	0	0		X		1	X		X	
258	9	8	5	28	1	2	0	27	1	0	62	15.8	0	0	0		X		1	X		X	
259	24	8	5	27	1	1	0	76	1	0	109	16.7	0	0	0		X		1	X		X	
260	15	8	3	25	1	1	0	24	1	6	59	16.7	0	1	0		X		1	X		X	
261	22	8	6	36	1	1	0	37	1	0	80	16.4	0	0	0		X		1	X		X	
262	23	8.5	7	38	1	3	0	29	1	2	79	16.7	0	1	0		X		1	X		X	
263	11	8.5	6	33	1	2	0	33	1	4	78	16.7	0	1	0		X		1	X		X	
264	6	8	5	47	1	2	0	27	1	0	81	15.8	0	0	0		X		1	X		X	
265	12	8.5	5	39	1	5	0	31	1	16	96	16.4	0	3	0		X		1	X		X	
266	7	8.5	5	34	1	2	0	32	1	3	76	16.7	0	1	0		X		1	X		X	
267	2	8	4	31	1	3	0	25	1	10	73	15.5	0	2	0		X		1	X			X
268	10	8	6	35	1	2	0	31	1	9	83	15.8	0	2	0		X		1	X			X
269	15	8	5	26	1	1	0	25	1	14	71	16.7	0	3	0		X		1	X			X
270	9	8	5	26	1	4	0	35	1	0	70	15.8	0	0	0		X		1	X			X
271	22	8	5	48	1	2	0	30	1	0	85	16.4	0	0	0		X		1	X		X	
272	23	8	6	33	1	2	0	17	1	0	58	16.7	0	0	0		X		1	X			X
273	11	8	6	26	1	2	0	28	1	0	62	16.7	0	0	0		X		1	X			X

275	2	8	4	35	1	1	0	26	1	2	68	15.5	0	1	0		X		1	X		X	
276	6	8	7	30	1	1	0	30	1	2	70	15.8	0	1	0		X		1	X		X	
277	11	8	6	32	1	2	0	28	1	8	76	16.7	0	2	0		X		1	X		X	
278	23	8	6	28	1	3	0	36	1	0	73	16.7	0	0	0		X		1	X		X	
279	5	8	6	34	1	2	3	31	1	0	76	16.2	1	0	0		X		1	X		X	
280	1	8	5	28	1	2	0	34	1	0	69	15	0	0	0		X		1	X		X	
281	12	8	7	28	1	3	0	33	1	0	71	16.4	0	0	0		X		1	X		X	
282	16	8	6	36	1	3	0	49	1	1	95	16.7	0	1	0		X		1	X		X	
283	10	8	7	40	1	2	0	33	1	0	82	15.8	0	0	0		X		1	X		X	
284	24	8	7	33	1	1	0	29	1	0	70	16.7	0	0	0		X		1	X		X	
285	2	8	6	32	1	3	0	32	1	2	75	15.5	0	1	0		X		1	X		X	
286	6	8	4	33	1	2	0	41	1	9	89	15.8	0	2	0		X		1	X		X	
287	9	8	7	37	1	1	0	29	1	0	74	15.8	0	0	0		X		1	X		X	
288	15	8	11	26	1	2	0	29	1	5	73	16.7	0	1	0		X		1	X		X	
289	22	8	5	43	1	2	0	34	1	5	89	16.4	0	1	0		X		1	X		X	
290	11	8	6	40	1	2	0	29	1	0	77	16.7	0	0	0		X		1	X		X	
291	5	8	8	36	1	3	0	44	1	10	101	16.2	0	3	0		X		1	X		X	
292	12	8	4	40	1	3	0	30	1	7	84	16.4	0	2	0		X		1	X		X	
293	16	8	7	36	1	2	0	26	1	4	75	16.7	0	1	0		X		1	X		X	
294	24	8	4	30	1	1	0	25	1	1	61	16.7	0	1	0		X		1	X		X	
295	10	8	7	40	1	2	0	36	1	0	85	15.8	0	0	0		X		1	X		X	
296	2	8	9	34	1	1	0	29	1	0	73	15.5	0	0	0		X		1	X		X	
297	9	8	6	29	1	4	0	30	1	6	75	15.8	0	1	0		X		1	X		X	
298	15	8	5	26	1	2	0	27	1	0	60	16.7	0	0	0		X		1	X		X	
299	6	8	7	32	1	2	0	28	1	0	69	15.8	0	0	33	test	X		1	X		X	
300	11	8	7	33	1	2	0	27	1	0	69	16.7	0	0	0		X		1	X		X	
301	22	8	7	36	1	2	0	28	1	0	73	16.4	0	0	0		X		1	X		X	
302	24	8	6	29	1	2	0	30	1	0	67	16.7	0	0	0		X		1	X		X	
303	16	8	5	33	1	2	0	35	1	0	75	16.7	0	0	0		X		1	X		X	
304	12	8	5	31	1	2	0	30	1	0	68	16.4	0	0	0		X		1	X		X	
305	5	8	6	29	1	1	0	26	1	0	62	16.2	0	0	0		X		1	X		X	
306	7	8	5	32	1	2	0	24	1	0	63	16.7	0	0	0		X		1	X			X
307	11	8	6	33	1	1	0	33	1	0	73	16.7	0	0	0		X		1	X			X
308	15	8	5	32	1	2	0	20	1	0	59	16.7	0	0	0		X		1	X			X
309	20	8	6	35	1	2	0	33	1	0	76	16.4	0	0	0		X		1	X			X
310	24	8	5	33	1	1	0	27	1	0	66	16.7	0	0	0		X		1	X			X
311	6	8	7	31	1	2	0	60	1	5	105	15.8	0	1	32	tyre	X		1	X			X
312	16	8	6	33	1	2	0	38	1	2	81	16.7	0	1	0		X		1	X			X
313	7	7.5	6	32	1	1	0	28	1	6	73	16.7	0	2	0		X		1	X		X	
314	15	7.5	6	28	1	2	0	35	1	7	78	16.7	0	2	0		X		1	X		X	
315	11	7.5	5	33	1	1	0	30	1	7	76	16.7	0	2	0		X		1	X		X	
316	18	8	5	34	1	1	0	36	1	0	76	16.4	0	0	0		X		1	X		X	
317	24	7.5	4	35	1	1	0	27	1	8	75	16.7	0	1	0		X		1	X		X	
318	20	8	6	33	1	1	0	36	1	1	77	16.4	0	1	0		X		1	X		X	
319	23	7.5	5	37	1	2	0	23	1	2	69	16.7	0	1	0		X		1	X		X	
320	12	7.5	6	44	1	2	0	28	1	2	82	16.4	0	1	0		X		1	X		X	
321	16	7.5	5	35	1	1	0	23	1	0	64	16.7	0	0	0		X		1	X		X	
322	7	7.5	6	32	1	1	0	27	1	0	66	16.7	0	0	0		X		1	X		X	
323	6	7.5	6	30	1	1	0	37	1	0	74	15.8	0	0	0		X		1	X		X	
324	15	7.5	6	32	1	2	0	33	1	0	73	16.7	0	0	0		X		1	X		X	
325	11	7.5	6	34	1	2	0	30	1	0	72	16.7	0	0	0		X		1	X		X	
326	18	7.5	12	32	1	1	0	37	1	0	82	16.4	0	0	0		X		1	X		X	
327	24	7.5	6	37	1	2	0	32	1	0	77	16.7	0	0	0		X		1	X		X	
328	20	7.5	6	38	1	2	0	25	1	0	71	16.4	0	0	0		X		1	X		X	
329	23	7.5	5	31	1	1	0	24	1	0	61	16.7	0	0	0		X		1	X		X	
330	16	7.5	6	31	1	2	0	27	1	0	66	16.7	0	0	0		X		1	X		X	
331	7	7.5	5	30	1	2	0	33	1	0	70	16.7	0	0	0		X		1	X		X	

332	24	8.5	7	30	1	2	0	30	1	0	69	16.7	0	0	0		X		1	X			X
333	15	8.5	5	35	1	2	0	36	1	0	78	16.7	0	0	0		X		1	X			X
334	23	8.5	5	45	1	4	7	36	1	1	98	16.7	1	1	0		X		1	X			X
335	12	8.5	5	40	1	6	0	36	1	0	87	16.4	0	0	0		X		1	X			X
336	16	8.5	5	39	1	2	7	34	1	1	88	16.7	1	1	0		X		1	X			X
337	6	8.5	8	47	1	4	0	48	1	0	107	15.8	0	0	0		X		1	X			X
338	20	8.5	6	66	1	5	0	33	1	3	113	16.4	0	1	9	dozer work	X		1	X			X
339	24	8.5	5	37	1	3	0	31	1	7	83	16.7	0	1	0		X		1	X			X
340	15	8.5	6	28	1	2	0	96	1	2	134	16.7	0	1	0		X		1	X			X
341	12	8.5	6	37	1	4	0	54	1	5	106	16.4	0	1	13	due to oper	X		1	X			X
342	23	8.5	6	43	1	8	0	37	1	0	94	16.7	0	0	0		X		1	X			X
343	16	8.5	7	41	1	2	4	39	1	0	93	16.7	1	0	12	fuel	X		1	X			X
344	20	8.5	8	41	1	5	4	32	1	0	90	16.4	1	0	0		X		1	X			X
345	24	8.5	5	39	1	3	8	33	1	0	88	16.7	1	0	0		X		1	X			X

Project Name:Kality-Tullu Dimtu Round About Road Project
Consultant: Enginer Zewude
Project Location: Addis Ababa, Akaki kality Sub-city
Contractor: IFH Engineering
Client: Addis Ababa City Administration Road Authority (AACRA)
Su-Contractor Contractor: ASER Construction Plc
Working Time: Morning (7:30-12:30) and Afternoon (13:00-17:30)

Type of Material : Wastage(soil/Rock) [ ] Natural (Gravel /Granullar) soil [ ] Crushed Stone (unbound) [X]

Data No.	Truck Code	Distance (Km)	All Data in Time (t) Minutes									Delivered (M^3)	Queue Length at Quarry (No.)	Queue Length at Site (No.)	Idle time (Min)	Reason	Loading Equipment			Type of Material		Type of work/Task	
			Loading	Hauling	Path	Dumping	Waiting	Returning	Path	Waiting	Total Time						Excavator	Loader	No	NGS	CUS/ Agg.	**Road Way**	**Embankment**
1	37		3	23	2	1.92	0	21	1	0	48.92	17.03	0	0	0			X	1		X	X	
2	16		4	20	1	1.75	0	20	2	0	45.75	16.7	0	0	0			X	1		X	X	
3	16		2	22	1	1.67	0	21	2	1	47.67	16.7	1	0	0			X	1		X	X	
4	39		2	21	2	1.5	0	21	2	0	45.5	16	0	0	0			X	1		X	X	
5	26		2	23	2	2.83	0	19	1	0	46.83	14	0	0	0			X	1		X	X	
6	37		3	24	1	3.22	0	17	2	0	47.22	17.03	0	0	0			X	1		X	X	
7	25		2	21	1	1.77	0	21	1	0	45.77	14	0	0	0			X	1		X	X	
8	33		2	24	2	1.43	0	22	2	0	49.43	14	0	0	0			X	1		X	X	
9	31		2	24	2	1	0	24	2	2	53	14	1	0	0			X	1		X	X	
10	40		2	22	2	2	0	17	1	3	46	16.7	1	0	0			X	1		X	X	
11	24		2	21	2	1.23	0	21	2	3	48.23	16.7	1	0	0			X	1		X	X	
12	35		3	23	2	2.37	0	34	1	0	62.37	16.7	0	0	0			X	1		X	X	
13	32		2	20	1	4	0	15	2	4	45	14	1	0	0			X	1		X	X	
14	27		2	36	1	2.18	0	20	2	0	60.18	16	0	0	0			X	1		X	X	
15	15		2	25	2	2.6	0	17	1	0	46.6	16.7	0	0	0			X	1		X	X	
16	16		1	31	1	1.37	0	18	2	0	51.37	16.7	0	0	0			X	1		X	X	
17	39		3	30	2	3.18	0	18	1	0	54.18	16	0	0	0			X	1		X	X	
18	26		2	26	2	4.57	0	17	2	0	49.57	14	0	0	0			X	1		X	X	
19	37		3	25	2	1.45	0	17	1	4	50.45	17.03	1	0	0			X	1		X	X	
20	25		2	24	2	2.33	0	19	2	3	50.33	14	1	0	0			X	1		X	X	
21	33		3	24	2	3.33	0	21	2	0	51.33	14	0	0	0			X	1		X	X	
22	38		3	28	2	2.22	0	18	1	0	51.22	16	0	0	0			X	1		X	X	
23	40		3	19	2	1.67	0	18	2	0	41.67	16.7	0	0	0			X	1		X	X	
24	31		3	27	2	1.45	0	26	2	0	57.45	14	0	0	0			X	1		X	X	
25	24		4	20	2	1.57	0	22	1	0	47.57	16.7	0	0	0			X	1		X	X	
26	32		2	21	2	1.7	0	20	1	1	45.7	14	1	0	0			X	1		X	X	

27	15		4	19	2	1.48	0	19	2	0	43.48	16.7	0	0	0			X	1		X	X	
28	16		4	19	2	1.62	0	15	1	0	39.62	16.7	0	0	0			X	1		X	X	
29	35		3	23	2	2.16	0	50	2	0	78.16	16.7	0	0	0			X	1		X	X	
30	39		3	22	1	1.55	0	19	2	0	45.55	16	0	0	0			X	1		X	X	
31	26		4	25	1	3.16	0	22	1	0	54.16	14	0	0	0			X	1		X	X	
32	37		3	25	2	2.42	0	19	1	0	49.42	17.03	0	0	0			X	1		X	X	
33	25		3	24	2	2.87	0	19	2	0	48.87	14	0	0	0			X	1		X	X	
34	40		3	24	2	2	0	18	2	0	47	16.7	0	0	0			X	1		X	X	
35	33		3	24	1	2	0	20	2	0	49	14	0	0	0			X	1		X	X	
36	38		2	24	2	2.33	0	18	1	0	46.33	16	0	0	0			X	1		X	X	
37	32		3	24	2	3.23	0	17	1	0	47.23	14	0	0	0			X	1		X	X	
38	24		3	26	2	2.3	0	18	2	0	49.3	16.7	0	0	0			X	1		X	X	
39	31		2	27	1	2.17	0	19	1	0	50.17	14	0	0	0			X	1		X	X	
40	15		3	22	2	3	0	16	2	0	44	16.7	0	0	0			X	1		X	X	
41	16		2	26	2	2	0	20	2	0	50	16.7	0	0	0			X	1		X	X	
42	39		3	27	2	1.85	0	19	2	0	50.85	16	0	0	0			X	1		X	X	
43	26		2	22	1	4.4	0	18	2	0	46.4	14	0	0	0			X	1		X	X	
44	37		3	27	2	2.17	0	15	1	0	47.17	17.03	0	0	0			X	1		X	X	
45	25		2	29	2	2.42	0	17	2	0	50.42	14	0	0	0			X	1		X	X	
46	38		3	26	1	2.32	0	18	2	0	49.32	16	0	0	0			X	1		X	X	
47	40		2	37	2	2.25	0	18	2	0	59.25	16.7	0	0	0			X	1		X	X	
48	24		3	22	1	1.6	0	13	1	0	39.6	16.7	0	0	0			X	1		X	X	
49	34		4	18	2	1.32	0	20	2	0	43.32	16	0	0	0			X	1		X	X	
50	15		3	19	1	1	0	16	2	2	41	16.7	1	0	0			X	1		X	X	
51	30		3	21	2	1.43	0	21	2	0	46.43	14	0	0	0			X	1		X	X	
52	28		3	22	2	1.75	0	16	1	0	42.75	16	0	0	0			X	1		X	X	
53	14		3	22	1	1.63	0	16	2	0	42.63	14	0	0	0			X	1		X	X	
54	36		3	22	1	1.67	0	16	2	0	42.67	16.7	0	0	0			X	1		X	X	
55	29		2	24	2	1.48	0	19	1	0	46.48	15	0	0	0			X	1		X	X	
56	24		2	17	1	1.82	0	17	2	0	37.82	16.7	0	0	0			X	1		X	X	
57	40		2	18	2	1	0	17	2	3	41	16.7	1	0	0			X	1		X	X	
58	34		2	22	1	1.55	0	17	2	0	42.55	16	0	0	0			X	1		X	X	
59	15		3	18	1	1.33	0	15	1	0	37.33	16.7	0	0	0			X	1		X	X	
60	30		2	22	2	1.47	0	16	2	0	41.47	14	0	0	0			X	1		X	X	
61	28		3	24	2	1.57	0	13	2	2	43.57	16	1	0	0			X	1		X	X	
62	14		2	23	2	1.37	0	16	1	1	43.37	14	1	0	0			X	1		X	X	
63	36		3	22	2	2.75	0	16	1	0	43.75	16.7	0	0	0			X	1		X	X	
64	24		2.75	20.47	1	1.55	0	14	2	0	38.77	16.7	0	0	0			X	1		X	X	
65	29		3	19	1	1.6	0	16	2	0	39.6	15	0	0	0			X	1		X	X	
66	40		3	19	1	1.7	0	15	1	0	38.7	16.7	0	0	0			X	1		X	X	
67	15		2	26	2	1.33	0	13	2	0	42.33	16.7	0	0	0			X	1		X	X	
68	34		3.25	19.75	2	1.37	0	18	1	0	42.37	16	0	0	0			X	1		X	X	
69	30		2.72	19.28	2	3	0	19	2	0	44	14	0	0	0			X	1		X	X	
70	28		2.22	20.78	1	1.55	0	14	2	0	38.55	16	0	0	0			X	1		X	X	
71	14		3.2	20.8	2	1.32	0	18	2	0	43.32	14	0	0	0			X	1		X	X	
72	36		2.4	18.9	2	1.78	0	18	1	0	41.08	16.7	0	0	0			X	1		X	X	
73	24		4.47	18.53	2	1.63	0	17	2	0	41.63	16.7	0	0	0			X	1		X	X	
74	29		2	19	2	2.5	0	21	2	0	44.5	15	0	0	0			X	1		X	X	
75	40		2	22	2	1.57	0	17	1	0	42.57	16.7	0	0	0			X	1		X	X	
76	15		2	25	2	2	0	18	2	0	47	16.7	0	0	0			X	1		X	X	

Appendix B: Summary Collected Data

SUMMARY OF THE COLLECTED DATA

Total delivery cycle observed	Observed data collected for basic four cycle								Total deliver amount of Soil and Aggregate			
	Loading time in No.		Traveling time in No.		Placing time in No.		Return time in No.		Grannualr Soil		Crushed Unbounded	
	Grannular	Crushed	Grannular	Crushed	Grannular	Crushed	Grannular	Crushed	In (M^3)	In Cycle	In M^3	In Cycle
421	345	76	345	76	345	76	345	76	5647.70	345.00	1193.96	76

Deliver time record data

Type of Material	Delivery Count and Quantity		Type of Activities to be done	Delivered amount Material		Delivery Route used (Path 1 /path 2)						Loading Equipment	Delivery Count and Quantity	
						Traveling			Return					
	In Cycle	In (M^3)		In Cycle	In (M^3)	Path	Cycle	%age	Path	Cycle	%age		In Cycle	In (M^3)
Natural Granular Soil	345	5648.70	Normal Road(Sub-Grade)	287	4699.6	1	287	100%	1	287	100%	Excavator	345	5648.70
						2	0	0	2	0	0%			
			Embankment of Retaining/Box culvert	58	949.1	1	58	100%	1	58	100%			
						2	0	0	2	0	0%			
Crushed Unbounded Aggregate	76	1193.85	Normal (Sub-Base)	76	1193.85	1	24	32%	1	33	43%	Loader	76	1193.85
						2	52	68%	2	43	57%			
Allover	421	6842.55	Normal Road(Sub-Grade or Base	363	5893.45							Both	421	6842.55
			Embankment of Retaining/Box culvert	58	949.1									

Appendix C: Simulation Input Data Summary

Simulation Input data summary

Overall Crushed Unbound Aggregate (Sub-base/base-coarse) Material

Delivery Cycle		Estimation Method	Distribution Fittings: Distribution Types	Distribution Fittings: Distribution Parameters	Input data Results: Count	Min	Max	Mean	StDev	Goodness of Fit Test: K-S values	X2 Values	Fitting Criteria	Remark
Loading Cycle		Least Square	Cauchy (Location, Scale)1	Cauchy (2.148, 0.346)	76	1.00	4.47	2.66	0.67	0.389	210.58		Chi-square test
			Gamma (Shape, Scale)	Gamma (10.063, 0.224)						0.359	188.74		
		Maximum Likelihood	Beta(alpha, beta, low, high)	Beta(2.686,2.935,1,4.47)						0.222	185.05		
			Weibull(shape, Scle, loacation)	Weibull(2.989,2.098,0.73)						0.231	184.79		
		Moment Matching	Beta(alpha, beta, low, high)	Beta(2.686,2.935,1,4.47)						0.222	185.05		
			Normal(mean, StDev)	Normal(2.658,0.674)						0.244	184.79		
Traveling Cycle	Path-1	Least Square	Uniform(low, high)	Uniform(17.509, 24.663)	24	17.00	36.00	22.55	4.13	0.211	4.33		Chi-square test
			Uniform(low, high)	Uniform(17.509, 24.663)						0.211	4.33	auto fit	
		Maximum Likelihood	Weibull(shape, Scale, loacation)	Weibull(1.449, 6.331, 16.812)						0.181	3.08		
			Gumbel(loacation, Scale)	Gumbel(20.827, 2.795)						0.190	1.83		
		Moment Matching	Beta(alpha, beta, low, high)	Beta(0.989,2.397,17.36,22.55)						0.185	6.42		
			Gamma (Shape, Scale)	Gamma (29.879, 0.754)						0.238	1.83		
	Path 2	Least Square	Uniform(low, high)	Uniform(17.509, 27.663)	52	18.00	37.00	23.26	3.46	0.140	13.77		Chi-square test
			Weibull(shape, Scle, loacation)	Weibull(3.489, 10.279, 13.301)						0.164	12.38	aautofit	
		Maximum Likelihood	Logistics(Loacation, Scale)	Logistics(23.068, 1.861)						0.103	6.85		
			Laplace(Loacation, Scale)	Laplace(23.000, 2.591)						0.141	6.50		
		Moment Matching	Gamma (Shape, Scale)	Gamma (45.092, 0.516)						0.108	6.85		
			Gamma (Shape, Scale)	Gamma (45.092, 0.516)						0.108	6.85		
DumpingCycle		Least Square	Weibull(shape, Scale, loacation)	Weibull(0.977, 0.746, 1.268)	76	1.00	4.57	2.02	0.74	0.071	9.26		Chi-square test
			Weibull(shape, Scale, loacation)	Weibull(0.977, 0.746, 1.268)						0.071	9.26	auto fit	
		Maximum Likelihood	Weibull(shape, Scale, loacation)	Weibull(1.487, 1.172, 0.964)						0.104	15.84		
			Gumbel(loacation, Scale)	Gumbel(1.704, 0.511)						0.109	11.89		
		Moment Matching	Gumbel(loacation, Scale)	Gumbel(1.689, 0.576)						0.100	14.26		
			Gumbel(loacation, Scale)	Gumbel(1.689, 0.576)						0.100	14.26		
Returning Cycle	Path-1	Least Square	Uniform(low, high)	Uniform(14.122, 20.348)	28	13.00	34.00	18.29	3.73	0.217	5.13		Chi-square test
			Uniform(low, high)	Uniform(14.122, 20.348)						0.217	5.13	auto fit	
		Maximum Likelihood	Logistics(Loacation, Scale)	Logistics(17.826, 1.667)						0.119	0.71		
			Logistics(Loacation, Scale)	Logistics(17.826, 1.667)						0.119	0.71		
		Moment Matching	Gumbel(loacation, Scale)	Gumbel(16.607, 2.909)						0.141	9.29		
			Laplace(Loacation, Scale)	Laplace(18.286, 2.638)						0.194	3.71		
	Path 2	Least Square	Normal(mean, StDev)	Normal(17.748, 2.685)	48	13.00	50.00	18.92	5.21	0.161	10.67		Chi-square test
			Normal(mean, StDev)	Normal(17.748, 2.685)						0.16	9.09	autofit	
		Maximum Likelihood	Cauchy (Location, Scale)	Cauchy (18.097, 1.505)						0.109	13.33		
			Logistics(Loacation, Scale)	Logistics(18.313, 1.891)						0.123	3.33		
		Moment Matching	Laplace(Loacation, Scale)	Laplace(18.917, 3.682)						0.201	15.33		
			Laplace(Loacation, Scale)	Laplace(18.917, 3.682)						0.201	15.33		

Selected Material (Natural Granular Soil)												
Delivery Cycle	Estimation Method	Distribution Fittings		Input data Results					Goodness of Fit Test			Remark
		Distribution Types	Distribution Parameters	Count	Min	Max	Mean	StDev	K-S values	X2 Values	Fitting Criteria	
Loading Cycle	Least Square	Uniform(low, high)	Uniform(2.928, 6.464)	345	3.00	12.00	5.33	1.35	0.319	1,303.48		Kolmogorov-Simirnov test
		Exponential(mean)	Exponential(5.339)						0.484	1,210.96		
	Maximum Likelihood	Weibull(shape, Scale, loacation)	Weibull(1.983, 2.899, 2.757)						0.185	1,224.84	auto fit	
		Uniform(low, high)	Uniform(3, 12)						0.507	1,210.63		
	Moment Matching	Gamma (Shape, Scale)	Gamma (15.701, 0.339)						0.189	1,224.84		
		Exponential(mean)	Exponential(5.330)						0.484	1,210.96		
Traveling Cycle	Least Square	Logistics(Loacation, Scale)	Logistics(17.214, 1.443)	345	21.00	90.00	35.17	6.80	0.080	82.31		Kolmogorov-Simirnov test
		LogNormal(Loacation, Shape)	LogNormal(2.843, 0.139)						0.084	73.17		
	Maximum Likelihood	Gumbel(loacation, Scale)	Gumbel(32.269, 5.109)						0.060	67.00	auto fit	
		Normal(mean, StDev)	Normal(2.658,0.674)						0.098	37.70		
	Moment Matching	Gamma (Shape, Scale)	Gamma (29.879, 0.754)						0.073	37.70		
		Gamma (Shape, Scale)	Gamma (29.879, 0.754)						0.073	37.70		
DumpingCycle	Least Square	ChiSquare(freedom)	ChiSquare(2)	345	1.00	12.00	2.30	1.18	0.415	1,650.22		Kolmogorov-Simirnov test
		ChiSquare(freedom)	ChiSquare(2)						0.415	1,650.22		
	Maximum Likelihood	Gamma (Shape, Scale)	Gamma (4.665, 0.494)						0.226	1,654.63	auto fit	
		Triangular(low, high, mode)	Triangular(0.999, 12.153, 0.999)						0.558	1,649.67		
	Moment Matching	Gumbel(loacation, Scale)	Gumbel(1.774, 0.919)						0.240	1,654.63		
		Exponential(mean)	Exponential(2.304)						0.363	1,649.78		
Returning Cycle	Least Square	Beta(alpha, beta, low, high)	Beta(5.019, 24.624, 17, 96)	345	17.00	96.00	31.83	8.64	0.081	107.97		Kolmogorov-Simirnov test
		LogNormal(Loacation, Shape)	LogNormal(3.395, 0.178)						0.081	93.87		
	Maximum Likelihood	Gumbel(loacation, Scale)	Gumbel(28.661, 5.176)						0.080	83.08	auto fit	
		Gamma (Shape, Scale)	Gamma (18.935, 1.681)						0.121	73.94		
	Moment Matching	Gumbel(loacation, Scale)	Gumbel(27.939, 6.739)						0.126	119.54		
		Gumbel(loacation, Scale)	Gumbel(27.939, 6.739)						0.126	119.54		

Selected Material (Natural Granular Soil) Excluding the Embankment Work													
Delivery Cycle	Estimation Method	Distribution Fittings		Input data Results					Goodness of Fit Test			Remark
		Distribution Types	Distribution Parameters	Count	Min	Max	Mean	StDev	K-S values	X2 Values	Fitting Criteria	
Loading Cycle	Least Square	Uniform(low, high)	Uniform(2.842, 6.530))	287	3.00	12.00	5.33	1.41	0.299	963.03		Kolmogorov-Simirnov test
		Chi-square (freedom)	Chi-square (5)						0.398	878.48		
	Maximum Likelihood	Weibull(shape, Scale, loacation)	Weibull(1.884, 2.894, 2.758)						0.175	891.53	auto fit	
		Uniform(low, high)	Uniform(3, 12)						0.496	877.61		
	Moment Matching	Gamma (Shape, Scale)	Gamma (14.271, 0.374)						0.180	891.53		
		Pareto (scale, shape)	Pareto (2.995, 2.283)						0.431	887.26		
Traveling Cycle	Least Square	Gamma (Shape, Scale)	Gamma (33.789, 1.014)	287	21.00	62.00	35.01	6.11	0.072	35.43		Kolmogorov-Simirnov test
		Gamma (Shape, Scale)	Gamma (33.789, 1.014)						0.072	35.43		
	Maximum Likelihood	Gumbel(loacation, Scale)	Gumbel(32.172, 5.116)						0.054	61.27		
		Weibull(shape, Scale, loacation)	Weibull(2.483, 16.271, 20.558)						0.063	24.90	auto fit	
	Moment Matching	Beta(alpha, beta, low, high)	Beta(3.124, 6.019, 21, 62)						0.058	26.28		
		Beta(alpha, beta, low, high)	Beta(3.124, 6.019, 21, 62)						0.058	26.28		
DumpingCycle	Least Square	ChiSquare(freedom)	ChiSquare(2)	287	1.00	12.00	2.17	1.09	0.393	1,414.09		Kolmogorov-Simirnov test
		ChiSquare(freedom)	ChiSquare(2)						0.393	1,414.09		
	Maximum Likelihood	Gamma (Shape, Scale)	Gamma (4.986, 0.435)						0.246	1,429.03	auto fit	
		Weibull(shape, Scale, loacation)	Weibull(2.098, 2.447, 1)						0.576	1,414.09		
	Moment Matching	Gamma (Shape, Scale)	Gamma (3.965, 0.547)						0.261	1,414.97		
		Weibull(shape, Scale, loacation)	Weibull(2.098, 2.447)						0.576	1,414.09		
Returning Cycle	Least Square	Gumbel(loacation, Scale)	Gumbel(27.746, 4.202)	287	19.00	84.00	31.22	7.72	0.089	86.86		Kolmogorov-Simirnov test
		Beta(alpha, beta, low, high)	Beta(3.899, 19.170, 19, 84)						0.089	86.11		
	Maximum Likelihood	Gumbel(loacation, Scale)	Gumbel(28.377, 4.645)						0.084	75.57		
		Gumbel(loacation, Scale)	Gumbel(28.377, 4.645)						0.084	75.57	auto fit	
	Moment Matching	Gumbel(loacation, Scale)	Gumbel(27.744, 6.016)						0.123	92.63		
		Gamma (Shape, Scale)	Gamma (16.369, 1.907)						0.133	92.38		

Overall Crushed Unbound Aggregate (Sub-base/base-coarse) Material-Best Fitting										
Delivery Cycle		Input data Results					Distribution fittings			Test Method
		Count	Min	Max	Mean	StDev	Distribution Type	Parameter	Best fit	
ading Cycle		76	1.00	4.47	2.66	0.67	Least Square	Gamma	auto fit	Chi-square test
Traveling Cycle	Path-1	24	17.00	36.00	22.55	4.13	Least Square	Uniform	auto fit	Chi-square test
	Path 2	52	18.00	37.00	23.26	3.46	Least Square	Weibull	auto fit	Chi-square test
DumpingCycle		76	1.00	4.57	2.02	0.74	Least Square	Weibull	auto fit	Chi-square test
Returning Cycle	Path-1	28	13.00	34.00	18.29	3.73	Least Square	Uniform	auto fit	Chi-square test
	Path 2	48	13.00	50.00	18.92	5.21	Least Square	Normal	auto fit	Chi-square test
Amount of Crushed Material		Truck capacity (m3)			Resource (No.)				Remark	
Truck load	m3	Max	Min	Aver.	Truck	Loader	Grader	Spoter		
1,000	15,710	17.03	14.00	15.71	28.00	1.00	1.00	1.00		

Overall Crushed Unbound Aggregate Material-Best Fitting-Using Excavator and Loader as loading equipment										
Delivery Cycle		Input data Results					Distribution fittings			Test Method
		Count	Min	Max	Mean	StDev	Distribution Type	Parameter	Best fit	
Loading Cycle	Excavator	121	2.03	5.08	2.99	0.54	Least Square	Gumble	auto fit	Chi-square test
	Loader	76	1.00	4.47	2.66	0.67	Least Square	Gamma	auto fit	Chi-square test
Traveling Cycle	Path-1	24	17.00	36.00	22.55	4.13	Least Square	Uniform	auto fit	Chi-square test
	Path 2	52	18.00	37.00	23.26	3.46	Least Square	Weibull	auto fit	Chi-square test
DumpingCycle		76	1.00	4.57	2.02	0.74	Least Square	Weibull	auto fit	Chi-square test
Returning Cycle	Path-1	28	13.00	34.00	18.29	3.73	Least Square	Uniform	auto fit	Chi-square test
	Path 2	48	13.00	50.00	18.92	5.21	Least Square	Normal	auto fit	Chi-square test
Amount of Crushed Material		Truck capacity (m3)			Resource (No.)					Remark
Truck load	m3	Max	Min	Aver.	Truck	Loader	Excavator	Grader	Spoter	
1,000	15,710	17.03	14.00	15.71	33.00	1.00	1.00	1.00	1.00	

Overall Selected Material (Natural Granular Soil)-Best Fitting										
Delivery Cycle		Input data Results					Distribution fittings			Test Method
		Count	Min	Max	Mean	StDev	Distribution Type	Parameter	Best fit	
Loading Cycle		345	3.00	12.00	5.33	1.35	Maximum Likelihood	Weibull	auto fit	K-S Test
Traveling Cycle		345	21.00	90.00	35.17	6.80	Maximum Likelihood	Gumbel	auto fit	K-S Test
DumpingCycle		345	1.00	12.00	2.30	1.18	Maximum Likelihood	Gamma	auto fit	K-S Test
Returning Cycle		345	17.00	96.00	31.83	8.64	Maximum Likelihood	Gumbel	auto fit	K-S Test
Amount of Grannular Material		Truck capacity (m3)			Resource (No.)					Remark
Truck load	m3	Max	Min	Aver.	Truck	Excavato	Dozer/D8R	Dozer/D6R	Spotter	
1,000	16,370	16.70	15.00	16.37	10.00	1.00	1.00	1.00	1.00	

Selected Material (Natural Granular Soil) excluding Embankment Work-Best Fitting										
Delivery Cycle		Input data Results					Distribution fittings			Test Method
		Count	Min	Max	Mean	StDev	Distribution Type	Parameter	Best fit	
Loading Cycle		287	3.00	12.00	5.33	1.41	Maximum Likelihood	Weibull	auto fit	K-S Test
Traveling Cycle		287	21.00	62.00	35.01	6.11	Maximum Likelihood	Weibull	auto fit	K-S Test
DumpingCycle		287	1.00	12.00	2.17	1.09	Maximum Likelihood	Gamma	auto fit	K-S Test
Returning Cycle		287	19.00	84.00	31.22	7.72	Maximum Likelihood	Gumbel	auto fit	K-S Test
Amount of		Truck capacity (m3)			Resource (No.)					Remark
Truck load	m3	Max	Min	Aver.	Truck	Excavator	Dozer/D8R	Dozer/D6R	Spotter	
1,000	16,370	16.70	15.00	16.37	10.00	1.00	1.00	1.00	1.00	

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