University of Nevada, Reno

MULTIPLE DISCRETE-EVENT SIMULATION AND ANIMATION MODELS TO ASSIST MODERN MINING OPERATIONS

A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DOCTORAL DEGREE IN
GEO-ENGINEERING

by

Ebrahim Karimi Tarshizi

Dr. Danny Taylor/Dissertation Advisor

December, 2014

THE GRADUATE SCHOOL

University of Nevada, Reno
Statewide • Worldwide

We recommend that the dissertation
prepared under our supervision by

EBRAHIM KARIMI TARSHIZI

entitled

MULTIPLE DISCRETE-EVENT SIMULATION AND ANIMATION MODELS TO ASSIST MODERN MINING OPERATIONS

be accepted in partial fulfillment of the
requirements for the degree of

DOCTOR OF PHILOSOPHY

Danny Taylor, Ph.D., Advisor

Jaak Daemen, Ph.D., Committee Member

Charles Kocsis, Ph.D., Committee Member

Frederick C. Harris, Ph.D., Committee Member

Kambiz Raffiee, Ph.D., Graduate School Representative

David W. Zeh, Ph.D., Dean, Graduate School

December, 2014

Abstract

This research investigation was conducted to develop, execute, and analyze a collection of discrete-event system simulation and animation models for different modern mining operations and systems, including two open-pit gold mines, an aggregate mine (sand and gravel), an open-cast (strip) coal mine, and an underground mine evacuation operation. The mine simulation and animation models aimed to study and assess a wide range of practical unique and common "what if?" scenarios that the mine engineers and managers of the case studies posed in different aspects during the research. A comprehensive and detailed literature review was also performed to provide a summary of the published discrete-event system simulation projects and their applications in the mining and mineral industry. The simulation results of the investigation were effectively implemented to assist the engineers in maximizing the productivity of the mines, improving the operation processes, reducing the environmental impact of the haulage operations, and enhancing the equipment utilization in various case studies. In addition, due to the shortage of powerful and flexible computer simulation tools in designing and analyzing underground mining evacuation operations and rescue equipment with respect to the mine operating characteristics and layout, the discrete-event system simulation and animation technique was innovatively implemented for modeling these complex systems. GPSS/H® and PROOF Professional® were the simulation language and animation software used for this research work.

Keywords: discrete-event system simulation, animation, mine optimization, mine planning, underground mine evacuation, GPSS/H® and PROOF Professional®.

Acknowledgements

The author is indebted to Dr. Danny Taylor, the advisor and the committee chair, for his valuable advice, support, and encouragements during the research investigation. The members of the graduate advisory committee, Prof. Jaak Daemen, Prof. Frederick Harris, Prof. Kambiz Raffiee, and Dr. Charles Kocsis are also greatly appreciated for their valuable feedback and comments.

Besides the committee members, the author is always grateful to Prof. John R. Sturgul for teaching him programing using GPSS/H® and mine system simulation modeling, as well as his great help, support, and advice. The author would also like to thank Ms. Virginia Ibarra for her effort and contribution to the Chapter 7 of this dissertation. The author wishes to thank the Barrick Gold Corporation for the generous support.

Special thanks go to all faculty members and personnel of the Mackay School of Earth Sciences and Engineering, Department of Mining and Metallurgical Engineering at the University of Nevada, Reno, for their support.

The author would especially like to thank his family who provided him unlimited emotional support and confidence in the course of his doctoral degree. He humbly dedicates this work to his beloved parents for their endless love and encouragement.

Finally, the author would like to express his sincere appreciations to his lovely sister and great friends.

Table of Contents

List of Tables

List of Figures

Chapter 1. Introduction

This chapter presents an overview of the conducted mine simulation projects, introductory remarks, and the research scope of work, including the problem statement and research objectives. An outline of the dissertation structure is provided in the chapter.

1.1. Introductory Remarks

In spite of type, size, method, and complexity of mine operations, discrete-event system simulation models can be applied to analyze and study both existing operations and/or proposed plans of new development phases. The importance of discrete-event system simulation models in mine design and planning has been acknowledged and accepted by mining engineers in the United States for many years (Sturgul, 1999) and several excellent mine simulation cases are in evidence (Sturgul, 1999), (Govinda Raj, 2009), and (Karimi-Tarshizi, 2012). Nevertheless, the mining industry has not embraced and benefited from discrete-event system simulation studies as extensively as other industries (Sturgul, 1999). In general, computer simulation techniques use numerical and mathematical approaches to model a real system under uncertainties to evaluate and anticipate the impact of the changes on the system's performance. Discrete-event system simulation modeling in mining, known as mine system simulation or mine simulation, has been used as a powerful, flexible and valuable tool in mine design, planning, and optimization for several decades. Mine simulation is obviously an important method for studying and improving the performance of mine design, short-term, medium-term and long-term mine planning, and equipment selection.

Mine system simulation is a “what if?” analysis technique to assist mining engineers to efficiently investigate a wide range of proposed mine design and planning scenarios, which can result in improved decision-making. Considering mine operating and capital expenditures, a discrete-event system simulation model of a mine enables engineers to test a series of circumstances in mine operations without incurring the implementation costs. This can effectively support the process of decision-making in mine management by the best possible use of capital and operational budgets (Karimi-Tarshizi, 2012). Mine simulation can be used for modeling production schedules, equipment fleet type and size, mine profile/layout, operating/dispatch rules, equipment breakdowns/failures etc. in a surface or underground operation. These models can be modified and changed quickly, and the possible impacts on the mine production rate and the utilization of prominent equipment can be analyzed reliably. Mine system simulation studies can play a significant role in assessing and reducing the risk of mine design and planning projects, particularly where the traditional methods are unable to deal with complex mining issues in a rapid manner.

This research was conducted to address various applications of discrete-event system simulation models in different modern mining methods and operations. The study contributed to the field by assessing the capability of discrete-event system simulation and animation to solve complex and practical “what if?” questions in planning and optimizing in highly mechanized mines. This investigation provided a pioneering approach to use the discrete-event system simulation technique and its feasible applications in reducing the environmental impact of the mining operations, and improving underground mine rescue and evacuation procedures. In addition, mine simulation models for aggregate operations have rarely been developed, constructed, and published to illustrate the possible benefits of mine simulation technique for this type of mining (quarrying). A part of this research analyzes the benefit of a sand and gravel mining system modeling to compare different haulage systems using simulation and animation. Moreover, a broad description of a state-of-the-art simulation and animation model of an underground mine evacuation system is provided. This model was set up to evaluate the unique applications of discrete-event system simulation and animation in mine evacuation operations and rescue equipment design. Such a detailed simulation and animation model has not been previously developed in the field of mine health and safety. GPSS/H® (General Purposes Simulation System) and PROOF Animation®, a simulation and animation software package, was used to model the complex and difficult mining situations and projects in this investigation.

1.2. Scope of Work

The main purpose of this study is to develop several different and unique discrete-event system simulation and animation models for various modern and highly-mechanized mining systems and methods to achieve the study objectives and answer the critical questions. This investigation also illustrates and discusses the applications of mine discrete-event system simulation modeling in a wide range of today's technical issues in mine management, design, optimization, and importantly health and safety, in the following chapters. In addition, a broad literature review of the mine simulation projects performed around the world is presented. This literature review provides a comprehensive evaluation of recent and past states of mine simulation research and current needs of the mining and mineral industry.

1.3. Problem Statement

The key question this research investigation deals with is how discrete-event system simulation and animation models can effectively benefit modern mining operations with a variety of classic and unique "what if?" analyses, which traditional and mathematical methods are unable to efficiently and rapidly accomplish.

Mining engineers, compared with other disciplines, seem to have been gradual in implementing the discrete-event system simulation technique for solving difficult issues in both large-scale mines and small operations. In general terms, the main purpose of running every business is generating profits, and mining businesses are not exceptions. Every mining company is always looking for methods or new technologies to improve operations, decrease costs, and maximize productivity and efficiency. Mining involves a lot of uncertainty, and it can be mentioned as one of the most risky industries or businesses. Considering current global volatility of mineral commodity markets, mining companies and operations face daunting challenges in managing their mine operations efficiently. This price volatility can certainly impact the total marginal costs and benefits of the extraction and process of minerals. Mining engineers, therefore, need to use additional advanced and practical computer modeling tools, especially discrete-event system simulation to analyze and improve decision-making process in short-term, midterm, and long-term planning. In fact, mine system simulation can be used as a valuable daily mine plan tool during the life the mine.

However, several methods and mathematical approaches, such as heuristic, statistical, optimization (integer programming), and artificial intelligence techniques have been introduced and used for mine design, planning, and equipment selection (Burt, 2008). Discrete-event system simulation is known and accepted as one of the most effective, flexible, and rapid methods available in the field. In fact, in order to have cost-effective and high performance operations, mining companies need to apply the discrete-event system simulation technique in mine design, equipment selection, planning, and optimization more than before. Discrete-event system simulation in mining can be technically used in any mine operations, methods, and systems to effectively maximize the equipment utilization and productivity.

Additionally, this practical technique can be used to examine the effectiveness of proposed mine plans and equipment fleet performance, considering type and size before implementing and spending allocated budgets. This can allow mining operations to possess a competitive advantage and outperform their rivals by reducing the production costs (e.g. per ton) of mineral commodities, which, in turn, delivers maximum profitability. Modeling of the mine operations using discrete-event system simulation helps the engineers to examine different mine design and plan scenarios and select the best option to achieve the mine production target and objective. Discrete-event system simulation can be used as an engineering technique for everyday use in mines, to accurately model and assess mine planning, layouts, production schedules, equipment selections (size and number), Dispatch rules/criteria, equipment performance/failure analysis, crew management, traffic patterns, mine project management strategies, etc. for both existing mine operations and the development phases of new operations.

Nowadays, the mining industry is dealing with important issues related to negative environmental impact during the five stages of the life of a mining project (prospecting, exploration, development, exploitation, and reclamation). Mine system simulation method was used in one of these studies as the most powerful and flexible technique to study and mitigate the equipment environmental impact by optimizing the utilization of large and heavy mining machinery. Mine engineers are also investigating new methods and strategies to decrease the environmental impact and hazards of the operations. In particular, open pit mines, one of the most common mining methods, can be operated in a more ecologically-friendly way by running optimum equipment match, especially appropriate truck/shovel (excavator) allocation. Mine system simulation method can assist the mining engineers in evaluating and employing correct strategies and plans to minimize the environmental and public health issues of operating heavy mining equipment, including dust pollution, noise pollution, and emissions.

Currently, in the mining industry, there is a lack of a fast, effective, inexpensive, and more importantly capable computer simulation programs to help underground mining engineers and rescue trainers to model and analyze the efficacy of mine evacuation and rescue alternatives, including the mining systems and layouts. One purpose of this research investigation is to conduct an innovative simulation and animation model using the discrete-event system simulation platform to model and assess an underground mine evacuation and rescue operation and equipment. The mine rescue simulation program was written so that it could be expanded easily to be used for several purposes, including both training programs and training materials. The program also can include precise timings of the movement of miners from various work zones to the assigned safe places to analyze the effectiveness of the mine evacuation plans.

1.4. Research Objectives

Several mine system simulation and animation models of various operations need to be conducted to answer the main research question, which is how practically and effectively discrete-event system simulation and animation models can benefit modern and highly-mechanized operations with a wide range of typical and unique “what if?” scenarios in mine planning, design, equipment fleet, management, and health and safety. Furthermore, this research intends to answer the following critical inquiries:

- How actual/real data and statistical distributions of each component in a mine operation can be significant to develop and accurately calibrate a mine simulation model? Would it be feasible to deliver a complete mine simulation model without access to actual primary data and precise distributions for the haulage operation? Is the general/average data from Dispatch fleet management systems sufficient to conduct a mine simulation study, particularly for large-scale mines?
- Would it be practical to incorporate economic analysis into mine system simulation? Does the discrete-event system simulation approach only have an application for modeling mine haulage operations or can be applied to solve other complex issues in mining planning and design?

- Is it beneficial to use mine simulation for aggregate operations/small mines? What is the main difference between a small mine simulation project and a large and complex simulation model?
- What is the advantage of using mine simulation in modeling conveyer belts and haul truck operations (a combination of both)?
- Is it possible to use discrete-event system simulation in modeling mining operations to reduce the environmental impact of mine equipment?
- Would it be conceivable to apply the discrete-event system simulation technique in modeling mine evacuation operations and planning rescue equipment in underground mining, or is the application only limited to mine design, planning, management, and optimization? How can data be collected and analyzed for a mine evacuation and rescue model? How would it be possible to verify and validate this type of simulation in mine evacuation and rescue operation? What if there is no access to real data?
- What are the benefits of using an interactive secure content management website to improve and enhance the quality of an online discussion between modelers/researchers and mine site engineers during the implementation of a simulation project?
- Is the GPSS/H® simulation still powerful and flexible to conduct complex mine simulation projects in different situations? What are the benefits of animating the mine simulation projects?

In addition to those questions, the proposed future studies of this investigation address the following concerns:

- What is the advantage of 3D animation modeling in mine evacuation and rescue simulation?
- What would be the extendable applications of discrete-event system simulation in mine evacuation and rescue operations?
- Which would be more flexible and faster in performance in modeling very complex systems, SLX® or GPSS/H®?

1.5. Dissertation Outline

An introduction and general overview of the research investigation is provided in Chapter 1. This chapter also includes the scope of research and work plan, the statement of problems, and research purposes.

Chapter 2 is a literature review, including comprehensive information on the literature for mine system simulation that have been published until 2007, as well as providing a detailed literature survey on the published mine simulation models from 2008 to date.

Chapter 3 gives an overview of simulation in general and contains several sections discussing the application of simulation in other sciences, advantages and disadvantages of simulation models, discrete-event system simulation, simulation project development in steps, application of discrete-event simulation in the mining industry, purposes of using GPSS/H® in this research, animation program applied in the mine simulation studies, verification and validation of simulation, benefit of using animation for modeling mine simulation, and animation misuse in simulation.

Two simulation and animation models of a large-scale gold mine operation are given and discussed in detail in Chapter 4. This chapter provides a description of the gold mine and construction of both simulation models. A conclusion and discussion of the developed simulation and animation models are included.

A simulation and animation of the Gap Pit mine in the Cortez Hills complex operation, the largest producer of gold in North America, is presented in Chapter 5. A description of the data collection and model development, involving verification and validation is also provided. This chapter includes the Gap Pit simulation results, economic analysis of the simulation throughput, and suggestions for future work.

Chapter 6 contains an overview of an aggregate (sand and gravel) mine operation, as a case study, and its simulation and animation model. A discussion on the system and economic benefits of haul truck operation compared with conveyer belts and the simulation overview and results are given.

Chapter 7, a surface coal mine simulation and animation, covers different subjects, including the developed simulation and animation program construction and relevant investigation. The chapter describes the simulation results, in respect to the mine economic analysis and environmental impact of the mine haul trucks.

Chapter 8 discusses an innovative approach using discrete-event system simulation and animation to model and analyze a mine evacuation emergency plan and effectively evaluate new different locations of the mine refuge chambers in the operation. The results of the developed simulation and animation model are detailed and future studies of this simulation investigation are recommended.

Chapter 9 includes the dissertation research summary and conclusions. It also provides the research contributions and suggestions for future studies in the field.

Chapter 2. Literature Review

This chapter gives a comprehensive discussion of mine system simulation projects around the world and of the literature published by numerous researchers.

2.1. Mine Simulation Applications Worldwide – A Broad Review

Sturgul (1997) provided a list of every discrete system mine simulation paper published to solve or study mining problems, and simulation languages used over 34 years, from 1961 to 1995 (Sturgul, 1997).

A series of outstanding reviews of discrete-event system simulation applications in mining operations/projects around the world were published in the International Journal of Surface Mining, Reclamation and Environment, currently known as International Journal of Mining, Reclamations and Environment, in 1999 (Sturgul, 1999), (Turner, 1999), (Panagiotou, 1999), (Knights and Bonates, 1999), (Konyukh et al., 1999), (Vagenas, 1999), and (Basu and Baafi, 1999).

An excellent overview of the history of mine simulation, from 1950 to 1999, in the United States, was given by Sturgul (1999). Sturgul argued that the US mining industry has been slow but steady in accepting and applying the discrete-event system simulation technique. However, development of advanced simulation languages and software packages have shown a gradual increase of interest in using simulation in the US mining industry (Sturgul, 1999). In addition, Sturgul provided a complete review of simulation languages that have been used or have a possibility to be implemented for mining simulation projects. Sturgul also discussed techniques and software classifications to perform mine discrete-event system simulation studies (Sturgul, 1997).

Turner (1999) gave a summary of collected case studies and simulation models in mining in South Africa. The South African mining industry have extensively used mine simulation techniques to analyze complex and costly mining projects to reduce the risks affiliated with these projects. Moreover, the simulation approach has been implemented both in designing new mines and in planning current mines in South Africa. In addition, applications of simulation in mining have seen sustainable growth in the area due to the increasing production costs and the unstable commodity prices (Turner, 1999).

Panagiotou (1999) provided an assessment of discrete-event-system simulation applications in European surface mine operations, and stated that since the 1950s, European mining engineers have been leaders in using mine simulation, however, owing to the tough environmental regulations and the low probability of mines in Europe, mine projects and mine simulation studies have been on the decline (Panagiotou, 1999).

Knights and Bonates (1999) presented an overview of mine system simulation studies in South America. The review included the type of implemented simulation projects in mining and different simulation languages that have been used in the South American mining industry. The study showed that mine simulation has been successfully used mostly by the universities and large mining companies with sizeable mines. In conclusion, the authors provided a number of reasons for the lack of simulation models/projects in mining operations in South America (Knights and Bonates, 1999).

Konyukh et al. (1999) described mine simulation studies and examples in Asia, mainly in Central Asia and China. Due to the conservative management in Asian mines, simulation tools have been applied slowly to benefit operations in the region. However, some groups have attempted to use the Monte Carlo simulation technique in modeling and simulating mines, but only one team of researchers, in Kemerovo, located in Russia, applied discrete-event system simulation language (GPSS/H® and PROOF Animation®) to real mining problems (Konyukh et al., 1999).

In 1999, a summary of Canadian mine simulation projects was provided by Vagenas, which discussed the simulation software packages used in several mine operations in the country. Discrete-event simulation was pointed out to be a tool to obtain “lean mining”, which benefit the mines with effective and high performance operations, and reduced uncertainty. In addition, it was states that the simulation technique with 3D animation software in mining would be an essential methodology in the upcoming years (Vagenas, 1999).

Australia is known for its numerous small and large ore deposits and rich mineral resources. While, coal mine operations are located in the eastern states, the western states of Australia include plentiful iron, nickel, gold mines (Basu and Baafi, 1999). The authors mentioned that simulation packages were widely applied for designing mining systems in Australia and general haulage simulation programs, such as TALPAC® were routinely used in various mines. However, the authors added that the large mining companies have benefited from simulation studies more than small operations due to the high expense of simulation projects undertaken by the consulting firms in the region (Basu and Baafi, 1999).

In 2009, a critical and impressive review of using mine simulation models for optimizing mining productivity was published (Govinda Raj et al., 2009). The authors also classified the published simulation projects conducted in the mining/minerals industry. It provided a broad and detailed explanation of the mine simulation programs and their application in mine optimization for both surface and underground operations, from 1961 through 2007.

A comprehensive literature review on using discrete-event system simulation in mining engineering, from 2008 to 2014, is given below:

2.2. Discrete-Event System Simulation Applications in Mining Projects – A Detailed Review from 2008 to 2014

2.2.1. Mine Simulation in 2008

Yuriy et al. (2008) modeled an underground mine in two different simulation software/environments. Both AutoMod® and Simul8® showed the impact of equipment mechanical failures on the entire development cycle, which was analyzed by a combination of reliability assessment (using genetic algorithms) and discrete-event simulation. Moreover, the results of both simulation models proved that Simul8® can be a cost-effective alternative for AutoMod® in simulation projects (Yuriy et al., 2008).

Botha et al. (2008) discussed a deterministic simulation model developed for a block cave complex mine operation whose production rate relied on many interdependent elements and sub-systems. The model was constructed using the ARENA® simulation software for the ore handling system in the PT Freeport Indonesia's DOZ/ESZ Block Cave mine operation. The simulation model was validated based on the data in year 2006 to predict and achieve the maximum possible productivity in years 2010, 2012, and 2014 (Botha et al., 2008).

Hopkins and Labrecque (2008) used a simulation model for Xstrata-Nickel (formerly Falconbridge) to study various mining and development methods. The model of the Coleman 170 Orebody, an underground mine, included several events and components, such as mine development, production, geology, equipment fleets, equipment maintenance and random failures, direct manpower, shift schedules and calendar, and cycle activity times. The simulation model was constructed using AutoMod® and an Excel input interface. This project also emphasized how communication between the modelers and the engineers was significant in order to deliver an accurate and ‘proper’ simulation program. Furthermore, simulation was introduced as a strong and insightful tool to design and plan the 170 Orebody operation before it was actually worked (Hopkins and Labrecque, 2008).

The SIMAN simulation language was used by Saiang (2008) to model and simulate queue problems of the haul truck fleet in a large surface mine in Papua New Guinea. The model was constructed using the actual data collected from the mine. Simulation results showed that increasing equipment capacity in the operation can improve the mine productivity. The simulation results were confirmed by implementing the proposed plan in the operation (Saiang, 2008).

2.2.2. Mine Simulation in 2009

A general overview of discrete-event simulation in underground mining design, development, operational improvement and mine logistics, and its application in two general mining logistical issues in both soft-rock continuous mining and hard-rock mining was discussed by Hindle and Limmer (2009). Additionally, the advantages of modeling and simulating the entire logistic operations of underground mining, including conveyors, trucking, ore passes, trains, storages, and hoisting systems were presented. However, the main study focus was narrowed on the mine hoist/truck operations (Hindle and Limmer, 2009).

Botha et al. (2009) presented a simulation model constructed by SimMine® to maximize the underground development rate through improving the equipment and strategies at the Petra Diamonds' Cullinan Diamond Mine. The simulation model was sufficiently flexible to include the equipment and operating costs, in order to achieve the total costs of the mine operation for ultimately selecting optimum operational scenarios and strategies (Botha et al., 2009).

Jingxia (2009) performed a research project on developing a reliability assessment model using genetic algorithms and simulation to estimate equipment/mechanical failures (Load-Haul-Dump) and their effects on equipment utilization and productivity in underground mine operations. Two simulation programs, AutoMod® and Simul8®, were applied to model the systems during this study. In conclusion, simulation results showed that the mechanical failures of the LHDs played a significant role in the mine production rate (Jingxia, 2009).

Since reducing operational costs and risk management improvement are vital in performing mining projects, Chinbat and Takakuwa (2009) discussed how developing and using simulation techniques was beneficial and advantageous as an engineering and technical tool for evaluating project management and its risks. To model and optimize an open pit mine in Mongolia, a case study, ARENA® simulation program was selected. This mine simulation and optimization project mainly focused on evaluating and improving the risk management associated with mining projects (Chinbat and Takakuwa, 2009).

In another study, Chinbat (2009) discussed the simulation model used for an optimization project in a mining and iron production factory (MIPF). The simulation, using ARENA® software, was applied for the Monzol Ervie Khuder MIPF operations. The simulation model was run for several scenarios for obtaining the required number of trucks, drills, blasting, and other activities (Chinbat, 2009).

Planning roadway development for advance in the longwall mining method, a cost-effective method and efficient coal mine extraction, is very important for improving productivity. Gray et al. (2009) developed a discrete-event system simulation model (RoadSIM), using ARENA® simulation, to assist the evaluation of the mine roadway development process by analyzing its operational constraints in the Australian coal mining industry. The model also enabled the users to run a wide range of "what if?" questions for determining equipment fleet size and utilization to select best options (Gray et al., 2009).

2.2.3. Mine Simulation in 2010

Hodkiewicz et al. (2010) discussed using discrete-event simulation to model and simplify the reliability of the trucks, priority and maintenance strategies, and resourcing of the repair facilities in mining operations. During the investigation, simulation was applied as an accurate and appropriate tool to investigate truck shop operation changes and maintenance strategies that can be important to improve productivity (Hodkiewicz et al., 2010).

Raghavendra et al. (2010) set up a simulation program as a user-friendly practical tool to analyze and increase the roadway development rate in both planning and implementation. The computer simulation model was flexible, and assisted the investigators in testing and evaluating the utilization of the self-drilling rock bolting technology to finally improve the rate of roadway developments in longwall coal mining. The QUEST® simulation package was also chosen for this project (Raghavendra et al., 2010).

Galiyev et al. (2010) presented a simulation modeling of "excavator/truck/conveyer complex work." The simulation program provided details on mine equipment required for optimum mine operation. The output of the simulation program included the economic and technological elements of the modeled system and sub-system (Galiyev et al., 2010).

A simulation model was built up by Parreira and Meech (2010) using the EXTENDSIM® software to test and evaluate scale-up problems and limitations of autonomous vehicles compared to manual systems in any open-pit mine. The model was designed and programmed as a powerful and flexible method to predict and manage Key Performance Indicators (KPIs). The KPIs included mine productivity, safety, cost, equipment failures, fuel consumption, and tire life according to different mine road and load conditions (Parreira and Meech, 2010).

Knights and Paton (2010) argued that slower trucks can reduce the speed of faster trucks by creating 'bunching' issues in mining operations. This problem caused the loss of mining productivity by increasing the cycle times of haul trucks. A simulation program was developed to model a truck haulage return cycle (12.5 km) for a large open pit gold mine in the United States, operating a fleet of 35 trucks. The simulation model was particularly concentrated on determining and improving the mine truck payload variance. The results of the simulation suggested that a passing lane can increase the mine throughout/production rate up to 10% under the appropriate circumstances. GPSS/H® simulation language was applied to conduct this mine simulation project. The model was introduced as a valuable tool for the Continuous Improvement groups in large mining operations (Knights and Paton, 2010).

Two case studies for the PT Kaltim Prima Coal and Lihir Gold were given by Sandeman et al. (2010) to integrate the optimization and simulation techniques. The first case study simulation was performed to model a complex supply chain to provide several production types for customers. Integration of an optimization model obtained by running the simulation, using updated inputs, was considered as the second approach in this investigation. Finally, both case studies were compared and analyzed to illustrate the possible benefits of the simulation and optimization integration in mining projects. The simulation studies provided several advantages for the modelers, including the possible trade-offs for various possibilities in the capital costs and the assessment of different operational practices, such as maintenance options (Sandeman et al., 2010).

Hindle and Limmer (2010) used discrete-event system simulation to study and identify underground ore handling and shifting bottlenecks in a small potash mine, and a short examination of the simulation model application in hard rock mining was reviewed. The model was set up using Rockwell Automation's ARENA® discrete-event simulation platform and it was connected to Microsoft® Excel for the model interface. The results suggested that simulation was a powerful, flexible, and useful tool for day-to-day decision-making and it aided the mining operations during the life of mine for planning and operation processes (Hindle and Limmer, 2010).

Baafi and Porter (2010) used the ARENA® simulation environment to develop a simulation program to model and evaluate the roadway development performance as needed for supporting coal longwall mines in Australia. The program was named RoadSIM and allowed its users to examine different options to acquire the required development rate for the best support of longwall advance rates. The simulation was a "what if?" tool to evaluate equipment modifications and roadway development changes in underground coal mine operation (Baafi and Porter, 2010).

Zhou (2010) used a combination of mathematical programming (integer programming) and discrete-event system simulation to assess and optimize mill system performance in a mine operation in Canada. The model was constructed in Visual Basic® for Application (VBA) in Microsoft® Excel and the integer programming was formulated by the GLPK language using GUSEK®. The simulation, stochastic model, was used to model the maintenance and mechanical failures of the mill to be used in the IP model to create a new and better production plan and finally improve the performance of the mill operation (Zhou, 2010).

Marsh et al. (2010) used a simulation program to optimize the complex ore handling system of the Grasberg Block Cave mining operation in the Sudirman Mountain range of Papua in Indonesia. The simulation software used in this investigation was ARENA® with Microsoft® Excel interface for the entry parameters (Marsh et al., 2010).

O'Connell and Sturgul (2010) used GPSS/H® and PROOF Professional® to develop a simulation and animation model for the Stockton Coal Mine operation in the north western area of the South Island of New Zealand. The simulation program was run to analyze and obtain the optimum size of stockpiles to reach the planned coal production. The model was also used to modify the shipping plan for a better relationship between coal production types and to assess the stockpile sizes and coal qualities and their possible effects in the bulk and selective mining. This model was mentioned as one the largest computer simulation models developed for a surface mine to date (O'Connell and Sturgul, 2010).

2.2.4. Mine Simulation in 2011

Boden et al. (2011) used discrete-event simulation (DES) and optimization techniques to analyze the export supply chain of a coal mine, PT Kaltim Prima Coal, in Indonesia. This simulation program enabled the engineers to assess various operating practices and maintenance options, along with giving the option to decouple different phases of the operation and eventually obtain an individual optimization model for it. This approach was valuable for the project evaluation and strategic mine planning purposes (Boden et al., 2011).

Greberg and Sundqvist (2011) described a project, using simulation in mine planning and scheduling, and discussed the limitations, challenges, and benefits of mine simulation as a planning tool in mining. The case study of this investigation was the Newcrest Cadia East project, the largest underground operation in Australia, and simulation was applied for planning of the development of the mine panels in the future project. The results of the project indicated that various operational restrictions can impact the mine planned development processes and changes in priorities were very important during the implementation. The SimMine® software environment was used for this simulation project (Greberg and Sundqvist, 2011).

Xu et al. (2011) pointed out the use of discrete-event system simulation in modeling the transportation system of a large underground coal operation, Datun horizontal transportation project, in Xuzhou district in China. The model was developed to obtain the required mine transportation capacity and system type (Xu et al., 2011).

Fjellström (2011) gave an overview of a mine simulation investigation on evaluating different options to transfer ore to the crusher and waste to the backfilling room in the mine. This model assisted the modeler to eventually select the best alternative with lowest cost in the underground Renström mine. AutoMod software® with two Excel® interfaces for input and output data was used to construct the model. The research came to the conclusion that mine simulation can be used as a great tool to analyze underground mine transportation systems for the cheapest and most productive equipment (Fjellström, 2011).

Awuah-Offei et al. (2011) used discrete-event system simulation as an inexpensive and trustworthy program for modeling the truck/shovel system's energy efficiency. To illustrate how this can be done, a model of typical truck/shovel operations in a surface coal mine was presented and the results discussed. This simulation model could be used to assess and examine proposed mining operational strategies, including appropriate truck/shovel allocation, expanding loading equipment capacity, and decreasing haulage routs/roads to eventually improve the energy/fuel consumption in the truck/shovel operations. ARENA® simulation platform was applied to conduct this investigation (Awuah-Offei et al., 2011).

In 2011, Choi and Nieto used Google Earth®, KML, and GPSS/H® to design and develop an innovative software package that modeled a truck/shovel operation system in surface mines. The computer program was named Google Earth-based MIning SIMulation System (GEMISIMS). The simulation program enabled the user to analyze and find out the optimum road/route in the load-haul-dump process in mines. This simulation program not only could be used to optimize required trucks allocated to each road/route, but also it included a 3D render window by Google Earth® to visualize the trucks' movements in the mines. The developed simulation program was applied to an open-pit coal operation in Indonesia (Choi and Nieto, 2011).

2.2.5. Mine Simulation in 2012

A simulation model, using SimMine® simulation software package, of the Oyu Tolgoi, a large underground copper-gold panel caving mine in southern Mongolia, was developed by Li (2012) at the University of British Colombia for studying the mine pre-production development planning. This model was used for the development, planned optimization, and equipment selection in the mine (Li, 2012).

A simulation model using Visual Basic® and Excel® was created by Pereira et al. (2012) to model a room and pillar mine (Esperança mine) in Brazil to evaluate and compare several scenarios in the number of mined faces and distribution of panel equipment in the operation. The simulation results of the program indicated that the predefined decision of allocating equipment in the mine did not achieve a reduction in the productivity (Pereira et al., 2012).

Labrecque et al. (2012) used ARENA® simulation software for the planning and conducting the Oyu Tolgoi feasibility study in the South Gobi region of Mongolia. In this publication, an underground mine using panel caving techniques, it was explained how simulation was implemented to change the mine design processes and operating plans, and to evaluate the mine operating costs as a central information source. Assessing a series of the simulation results helped the engineers to increase the mine production rate, decrease the risks associated with the operational plans and evaluate factors that could exert an effect on the mine production rate and drawpoint construction rate (Labrecque et al., 2012).

Salama and Greberg (2012) pointed out the importance of simulation programs, using SimMine® software with a 3D animation environment, for modeling an underground haulage system, including a fleet of LHDs and dump trucks. The model was set up to test and analyze the impact of changing numbers of trucks working with the loading units in a deep underground mine. As a result of the simulation program, additional trucks were required to improve the loading equipment utilization and productivity in the mine (Salama and Greberg, 2012).

Since the longwall mining method has high extraction ratio, productivity, and safety, this mining technique has been used by more than 75% of underground coal mines in Australia. Cai et al. (2012) used Flaxim® with 3D animation to construct a simulation that aided management to evaluate the effects of technical and operating constraints in longwall mining productivity. Generally, this simulation model was developed to obtain optimum parameter scenarios that improve productivity in longwalls (Cai et al., 2012).

Pop-Andonov et al. (2012) presented a summary of the application of simulation as a powerful and efficient tool in improving efficiency in underground mine haulage systems (railway and vehicles) by providing hypothetical case studies. An ARENA® simulation package was used for modeling these cases. The model was applied to determine and analyze times and costs of transportation systems and ore flow to compare with other traditional methods (Pop-Andonov et al., 2012)

Tan (2012) constructed a simulation model of an open pit copper mine using Visual Basic® for Applications (VBA) programming to examine and create an output of truck dispatching control to validate the mine planning. The results showed that the simulation using Excel® and VBA programming could be helpful to increase the transportation performance of the trucks and decrease the associated costs (Tan, 2012).

Awuah-Offei et al. (2012) used ARENA® software to set up a discrete-event simulation to model and measure truck/shovel energy efficiency. For this purpose, required data and energy audits were collected and validated in a surface/strip coal operation. The research results presented how discrete-event simulation could be used to evaluate and compare different loading equipment and match optimum truck/shovel systems with respect to fuel efficiency in surface mines (Awuah-Offei et al., 2012).

A large open pit copper mine in Mongolia was simulated by Tan et al. (2012) to optimize the mine haulage operation, since the transportation costs were estimated to be high. For this purpose, a simulation was carried out to achieve the optimum number of trucks and the maximum capacity of the production. The data for modeling this operation was collected using the haul trucks' GPS (Global Positioning System) technology (Tan et al., 2012).

2.2.6. Mine Simulation in 2013

Stout et al. (2013) suggested using computer simulation programs, such as GPSS/H®, for short-term and long-term production planning, studying different parameters, for instance queuing problems, equipment utilizations, and production rates. The level of accuracy and capability of the stochastic simulation model, using GPSS/H®, developed by Stout et al. (2013) for a mine with multiple pit operations was as high as the existing deterministic planning methods at the mine. The model was able to simulate production operations for variable time frames, up to one year (Stout et al., 2013).

In the fierce market competition, appropriate selection of mining methods and equipment combination is of extreme importance. Upadhyay et al. (2013) discussed the popularity of continuous surface mining systems, owing to their cost-effectiveness and high efficiency. They analyzed two different cases: the continuous surface miner (CSM) system and the at-face slurrying (AFS) system, and compared the results based on the maximum production and optimum number of trucks. For simulation development, Visual SLAM with AweSim® software was used (Upadhyay et al., 2013).

Shelswell et al. (2013) presented a mine simulation program of an underground operation, the Young-Davidson Mine, which transports material using concurrent decline ramp truck haulage and skipping. The work included the theory, development, and analysis of the simulation. The model was structured to evaluate and compare the mine truck haulage performance with the capabilities of traditional TKM (tonne-kilometer) feet calculations. In the lower to moderate production rate scenarios, the simulation results and TKM calculations were found similar. However, in ramp-up and high production rate cases, simulation indicated more sensitivity in operating practices and factors that derived from the calculations driven by a single TKM figure. The Rockwell Automation ARENA® software was used during this simulation project. The simulation results demonstrated more flexibility in terms of highlighting several operational limitations that were considered in TKM calculations. By analyzing those limitations and identifying right strategies using simulation, it was feasible to optimize the mine productivity regarding truck fleet requirements/efficiency, mine scheduling targets, and operational practices (Shelswell at el., 2013).

Mining engineers need to have access to sufficient technical, geometrical, geographical and economic information to choose the best fleet type and size. This large number of variables, along with various ranges of brands, models and capacities of equipment in the market requires the use of a stochastic and deterministic simulation. Arroyo Ortiz et al. (2013) modeled an open-pit iron mine to determine the appropriate fleet selection using the software ARENA®, and analyzed different scenarios with various loading and haulage cycle distributions (Arroyo Ortiz et al., 2013).

A simulation model to improve truck/shovel operation efficiency was given by Torkamani (2013) in the Mine Optimization Laboratory at the University of Alberta. The simulation software ARENA® was applied to implement the model for an actual open-pit mine and it was linked to an optimal short-term production schedule. The program investigated queuing, equipment utilization, and production of mining operations and proved that the mine operational plan gained the optimum net present value in the mine scheduling phase (Torkamani, 2013).

Anani and Awuah-Offei (2013) discussed a discrete-event simulation approach to model a truck/shovel operation. This model was constructed, using ARENA® simulation software, to study a bunching issue due to slow trucks, which can occur in a haulage operation and increases cycle times in a mine operation. Consequently, the simulation model showed its useful application in modeling truck/shovel systems (Anani and Awuah-Offei, 2013)

2.2.7. Mine Simulation in 2014

Salama et al. (2014) used SimMine®, Swedish mining simulation software, to simulate an underground mine operation to analyze and select appropriate mining haulage and transportation equipment considering the mine productivity, traffic, and equipment utilization. They also compared two different haulage fleets and various scenarios to increase/improve the case study production. It included an overall review of mining simulation and different analytical methods for equipment selection in mining (Salama et al., 2014).

Vasquez-Coronado (2014) at the University of Arizona used discrete-event system simulation in a research project to evaluate and analyze various alternatives for a mining route/road design and queue study in order to optimize an open pit haulage operation. The simulation model was built in the ARENA® software. The model included both “As-Is” and “To-Be” models to assess and eventually optimize the haul trucks’ cycle times (Vasquez-Coronado, 2014).

Since mine development is a key in underground mining operations and it can impact the selection of excavation methods, selecting an appropriate method for this purpose is critical. Skawina et al. (2014) simulated mechanical excavation technique compared to a drill and blast method in one of Boliden Minerals AB’s mines in Sweden using AutoMod® to investigate and choose a suitable technique to boost the speed and efficiency of the mine development (Skawina et al., 2014).

Shelswell and Labrecque (2014) described the analysis and comparison of discrete-event system simulation and static spreadsheet programs to evaluate and analyze the oreflow efficiency of two conveyer systems in a block-cave expansion project (parallel conveyor streams and a conveyor stream in series). The ARENA® simulation software was used as a discrete simulation package to model the conveyor and hoist/materials handling system to transport materials from underground to the stockpiles on surface. The simulation results showed that random conveyor failures in both cases played an important role in daily rates/performances of the systems. The results also indicated that conveyor system performance was reliant upon the operating conditions, and other factors, such as the availability of maintenance people to conduct scheduled and unscheduled maintenance are also critical (Shelswell and Labrecque, 2014).

Salama et al. (2014) discussed a mine system simulation model using GPSS/H® to analyze different haulage methods with associated operating costs, and their effects on energy requirements when an underground mine’s depth increases. In this study, a combination of both discrete-event system simulation and mixed integer programming (MIP) was conducted to improve decision-making process in mine planning and optimization (Salama et al., 2014).

Cai et al. (2014) developed a simulation model using Flexim® simulation with 3D animation packages for longwall coal mines in Australia to model the mine roadway development and evaluate how different configurations in the operation can work with a wide range of uncertainties. The main aim of the project was to simulate the shuttle car routes to reduce and improve the cycle time of shuttle cars at the design stage in a case study. The model was able to run “what if?” questions in terms of examining equipment configurations, operational practices and different layouts for the mine roadway development and equipment utilization (Cai et al., 2014).

Mine to the mill or to the markets materials handling simulation models are rarely done and published. Sturgul et al. (2014) conducted a complex simulation project using GPSS/H® and PROOF Professional® to model a new iron mine, including hauling the mined ore to market by ships in South Australia. Several “what if?” questions were answered by using the model and the program results showed the advantage of having a third barge for loading the Panamax ship (Sturgul et al., 2014).

SLX® (Simulation Language with Extensibility), the latest simulation language of the Wolverine Software Company, with 3D animation, PROOF Professional® 3D software, were used by Sturgul et al. (2014) to model an underground cut and fill stoping gold mine in Ghana, West Africa. This simulation model assisted the mine engineers in running several “what if?” scenarios associated with a mine expansion, such as determination of the right number and size of haul trucks for the expansion project and the placement of passing bays in the mine (Sturgul et al., 2014).

Table 2.1 summarizes a list of the simulation languages or software packages used for the conducted mine simulation models from 2008 to 2014.

Table 2.1: List of Used Simulation Languages/Software (2008-2014)

Programs / Years	ARENA®	GPSS/H®	AutoMod®	Simul8®	SimMine®	Sundries
2008	✓		✓✓	✓		✓
2009	✓✓✓		✓	✓	✓	✓
2010	✓✓✓	✓✓				✓✓✓✓✓
2011	✓	✓	✓		✓	✓✓
2012	✓✓✓				✓✓	✓✓✓✓
2013	✓✓✓✓	✓				✓
2014	✓✓	✓✓			✓✓	✓✓

Table 2.2 also presents a summary of the mine types of the simulated and published projects. This comprehensive and detailed literature survey on the recent mine simulation projects was highly valuable for carrying out the research study.

Table 2.2: Summary of the Simulated Mining Techniques from 2008 to 2014

Mine Types / Years	Underground	Surface	Not-mentioned
2008	✓✓✓	✓	
2009	✓✓✓✓	✓✓	
2010	✓✓✓✓	✓✓✓✓✓✓	✓
2011	✓✓✓	✓✓✓	
2012	✓✓✓✓✓✓	✓✓✓	
2013	✓	✓✓✓✓✓	
2014	✓✓✓✓✓✓	✓✓	

Chapter 3. Simulation

A detailed discussion on discrete-event system simulation and animation modeling and procedures, and its applications in mining engineering is provided in this chapter.

Simulation is a flexible and powerful analysis tool (whether done manually or using a computer) to model a system to assess the behavior of possible changes in the system over time. Modern computer simulation programs allow the user to model and investigate more sophisticated systems to examine the effects of changes on the performance of the systems.

Various definitions of simulation have been provided by eminent experts in the field. Banks et al. (2010) described simulation as “the imitation of the operation of a real-world process or system over time.” Shogan (1988) defined simulation as “an experiment in which we attempt to understand how something will behave in reality by imitating its behavior in an artificial environment that approximates reality as close as possible” (Shogan, 1988). Maria (1997) described it as “a simulation of a system is the operation of a model of the system. The model can be reconfigured and experimented with; usually, this is impossible, too expensive or impractical to do in the system it represents.” Banks et al. (2010) explained that simulation models are specific types of systems’ mathematical models, which can be classified as static or dynamic, deterministic or stochastic, and discrete or continuous.

Simulation approaches can be generally divided in different simple classifications, such as Discrete-event System Simulation, Monte Carlo Simulation, System Dynamics, Continues System Simulation, and Virtual Reality.

3.1. Applications of Simulation in Other Disciplines

Simulation has vast and valuable applications in other fields and different sciences. To become familiar with and learn further about the latest simulation applications, there are several important international conferences and symposiums to attend. In particular, the Winter Simulation Conference (WSC), which is held every year, is very well-known and distinguished. The next WSC 2014 program, will be held in Georgia, and includes many recurrent subjects and a few new topics such as (Winter Simulation Conference, 2014):

- Big Data Simulation and Decision making
- Introductory and Advanced Tutorials
- Analysis Methodology
- Modeling Methodology
- Simulation Optimization
- Agent-Based Simulation
- Hybrid Simulation
- Scientific Applications
- Healthcare Applications
- Logistics, SCM and Transportation
- Manufacturing Applications
- Military Applications
- Project Management and Construction
- Business Process Modeling

- Homeland Security and Emergency Response
- Environmental and Sustainability Applications
- Networks and Communications
- Serious Games and Simulation
- Simulation Education
- MASM (Modeling and Analysis of Semiconductor Manufacturing)
- Vendor
- Industrial Case Studies

Since in this study, only discrete-event system simulation is used in modeling different mining operations and scenarios, a description of this type is provided in the following sections.

3.2. Advantages and Disadvantages of Simulation

A simulation model is developed and constructed to mimic what happens in a real world/system, hence it is very attractive to the people/researchers who are studying or observing the behavior of the system. Simulation allows the modelers/users to investigate the outputs of any possible changes in the real system and use it as a strong and flexible problem solving tool. Simulation techniques are used to ‘run’ and study different alternatives in a system to select the best option, rather than directly ‘optimize’ the system. Technically, simulation includes many advantages and few disadvantages (Banks et al., 2010). The following can be considered as the benefits of simulation:

i. Without interrupting and cutting-off an active system/ongoing operation, new operating procedures, proposed plans, information flows, decision rules, proposed changes can be investigated and assessed by simulation.

ii. Before allocating resources and financial budgets, hypothetical designs, new layouts, proposed systems, and alterations can be evaluated and verified.

iii. Assumptions on how and why certain phenomena and predicated events happen in a system can be analyzed and studied.

iv. Time for speeding-up or slowing-down of the effective phenomena under system examination process can be acquired and adjusted.

v. The interaction of variables can be examined for detailed analysis.

vi. The importance of variables in a system can be realized and sorted.

vii. Bottlenecks can be recognized and analyzed and their impacts on the system's behavior can be reduced.

viii. Understanding of how the system works can be obtained by simulation rather than judgments of individuals.

ix. "What if?" scenarios/questions can be considered and assessed without the implementation costs of the proposed plans. Designing a new stage/system can be tested and analyzed easily (Pegden et al., 2010).

x. Animation software working with simulation can enhance the quality of simulation and visualize simulation programs on a screen.

The disadvantages of simulation include:

i. Special training is required for modelers, which needs time and effort.

ii. It is difficult to interpret simulation outputs, since most of simulation results involve random variables.

iii. Developing a simulation model and analyzing the results require time and budget. Simulation studies can be expensive and time consuming.

iv. When simulation, a costly approach/technique, is implemented to solve problems that analytical solutions for those cases are readily available and can be applied. Simulation is an inappropriate technique under these circumstances (Pegden et al., 2010).

v. For large modeling projects, it can be labor-intensive and it cannot or should not be done in isolation.

vi. Simulation is used to "run" scenarios not to "solve" scenarios. Moreover, reproducing the 'exact' results of the actual/real systems is very rare; however, the simulation results can be very similar and close to reality.

3.3. Discrete-Event System Simulation

Discrete-event system simulation has been applied to many fields and technologies to model systems for a better understanding and performance analyses. "Discrete-event simulation software allows you to place your system under a microscope and explore its operation under laboratory conditions" according to the Wolverine Software Company's website (Wolverine Software Company, 2014). Banks et al. stated that a discrete-event system simulation "is the modeling of systems in which the state variable changes only at a discrete set of points in time" (Banks et al., 2010). Nance (1993) mentioned that "discrete event simulation utilizes a mathematical/logical model of a physical system that portrays state changes at precise points in simulated time. Both the nature of the state change and the time at which the change occurs mandate precise description." Good examples of discrete systems are manufactures, banks, barbershops, warehouses, gas stations, grocery stores, ports, traffic flows, airports, mines, etc.

As a clear explanation, if it would be assumed a train is traveling from city A to city B, the loading time of passengers in the station in city A and the unloading time of passengers in the station in city B are independent events of each other as well as the travel time that it takes the train from city A to city B. In fact, this system includes countable actions/events that can happen at any discrete point in time.

3.4. Steps in Developing a Simulation Model

The following items discuss a series of steps/processes that assist a modeler to design and develop a simulation model. Figure 3.1 shows the informative processes as a guideline for conducting a simulation study (Banks et al., 2010).

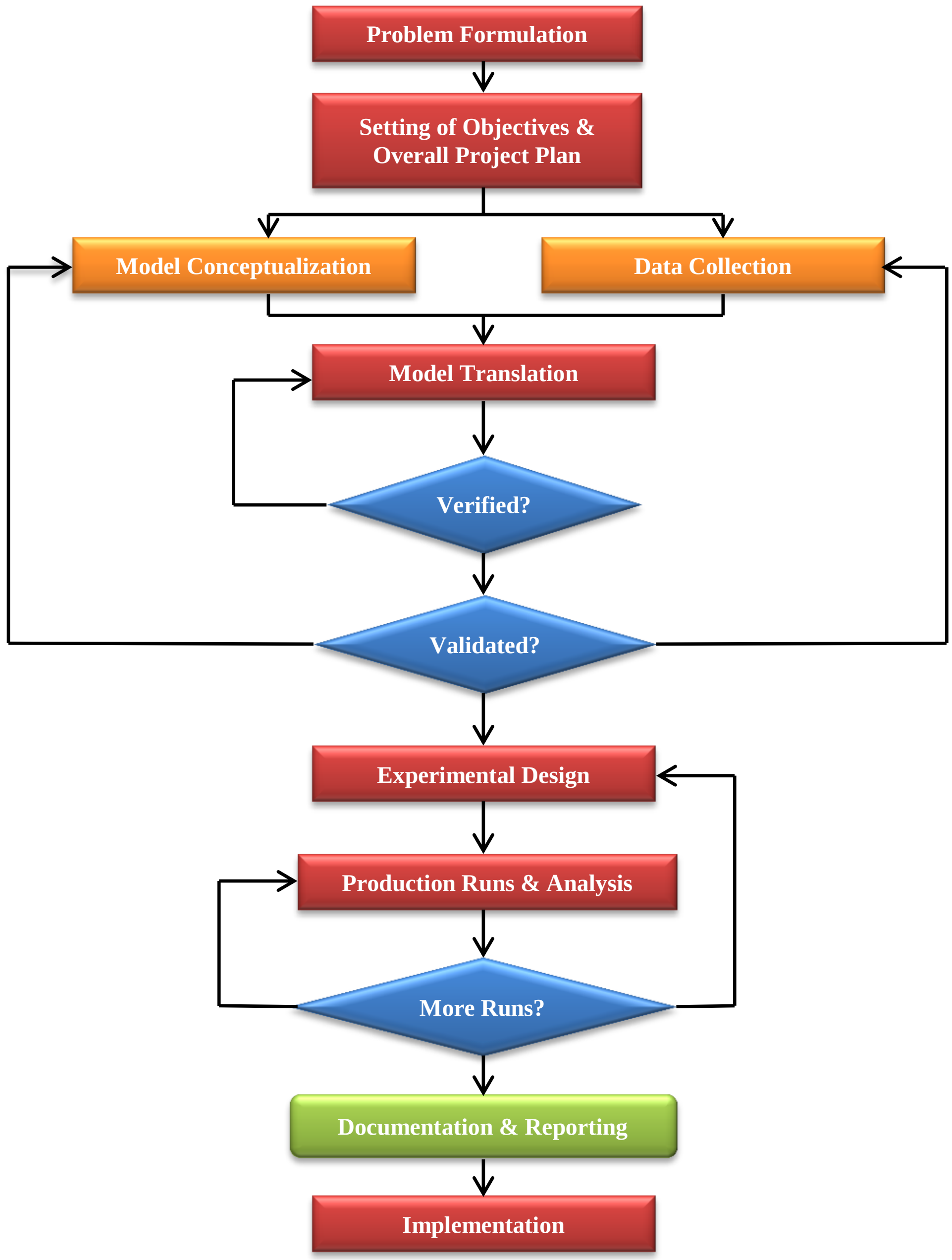


Figure 3.1: Procedure for Developing Simulation Programs (Banks et al., 2010)

1. **Problem Preparation/Formulation:** The first step in each analysis is the identification and description of the problem(s). The problem(s) should be defined clearly, either by clients or by analysts. Both parties should have a good

understanding of the problem and be aware of the potential changes of the problem formulation during the analysis.

2. **Setting of Objectives and Overall Project Plan**: After the problem is stated and formulated, a set of objectives should be identified, i.e. the questions that are to be answered by the simulation. The sufficiency of the simulation to address the defined problems and solutions are determined in this step. Assuming that simulation is the proper methodology for the problem, an overall plan is prepared. The plan consists of various alternative systems, and methods for their assessment. Moreover, the plan includes required man/hours for each stage, expected results at the end of each phase, and anticipated cost of the study.

3. **Model Development/Conceptualization:** To develop a successful and comprehensive model, several steps need to be taken: first, the vital features should be recognized and isolated; second, preliminary assumptions should be created and modified during the process, and finally, the model should be elaborated and enriched in different phases to achieve reasonable results. The best method to reach the required complexity is to start from a basic model, and add features as needed. The level of complexity of the model has a direct effect on model building time/cost. In general, there is no need for one-to-one mapping of the reality. An optimum model is a model that includes the essence of the problem, without going overboard on unnecessary details. It is recommended to involve the model user in this process. This will enable the user to familiarize with the model development and incorporate all important subroutines into the main process logic of the systems.

4. **Data Collection:** Type of data is usually imposed by the objectives of the study. Two important factors affect the collection of data. First, required data can change based on the complexity of the model; and second, since the process of data collection takes a considerable portion of required simulation time, it is advisable that this process be initiated as early as possible. The collected data can be used as input to the simulation model, or as benchmark for validation of the simulation.

5. **Model Translation:** Different computer programs can be used to accommodate the large volume of information and data interpretation required for real-world systems. Although the term "program" is used here, it should be noted that it does not necessarily mean that complicated coding is required for the simulation model. General simulation languages, such as GPSS/H® or simulation software can be used for modeling. Although simulation languages have lots of capabilities and flexibility, the use of simulation software, if possible, will greatly reduce the modeling time.

6. **Model Verification/Debugging:** In complex models, comprehensive debugging is required to verify the simulation model. In general, verification of the model depends on acceptable input parameters, correct logical structure of the model, and common sense.

7. **Model Validation:** Validation of the model takes place through calibration, i.e. the iterating process of checking/comparing the simulation results with actual system behavior and improving the model to achieve the desired accuracy.

8. **Experimental Design:** The goal of this step is to determine the alternatives to be simulated based on completed runs. Decisions about the length of initialization period, simulation runs, and the number of iterations for each runs should be made for each system.

9. **Production Runs and Analysis:** In order to estimate the performance of each simulated system, different production runs should be executed and analyzed.

10. **Subsequent More Runs:** In this step, based on obtained results, the analyst determines if additional runs are required.

11. **Documentation and Reporting:** Programs should be documented in a clear and understandable fashion for future access. This will enable both clients and analysts to assertively make decisions based on the analysis. This program documentation can be beneficial for both current and different analysts. With proper documentation, another analyst will be able to easily use the simulation model. Furthermore, model users can modify different parameters to investigate the relationship between input/output parameters, and/or to optimize the performance.

    Progress should also be reported and documented regularly to establish a chronological sequence of work and decisions, and keep the project on track. It is advisable to keep a log for all results, change requests, decisions, and other important items. Furthermore, by sending out regular updates to those who are not involved directly in the modeling process, it will help in identifying potential problems and misunderstandings in early stages. It is reasonable to have various small milestones in the life of the project, instead of having one absolute deadline/finish date. Reports should be made for these markers and they should meet their own individual deadlines. The final report of the study shall include clear and concise results for all the analyses to allow decision makers to review the final formulation, alternative systems and their comparison to each other, and recommended solutions to the problem.

12. **Implementation:** The result of this step relies on previous ones. As long as the performances of previous steps are acceptable and the model user has been involved in the simulation development, the implementation process will go smoothly. In contrast, if the model and its assumptions have not been checked with the user of the model, regardless of the validity of the model, there is a high risk for poor implementation (Banks et al., 2010).

3.5. Using Discrete-Event Simulation in Mining Engineering

Mine systems are dynamic and include concurrent operations in the development and production stages. Discrete-event system simulation is an appropriate and accurate tool to model complex systems, such as mining operations with many uncertainties, for better planning, design and management. In general terms, mine engineers need to know and study the limitations and other specifications of mining projects to be able to provide optimal mine design, planning, and operation. Furthermore, engineers are also required to maintain the mine operations as cost-effective as possible, owing to the volatile markets of mineral commodities. Some mineral commodities tend to be really volatile and this increases the market risk for this business. Therefore, mining engineers/managers have to carefully plan, allocate, and manage both capital and operational budgets during the life of mine. In many years, the application of discrete-event system simulation for analyzing and studying mining operations is well-known and established as an appropriate tool for mine design, equipment selection, planning, and optimization. The Lihir mine in Papua New Guinea was the first mine operation to be completely designed and planned by simulation and animation (Jacobsen et al., 1995).

Mining engineers need to take into consideration many uncertainties when designing, operating, and managing a mine. It is important to know the limitations, constraints, and other specifications of a mine to be able to maintain an efficient mining operation throughout the life of the mine. A mining operation takes a large amount of capital both in development and during the life of mine. The process of analyzing a mine’s existing operation and possible alternatives that can be implemented will prevent unnecessary expenditures in replacing and purchasing new equipment (Cetin, 2004).

A discrete-event system simulation model of a mining operation is one of the most flexible and insightful tools that can assist engineers to analyze alternatives before making a change in the proposed plans and both capital and operating budgets. This technique assists the mining engineers in efficiently analyzing the mine’s best existing and possible alternatives/strategies that can be implemented in the present and future. Simulation is also extremely flexible, powerful and quick to test and examine various “what if?” scenarios/analyses in planning both surface and underground mines. Even though a discrete-event simulation technique generally does not include a built-in optimizer tool due to its required natural flexibility, it is well-accepted for use to improve mining operations by running and investigating numerous possible changes. The most classic simulation programs of open-pit mines have been generally used for modeling and studying the haulage operations. The reason can be that typically more than 50% of mine operating expenditure in surface mining is haulage operations (Nel et al., 2011). A true and valid model of a real mine operation would be greatly beneficial for the engineers to examine “what if?” scenarios to attain the best possible choice in mine equipment, design and operation. Obviously, one of the most complex systems to consider and solve in surface mines is material load-haul-dump operations. Simulation has widely been used for selecting appropriate equipment fleet type and size in both surface and underground mines. Burt et al. (2005) also discussed equipment selection methodology, particularly integer programing, simulation, and artificial intelligence, which helps to determine a proper fleet type and size for trucks/shovel operation (Burt at al., 2005). Figure 3.2 illustrates a simple schematic of a truck/shovel operation in surface mines.

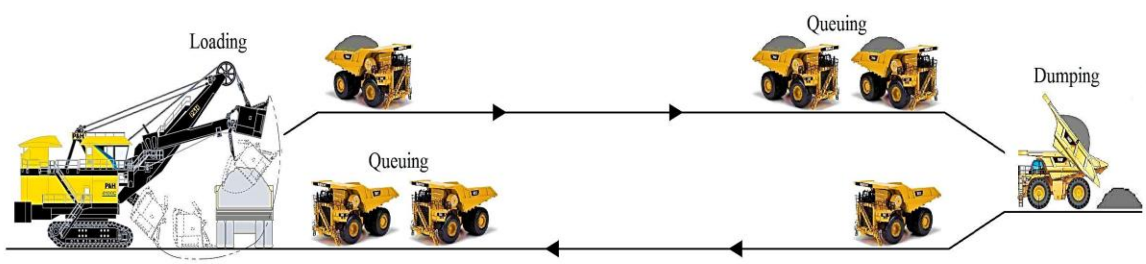


Figure 3.2: Schematic of Truck/Shovel System in Surface Mining

In modern and mechanized large surface and underground operations, mine simulation can be used very effectively and reliably to model the complexity of the operations that traditional methods are usually unable to perform. Mine simulation models, like other systems, can be constructed in either probabilistic (stochastic/non-deterministic) or deterministic forms or a combination of both. By conducting mine time studies and modeling the time distributions with appropriate type distributions, a mine probabilistic simulation model is developed for existing operations. If the model needs to be designed for non-existent new mine/phase operations or feasibility studies, typically a deterministic simulation model using available sources, such as equipment manuals and mining software calculators, is constructed due to the fact that actual time measurement is not possible. Validation and verification of the mine simulation models are always imperative to gain true/correct results. Govinda Raj et al. (2009) classified mine simulation studies/projects as shown in Figure 3.3.

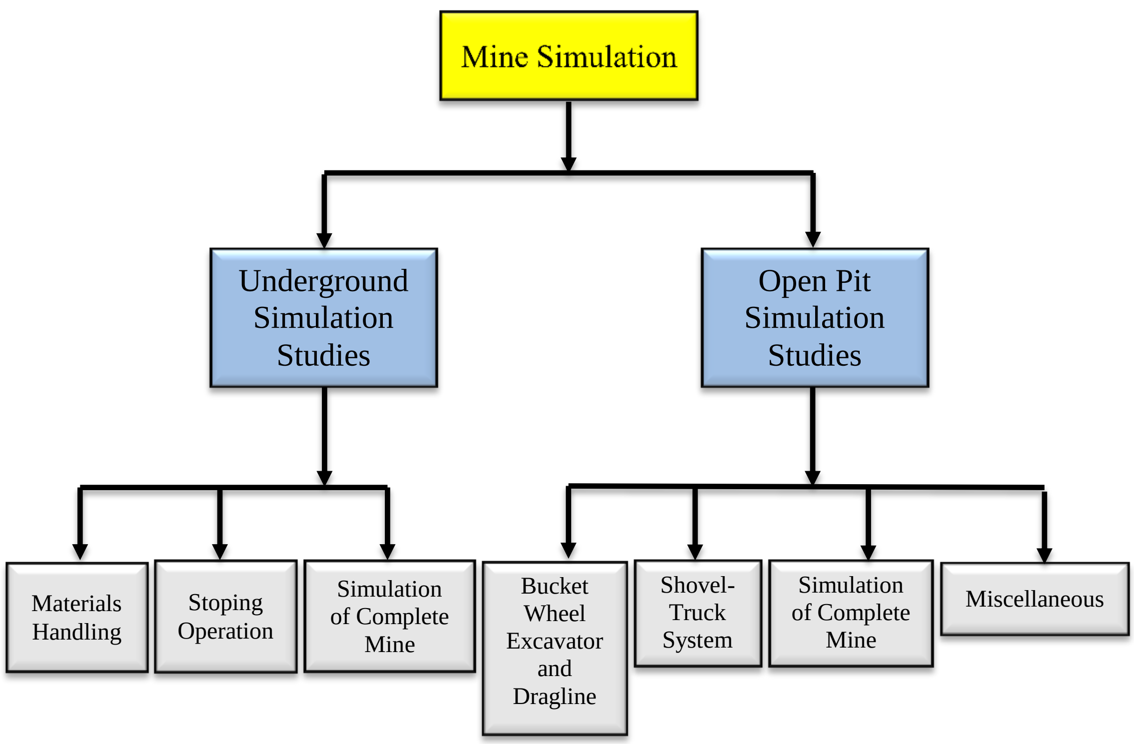


Figure 3.3: Classification of Mine Simulation Projects (Govinda Raj et al., 2009)

Major useful and valuable steps to perform a mine simulation and animation study are illustrated in Figure 3.4 (Karimi-Tarshizi, 2012).

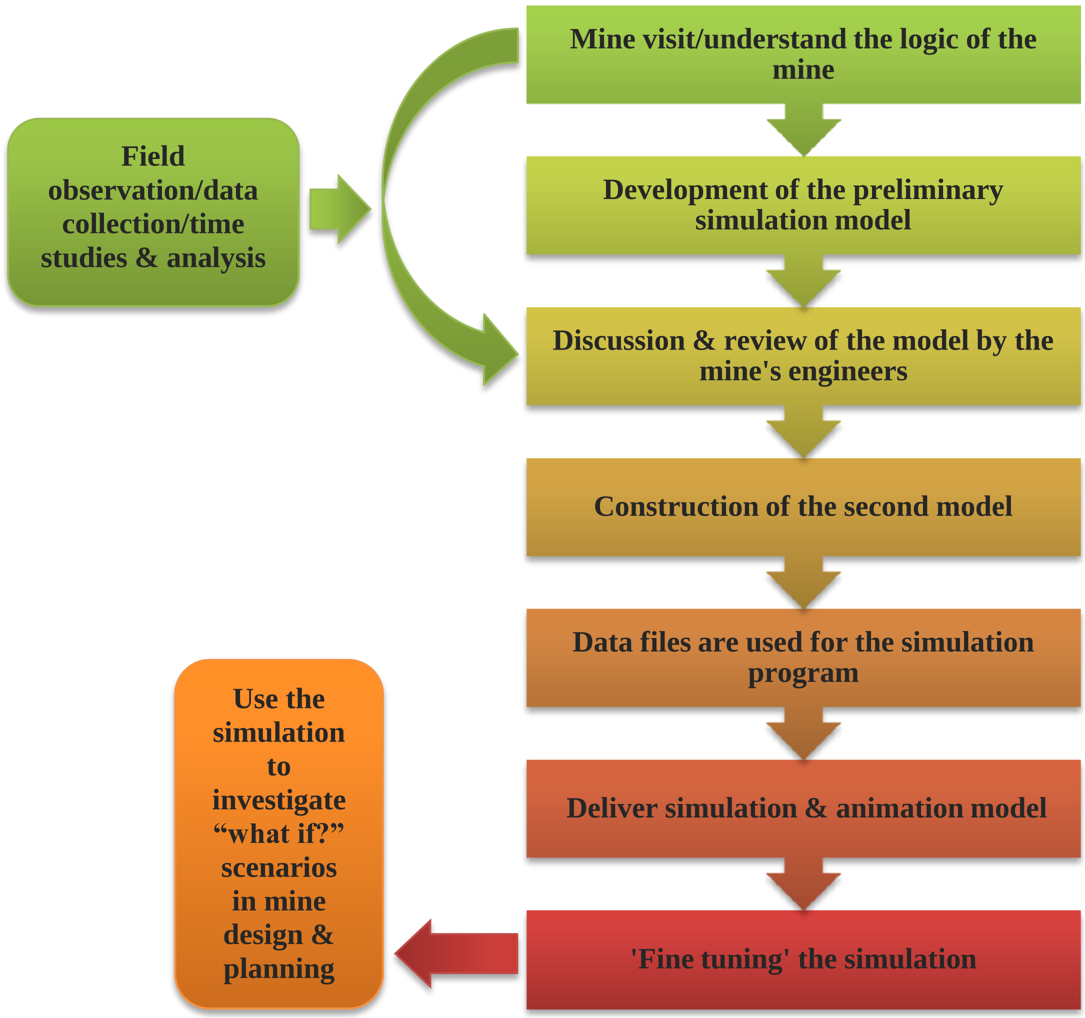


Figure 3.4: Mine Simulation and Animation Project Development in Different Phases

3.5.1. Classification of Computer Simulation Programs for Mining Projects

In general terms, the classifying of discrete-event system simulation tools for mining projects is quite feasible. Greberg and Sundqvist (2011) categorized computer simulation tools into four different groups:

1. General purpose programming languages (C, C++, Fortran, Visual Basic, and Java) have high modeling flexibility and capability, low cost or free, but require high proficiency and skill to develop complex simulation software.
2. General purpose simulation languages (SIMAN®, Simula®, SimPy®, GPSS®, Poses++®, and SLAM®) are based on object-oriented simulation, with great flexibility and power for modeling, but they need programming skills.
3. Simulation software packages (AutoMod®, Flexim®, Promodel®, Simul8®, Arena®, Witness®, AweSim, and Simio®) require less programming expertise, are easy to use, but they are less flexible.
4. Mining specific simulation program packages (SimMine®) are produced and designed for modeling underground mine operations, no programming skills are needed, ability to directly import mine layouts, but they are only suitable for underground mines (Greberg and Sundqvist, 2011).

3.6. Why is GPSS/H® Used for Mine Simulation Projects?

During these mining simulation studies, GPSS/H®, as a powerful simulation language, was used for modeling, even though other simulation languages exist that are quite well-known and flexible for simulation projects. Many advanced and popular discrete-event system simulation languages and software, such as ARENA®, SIMCRIPT II.5 (MODSIM)®, SLAM®, SIMPLE+®, ProModel®, AutoMOD®, GPSS/H®, SIMUL8®, SimMine®, FlexSim®, Witness®, Simio®, SLX® have been used in the mining and minerals industry.

GPSS/H®, known as a tried-and-true simulation tool, low-level, and a nonprocedural language, has been proved and shown its great capability and applicability in both academic and commercial simulation projects, particularly in mining engineering (Sturgul, 2000). GPSS, the General Purpose Simulation System, is 53 years old, but its three systems and family members: GPSS/H, GPSS World, and the educational aGPSS systems are still supported, improved, and used. The genealogy of the GPSS systems, starting from 1961 to 2011, is shown in Figure 3.5. In each cell, the name of the system followed by the year of introduction and number of block types are presented (Stahl et al., 2011).

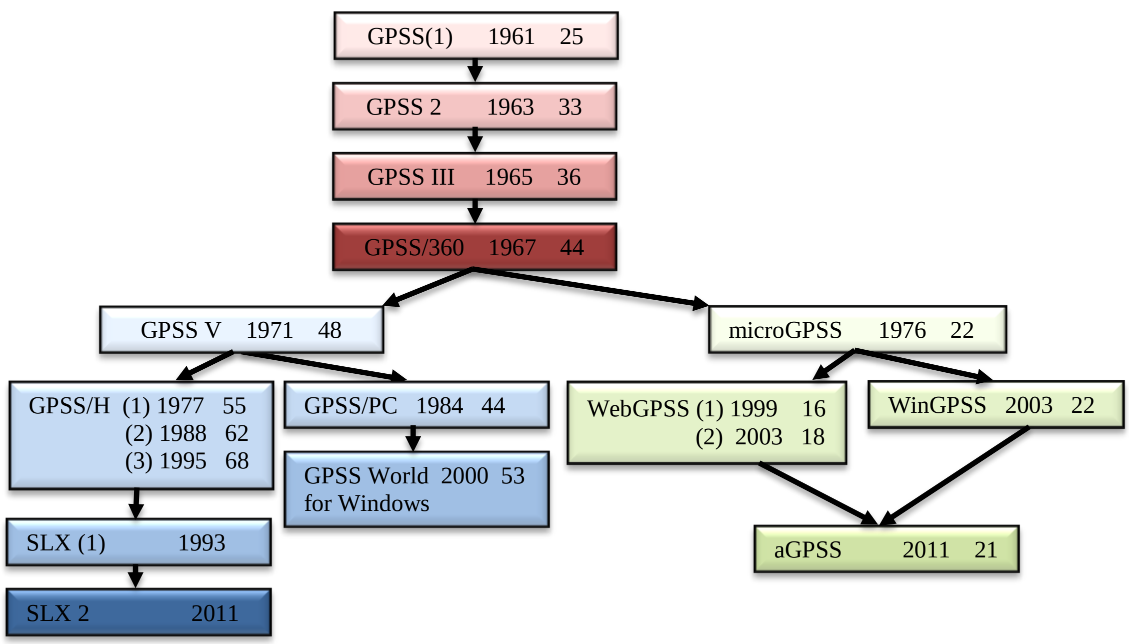


Figure 3.5: The family of GPSS systems (Stahl et al., 2011)

GPSS World is provided and supported by the Minuteman Software Company (www.minutemansoftware.com) and aGPSS, the streamlined version of GPSS, is maintained and sold by Ingolf Stahl (www.agpss.com). GPSS/H®, both a computer language and a computer program, is a version of GPSS that was developed by James O. Henriksen and also is supported by the Wolverine Software Company in Virginia, USA (www.wolverinesoftware.com). GPSS/H® has been commercialized since November 1997, and it has become well-recognized for its ability in fast-processing and dependability (Henriksen, 2000). GPSS/H® is the most advanced version of GPSS (Sturgul, 2000) and has shown a great history of success in commercial and academic simulation models (Crain, 1997). GPSS/H® has been used globally to simulate queuing systems, for instance manufacturing platforms, distribution plans, transportation systems, telecommunications, hospitals, computers, logistics, mining, etc. (Crain, 1997). Crain (1997) stated that "the process-interaction world view combines with the advanced features available in GPSS/H® to make one of the most powerful and flexible tools available, capable of handling the largest simulation projects with ease, yet still providing exceptionally high performance."

GPSS/H® was selected to conduct these mining system simulation projects for the following reasons:

- It has been successfully utilized in mine simulation projects by many researchers around the globe.
- GPSS/H® is constantly being supported and upgraded by the company.
- It has been acknowledged by the experts and experienced modelers for its flexibility, robustness, ease-of-use, and extremely high performance (Crain, 1997).
- It has been widely implemented in many other industries.

- It is a cost-effective, accurate, and fast-processing simulation language to perform both simple and complex discrete-event system simulation projects from many various sectors and industries.
- It has been applied to simulate some of the largest projects ever done.
- GPSS/H® programs are surprisingly short in comparison with other programs for the large and complicated systems; nevertheless, simulation models with more than 100,000 (!) lines of code have also been constructed (Sturgul, 2000).
- GPSS/H® has several features that enable the user(s) to implement the programs as the engine for other special-purpose simulators/models (Henriksen, 2000).

SLX® stands for Simulation Language with Extensibility, is an advanced and powerful extensible new generation of a simulation language, offered by the Wolverine Software. SLX® is distinguished from other simulation languages by its well-conceived and separated layers. This slightly new and extremely flexible simulation language allows its users to modify and extend its capabilities in modeling complex systems and to integrate with others simulation programs, involving high-level architecture (HLA). Henriksen (2000) also emphasized that “you’ll never get “stuck” with a problem you can’t solve with SLX.” Additionally, the SLX® has been mentioned as simulation software that stretches the boundaries of simulation (Henriksen, 2000). SLX® simulation can also be a rapid and high-performance simulation platform to be used for modeling both complex and large-scale underground and surface mine operations.

3.7. Animation Used for Mine Simulation Studies

Several animation software packages, such as CINEMA®, PROOF Animation®, ARENA® 3D Player, and SIMGRAPHICS® are available for post-processing and displaying simulation models/programs developed by the modelers/analysts. However, many simulation software packages contain their own animation utility, commonly as a combined package.

PROOF Animation®, supported by the Wolverine Software, is one of the top available commercial animation software in quality, power, and performance. PROOF Animation® is inexpensive and is a general-purpose animation software, which is run on PC computers to dynamically visualize the simulation entities and processes during the simulation project implementation. Obviously, the animation can act as a visualization interface for the simulation model. PROOF Animation® is outfitted with built-in precise drawing tools, which enable a user to import and export CAD files with .DXF format for creating a static layout for simulation. PROOF Animation® also benefits from Microsoft®'s Direct Draw interface to access the computers' graphic hardware (Henriksen, 2000). The animation program is ideally used as a post-processer, run after simulation, and especially for developing and debugging codes created by various simulation languages.

Any simulation languages or software, or non-simulation/general programming languages, such as C, C++, Python, Fortran, Java, and the programming languages that create or write Trace files (ATF) in the ASCII format can drive animation by PROOF Animation® (Henriksen, 2000). The quality and detail of the animation creatively depend on the artistic talents of the modelers.

PROOF Animation is offered by the Wolverine Software in different versions and packages, including PROOF 3D®, PROOF Professional®, Student PROOF Animation®, Run-time PROOF®, PROOF Demon Maker and Demo Viewer®, and PROOF for Extend®. An example of the truck/shovel system 3-Dimentional using PROOF 3D® animation is created and shown in Figure 3.6.

The version of PROOF that was used in this research was PROOF Professional®. This package includes many powerful features, such as drawing tools for layouts, defining and modifying object classes, defining paths, changing an object's shapes, rotating objects, adding sound to animation, varying the speeds of objects on the paths, importing and exporting .DXF files, creating bar graphs, changing the speed of displaying animation, making zoom-in and zoom-out, creating video files (AVI format), building presentations, setting different colors, and so on (Wolverine Software, 2014).

In this research project, various animations of the mine operations were designed and created concurrently with the simulation models.

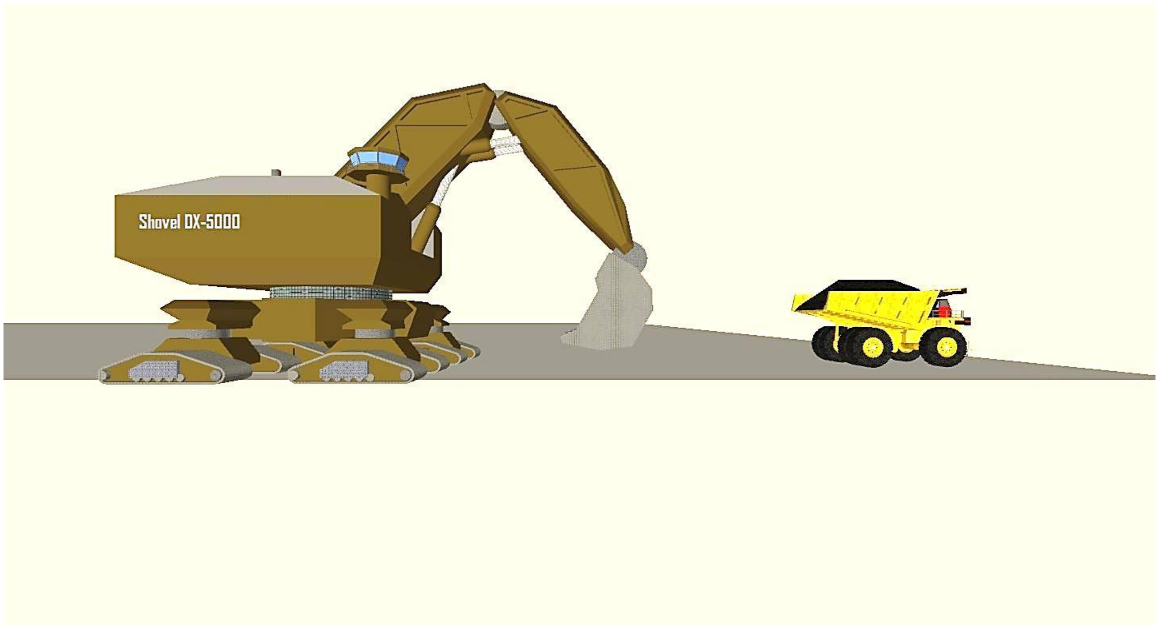


Figure 3.6: An Image of Developed Three-dimensional Truck/Shovel System using PROOF 3D®

3.8. Verification and Validation of a Simulation Model

Verification and validation of the simulation are of great importance. It is crucial for model developers to work closely with engineers, clients, and managers to improve model credibility. The model should represent the actual system behavior with acceptable accuracy in order to enable the end users to implement the simulation for system behavior analysis and prediction. Verification and validation of the simulation model is a part of the model development process. Verification of the model is checking the model to implement the simulation software correctly, and that the model has a logical structure and input/output. In other words, it is concerned with the model building accuracy. Validation is to confirm that the model is accurately presenting the real system, which usually involves the calibration of the model while comparing the performance of the simulation model with actual system behavior and improving based on the results (Banks et al., 2010)

There are several steps in building a model (Figure 3.7). The first step includes the investigation of the real system and data collection. For sufficient understanding of the real system, both observation and communication with the people familiar with the system are required. Secondly, a conceptual model is developed based on the assumed components and input data. The last step includes the implementation phase of an operational model, using the assumptions of the conceptual model (Banks et al., 2010). In fact, these processes are required in constructing a simulation model in mining projects.

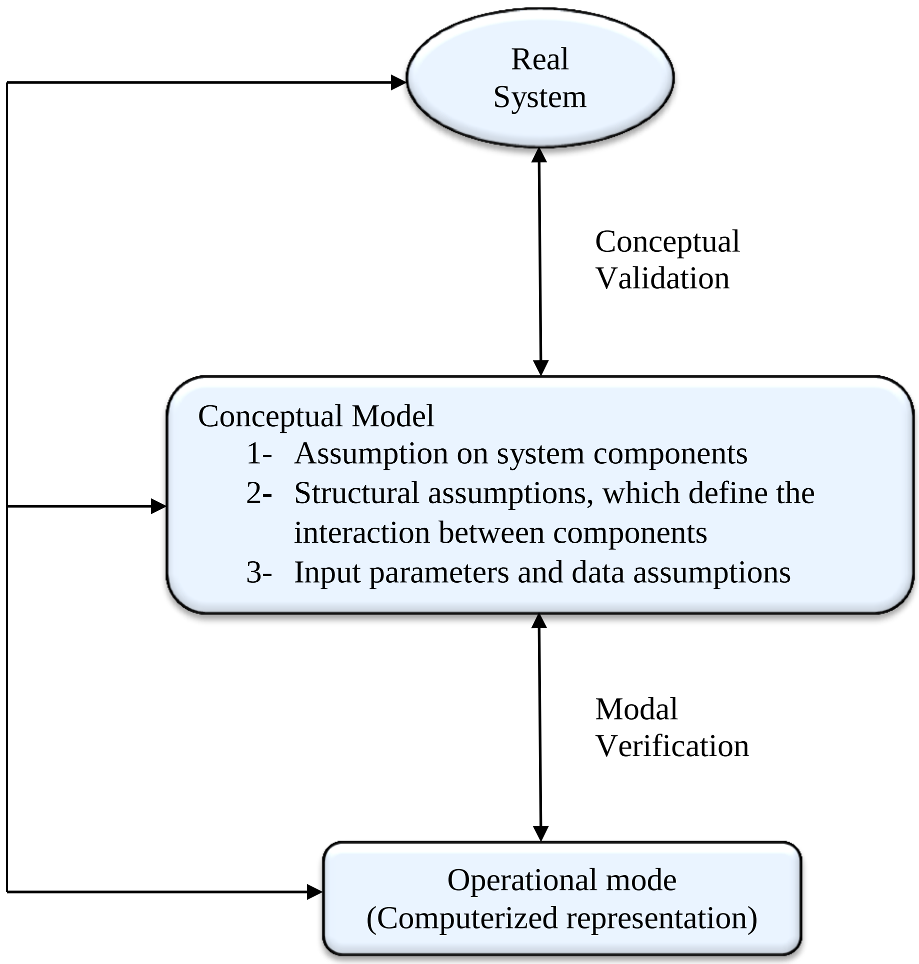


Figure 3.7: Verification and Validation of a Simulation Model (Banks et al., 2010)

3.9. Advantages of Animating a Mine Simulation

Animation generally enhances the quality and effect of simulation. In mining engineering, it is also very beneficial and helpful, in terms of visualizing mining operations on the computer screen. This can assist the mine engineers to thoroughly observe their mining operations and pose "what if?" scenarios to improve productivity. In other words, the animation helps mining engineers and managers to carefully "watch" and review the activities in their mines and to identify the bottlenecks of the current operation, or possible changes/plans that might create bottlenecks in the future.

Clearly, by observing entities and identifiable elements that move through a realistic system, the modelers or engineers can recognize and figure out why technical problems can happen/occur or why one option might be better than the others, especially in complex systems. Animation is not only an appropriate and insightful tool for presenting a simulation model and its results in a meaningful way, but also it is an effective approach to represent the logic of the modeled system.

Animation is accepted as a convenient technique to 'confirm' and 'verify' the simulation models in action, and assesses whether the simulation works correctly and replicates the real system precisely. Animation can always carry a surprise or un unexpected result for the modelers or analysts. Particularly, animation is very beneficial and applicable for debugging programs/codes by exposing possible errors and problems noticeably in the process of constructing a simulation project. As a visual examination tool, animation can make modelers to become more familiar with the components of the system and their operational logics. Animation also enhances a visual impact or sense of reality device for the many vendors of industrial equipment to 'sell' and present conceptual systems/models easier to customers (McHaney, 2009).

In addition to all the foregoing, while animation is the byproduct of simulation, it helps the mining engineers with drawing tools to develop and create drawings of mining equipment and other items, such as clocks, dumps, crushers, etc. in a cartoon fashion. Animation of mine simulation also allows the engineers/managers to see and better understand the results of the computer simulation (Sturgul, 1993).

3.10. Animation of Mine Simulation Misconceptions

It is believed that there are a few common pitfalls and misconceptions in animating a simulated dynamic process. This should be carefully considered by a modeler/analyst.

Typically, animation is only a tool to set up a 'good' mine simulation model, but still the correctness and accuracy of the model heavily relies on the flexibility of the simulation language/software, data collection, data analysis, the correct implemented logic of the system/case study, etc. The precision and trueness of a mine simulation model depend on the quality of data for a probabilistic/stochastic model or precise assumptions for a deterministic model. Therefore, if an animation displays the 'logic' of the operation realistically, a 'good-looking' animation may misinform the user/engineer that the simulation program creates correct and validated output/results (McHaney, 2009) and (Maria, 1997). In addition to causing overconfidence, creating an attractive mine animation can be time consuming and laborious. This may lead the modeler(s) to spend too much time and energy on setting up the animation instead of constructing a precise simulation model with suitable data analysis. Hence, animation should be utilized as a supplementary product or byproduct for simulation (McHaney, 2009). In fact, only by integrating the visual power of animation with a statistically valid simulation model, a 'complete' and 'fine' simulation model is obtained.

However, animation is a great tool for debugging and communication, but it is not an appropriate substitute for considering/viewing the results of simulation each time the analyst runs the model (Maria, 1997).

Last but not least, animation should not be accepted as a conclusion for a simulation output and a system's true behavior. The client should always be concerned about the analysis of simulation outputs rather than accepting the simulation model based on the animation program (McHaney, 2009).

Chapter 4. Simulation and Animation Model of a Large-Scale Gold Mine in Nevada

The main purpose of this simulation project is to study and develop two discrete-event system simulation and animation models using required data (cycle times, dump, load, and spot times) from a dispatch fleet management system, of a complex and large open pit gold mine in the state of Nevada. These models could assist the engineers and modelers in analyzing the limitations of using the general data in the complex and large models' accuracy and validation. GPSS/H® and PROOF Professional® were the software packages used for the research.

The early simulation model was carried out to exactly imitate the logic of the mine system and equipment. However, after 10 months, the second simulation model was constructed to contain both the logic of the mine operation and updated mine layout/profiles and equipment. The output of the model runs included analysis on the utilization and total mine production rate of the mine excavating units. The initial strategy for setting up these 'standard' simulation models was to assess the mine's long-range and day-to-day/short-range planning options, and investigating the possibility of using general travel times (only mean times) of the mine's haul trucks to accurately calibrate the models in order to reproduce the mine's production rate.

This chapter involves detailed explanations for the simulation models. These simulation programs include full animations of the mine's operation. Animations of these simulation models were created to verify activity sequence and their associated algorithms, and to confirm that the simulation codes are correct. The simulation models precisely mimic the logic of the gold mine operation.

4.1. Gold Mine Operation Description

The mine is located in Nevada, a state in the southwestern United States. The mine operates in two shifts/day of 12 hours/shift for 356 days per year. Shifts start at 4:00 a.m. and 4:00 p.m. Breaks are scheduled at 8:00 a.m. and 8:00 p.m. for 15 minutes, and lunch and dinner times are at 12:00 p.m. and 12:00 a.m., each 30 minutes. Blasts usually and preferably occur at 12:00 p.m. during the lunch break. The operation includes a large pit and multiple leaching pad locations, and its ore quality varies in different grades. The mine processing includes heap leach, milling, and gravity. The mine method for this operation is conventional open pit. The main equipment fleet used in the operation is provided in Table 4.1.

The case study's operation is equipped with a Dispatch® system that is used for mining optimization purposes. In general terms, the Dispatch® system includes several applicable features (Modular Mining, 2014):

- Real time simulation and production reporting/web reporting
- Haulage operation optimization
- Fuel system management
- Service management/tire management/crew management
- Truck payload recoding and analysis
- Auxiliary equipment tracking system
- Geotechnical monitoring system
- Drilling management system
- Blending and ore control system
- Qualifications management

- Remote management system/control
- And others

Table 4.1: Equipment of the Gold Mine

Vehicle Type	No.
Haul Trucks	
CAT 789	**13**
CAT 793	**17**
Loading Units	
Loaders	**7**
Shovels	**3**
Miscellaneous	
Drills	**6**
Dozers	**1**
Foreman	**2**

4.2. Simulation Models of the Gold Mine

Two simulation models of the large gold open pit mine with generic data distributions were developed. Comprehensive explanations on the development of the models are provided as follows.

4.2.1. Preliminary Simulation and Animation Model Development

A quick preliminary discrete-event system simulation and animation model of a large gold mine was developed and programmed in three days with generic data to represent the logic of the mine system. This study was conducted to investigate the rapidity and flexibility of GPSS/H® and PROOF® animation in implementing large and complex mining simulation projects. This model was made in collaboration with the mine's engineers to verify that the process logic of the operation was properly coded/programmed. This simulation did not contain the actual mine profile of the operation, and since the model worked with the generic data and hypothetical mine layout, no attempt was made to validate this model's throughput.

As the mine's engineers requested, the simulation model was created to include two shovels and two loaders, as loading equipment, working with two haul truck types (CAT 793 and CAT 789). Creating the animation as a visualized interface commenced concurrently with developing the simulation model. A screenshot of the animation of the preliminary simulation model is presented in Figure 4.1. In general terms, the animation enhanced the quality of the model used by the technical people to review the gold mine hauling and loading fleet simulation.

The output data of the preliminary simulation model on the animation screen are summarized as follows:

- number of loads for each truck type (CAT 793 and CAT 789), from loaders and shovels
- shovels and loaders utilization
- amount of each load at shovels and loaders per truck types
- number and amount of loads for each truck type arriving at waste areas, leach pads and the crusher
- total waste production
- total ore production
- number of each truck type running in the mine

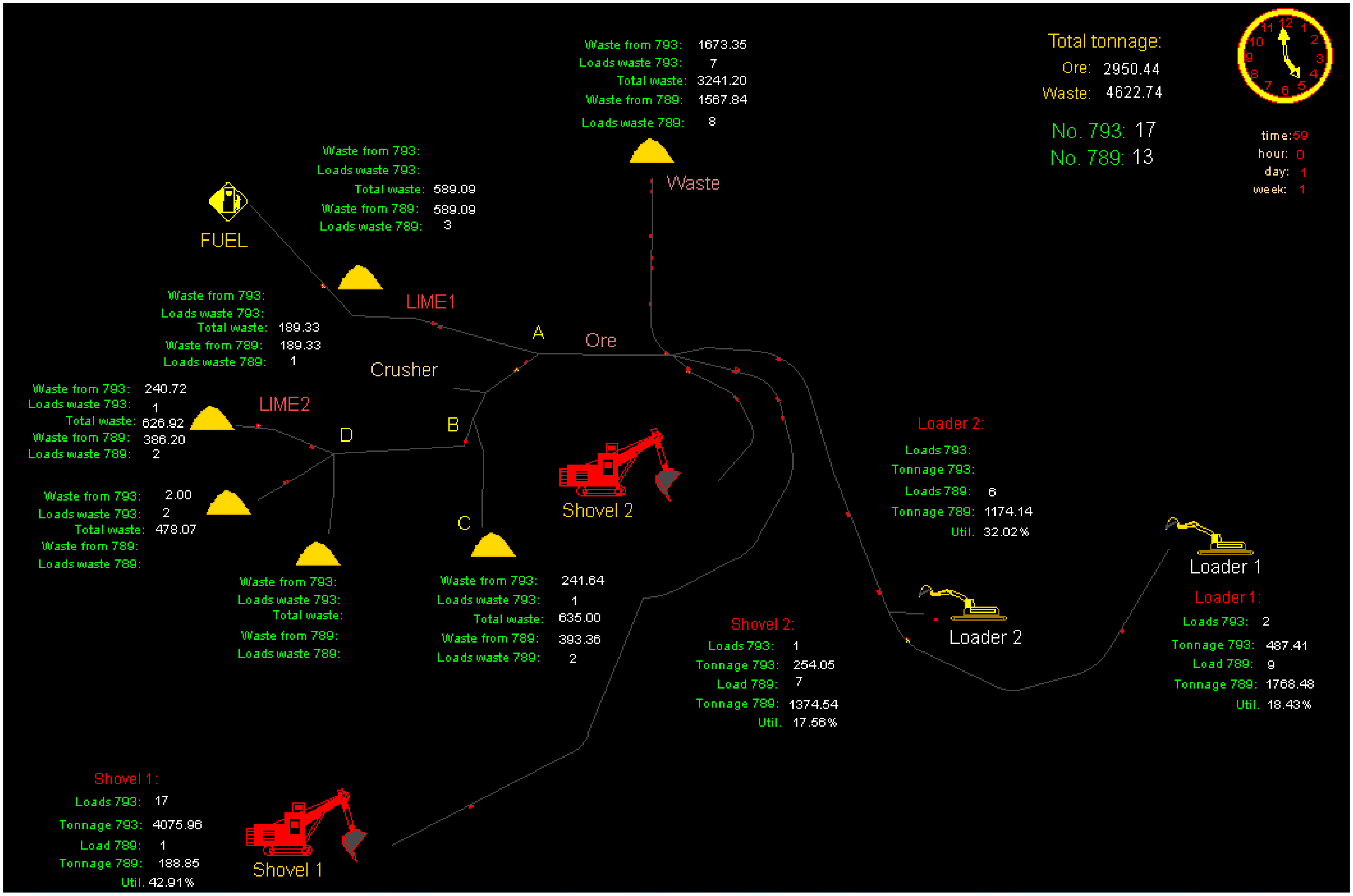


Figure 4.1: Screen Image of the Initial Simulation Model for the Gold Mine

In this preliminary simulation model hundreds segments, approximately 1180 lines of code, were designed and developed, using GPSS/H®. The logic of the simulation model that imitates the actual mine operations is explained in the following:

Empty trucks are loaded by two mine shovels and two large loaders from the pit to move both overburden and ore to the multiple locations of dumps, leach pads and the crusher. The assignment of material types hauling from the pit to different destinations was based on the data provided by the mine's engineers using the stochastic distribution. On the way to the leach pads, the some trucks receive lime from the lime silos. Based on the trucks fuel need, the haulage trucks can be sent to the mine's fuel station. After dumping the ore and waste in various locations, on the return path, the mine Dispatch system assigns each truck, at the main intersection, to go to the nearest available loading units, taking into account the number of trucks, travel times, loading times, and spotting times at both the shovels and loaders. The simulation model also contains the queue time for each mucking unit. At the leach pads, dump areas, and crusher only one truck at a time can dump due to the narrow positioning.

In the end, the simulation model included 72 generic segments with dummy statistical distributions for haul paths for both truck types to transfer different materials to the assigned locations. A snapshot of the preliminary simulation program in GPSS/H® is shown in Figure 4.2. Appendix A includes the GPSS/H® code of this preliminary simulation and animation model.

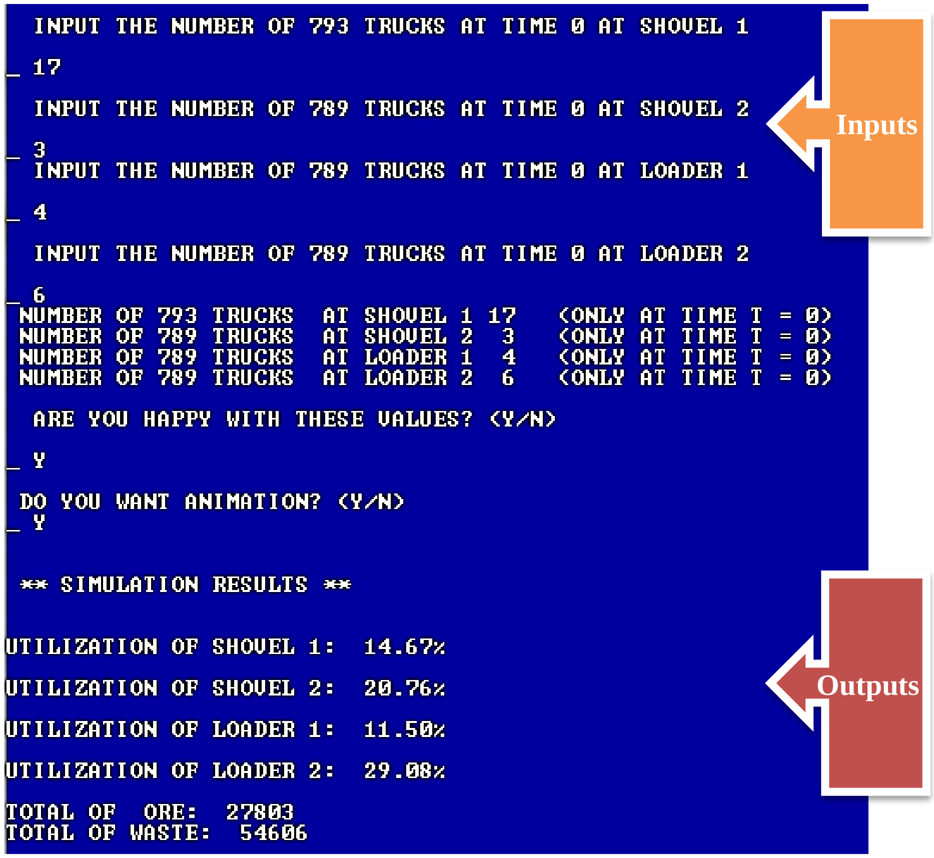


Figure 4.2: Inputs and Outputs of the Initial Simulation Program (GPSS/H® Display-Generic Data)

4.2.2. Second Simulation and Animation Model Development

The key focus of the second developed simulation model of the large gold mine was to include the actual mine layout/haulage profile and add one additional shovel to take into consideration the latest update of the mine system. However, the second simulation model also used the generic travel times for the haul trucks' movement. Figure 4.3 illustrates the animation interface of the second simulation model of the case study.

The subsequent steps were followed in order to create the animation concurrently with developing the simulation program:

- Haulage profile was precisely drawn from the mine layout provided by the Dispatch® system and the mine's planning group, using PROOF Animation's drawing tools.
- Equipment, facilities, and images were made in different object classes, and required status massages were added to the program.
- Different paths were specifically defined to move the object classes.
- Additional code was written in the simulation to create a Trace file (ATF) to display and move the defined elements/objects on the screen.

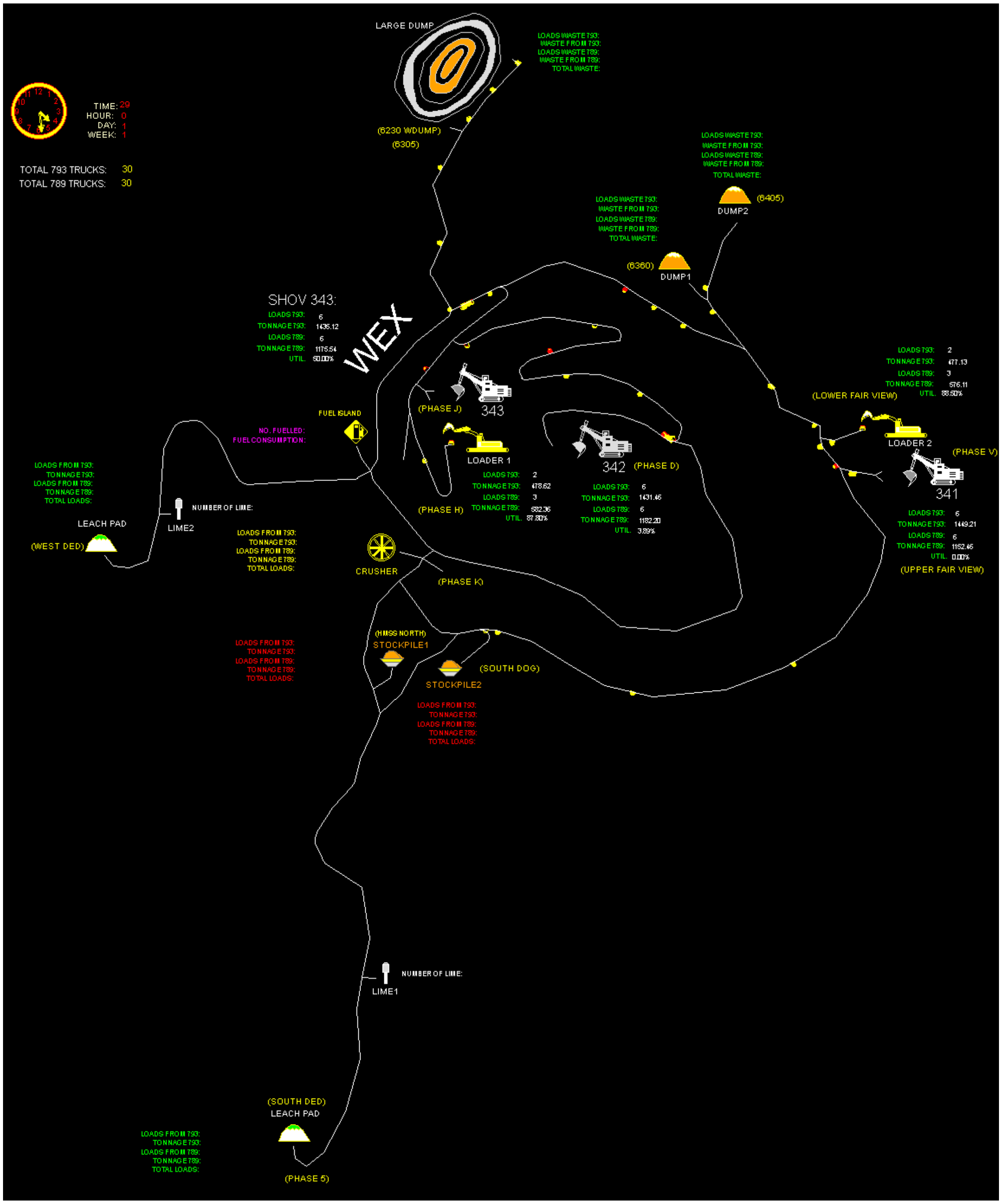


Figure 4.3: Screenshot of the Second Simulation and Animation Model including the Actual Mine Layout

This simulation model consists of more details, output parameters, and segments developed by 2000 lines of GPSS/H® simulation language. The animation also created to display the simulation model on the computer screen in 'cartoon' mode. The animation program was applied to verify the mine system simulation and debug possible errors in the simulation code.

Based on the mine's engineers plan, the second simulation model was designed to include two types of trucks (CAT 793 and CAT 789) moving waste and gold ore from two loading areas, with three shovels and two loaders, to three dump locations, two leach pads, two stock piles and one crusher. The simulation model was constructed line-by-line to mimic the complex gold mine system. On the animation interface of this simulation, a series of output data of valuable parameters for each important component were shown, such as:

- number of loads for each truck type at shovels and loaders
- amount of loads by trucks at each loading unit
- utilization of loading equipment fleet
- number of fueled trucks and amount of fuel loaded at the fuel station
- number of times adding lime to the loaded trucks at the lime silos
- total number of haulage trucks and amount of ore and waste transported by two truck types at the leach pads, stock piles, waste areas, and crusher

The animation of a loading area in the mine operation (phase V) is enlarged and illustrated in Figure 4.4.

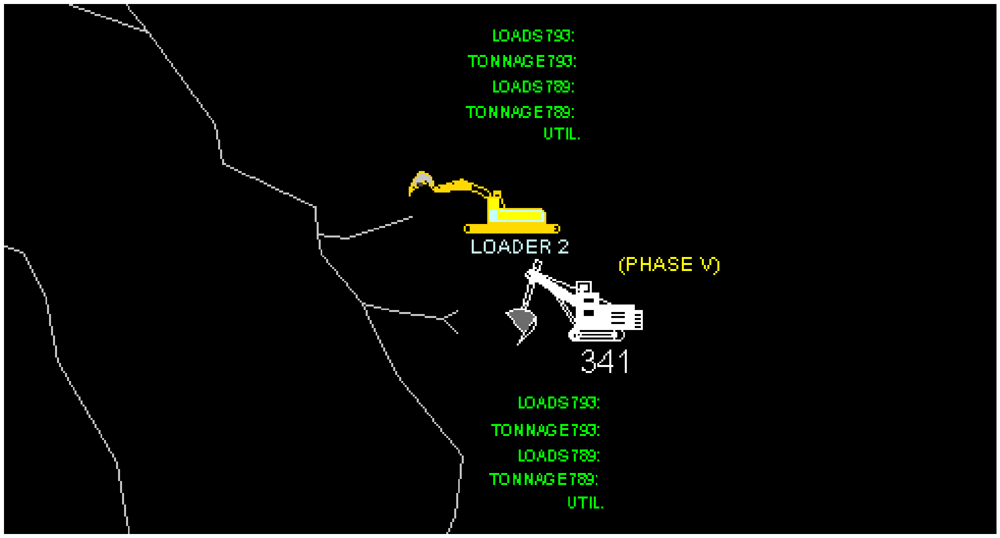


Figure 4.4: Detail View of the Loading Area in Phase V

During the implementation of the second simulation project, an interactive secure content management website was set up for the convenience of the mines' engineers. This system contained sub-directories, which included both simulation models as they were developed. In addition to these programs, miscellaneous files for the instruction of the software, learning software, other files which give the simulation models in detail, etc. were uploaded and archived.

Despite the fact the simulation model works with generic trucks' travel times, once the actual travel time distributions would be inputted into the simulation model, it can be validated to mimic the large gold mine system within 1% to 5% of the way the mine is operating. After the model calibration and validation processes, this simulation can be run for "what if?" mine planning questions, equipment fleet analysis as well as subsequent optimization alternatives.

4.3. Data Analysis for a Mine Simulation Model

The following provides a brief explanation on mine simulation data collection and analysis; however, the simulation models, in this chapter, were developed with generic truck travel times.

As for data analysis in a mine simulation model, it is needed to measure and analyze a range of data for each event in the operation, for example haul truck travel times (loaded and unloaded), spot times, dump times, load times at each loading unties, production delays, equipment/mechanical downtimes, etc. In other words, the times for each of these transactions and the statistical distributions of each of these times are needed. Generally, queue times are not necessary to be acquired due to the fact that simulation outputs/models generate possible queues in the system. It should be noted that the mine simulation models use statistical distributions, not averages. Typically, the general data from a Dispatch system database that provides total cycle times is rarely usable in constructing a precise and appropriate mine simulation model since it tends to give total times, not required times with frequency. In fact, it would be desirable to achieve raw/primary data from the mine and perform time studies rather than average times given by Dispatch systems.

As a simulation model of a mine system samples statistical distributions for all time data in the system, it is critical to ensure that all data are in the same order of magnitude. For instance, if the loading times for a haul truck are assumed in the order of 3 minutes and the truck travel time to the crusher is between 30-35 minutes, it is preferable to break down the travel time into 4 or 5 different segments each having its own appropriate statistical distribution in the simulation. As a result of this investigation, using general entire cycle times provided by Dispatch systems can lead to serious difficulties and issues in the simulation calibration stage. This directly indicates the importance of raw/primary data and fitting statistical distributions to carry out a successful and accurate discrete-event system simulation program in any modeling projects.

4.4. Concluding Remarks and Discussion

Two mine simulation models of a large-scale gold mine with general haul truck travel times were developed at 10 months apart. GPSS/H® simulation and PROOF Professional® software were used for this simulation. During this simulation investigation, results showed that the data of trucks' travel times (cycle times) provided by the mine Dispatch system was too general to precisely validate and calibrate the final developed simulation model of the large gold mine with different truck types. In fact, the results indicated that mine simulation models critically depend on statistical distributions to reproduce the actual mine history production within 1% to 5%. The results obtained from the research study demonstrated that generally total cycle times or average/mean times extracted from the dispatch database were not sufficient enough to construct the accurate models with several segments for the complex operation.

Once the accurate data with appropriate statistical distributions of the mine trucks' travel times is provided and utilized in the second gold mine simulation model, it can evaluate the mine potential investigations, notably:

- numerous configurations of new mine equipment fleets to possibly replace old ones as determined by the mining engineers

- analysis of trucks hauling ore and/or waste from the pit to the crusher, leach locations, dumps, and storage units
- different configurations of truck/shovel (loader) fleets in the operation
- evaluating options/factors to increase the performance of the mine truck/shovel system
- the economic benefit of adding additional trucks into the system
- other possible "what if?" questions/analysis associated with the mine equipment, design and planning

Additionally, the latest simulation model developed can completely consider the impact and interaction of the mine mechanical failures of equipment, either scheduled maintenance or unscheduled breakdowns after the model calibration. The effect of changes in several aspects also can be easily analyzed and evaluated using this simulation model.

In conclusion, a mine simulation model does not 'solve' a mining problem or technical issue but provides the engineers with reliable information to make a clever choice in managing the mine operation as efficiently as possible. The financial benefits of mining operations and/or companies can arise from simulation studies that can efficiently create a sustainable competitive advantage in mine design and planning (Karimi-Tarshizi, 2012). Moreover, to develop and prepare a 'good' and precise simulation model of a mining system, appropriate data and times of the model transactions and events with suitable statistical distributions are necessary. This study implied that only average cycle times provided by a Dispatch fleet system are not sufficient to construct an 'accurate' and appropriate complex mine simulation model with numerous separated segments. During the simulation study, it was also learned that mine simulation models like other simulation projects cannot be performed in isolation. In fact, to deliver an accurate and fine simulation model, effective and interactive commutation and working in close collaboration with the project engineers is a key to success.

Chapter 5. Cortez Hills' Surface Mine Simulation and Animation Model

5.1. Gap Pit Simulation Project Introduction

This chapter discusses a mine simulation project developed for the Gap Pit gold operation of the Barrick Gold Corporation's Cortez Hills complex in Nevada, USA. This simulation model was used to analyze different mine design and planning projects and various "what if?" scenarios to assist the mining engineering in the process of the decision-making.

Barrick's Cortez Hills gold mine complex, located about 100 kilometers (62 miles) southwest of Elko, Nevada, USA, includes three closely associated surface gold mine operations, the Pipeline, South Pipeline, and Cortez open pits. A discrete-event system simulation and animation model of the Gap Pit mine operation in the Cortez Pipeline property was designed and developed to assist the mine engineers with a practical technique to quickly analyze a variety of truck/shovel situations. The simulation studies were performed to investigate the efficiency of potential "what if?" changes in the operation. Simulation analysis provided valuable information with respect to efficiently managing the mine equipment fleet operation (load-haul-dump cycles). This simulation and animation model, using GPSS/H® and PROOF Professional® simulation software packages, describes an investigation into the allocation of trucks to the loading equipment (shovels) in the Gap Pit. An 'appropriate' simulation model should imitate/mimic the real mine system and production within 1% to 5% of the way it is actually working before it can be used with confidence as succeeding optimization tools and strategies.

5.2. Barrick's Cortez Hills Complex Mine Operations

Barrick Gold Corporation, the world's largest gold producer, has several mine operations around the world (five continents). For the company, the main gold producing region is North America. In the state of Nevada, Barrick Gold Corp. owns Bald Mountain, Cortez Hills, Goldstrike, Round Mountain (50%), Ruby Hill, and Turquoise Ridge (50%) (Barrick Gold Corporation, 2014). In North America, from January 2013 to September 2013, Barrick produced 2.70 million ounces of gold at $798 all-in sustaining cost per ounce. The main priorities and progress of Barrick Gold Corporation are illustrated in Figure 5.1 (Denver Gold Forum, 2013).

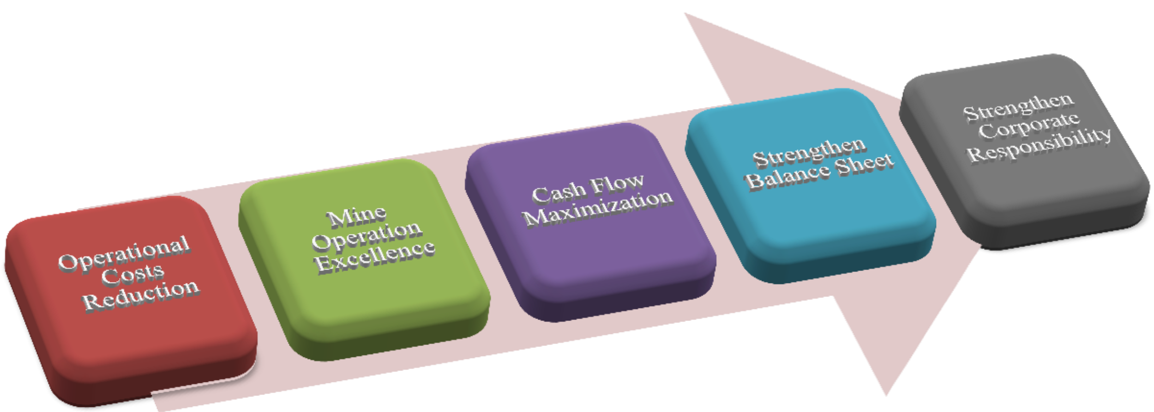


Figure 5.1: Key Priorities of Barrick Gold Corporation (Denver Gold Forum, 2013)

The Cortez Hills mine, an open-pit operation, is situated in Lander County, approximately 100 kilometers southwest of Elko, Nevada (Figure 5.2). Cortez holds several properties that include the Cortez Pipeline, Cortez South Pipeline, Cortez

Pediment, and Cortez Hills deposit all of which encompass 2,800 square kilometers of land. This large open-pit mine operation is known for its low-cost production, being one of the largest gold mines that exist, and its highly prospective mineral trends. Cortez Hills mine complex is the most cost-effective gold mine in the world (Visual Capitalist, 2013). Additionally, Cortez Hills complex generates the largest part of Barrick's gold production and cash flow (Denver Gold Forum, 2013).

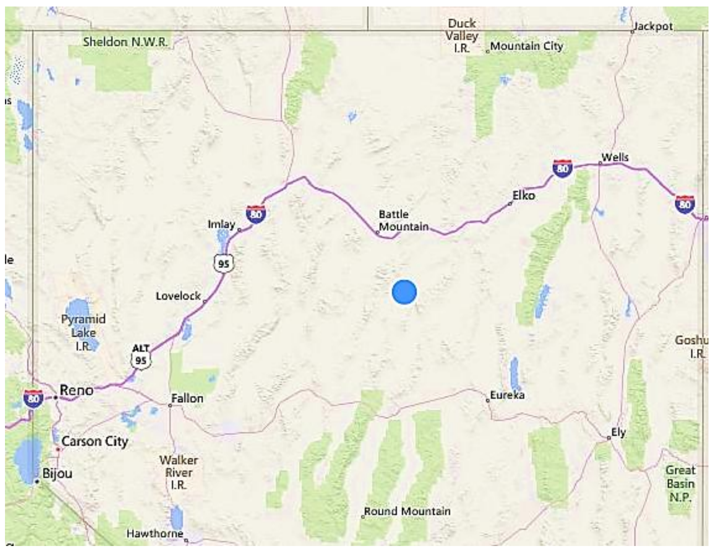


Figure 5.2: Cortez Hills Complex Mine Operations Location Map (Barrick Gold Corporation, 2014)

Three different metallurgical processes are utilized at Cortez to extract gold. As of December 31, 2012, Cortez was estimated to have 15.1 million ounces of gold in validated and presumed gold reserves (Barrick Gold Corporation, 2013). Last year the Cortez mine produced 1.34 million ounces of gold from January through September at $433 all-in sustaining cost per ounce. It is confidently predicted for 2014 that production should be in the 0.9 - 1.0 million ounces (Barrick Gold Corporation, 2014).

At Cortez Hills operation the loading-hauling equipment fleet is split between two complexes; Cortez Hills and Pipeline. At the Pipeline complex there are a number of different phases. As the South Gap pit is currently being mined the simulation was built to model this pit. In the South Gap pit there are three excavators: one P&H 4100 XPC electric cable shovel, one P&H 2800 XPB electric cable shovel, and one LeTourneau 2350 loader. Thirty CAT 795F AC series haul trucks with a nominal payload of 315 tons work in the mine.

Production rate in the South Gap pit averages 200,000 tons per day. The major support equipment around the mine includes: CAT D11, D10, and D9 dozers, CAT 14H and 24H motor graders, CAT 385 CL excavators, and CAT 854 rubber tire dozers. An aerial image of the Cortez Gap Pit mine operation is shown in Figure 5.3.

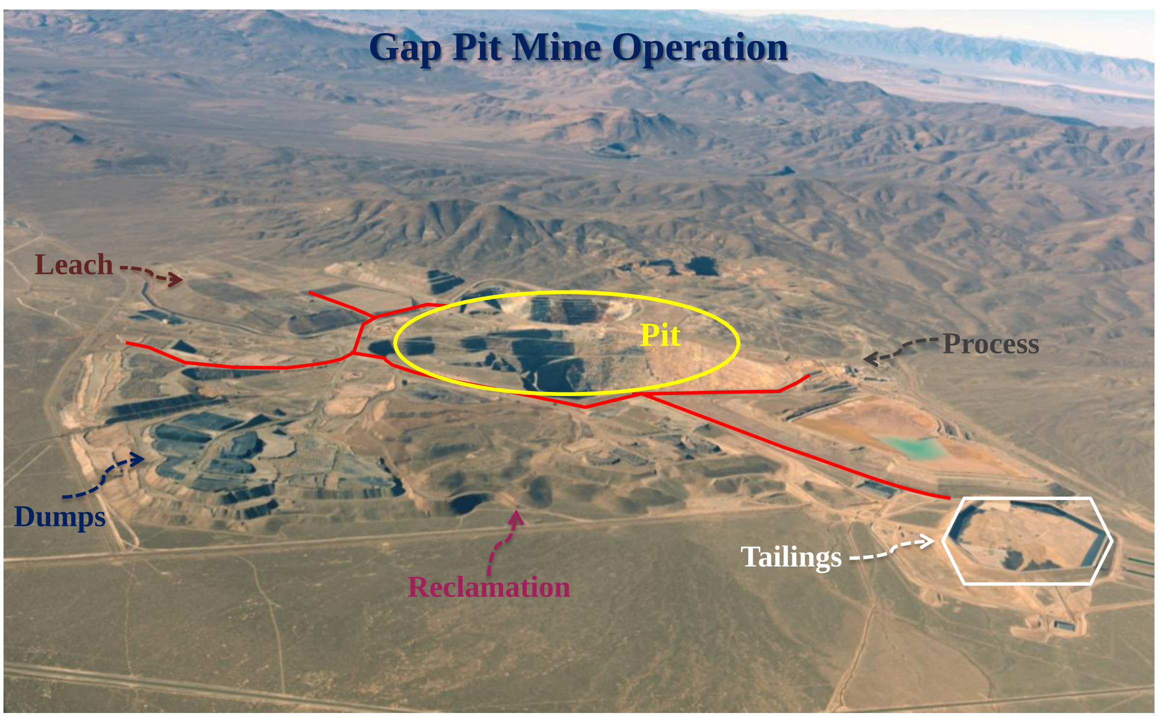


Figure 5.3: Cortez's Gap Pit Mine Operation Layout

5.3. Gap Pit Mine System Simulation and Animation

Discrete-event system simulation and animation models of the Cortez's Gap Pit mine operation were developed using GPSS/H® simulation language and PROOF Professional® animation software by the Wolverine Software. Figures 5.4 and 5.5 illustrate the snapshots of the created animation of the Gap Pit initial or preliminary simulation and completed models, respectively.

The completed simulation model, known as the Gap Pit simulation model, was used by the mine engineers in studying and assessing the various options and scenarios in the Gap Pit mine plan and design. This model was constructed and programmed to simulate the logic of Gap Pit mine operation as it was truly currently working including a detailed animation interface.

The Gap Pit simulation and animation takes into account the impact and interaction of having equipment down circumstances, either for scheduled maintenance or at random times, and was used to study the effect of changes in numerous aspects in the mine productivity and equipment utilization. This includes the possible scenarios for shovel downtimes, either for scheduled maintenance or random down times. The Gap Pit computer simulation and animation program is written line-by-line, therefore, the feasible "what if?" questions associated with the mine operation can be easily posed, modeled, or changed. GPSS/H® simulation language was used to model this research project for the following reasons:

- Capabilities
- Availability
- Low level programming language

- Cost-effectiveness
- Fast processing/Quick running
- Flexibility to model complex discrete-event systems (e.g. mining operations) (O'Connell and Sturgul, 2010).

Animation software was applied as an excellent and vital tool to reflect the possible Gap Pit Simulation model's errors. It helped the modelers to observe each minor detail of the simulation, and it was also used for debugging and verifying the model. Animation also enabled the Cortez mine's engineers and managers to visualize the important components of the mine system and observe the interactions between in these elements on the computer screen. PROOF Professional® was the program that provided a realistic visual program of the Gap Pit simulation model over time. In fact, when animation and simulation are in combination, they become a powerful pair that will result in an absolute illustration of real systems (Henriksen, 2000).

The preliminary simulation animation model of the Gap Pit mine is shown in Figure 5.4. The final Gap Pit simulation and animation model represented the mine system and operation precisely (less than 1%), which include a pit, rock crusher, ore crusher, leach pad, roast area, two active dump areas and two possible dump locations, parking area, and fuel skid/station, see Figure 5.5. The simulation model was carefully validated using the mine historical production data to confirm its accuracy and reliability. The source code of the Gap Pit mine simulation and animation program is provided in Appendix B.

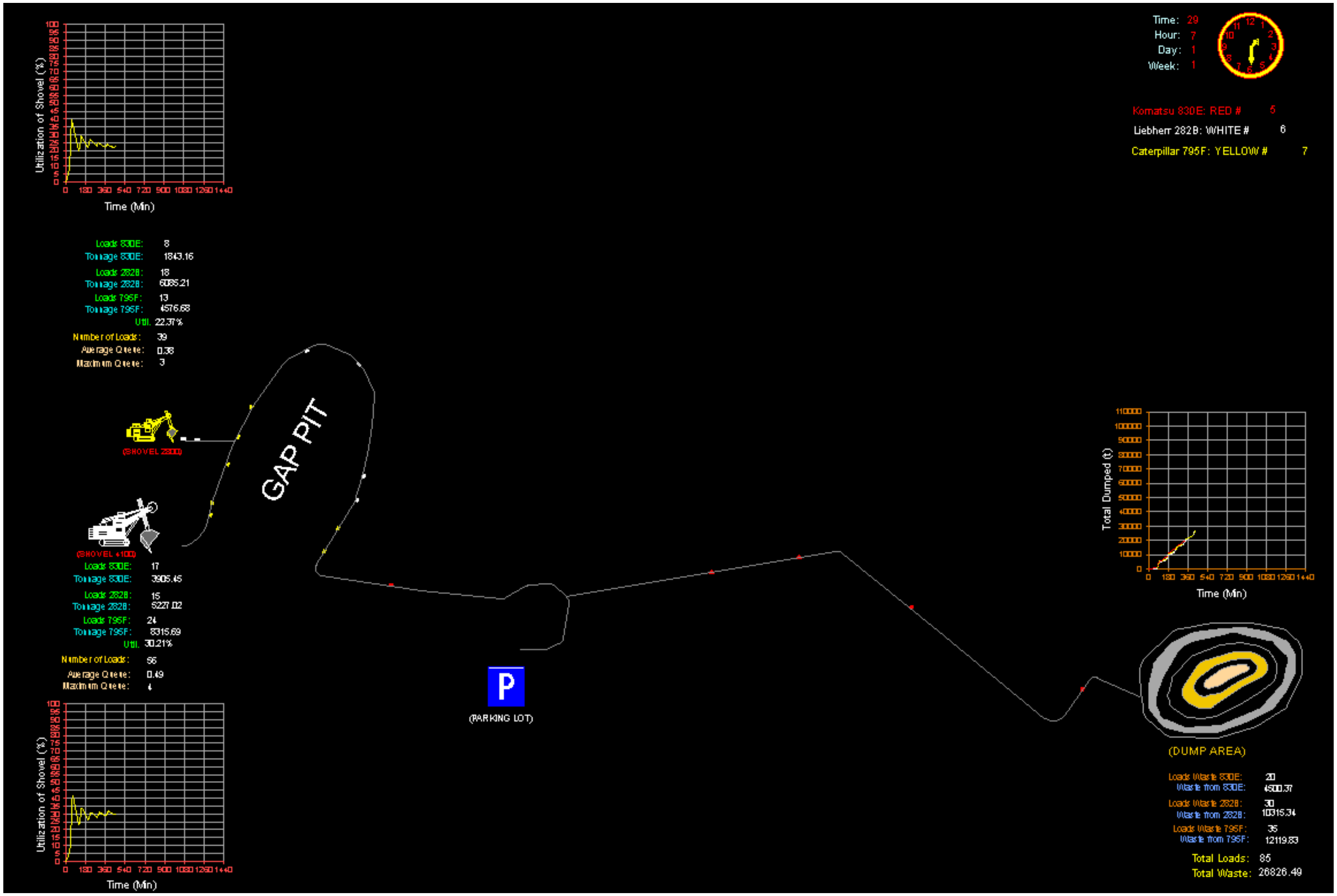


Figure 5.4: Screen View of the Gap Pit Preliminary Simulation and Animation Program

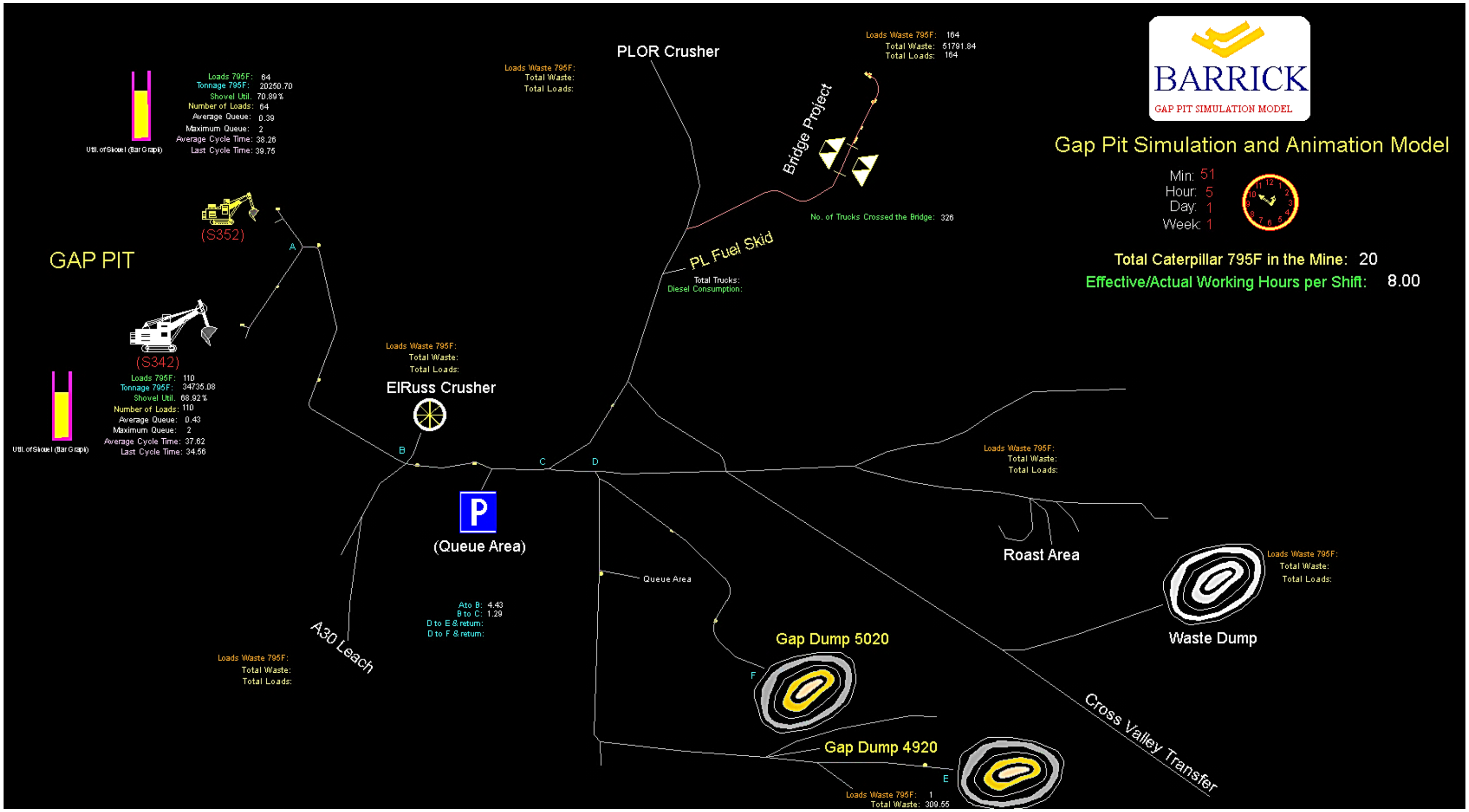


Figure 5.5: Screenshot of the Gap Pit Mine Layout and Completed Simulation and Animation Model

5.4. Data Acquisition and Analysis for Gap Pit Simulation

The Gap Pit simulation and animation model was constructed to accurately mimic the actual mine system. Data collection, field observation, and data analysis is one of the key factors in implementing a successful mine simulation project. A correct mine simulation model of a probabilistic project requires appropriate data with statistical analysis, not average or means times.

During this mine simulation project, over three months of data from the mine was collected and field observations were conducted to study the logic of the operation. The actual mine time data, such as travel times of trucks (full and empty) for various segments, load times, spot times, and dump times were measured and recorded in data sheets. In addition to the obtained data, the Gap Pit mine production history over those three months was obtained using the Modular DISPATCH® fleet management system for the simulation model validation. The field data of the Gap Pit simulation was collected and measured in order to construct probability distributions for the following; Figure 5.6 shows a typical distribution of one of the mine shovels' load times. Moreover, Figures 5.7 and 5.8 present the histograms of the spot and dump times at the dump areas in the operation.

- Truck travel times (loaded and unloaded) for more than 55 separate segments
- Truck spot times at each shovel, dump area, leach pad, rock, and ore crusher
- Shovel spot times at loading locations and dumping areas
- Truck load times at each loading unit
- Truck dump times at each dump area, leach pad, rock, and ore crusher

The main reason for using the three-month history data of the mine production for the simulation and animation model verification process was the Gap Pit mine had been working for only three months before the simulation model development. The simulation model was constructed using 75 segments to be able to provide flexibility for the mine operational changes. Actual statistical data was used for each segment in the Gap Pit simulation and animation program. The GPSS/H® allows the user(s) to build up functions directly from raw and primary data (Sturgul, 2000). Using actual data distributions can have profound impacts on the results and accuracy of a simulation model (Sturgul, 1992). However, exponential distributions were considered for the trucks' spot times at each shovel to enable the simulation model to match carefully the actual mine operation cycle times. Time studies and data analysis were carried out for each designed segment in the Gap Pit simulation and animation model. Further data analysis and time studies of the simulation and animation study are presented in Appendix B.

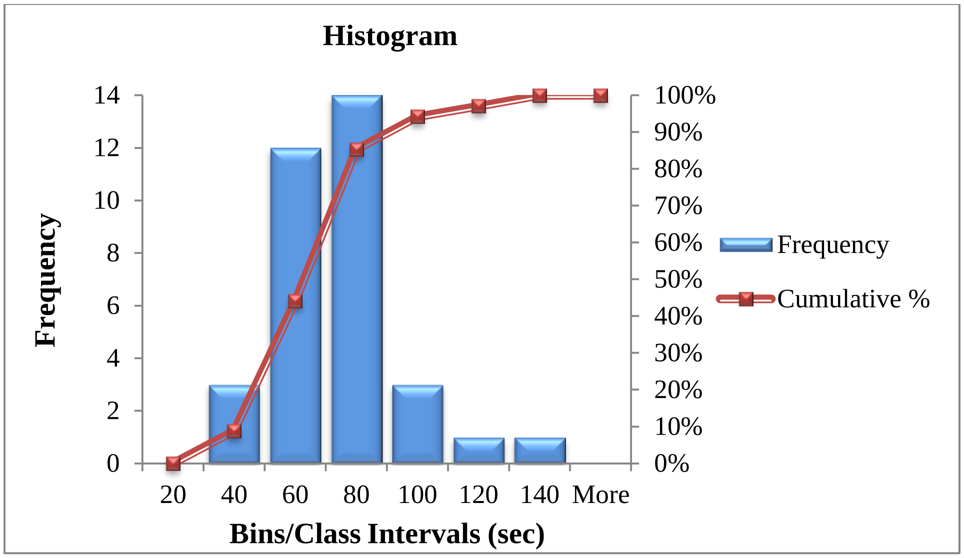


Figure 5.6: Typical Distribution of a Shovel's Load Times in the Mine

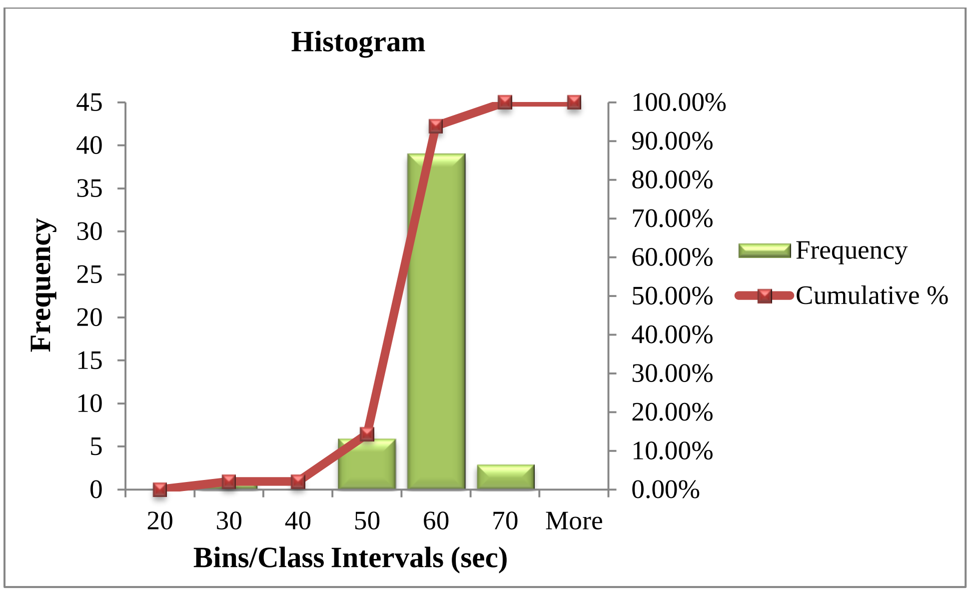


Figure 5.7: Graphical Representation of Data Distribution (Truck Dump Times at the Mine Dump Locations)

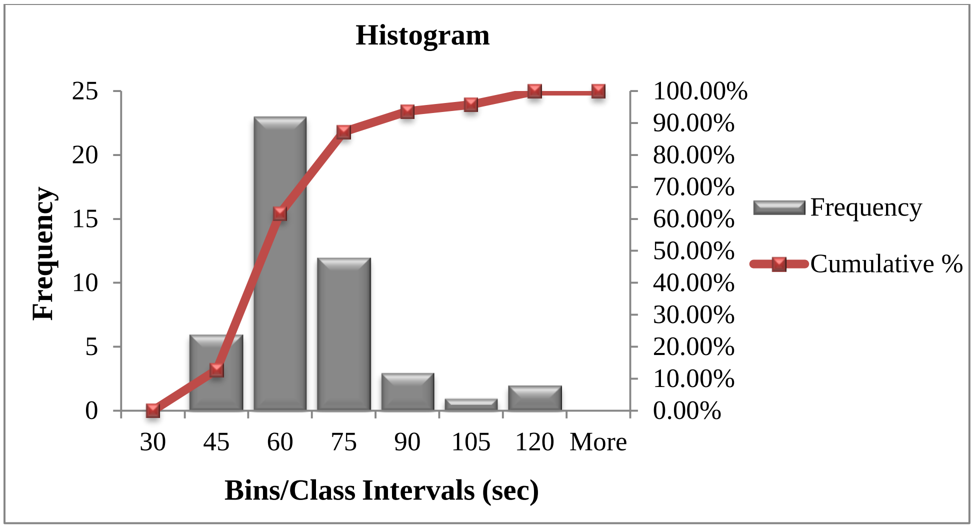


Figure 5.8: Histogram of Data Distribution of the Truck Spot Times at the Mine Dump Locations

5.4.1. Using Real Data in GPSS/H® for Truck/Shovel Modeling

Several simulation programs and packages have been used to simulate and optimize mining systems and one particularly is GPSS/H® language. An important factor in these models is the simulation of the cycle times for trucks and loading equipment. Many approaches have been used to estimate the assigned times, such as using mean values, predefined statistical distributions, and exact statistical distributions. Although all three methods may have the same mean value, the final simulation results greatly depend on the type of statistical distributions used. To obtain more precise simulation results, it is recommended to achieve and use exact distributions (Sturgul, 1992). GPSS/H® simulation language has the feature to enables its users to use actual statistical distributions as inputs in conducting simulation projects.

5.5. Calibration and Validation of Gap Pit Simulation

The conceptual simulation model was validated and calibrated over a three-month period of the Gap Pit mine production. To calibrate and validate the Gap Pit simulation model, it was run with one set of random numbers to obtain the results. The same model was run each time with a different set of random numbers. If each successive model produces identical or nearly identical results, the model is said to show “precision”. The accuracy of a model depends on the model simulating the correct logic of the system and suitable data distributions. Table 5.1 summarizes the comparison between the actual mine production and the simulation outputs. The simulation model accurately reproduced the Gap Pit mine production and showed a less than 1% difference with the actual production. This can occur once a mine simulation model utilizes statistical and cumulative frequency distributions directly from primary data. However this simulation model did not include the actual data distributions for the equipment failures in the operation, but the code was written and developed for this parameter.

Table 5.1: Data Comparison of the Gap Pit Mine Production and the Simulation Output

Actual Mine Operation Data	90 Day Loads (#)	Loads per Shift (#)	Total Tonnage Last 3 Months (tonnes)	Average Cycle Time (min)
Shovel 342	30,085	167	9,476,775 (t)	27.6 (min)
Shovel 352	17,894	100	5,636,610 (t)	27.6 (min)
TOTAL	47,979	267	15,113,385 (t)	
Simulation Results				
Shovel 342	29,556	164	9,357,808 (t)	27.67 (min)
Shovel 352	18,950	105	5,998,475 (t)	27.42 (min)
TOTAL	48,506	269 **>0.7%**	15,026,283 (t) **<0.5%**	

5.6. Gap Pit Simulation Results and Discussion

A wide range of scenarios and operating options were run and evaluated for the Gap Pit mine operation to assist the mine engineers for better and precise operational decision-making. In addition to these projects, further investigations would be possible to be conducted using the model by the mine engineers. The Gap Pit simulation and animation generates the following results on the GPSS/H® screen:

- number of loads per shift from each shovel
- shovels' utilization
- queue size at each shovel
- maximum number of queue at each loading unit
- truck cycle times
- average truck times (spot and load) at each shovel
- number of loads and tonnage at the mine dump areas, roast, leach pads, ore crusher, and rock crusher

The Gap Pit simulation and animation model was developed as user-friendly software. In fact, for the convenience of the user, the simulation model generated results in three different modes/formats, including GPSS/H® display, animation interface using PROOF Professional®, and export files, involving .DAT file extension (Data file) and .XLS for the Microsoft Excel®. A typical example of the Gap Pit simulation results in a spreadsheet in Excel is provided in Figure 5.9.

--- RESULTS OF GAP PIT SIMULATION PROGRAM IN EXCEL FILE ---
NUMBER OF TRUCKS: 21
SHIFTS TO SIMULATE FOR: 180
HOURS OF ACTUAL WORK: 7.60
==
NUMBER OF LOADS PER SHIFT FROM SHOVEL 4100: 201
UTILIZATION OF SHOVEL 4100: 98.38%
AVERAGE QUEUE AT SHOVEL 4100: 1.78
AVERAGE RESIDENCE TIME OF TRUCKS AT SHOVEL 4100: 4.03
CYCLE TIME FOR TRUCKS AT SHOVEL 4100 30.13
AVERAGE TIME FOR TRUCKS AT SHOVEL 4100: 6.26
==
NUMBER OF LOADS PER SHIFT FROM SHOVEL 2800: 119
UTILIZATION OF SHOVEL 2800: 99.74%
AVERAGE QUEUE AT SHOVEL 2800: 1.87
AVERAGE RESIDENCE TIME OF TRUCKS AT SHOVEL 2800: 7.18
CYCLE TIME FOR TRUCKS AT SHOVEL 2800 29.55
AVERAGE TIME FOR TRUCKS AT SHOVEL 2800: 11.00
==
TOTAL NUMBER OF LOADS PER SHIFT INTO DUMP SOUTH AREA: 309
TOTAL OF WASTE PER SHIFT: 97660
TOTAL NUMBER OF LOADS PER SHIFT INTO ORE CRUSHER: 0
TOTAL ORE CRUSHER PER SHIFT: 232
==
TOTAL NUMBER OF LOADS PER SHIFT INTO ROAST: 0
TOTAL ROAST PER SHIFT: 0
==
TOTAL NUMBER OF LOADS PER SHIFT INTO LEACH PADS: 9
TOTAL LEACH PADS PER SHIFT: 2699
==
BARRICK GOLD CORPORATION

Figure 5.9: Gap Pit Simulation Results in the Excel Spreadsheet Format

After the Gap Pit simulation and animation model's verification, calibration, and output data validation processes, it was used with confidence to run and evaluate the following critical projects and scenarios in the mine:

5.6.1. Project 1: Simulation of Truck/Shovel Allocation

Appropriate truck/shovel allocation is one of the most significant activities to maximize mine productivity and equipment utilization since, in a surface mine, an operating truck/shovel system can constitute more than 50% of the total mining operational budget (Nel et al., 2011). In any mining operations, numerous factors including, performance factors, design factors, support factors, and cost factors should be carefully considered for selecting a loading unit (Hartman and Mutmansky, 2002). To determine truck/shovel fleet productivity, one of the important mathematical approaches that is used by Dispatching systems is Match Factor (MF), which is a productivity index and calculated by the following formula:

$$\text{MF: } \frac{(Number\ of\ Trucks \times Loader\ Cycle\ Time)}{(Number\ of\ Loaders \times Truck\ Cycle\ Time)} \qquad (5.1)$$

If a Match Factor is less than 1.0, it would illustrate under-trucked situation in the mine, and if a Match Factor is larger than 1.0, it could indicate that the operation is over-trucked (Burt, 2008) and (Morgan and Peterson, 1968). Bunching and Queuing theory are other main methods to obtain truck/shovel productivity (Burt, 2008). However the discrete-event system simulation modeling method was used, in this project, to achieve the appropriate equipment selection (truck/shovel system) for the Gap Pit operation, several other techniques, such as heuristic, statistical, optimization, and artificial intelligence methods can be applied for this purpose (Burt, 2008).

During this project, the truck/shovel operation analysis was performed using the Gap Pit simulation model to achieve possible optimum matches considering the operating cost of running trucks in this cost-effective mine operation. For this purpose, economic analysis was integrated with the simulation results for a better investigation and decision-making process by the managers and engineers. These scenarios were carefully studied using 10 to 22 trucks (CAT 795) in the Gap Pit, in order to compare the average number of loads and tonnages per shift and possible queue size at each shovel to maximize the fleet productivity. Figure 5.10 illustrates the truck and shovel matching analysis of the simulation results in the Gap Pit operation. In addition, an analysis of the shovels' utilization operating with a range of trucks is presented in Figure 5.11. This results from the investigation could improve the load-haul-dump operation and maximize the mine production rate, through determining optimum truck-shovel matching.

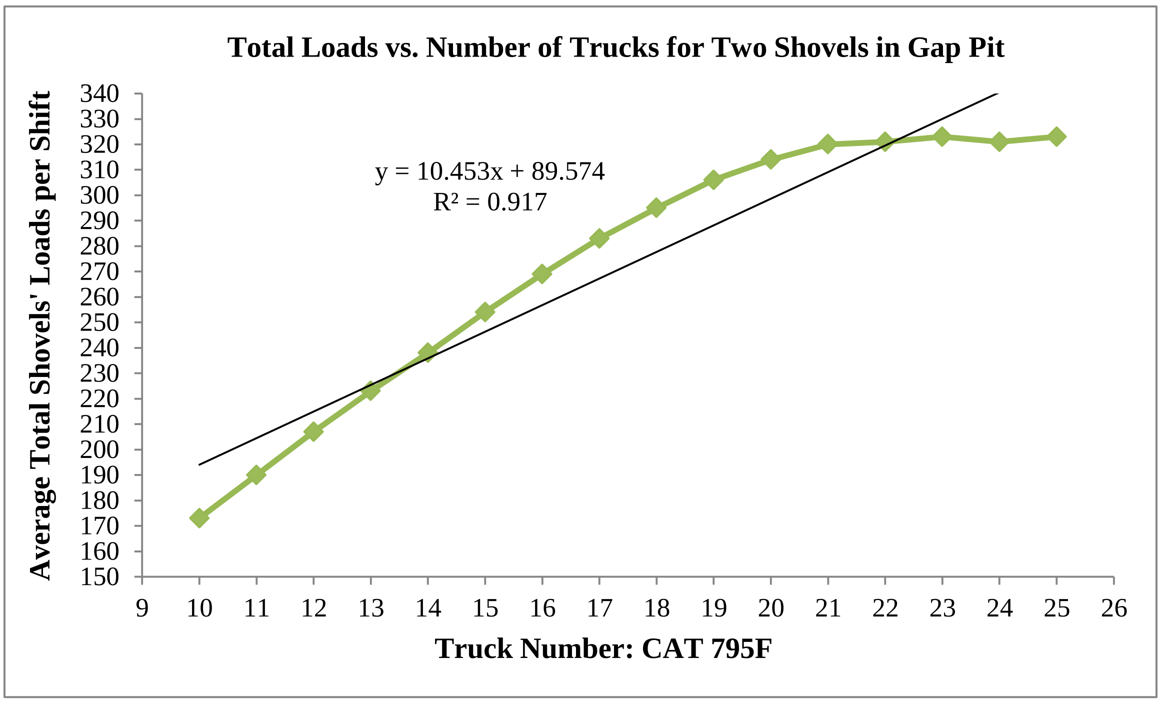


Figure 5.10: Simulation Results of Truck/Shovel Matching, including Two Shovels

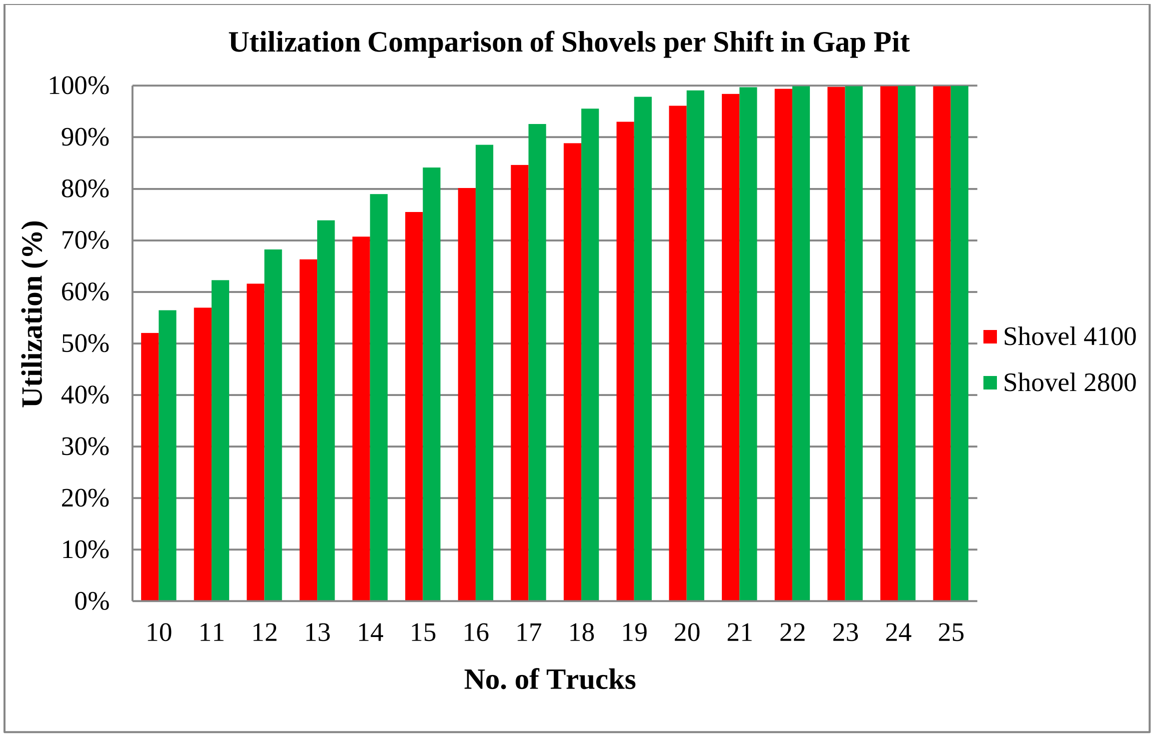


Figure 5.11: Analysis of the Average Utilization of the Mine Shovels

The input and output of the simulation were also placed in a Microsoft Excel® spreadsheet which facilitated data analysis and throughput delivery. The simulation results assisted the mine engineers in studying and evaluating potential mine operation cost reduction and the improvement of the equipment efficiency by assigning the appropriate number of trucks in the Gap Pit mine. Appendix B provides the output of the simulation execution for numerous scenarios in the Excel® spreadsheet. Figure 5.12, Figure 5.13, and Figure 5.14 present the data analysis of the simulation results for the average amount of waste material in the mine dump locations, and ore into the crusher and leach pads by the number of trucks per shift, respectively. Truck average queue length and average time in queue (all trucks) are illustrated in Figure 5.15 and Figure 5.16. As can be seen, all the results showed that optimum number for the trucks allocated with the two loading unties is 21. Results from the simulation model were carefully reviewed and considered by the mine's engineers for an accurate designing-making. In addition, the analysis, later, was also validated by the Gap Pit mine' engineers, using the DISPATCH® system.

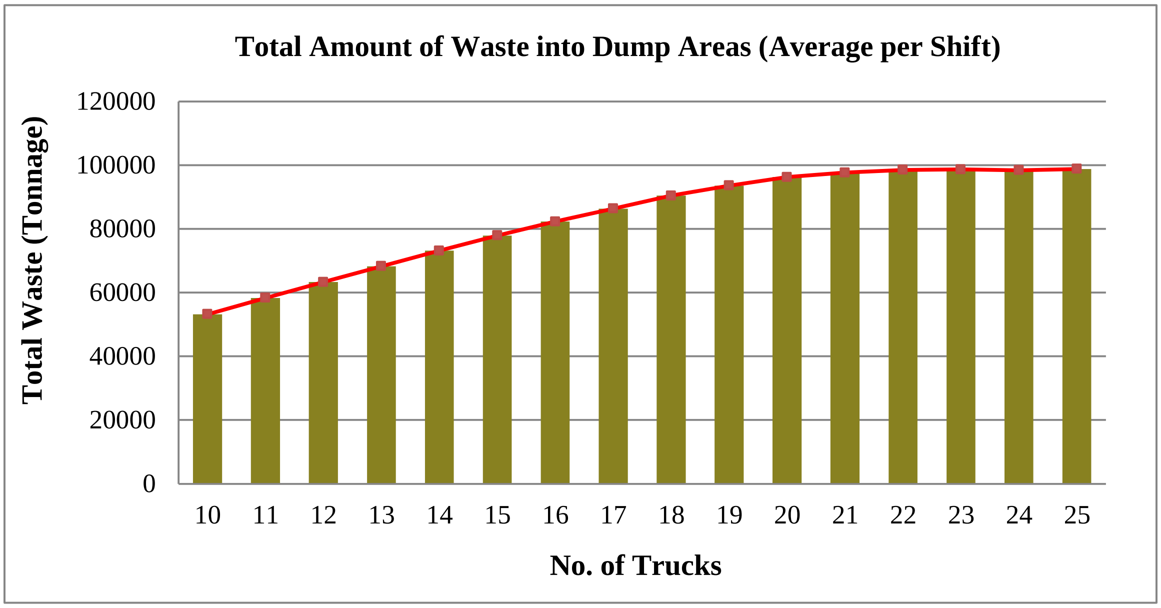


Figure 5.12: Analysis of the Average of Waste Tonnage per Shift in the Gap Pit

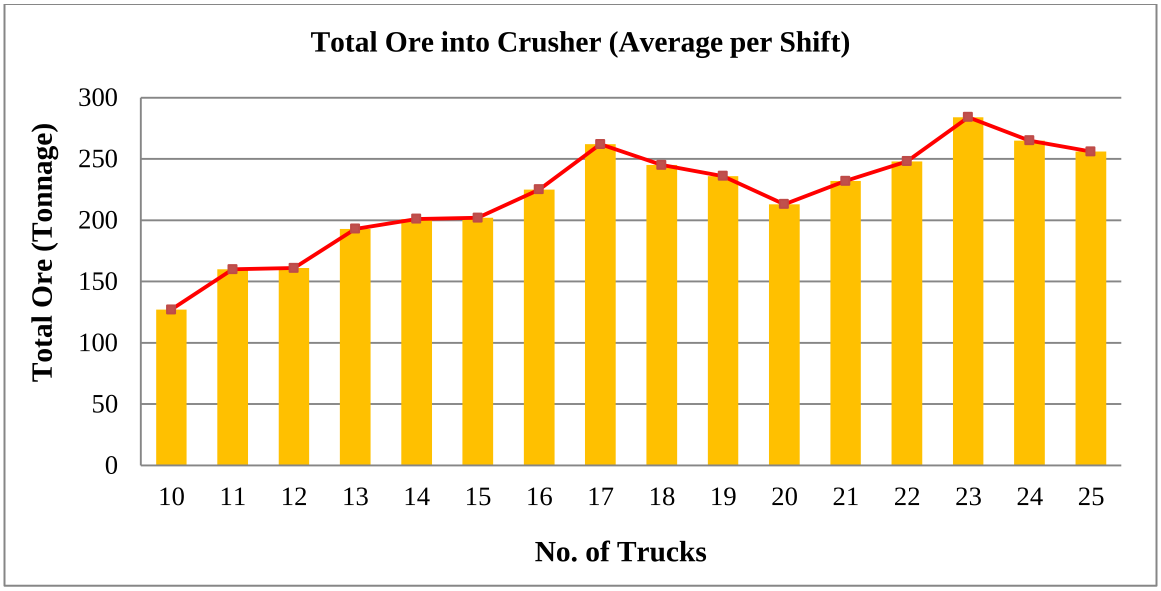


Figure 5.13: Analysis of Ore Tonnage per Shift in the Gap Pit (Crusher)

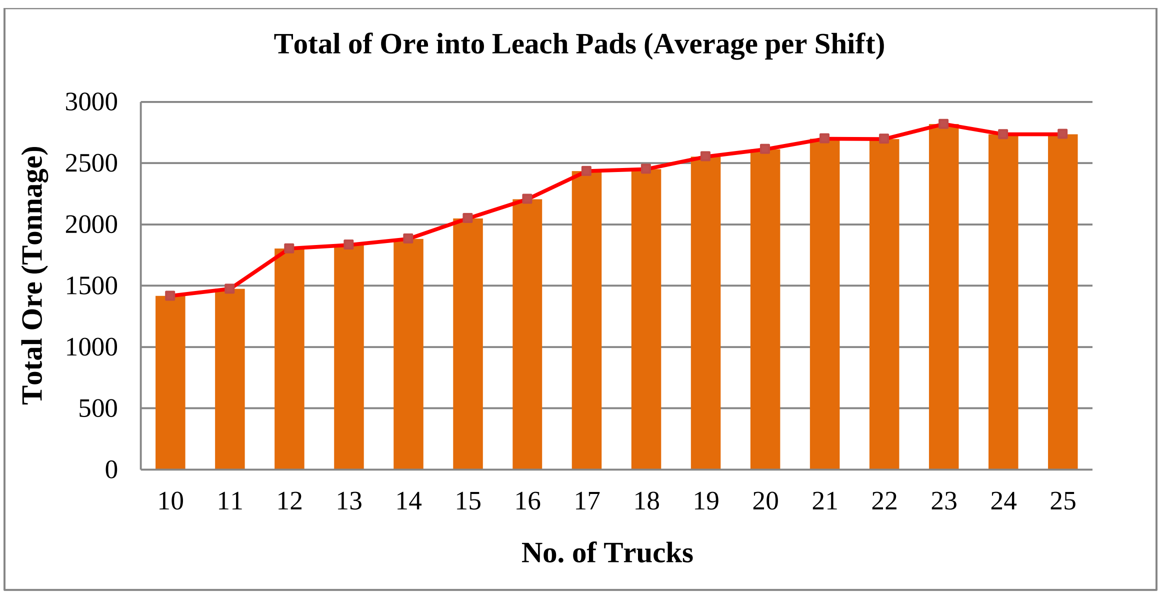


Figure 5.14: Analysis of Ore Tonnage per Shift in the Gap Pit (Leach Pads)

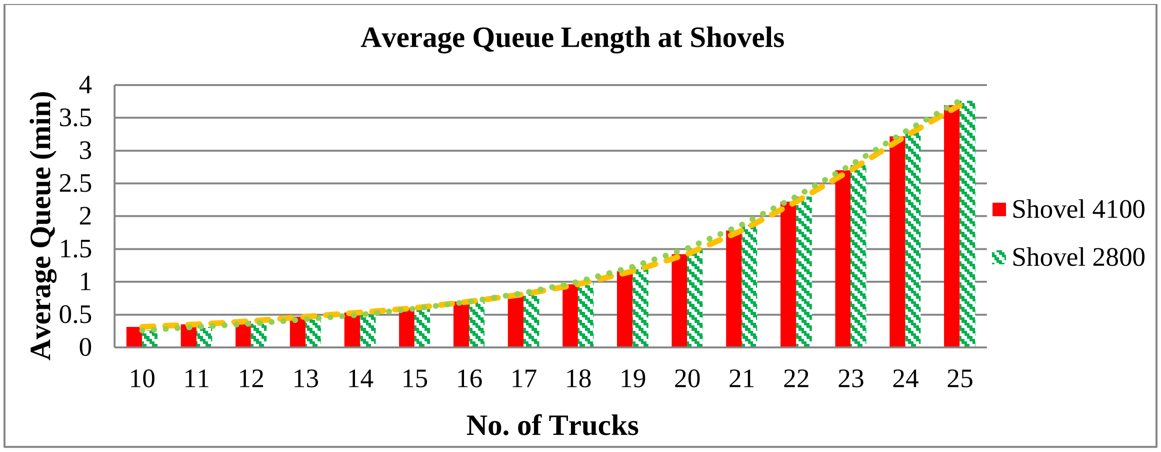


Figure 5.15: Truck Average Queue Length in Gap Pit

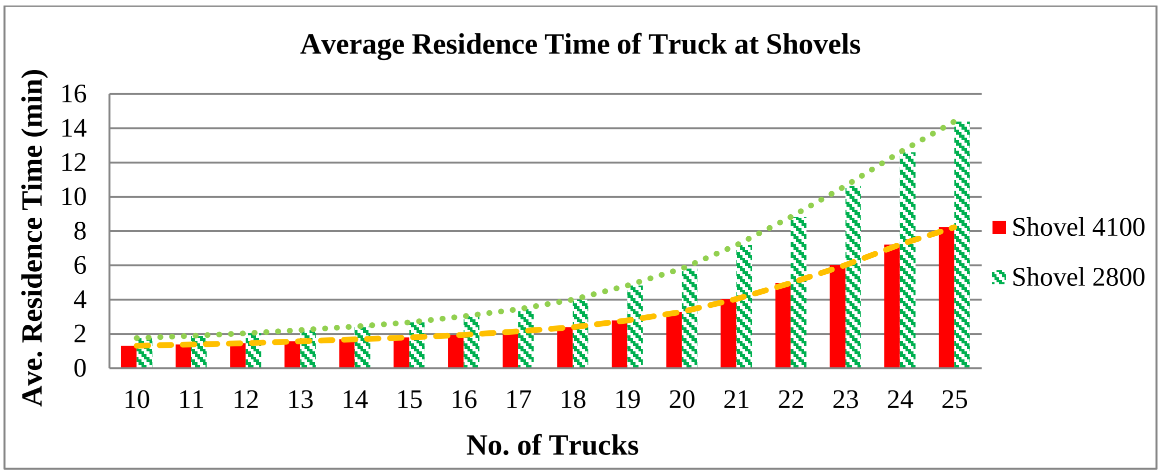


Figure 5.16: Truck Average Time in Queue in Gap Pit

5.6.2. Project 2: Simulation of Shovel Downtimes

During this mine simulation study, one of the shovels was assumed to be down to determine the optimum number of required trucks allocated to the remaining shovel to prevent over-trucked and under-trucked situations in the operation. This scenario was simulated for the next shovel to assist the engineers to find out how many trucks should be operated for each shovel during each possible downtime. The results can help the mine engineers to reach a decision on moving extra trucks from the Gap Pit mine operation to the Cortez Pit mine operation during shovel downtimes. The simulation results for the truck/shovel allocation scenarios for the shovels P&H 2800 and P&H 4100 are shown in Figure 5.17 and Figure 5.18, respectively.

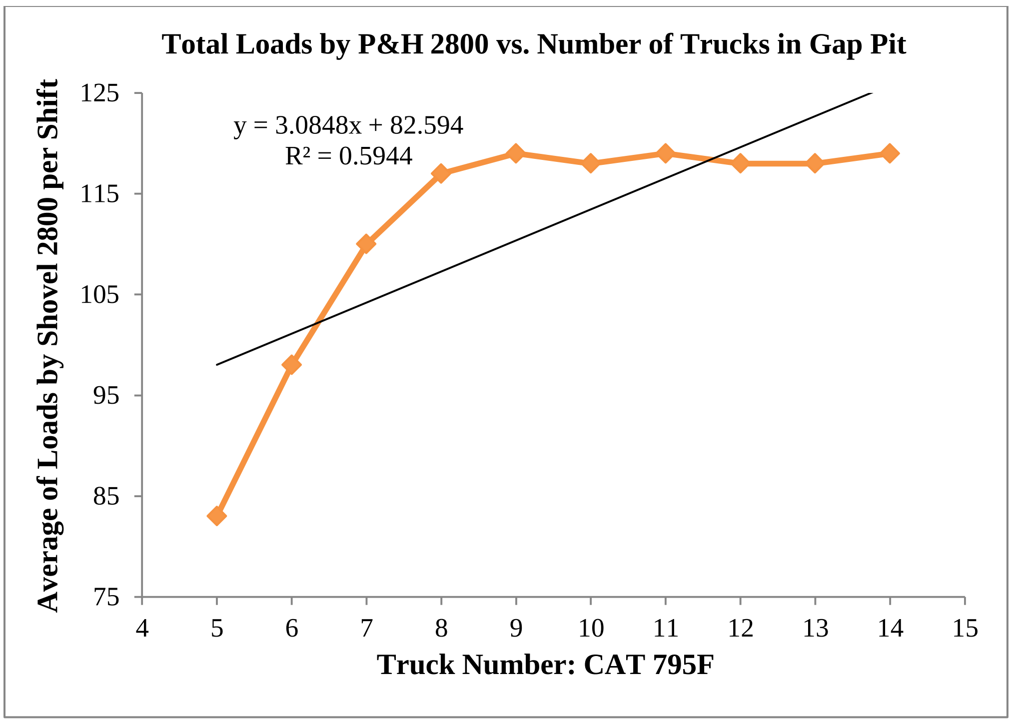


Figure 5.17: Truck/Shovel Allocation Analysis (Shovel P&H 2800)

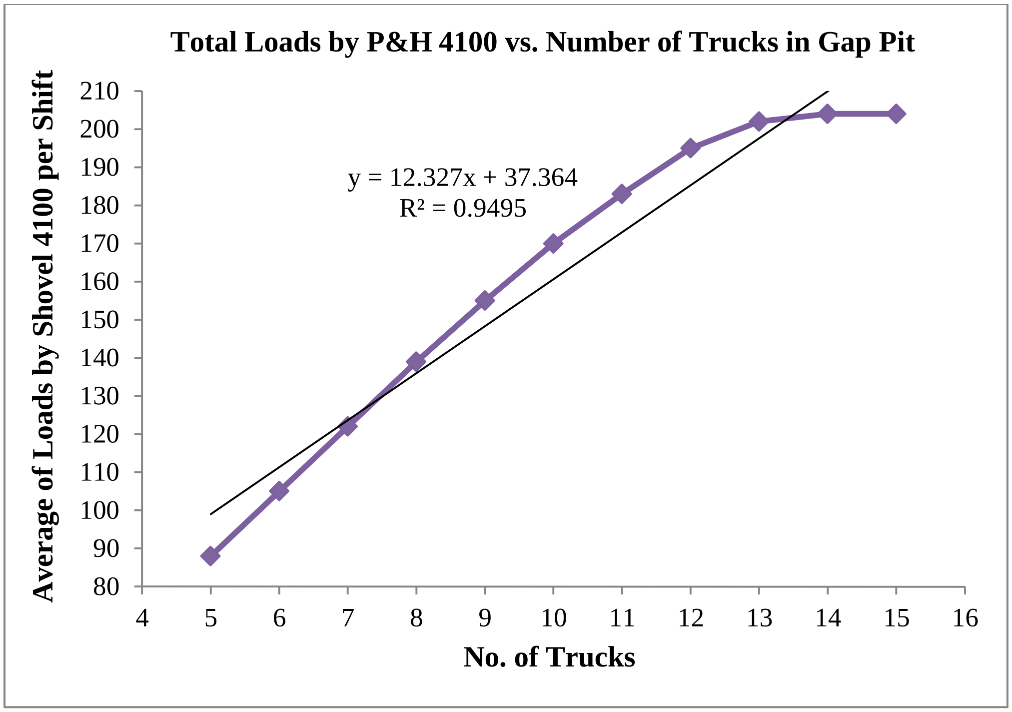


Figure 5.18: Truck/Shovel Allocation Analysis (Shovel P&H 4100)

This decision assisted the mine's engineers to enhance the mine productivity by improving the equipment utilization. The simulation project was significantly important for the haulage operation, since it could assist the Gap Pit mine's engineers in analyzing appropriate options to minimize the trucks' queue times at the loading units or reduce shovels' hang/idle times. Figure 5.19 illustrates the average utilization comparison of the shovel 2800 and shovel 4100 in different downtime configurations. The analysis of total dumped material in the waste locations is presented in Figure 5.20. Figure 5.21 and 5.22 show the truck average queue length and average time of all trucks in queue, considering the mine shovels' downtimes scenarios.

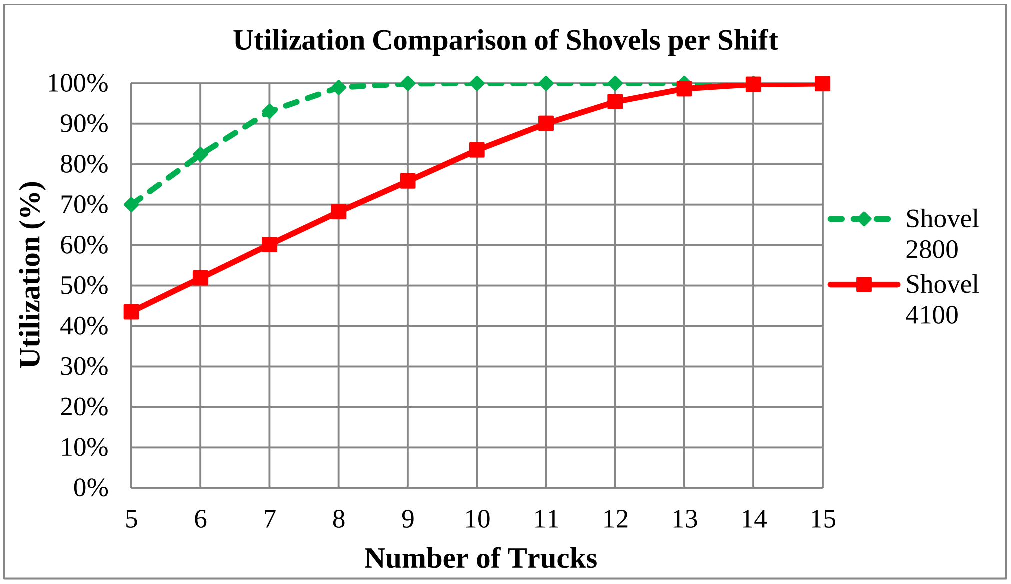


Figure 5.19: Average Utilization of Shovels in Different Downtime Scenarios

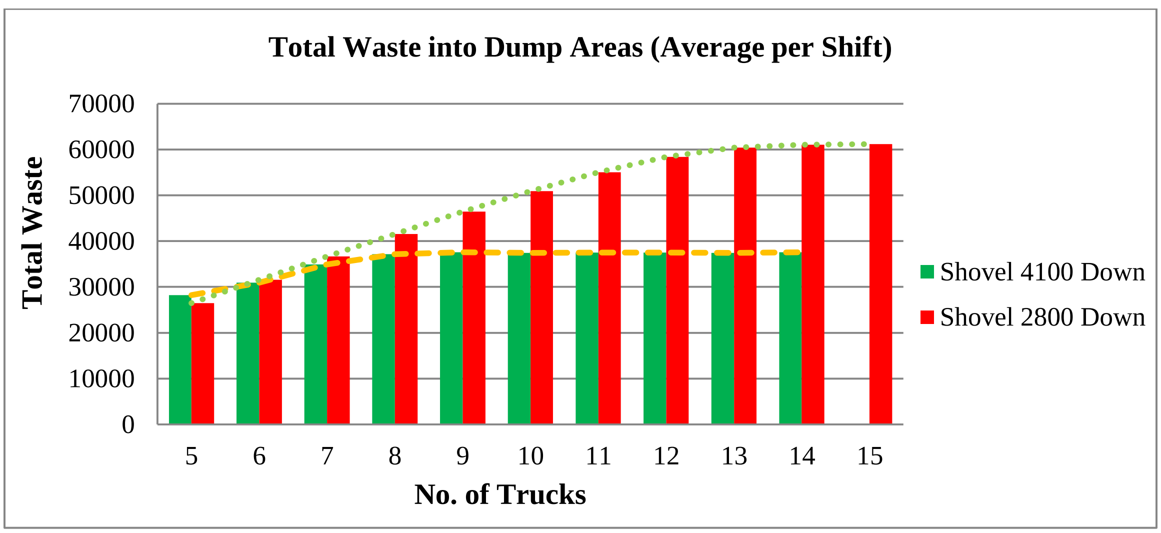


Figure 5.20: Analysis of Total Amount of Waste by Shovel 4100 and Shovel 2800

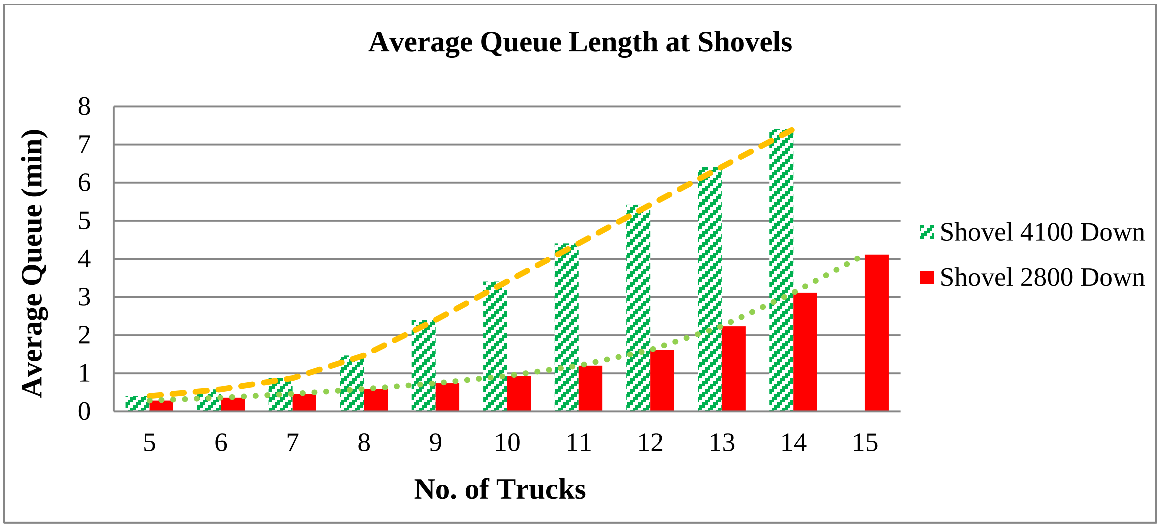


Figure 5.21: Truck Average Queue Length Analysis in Two Scenarios

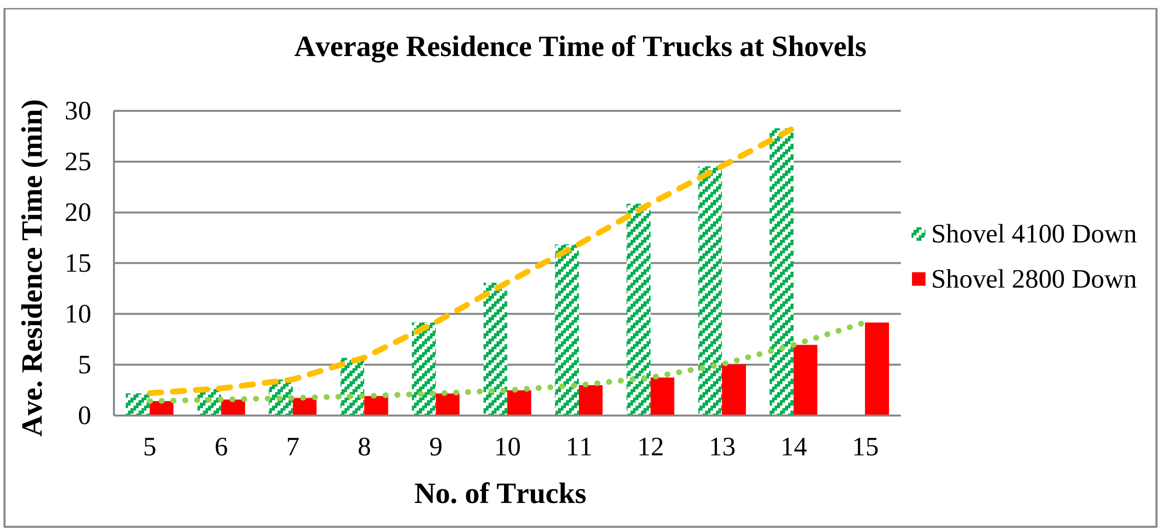


Figure 5.22: Truck Average Time in Queue Analysis in Two Scenarios

Since only shovel 4100 sends different ore types to the mine ore crusher and leach pads, data analysis graphs of the simulation throughout for this shovel are provided in Figure 5.23 and Figure 5.24.

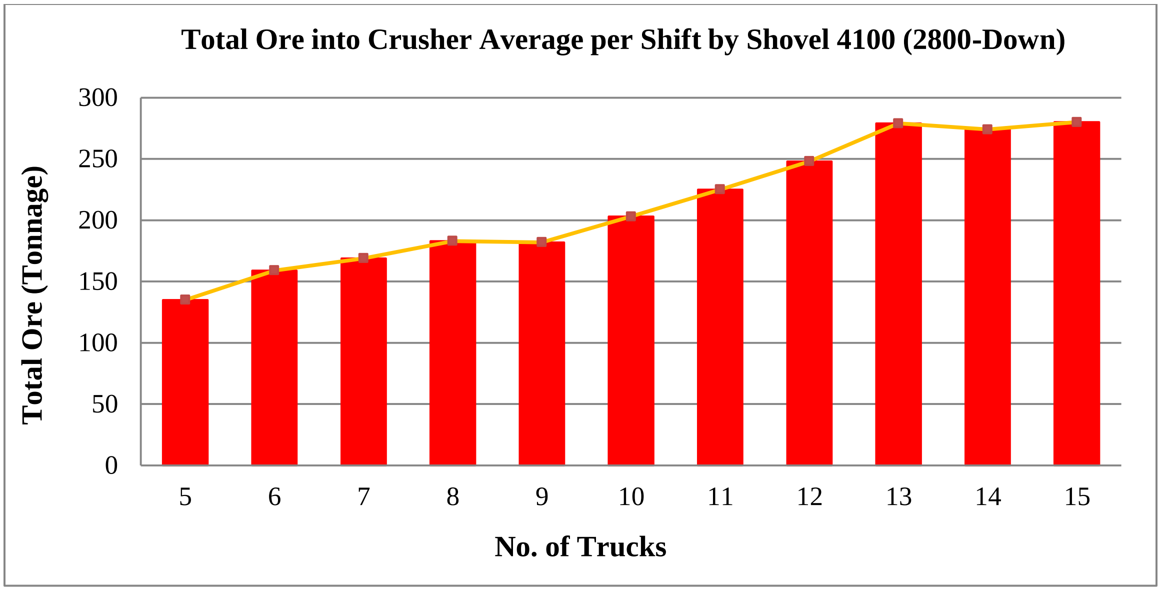


Figure 5.23: Analysis of Total Ore into Crusher by Shovel 4100

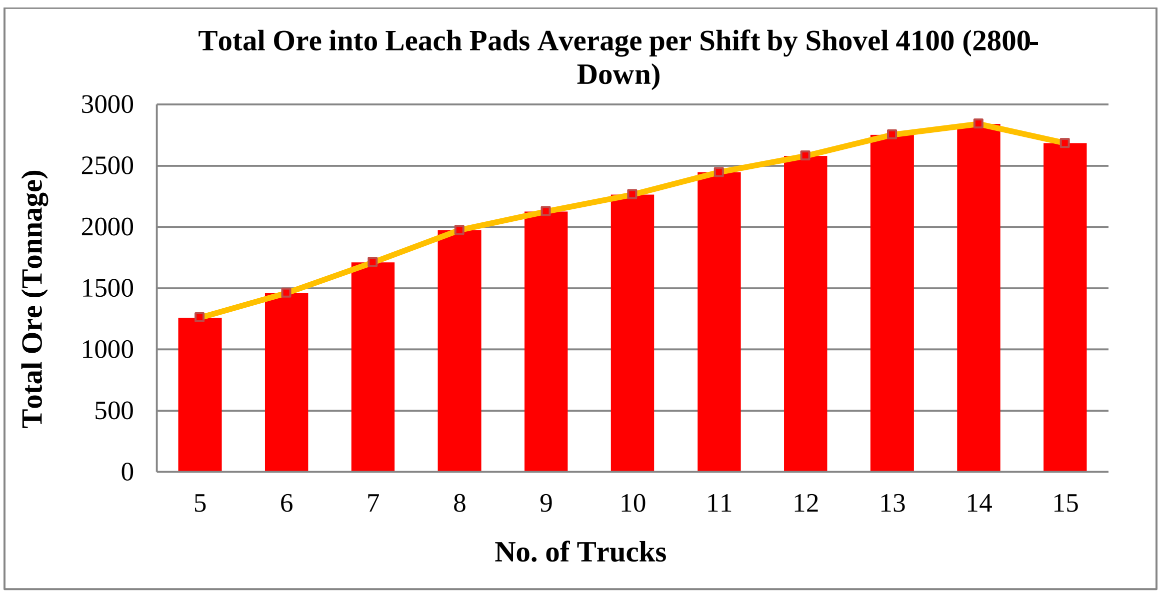


Figure 5.24: Analysis of Total Ore into Leach Pads by Shovel 4100

5.6.3. Project 3: Bridge Expansion Simulation Project in Gap Pit

One example of how simulation helped mining engineers at Cortez Hills was during the design stages of the tailings facility expansion for the Gap Pit mine operation. In order to get to the expansion site, there was a small section of road (bridge) that crosses over a conveyor belt. This crossing was narrow enough to warrant one lane traffic over it. As the open pit operations group were planning on hauling the material for the expansion with their large truck fleet, it was critical to ensure this haul was going to be as efficient as possible.

As the management team wanted to ensure that there would not be any impact on shovel productivity they were curious to investigate if there was any potential for excessive delays at the conveyor crossing. If the planning group identified that there would be excessive delays an economic analysis could be conducted to see if expanding the road was economically viable. Using the Gap Pit simulation, planning engineers were able to model the one lane road to the expansion. The data produced showed no drop in shovel productivity as trucks rarely queued waiting for another truck to clear the crossing. This saved time and money (the project estimation was approximately $1.5 million - according to an estimation by the mine’s engineers) by not having to undergo an economic analysis to see if it was viable to expand the bridge.

This project was performed in two different stages. The first stage of this project was modeled according to the last three months mined materials distributions from the shovels to the different locations in the operation. In the second stage of the project, the mine engineers requested that in a simulation scenario, sending trucks from the two shovels to the tailings to reach 50,000 tonnes first and then sending the remaining waste loads to the dump areas during a shift to determine whether the one way bridge causes any wait time at the bridge in this situation. A detailed view of the animation of the bridge simulation project is given in Figure 5.25.

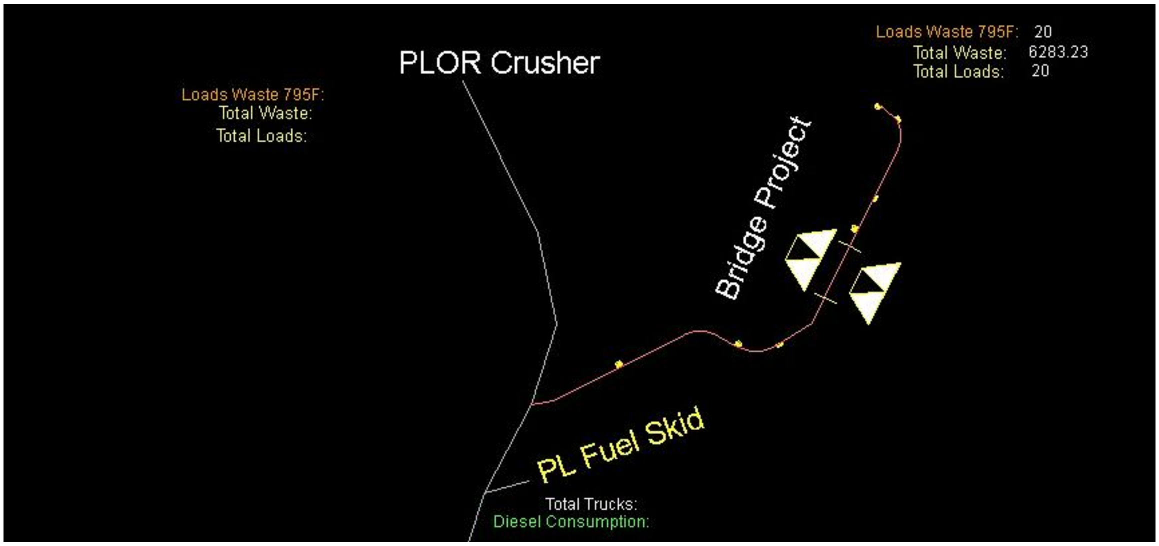


Figure 5.25: Close-up View of the Bridge Simulation Model

A comparison of the mine production rate considering the one-way or two-way bridge project using the simulation results is shown in Figure 5.26. In addition, Figure 5.27 and Figure 5.28 present a comparison between shovels' utilization in both one-way and two-way bridge traffic scenarios.

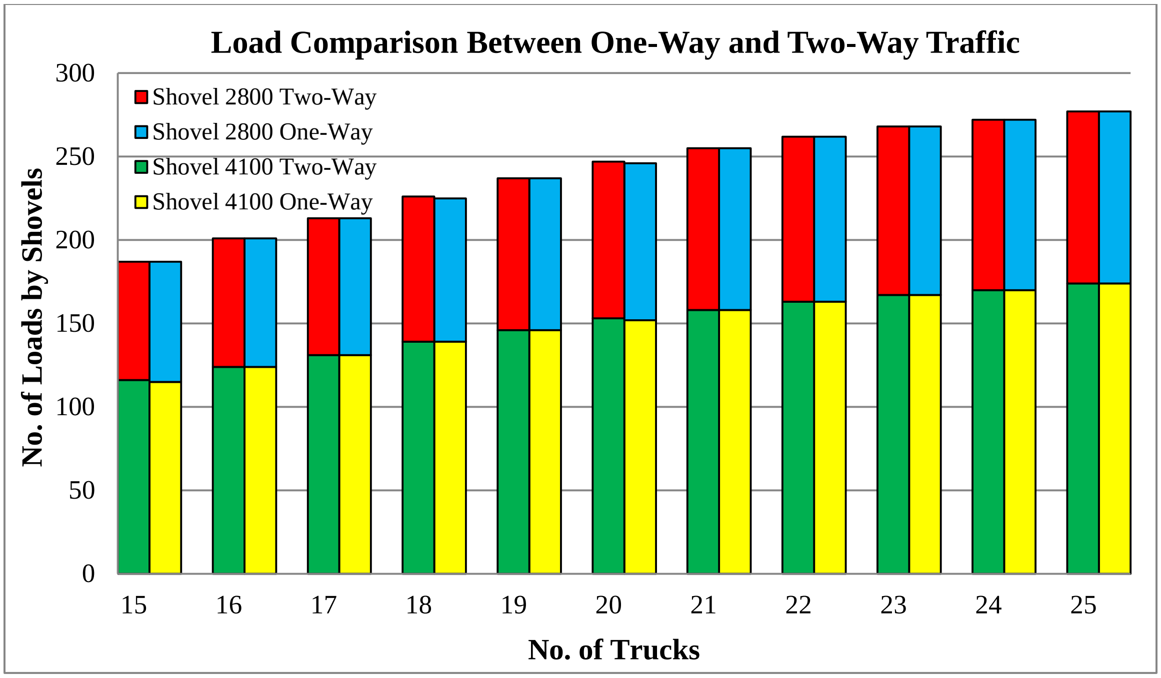


Figure 5.26: Average Mine Production Comparison in Two-Way and One-Way Bridge Project Scenarios

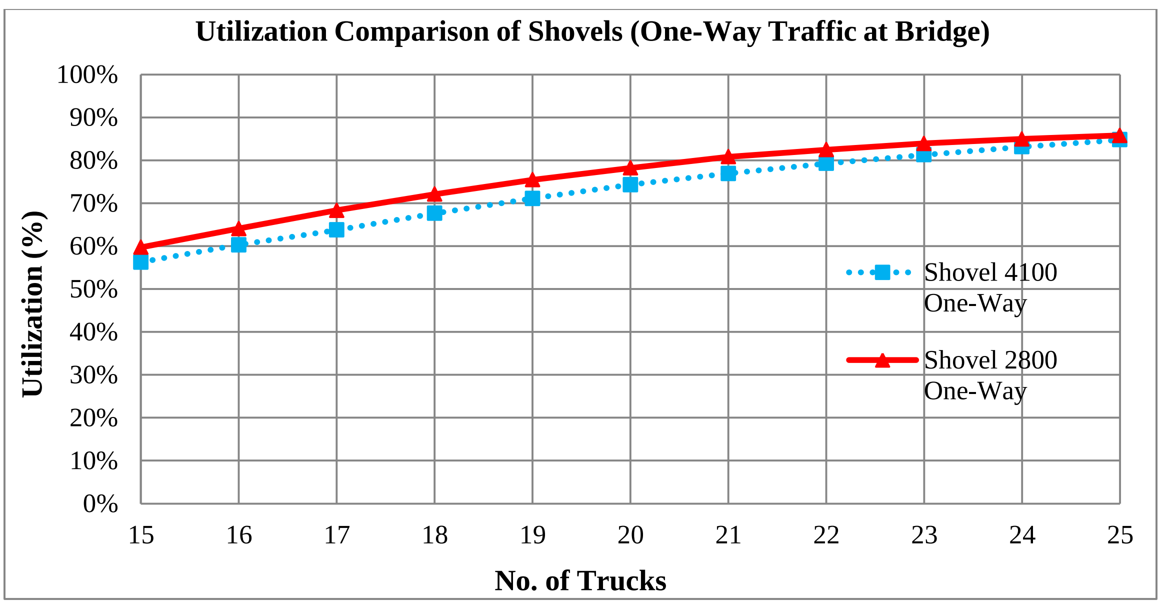


Figure 5.27: Utilization of Shovels Analysis (One-Way Traffic Situation)

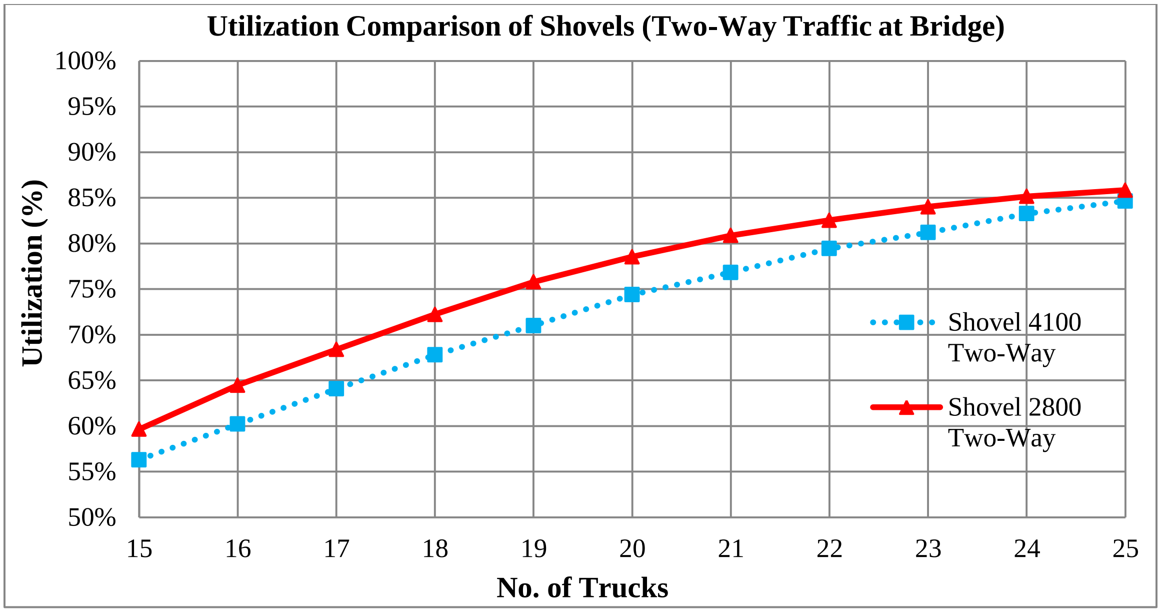


Figure 5.28: Utilization of Shovels Analysis (Two-Way Traffic Situation)

5.7. Economic Analysis of Simulation Models

According to the mine's engineers, the cost of operating trucks (CAT 795F) was assessed at $450/hour (U.S. Dollar). Using this estimation at Gap Pit mine operation, the total costs of running trucks versus the tonnage of the mined materials per mine effective working hours during a shift can be seen in the Figure 5.29. In fact, Figure 5.29 gives a comparison between the truck operating cost and possible mine production considering different number of trucks in the Gap Pit. The simulation model was run for a range of 10 to 25 trucks (CAT 795F) to analyze decreasing the size of potential queues and shovel hang or idle times for the long-term mine plan. As can be seen, the results indicated that the maximum production levels out at 21 trucks and once additional trucks were added to the operation the mine production rate will not increase efficiently. Simulation results can help decide the best feasible truck allocation/match to the two mine shovels considering truck operation costs in the Gap Pit. Table 5.2 also provides a concise summary of the expenditures analysis of the haul truck operation with respect to the simulation results in the Gap Pit mine. However this research does not include in-depth economic analysis of the mine's operational costs, additional model outputs and results of the conducted study are presented in Appendix B.

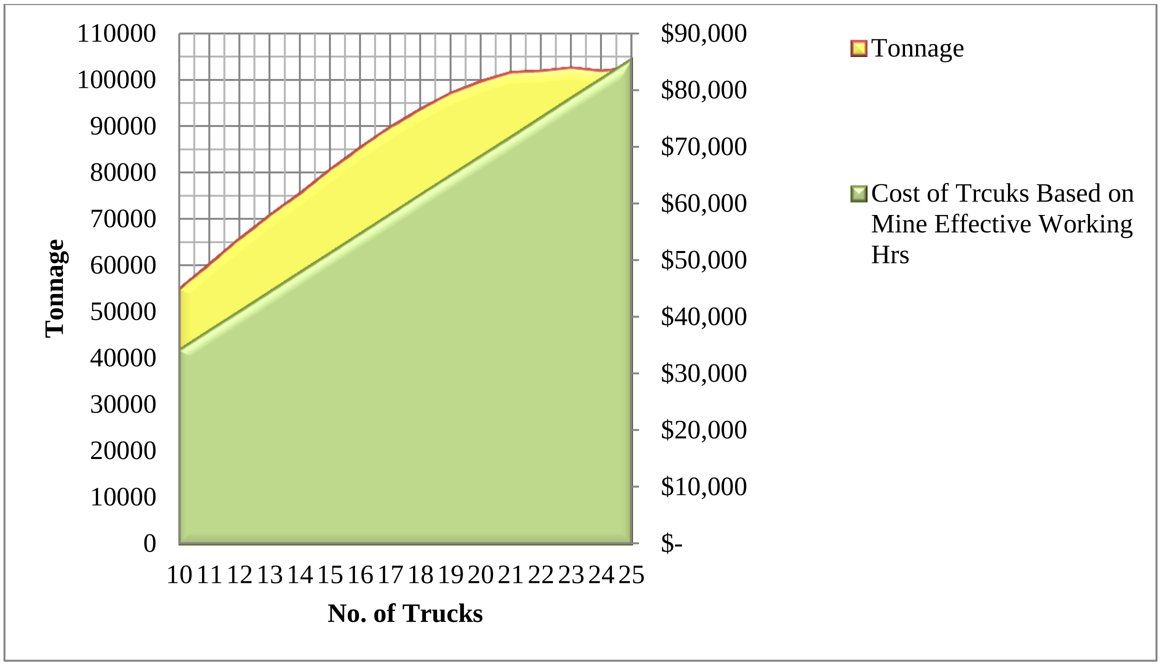


Figure 5.29: Cost Analysis of Truck Operating per Shift in the Gap Pit Mine

Table 5.2: Simulation Results Integrated with the Haul Truck Operational Costs in Gap Pit

No. of trucks	Tonnage	Cost of trucks per shift based on Effective Work Hrs.	Cost of running trucks per shift
10	54956.33	$34,200.00	$56,250.00
11	60356.67	$37,620.00	$61,875.00
12	65757.69	$41,040.00	$67,500.00
13	70840.41	$44,460.00	$73,125.00
14	75605.46	$47,880.00	$78,750.00
15	80688.18	$51,300.00	$84,375.00
16	85453.23	$54,720.00	$90,000.00
17	89900.61	$58,140.00	$95,625.00
18	93712.65	$61,560.00	$101,250.00
19	97207.02	$64,980.00	$106,875.00
20	99748.38	$68,400.00	$112,500.00
21	101654.4	$71,820.00	$118,125.00
22	101972.1	$75,240.00	$123,750.00
23	102607.4	$78,660.00	$129,375.00
24	101972.1	$82,080.00	$135,000.00
25	102607.4	$85,500.00	$140,625.00

Since several factors and variables, such as truck load, speed, weight, power, engine condition, accelerations, mechanical condition, idle time, fuel quality, tire and road qualities and conditions, driver's skill, weather, and maintenance schedules are important to obtain a dump truck's fuel consumption, the most precise way to determine fuel consumption is to directly measure and analyze the data from a mine operation (Kecojevic and Komljenovic, 2010). However, it would be possible to estimate the fuel consumption of a machine, if the types and applications are identified. In this investigation, an approximation of the CAT 795F hourly fuel consumption, assuming medium load factors, was considered for the analysis using Table 5.3 (Caterpillar Performance Handbook, 2012).

Table 5.3: Truck CAT 795F Fuel Consumption for Different Load Factors

Truck Type	Low (20%-30%)		Medium (30%-40%)		High (40%-50%)	
795F	123.3-184.9 (L)	32.6-48.9 (U.S. gal)	184.9-246.6 (L)	48.9-65.2 (U.S. gal)	246.6-308.2 (L)	65.2-81.4 (U.S. gal)

In addition, the following formula can be applied to calculate hourly fuel cost of mining dump trucks (Caterpillar Performance Handbook, 2012):

Hourly Fuel Consumption × Local Unite Price of Fuel = Hourly Fuel Cost (5.2)

Figure 5. 30 illustrates the fuel consumption analysis of CAT 795F trucks for different numbers of trucks during a shift in the Gap Pit using the simulation results. The figure shows that the fuel consumption of the mine dump trucks goes up with a constant rate for different number of trucks, while the mine production rate increases substantially since it reaches the optimum number for trucks (21) in the operation.

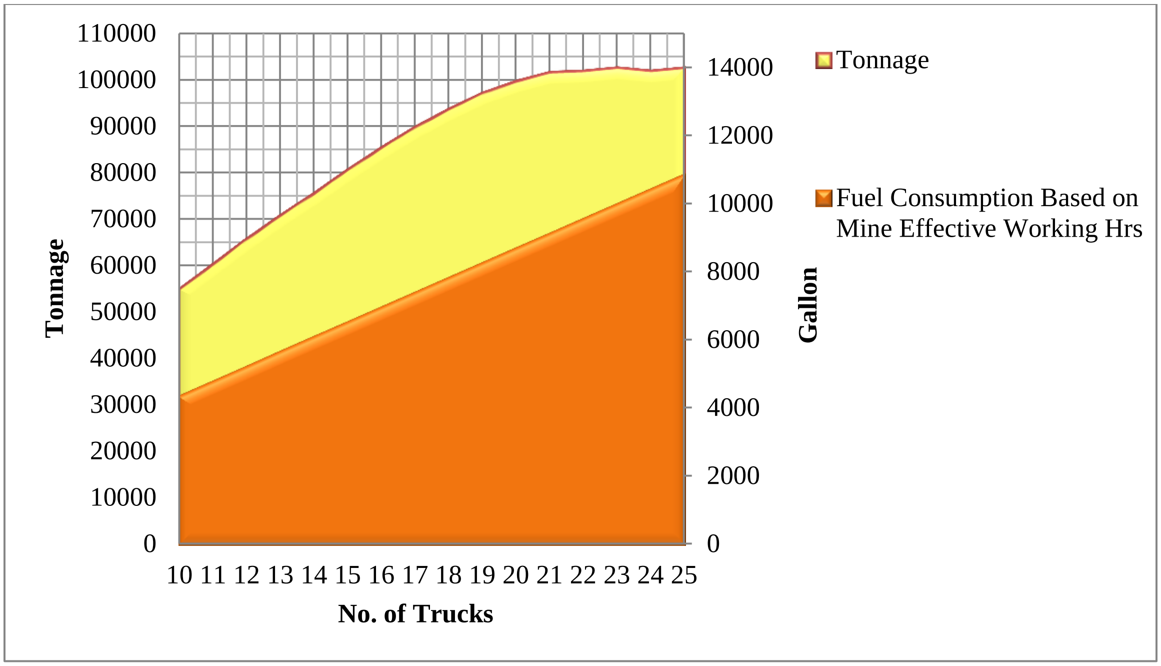


Figure 5.30: Fuel Consumption Analysis of Dump Trucks (CAT 795F) per Shift in the Gap Pit

5.8. Conclusions and Future Study

A discrete-event system simulation and animation model of Gap Pit mine operation was designed and created using GPSS/H® and PROOF Professional® software. Animation of the simulation model enhanced the effect of the program by visualizing the mine operation on the display. The animation technique was also applied to debug possible simulation errors and visualize the results of simulation on the PC screen in 'animated cartoon' mode. The Gap Pit mine simulation and animation was a flexible and cost-effective tool for the mine's engineers to examine and evaluate various mine plans before actually implementing and changing the mine system.

Moreover, the model was utilized to study the effects of truck/shovel matching and many scenarios on the mine operation efficiency and performance. During this mine simulation investigation, various case studies were performed using the simulation and animation model to provide the mine engineers with more accurate analyses, resulting in improved decision-making process. Since the Gap Pit mine was in the development phase, a right and accurate design in the truck/shovel allocation was critical doe the engineers and managers. As a result, optimum truck/shovel system matching was evaluated and determined using the simulation and animation. Furthermore, the tailings facility expansion simulation project, a complex and important plan, was prominently beneficial and valuable, in terms of determining the possible impact of spending over 1 million dollars to add a passing line to the bridge. The results indicated that current situation will not generate any passing traffic and reduce the mine shovels' productivity. Using the simulation results enhanced the confidence in making decisions in the Gap Pit mine design and planning.

Other technical "what if?" mine planning and management scenarios would be possible to be investigated to reduce costs and improve the Gap Pit mine productivity using the developed simulation. This simulation and animation model could also be effectively used for any proposed plans in the operation to assess if the project can be technically possible and economically valuable for the mine and company.

Chapter 6. Simulation and Animation Model of an Aggregate Mine to Assist Engineers in the Operation of Haulage Systems

This chapter discussed the application of mine system simulation in modeling an aggregate mine and analyzed how discrete-event system simulation can be possibly and beneficially applied for modeling modern small and medium-sized mine operations.

According to the literature studies, discrete-event system simulation and animation models of aggregate mining operations have seldom been conducted and published. Furthermore, simulation studies, as a quick and inexpensive technique, demonstrated its capability and aid in loading-haulage equipment selection in the mineral industry. Rasche and Sturgul (1991) discussed that small and medium-sized mines can benefit from the use of mine simulation studies. This research was carried out to set up a simulation and animation model for an aggregate (sand and gravel) operation to test and evaluate several equipment options in the haulage system.

Sand and gravel are very critical for the construction activities and road building in all states in the USA. All of the states have sand and gravel deposits and produce construction sand and gravel. The largest states' producers are California, Texas, Michigan, Ohio, Arizona, Colorado, Minnesota, Washington, and Utah (Minerals Education Coalition, 2014). Sand and gravel, as an important commodity, have widely applications in various industries, such as construction, road development, cement production, glass, steel, petroleum, etc.

A hypothetical mine layout/haulage profile of a sand and gravel mining operation was created for the simulation studies of different haulage systems. This simulation model enabled the investigators to compare truck/loader and conveyor belt systems to finally obtain the most productive and efficient materials handling method. In fact, the investigation was conducted to study and analyze whether it would be more beneficial to purchase one or two trucks, or add a conveyor belt to the current materials handling system in the operation. Overall, in surface mining, selecting the best optimum and efficient materials hauling options is one of the most important decisions for mining engineers. For this purpose, several factors need to be carefully considered, such as technical feasibility, economic conditions, and mine safety (Hartman and Mutmansky, 2002).

6.1. Sand and Gravel Mining Operation Overview

The mining project is situated on 660 acres in the North of California. In the operation the mining, reclamation, and processing adhere to the latest standards of Surface Mining and Reclamation Act, federal, state, and local laws. The mining operation will be carried out in three areas, each having the duration of 8-10 years (EIP Associates and Sharrah, Dunlap, Sawyer, Inc., 2005).

This life of mine will vary due to any number of factors, such as the quality of aggregate and the demand of aggregate in this region. A geotechnical report was prepared for this project and the results were as follows: 0-3 meters deep clay, silt, sand and topsoil; the aggregate layer is 3 to 7.6 meters below this and consists of sand to 15cm cobbles. Overburden is used for mining, backfilling, flood control, and reclamation. Some aggregate is also used for project infrastructure, such as on-site roads (EIP Associates and Sharrah, Dunlap, Sawyer, Inc., 2005).

This operation has three areas with a total life of the mine estimated to be 24 to 29 years. Dealing with overburden at each area will be different. Overburden is used to build the proposed levee, a spur dike along the boundary, and for backfilling each area for reclamation. The aggregate mine has no impact on surrounding properties. For this mining project, water is pumped to the site and it has an on-site processing plant (EIP Associates and Sharrah, Dunlap, Sawyer, Inc., 2005).

The sand and gravel mine complies and carries the necessary actions for the following: dust and noise control, natural resources protection, visual resources and project noise, terrestrial biological resources, and public safety. Equipment for this project includes a water truck, front-end loaders, a hydraulic excavator, off-highway trucks, self-loading scrapers, track dozer, and a 750 kilowatt diesel generator. The haulage systems should carry mined materials to the process and storage area from different mine planned areas (EIP Associates and Sharrah, Dunlap, Sawyer, Inc., 2005).

6.2. Belt Conveyors vs. Haul Trucks in Mining

Haul truck equipment system is presently the most accepted and used method in transporting materials in open-pit mines, including quarries. However, alternative bulk material handling methods, such as conveyor belt systems can safely, economically, and environmentally benefit mining operations (Nekoufar, 2014).

The comparison analysis, in this section, between haul trucks and conveyors is general and can be applied to any type of mine operation: small or large, underground or surface. In any of these systems, the basis of the mine design is determined by site specific parameters. There are several advantages and disadvantages for both truck hauling and conveyor belt systems when transporting materials. A few important parameters/factors to be compared and analyzed are topography, economic analysis, and environmental impact. In the initial mine design area the topography of the deposit determines existing surface restrictions for the transport of materials.

The economic analysis for both of these methods involves capital cost, operating cost, maintenance expenditure, the life expectancy of the equipment, and the resale value of the used equipment. From the start, both of the methods have relatively high initial costs; therefore, having a well-organized mine plan will determine which method(s) are most suitable throughout the life of the mine. Considering environmentally friendly procedures and equipment, mining operations look at the impact these items have towards the environment, for instance dust, emissions, noise, etc. A comparison of Haul Truck systems and Conveyor belt systems is as follows (Belt Benefits, 2013) and (Metzger, 2007):

Truck Haulage System – Advantages and Disadvantages

- Not a stationary system/flexible
- Haul route is dynamic
- Can haul any type of materials
- Need engineered haul roads
- Not able to maneuver through difficult terrain
- Haulage cycle may not be the shortest possible path - results in higher fuel consumption, exhaust emissions, and dust emissions
- Not designed for steep haul road grades - less efficient
- Possible high fuel cost and shortage of supply

- Parts may not be readily available in some places
- Lower initial/capital cost (depending on truck types)-more expensive in long-term
- Larger labor costs - to train, operate and maintain (Mitchell and Albertson, 1985; Metzger, 2007)
- Operating cost estimation is high: $0.87/ton (Metzger, 2007)

Conveyor System – Positives and Negatives

- Stationary system
- Conveyor path is not dynamic - though it can be shortened or lengthened if needed for mine design
- Materials probably need primary and/or secondary crushing at the face (Zaharis, 2011)
- Conveyor path can be through areas where trucks may not be able to travel
- Can handle inclines up to 35-degrees
- Parts are readily available
- Operating cost is low - reduction in operators, training, and maintenance
- Particulate matter and noise pollution is significantly lower (Mitchell and Albertson, 1985; Metzger, 2007)
- More eco-friendly
- Higher capital/initial cost (depending on size and capacity)-lower cost in long-term
- Less labor-intensive (Bearman and Munro, 2010)
- Cost estimate: $0.06 ton/tonne (Metzger, 2007)

6.3. Economic Comparison of Conveyor Belts and Truck Haulage System

A key parameter that needs to be considered in depth is the transportation of materials (e.g. ore and waste) in an open pit mining operation. When considering in what manner the material will be transported the following questions need to be answered; where is it going? What is the existing topography? What is the initial startup cost? What is the cost to maintain and operate? (Frizzell and Martin, 1992).

The method of choice for many years has been a truck hauling system but in more recent years, a conveyor belt system has come into focus due the need to reduce costs. Some of the advantages of having a truck hauling system are low capital cost, ability to adjust and conform in a dynamic mine operation, resale value, and its mobile ability. The haul truck has come a long way from where it started. Current models, some of the largest trucks ever designed that use diesel engines and electric wheel drives, interact with a Dispatch fleet management and have a monitoring system that results in improved efficiency. Disadvantages of haul truck system range from high fuel consumption (60% fuel energy to move the truck, 40% to transport payload), possible high fuel costs, inclement weather, requires high manpower, and high operating and maintenance costs. Furthermore, truck haulage system has an operating grade limitation of 10% (Frizzell and Martin, 1992).

A conveyor system is low cost in the long-term and handles material continuously. Some of its advantages are low energy costs, inclement weather does not bring the system to a halt, low operating and maintenance costs, reliable (90-95% availability), and requires low manpower. This system can handle steep grades, up to 30%, which reduces the need to remove overburden and implementing a haul road system. Disadvantages of this are high initial capital costs and the inability to be flexible in the loading area. A conveyor system has a life of 25 years where-as a truck has a life of 6 to 8 years (Frizzell and Martin, 1992).

Some parameters to consider when employing a truck system are extra trucks for extreme haulage routes and wear and tear of existing fleet. When comparing a traditional truck hauling system and a conveyor system with an in-pit (mobile) crusher(s), several mines have concluded that a conveyor system has lower maintenance, operating, and overall unit costs. A conveyor system should be highly sought after in a mining operation for its advantages (Frizzell and Martin, 1992).

6.4. Simulation and Animation of a Sand and Gravel Mine: Construction and Application

A simulation and animation program of a sand and gravel mine using two separate software packages, GPSS/H® and PROOF Professional®, was designed and developed to examine the mine operation with two possible haulage systems; a truck haulage system or its combination with a conveyor belt. This model allowed the mine engineers to investigate and consider the various options of haulage systems, which are critical for the operation productivity. The simulation identified some strengths and weaknesses in the current loading and hauling fleet of the mine, and resulted in some suggestions for improving the system.

Approximately 370 lines of GPSS/H® simulation language code was written for this simulation study to mimic the operation using only truck/leader system or a combination with a conveyer belt. The source code of the simulation and animation program is provided in Appendix C.

The simulation model included a haulage profile with truck movements separately or in combination with a truck and conveyor belt to carry overburden and aggregate to the process and storage area. A few “what if?” questions considering the type of the mine material handling systems were studied using the simulation and animation program to achieve the best operating scenario. This model assisted the modeler to investigate and analyze various material handling systems, either separately or in combination for the operation according to the short-term and long-term mine planning.

The spot, load, haul, dump, and return to cycle mine operation were discretely simulated in the program using GPSS/H® language. A general logic of the implemented haulage operation in the GPSS/H® for the case study’s simulation model is illustrated in Figure 6.1.

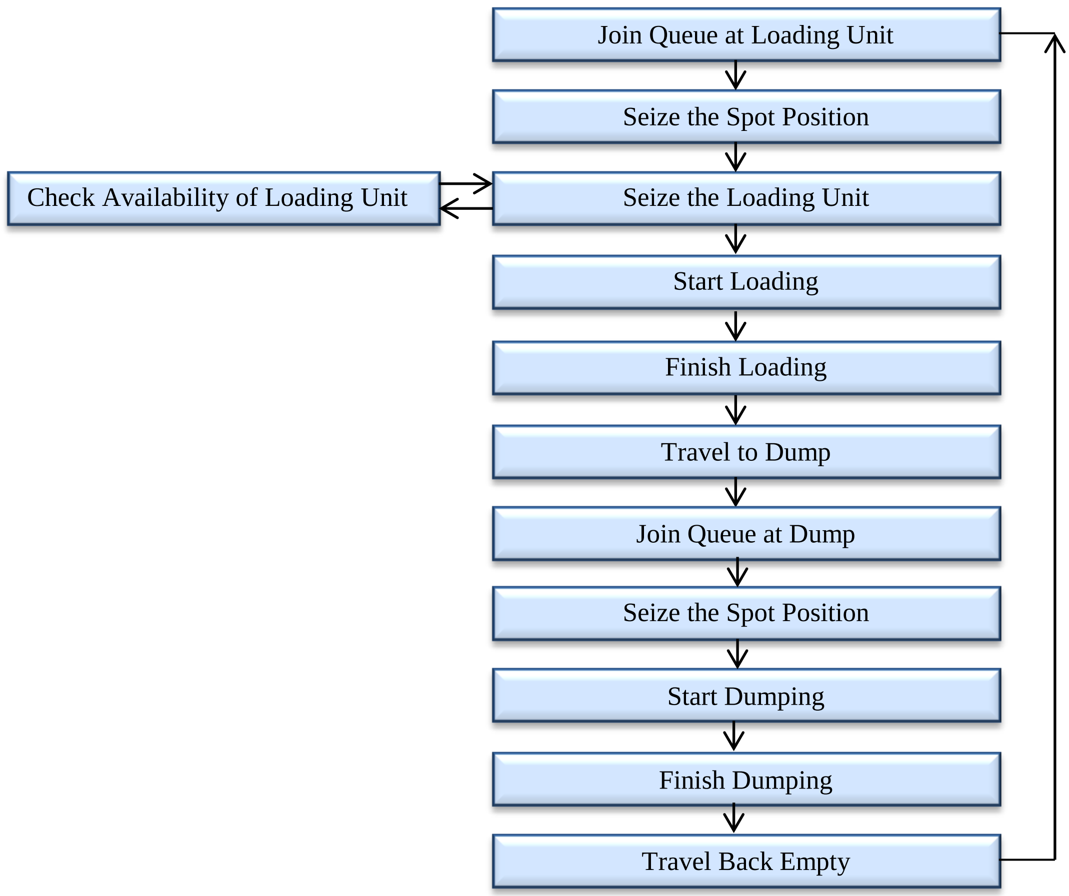


Figure 6.1: Simplified Logic of the Implemented Mine Simulation Model

Based on the experience, truck travel times in mining operations have been mostly observed to be symmetrical. Haul truck travel times and load time were simulated using the normal distribution with means and standard deviations for each segment (Sturgul, 2000). However, as it has been observed, the spot times of trucks were assumed to be non-symmetrical, and the exponential distribution was used in the simulation model. In addition to this data, constant travel time for the conveyor belt was considered and modeled. Figure 6.2 shows the GPSS/H® interface of the input and output of the simulation model.

Figure 6.2: Aggregate Mine System Simulation Program

The simulation included the animation of the mine system and operation. Animation as a graphic user interface was needed to enhance the benefit of the mine simulation model. By combining the visual power of animation with the mine simulation, a complete picture of the mine system was obtained and displayed. PROOF Professional®, the animation software, also assisted the modelers with the ability to display the aggregate simulation program in progress and results in a meaningful way. The animation of the simulation was necessary to verify a true representation of the mine. Animation was used not only to visualize the mine simulation code on the computer screen, but also to assist in removing programming 'bugs' from the model.

Different screenshots of the sand and gravel simulation and animation model are shown in Figures 6.3 and 6.4. The model shown in Figure 6.3 uses only haul trucks (CAT 772) for the mine haulage system, which transport materials from both area 1 and area 2 to the process and storage location. A snapshot of the animation running a combination of trucks (CAT 772) and a conveyor belt is presented in Figure 6.4. As can be seen, this animation included a conveyer belt and mobile crusher system that convey sand and gravel from area 2 to the mine process and storage area. The mobile crusher was fed by the loader 2 located in area 2.

The animation of the sand and gravel simulation model visualized statistical data at any point in time as they were updated continuously by the simulation program (O'Connell and Sturgul, 2010). The animation user interface of the simulation model displayed the following statistical data:

- loads of mined materials and tonnages at each loader
- the current time, hour, day, and week of the mine by a programmed clock
- utilization of loaders (%)
- the load and amount of materials dumped into the process and storage area

The model was also programmed to show the similar output on the GPSS/H® display for the users' convenience.

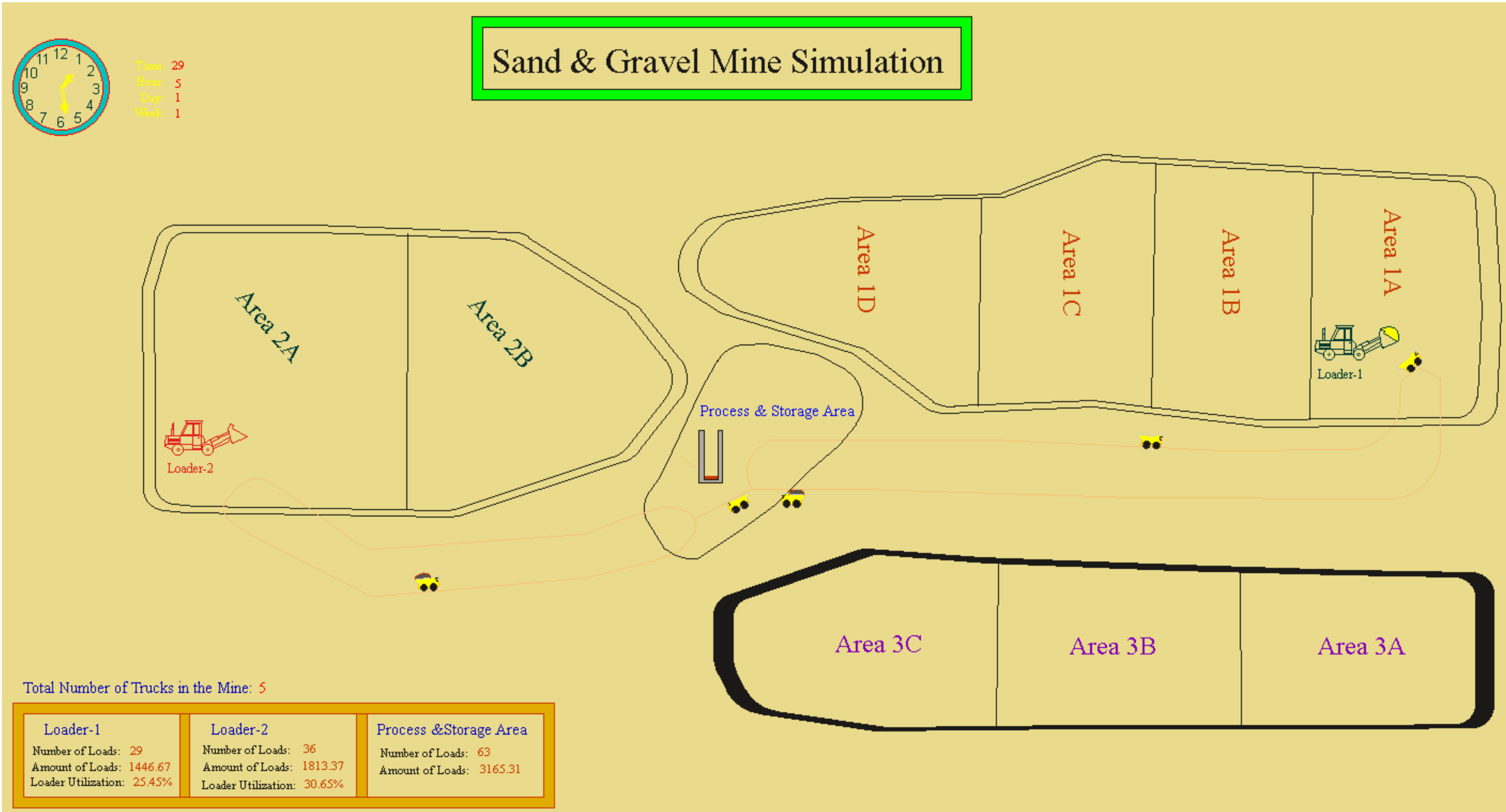


Figure 6.3: Screenshot of the Animation Program (Truck Haulage System)

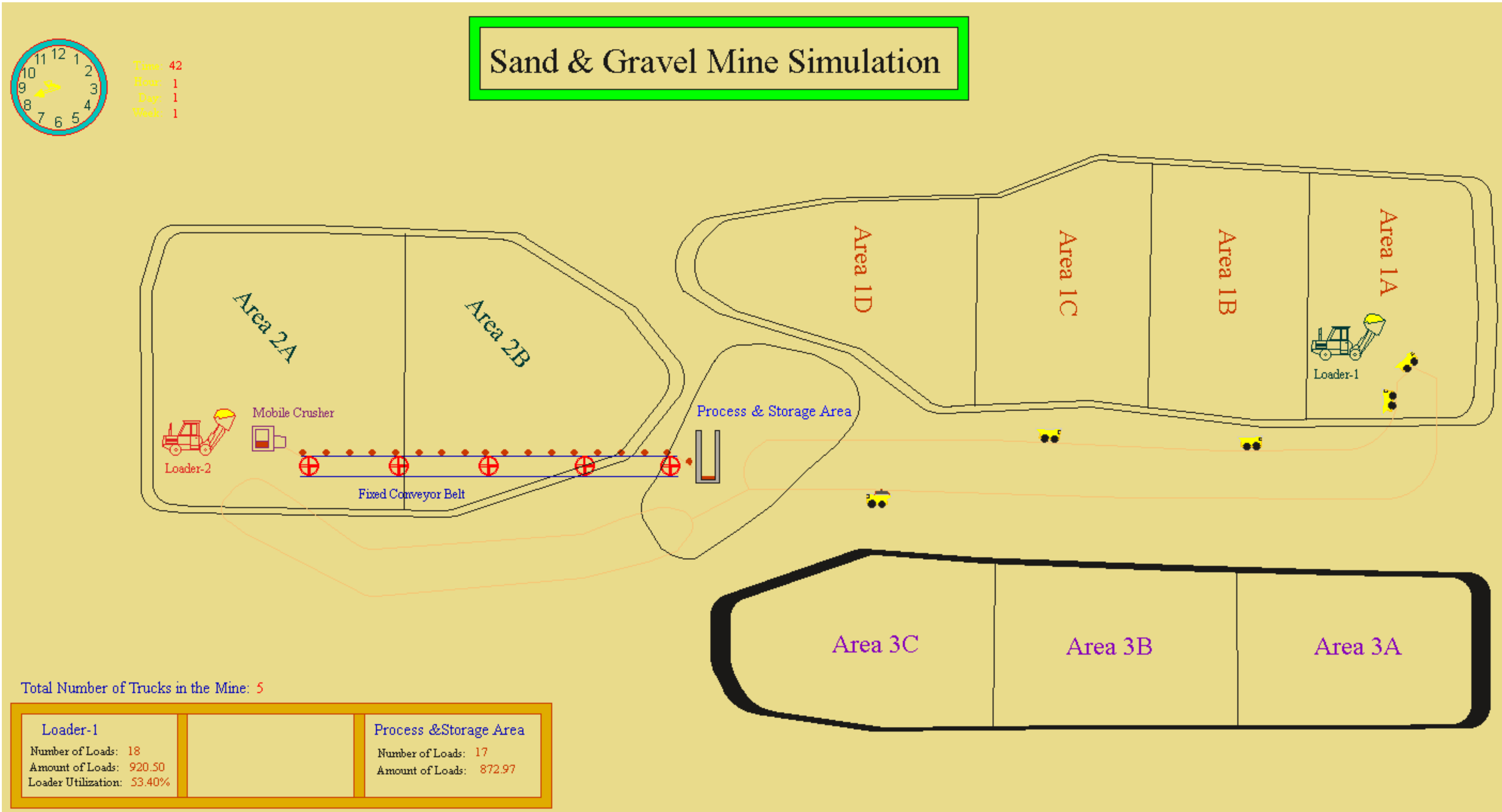


Figure 6.4: Screenshot of the Animation Program (Combination of Truck Haulage and Conveyor Belt System)

To implement a conveyor belt in the sand and gravel mine operation, a mobile crusher was also required. The mobile crusher can be seen on the animation program. A mobile crusher was positioned at the mine face where an excavator feeds right into the crusher. The mobile crusher has a built in transport mechanism that allows it to move with the excavator/loading unit (Frizzell and Martin, 1992).

6.5. Simulation Results and Discussion

Simulation of small mining operations, particularly aggregate mines have not been frequently conducted and discussed. Despite the fact that the application of discrete-event system simulation modeling of small and medium-sized mining operations have been accepted and performed by mining engineers (Sturgul, 1991), aggregate mining system modeling and simulation have been rarely performed. This simulation study specified aggregate mine operations also can benefit from mine system simulation and animation techniques as a low-cost and practical tool.

The main goal of this mine simulation project was to construct a discrete-event system simulation program to test and investigate a wide range of feasible material handling system selections in an aggregate (sand and gravel) mine operation. The simulation program was flexible to be modified to evaluate the effects of different conveyor belt types and/or the various haul truck models used in the mine. Animation of the simulation model was created with additional coding using GPSS/H® and PROOF Animation® software packages. The animation program was directly run by the generated Trace files (ATF) in the ASCII format as the simulation output. In general, the animation program was a byproduct of this simulation and helped the modeler to better understand the mine system and operation.

The simulation model was run to investigate a range of truck (CAT 772) number scenarios comparing with a conveyor belt in the aggregate mine as can be seen in Figure 6.5. After analyzing the mine system, the life of the mine, economic analysis, and the conveyor belt advantages, such as cost-effective operation, low noise pollution, dust emissions, operating and capital costs and mine simulation results, recommendations were made for an effective haulage operation.

Initially, the mine was working with 4 haul trucks (CAT 772) per shift that is 8 hours to transport materials from two areas to the process and storage area. The main concern to address was whether it would be beneficial to purchase only one more haul truck (CAT 772) or install a conveyor belt system in the area 2 of the operation. However addition simulation scenarios were carried out for analyzing the effect of operating 6 trucks or a combination of 5 trucks and a conveyor belt in the operation. Finally, as can be seen in Figure 6.5, simulation results indicated that operating 5 haul trucks (CAT 772) in 18 days/shifts, increases the mine production rate by 23.7%. However, to compare the combination of a conveyor belt (economical transportation system) working with 4 trucks can improve the current mine production by 5.4%. Nonetheless considering the operational cost of the haul trucks, which increases the total mine operation expenditure, a combination of both systems would be a beneficial decision for this mine and its operation characteristics. More effective data analysis of the mine simulation output for the number of loads done by the loader 1 and loader 2 in a few scenarios, including different haulage systems is compared and presented in Figure 6.6. Additionally, the mine loaders' utilization working with a range of 4 to 10 trucks was analyzed by the simulation model and presented in Figure 5.7.

Once again, mine system simulation proved that this technique is one the most powerful tool to determine the best efficient alternatives in selecting equipment to meet mining production schedules in an efficient way.

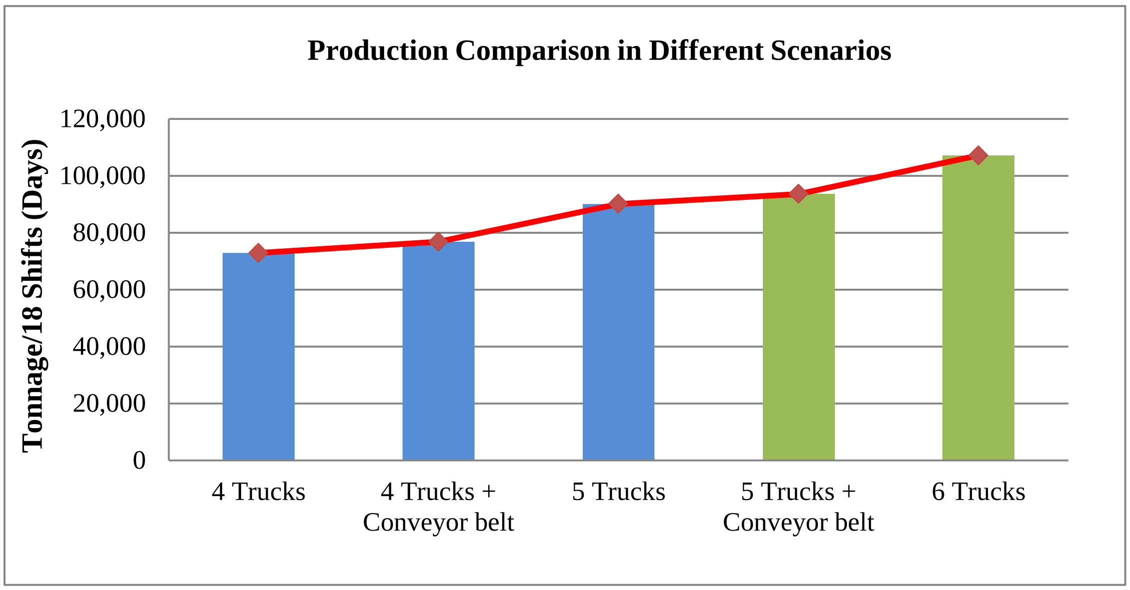


Figure 6.5: Truck vs. Conveyor Belt Simulation Analysis for the Aggregate Operation

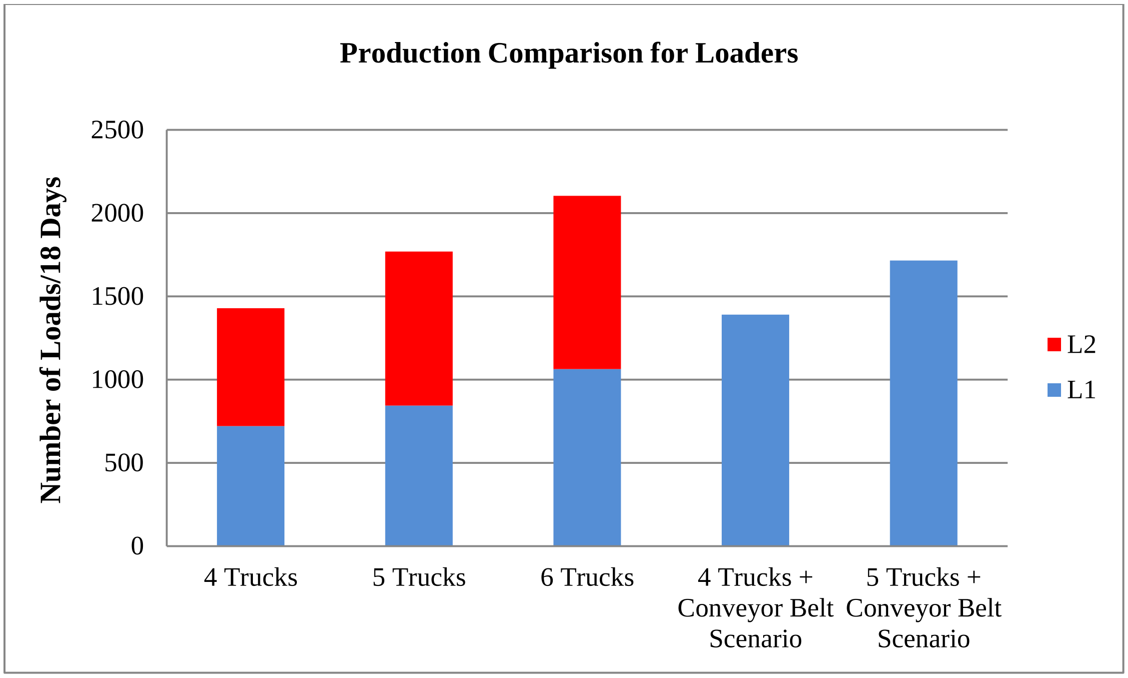


Figure 6.6: Analysis of the Mine Simulation Results for the Loaders (Number of Loads)

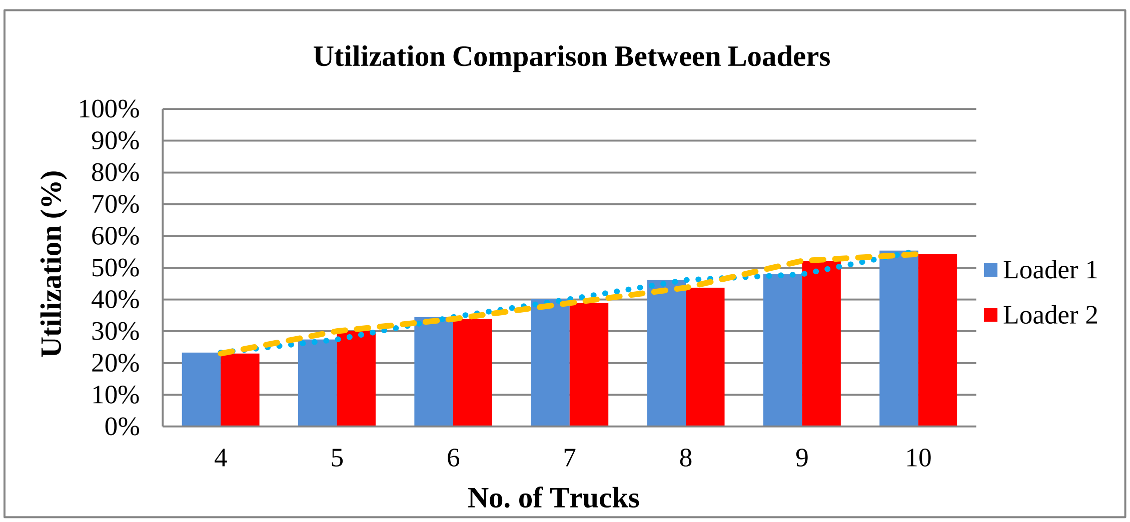


Figure 6.7: Utilization of the Loaders in the Sand and Gravel Operation

This simulation model can also be used to run for more additional “what if?” scenarios to analyze further material handling selections for the mine operation. Since the mine simulation model can widely be used to assess a variety of technical issues, such optimum number of truck, types and capacities of conveyor belts, number of back-up/spare equipment that the mine's engineers frequently may deal with, it is recommended to use this model for the future studies. For additional in-depth statistical analysis, it is also recommended to incorporate the repair/breakdown data (scheduled and unscheduled) of the mine haulage equipment into the simulation model. Moreover, optimum number of haul trucks working with the installed conveyor belt in the aggregate operation can be technically determined by running and changing the simulation with different additional projected trucks. Another practical application of the developed simulation and animation model can be determining required back-up units, in order to avoid production losses, reduce downtime, and increase productivity in the mine.

To sum up, one of the most important lessons learnt from this mine simulation study was that simulation can be a useful "what if?" analysis to benefit aggregate/simple/small operations by running scenarios in some way it have been applied in modeling large and complex mines, particularly haulage systems modeling. In addition to this experience, it is misconceive that mine simulation would be potentially expensive or not economically acceptable for aggregate/small mines, since the cost of modeling non-complex mines can be more reasonable due to their less time consuming and labor intensive effort.

Chapter 7. Using a Discrete System Simulation and Animation Model of a Coal Mine to Increase Equipment Efficiency and Reduce Environmental Impact

7.1. Introduction of the Coal Mine Simulation[1]

This chapter shows that the discrete-event system simulation technique of modeling mines not only can improve the equipment utilization and total mine productivity, but also can be implemented as a practical and useful tool to study and possibly reduce the environmental impact of heavy mining equipment and machinery in surface mines. This approach can be a part of the Research and Technical Development (R&D) of Green Mining Technology to increase the mine operation's efficiency and reduce its environmental impact (Mission 2016: Strategic Mineral Management, 2014). In this study, a discrete-event system simulation and animation model of a coal mine was developed to enhance the efficiency of a truck-excavator operation and decrease the environmental impact of haulage in an open-cut coal mine with multiple-pit operations.

In any mine, a key objective is to have sufficient equipment for production and not to have excess to where it becomes counterproductive. Due to the advent of responsible mining, environmental regulations, and eco-friendly practices, these factors must also be considered in the analysis. Simulation studies can be financially advantageous for both the optimization of existing mine operations and the development phases of new operations in a mine.

[1] The materials of this chapter are taken from a paper accepted to be published in the International Journal of Mining Science & Technology.

For this investigation, a typical large surface coal mine layout was created to illustrate the advantages of using discrete-event system simulation and animation to estimate and evaluate equipment needs for the mine haulage operation. Two coal mining operations were developed, namely pit 1 and pit 2, two excavators were assigned to pit 1 and four excavators to pit 2 exclusively to mine the waste material in each pit. The coal removal fleet was not considered in the simulation and animation model.

The two pits serve two separate waste areas and the overall layout is shown in Figure 7.1. Twenty CAT 789C trucks and two Hitachi EX3600 excavators were assigned to pit 1 and 40 CAT 789C trucks and four Hitachi EX5500 hydraulic excavators were assigned to pit 2. The simulation model was used to determine the optimum number of trucks for each pit to maximize waste removal from the two pits.

This study introduces a new approach for the use of discrete-event system simulation in mine systems modeling, in order to investigate environmental impact considering mining haulage performance and production target. The simulation includes the detailed animation of the operation. Animation is helpful and powerful to improve the benefit of a mine simulation model. GPSS/H® and PROOF Professional® were the software packages used for the simulation investigation.

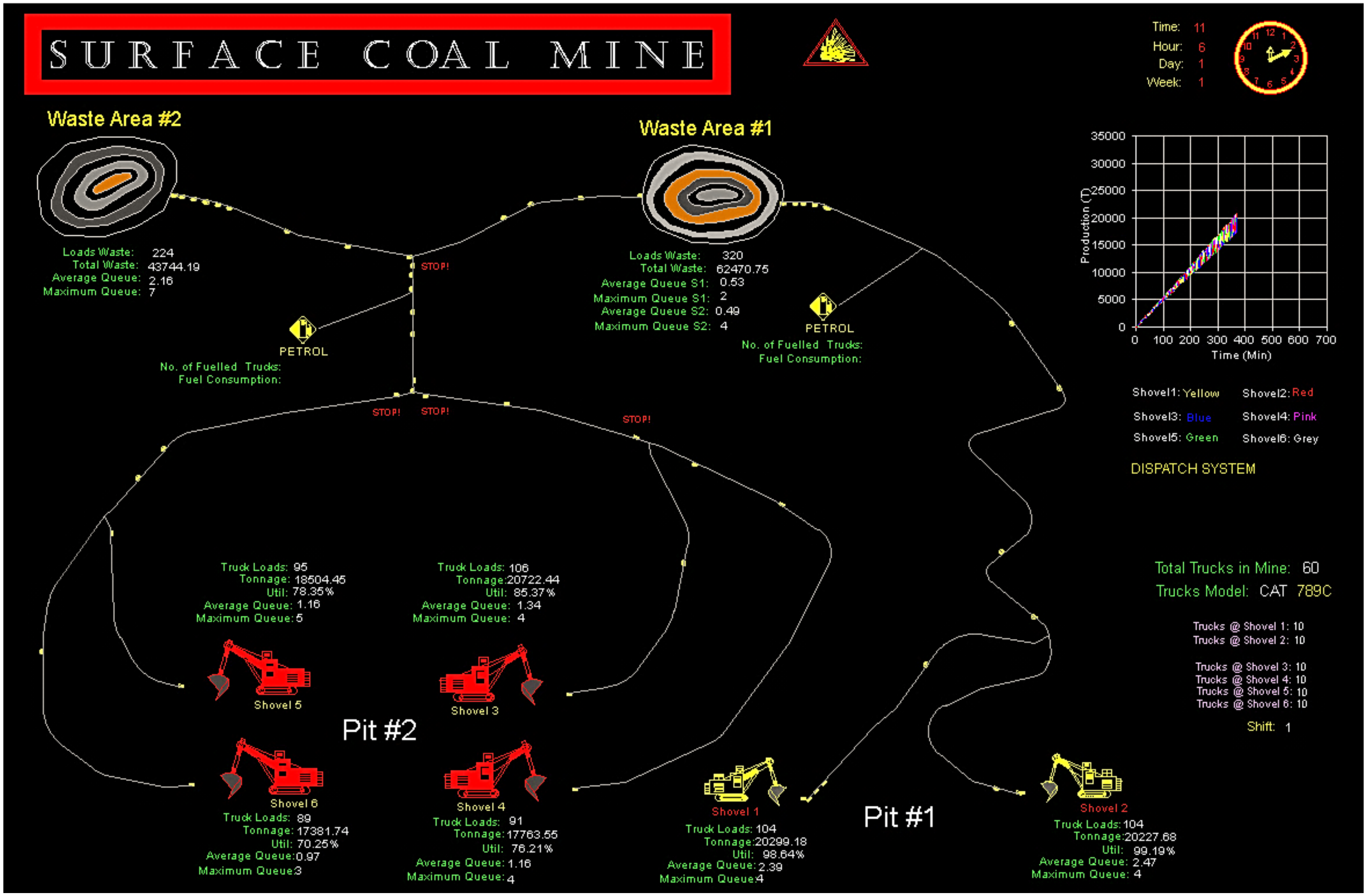


Figure 7.1: PROOF Animation of the Simulation Model of a Surface Coal Mine

7.2. Surface Coal Mine Simulation and Animation Construction

The software used for modeling this mining operation was GPSS/H®, a simulation programming language; PROOF Professional® was utilized for the animation. The software is produced by the Wolverine Software. GPSS/H® was used due to its low level programming language, cost effectiveness, fast processing, and flexibility to model complex discrete systems (such as mines) (O'Connell and Sturgul, 2010).

PROOF Professional® software facilitates a visual model of the simulation over time. The drawing tools provided in PROOF allow for an animation to be nearly realistic. PROOF also has the ability to import and export CAD files and the capability of zooming in and out without losing the images' sharp quality (Henriksen, 2000). If there is an error in the code or animation, the modeler(s) can easily catch it visually by running the animation after the simulation.

The developed simulation and animation program represents a model of the mining operation. It includes a screen display of the total production throughout the shift and a graph for each excavator showing loads, tonnage, utilization, and queue size. The screen includes a clock that shows the simulation time in minutes, hours, days and weeks. In addition, the number of trucks allocated to each shovel, total number of trucks, and shifts are shown for the convenience of the users. "STOP" signs are displayed on the animation when and where the trucks need to stop at the intersections for an appropriate time. Pit 2 can send trucks to both waste dumps, but Pit 1 to one waste dump only, as the dumping locations are independent for each pit (see Figure 7.1). The model plots the shovels' production (tonnes) versus time (minutes). Each shovel is displayed by different recognizable colors on the plot to make the production studies of the shovels easier to see on the screen (Karimi-Tarshizi, 2012).

The input parameters of the simulation allowed the user to change the number of trucks in the mine (two pits) to evaluate the performance of the operation. A screen capture of the simulation input is illustrated in Figure 7.2.

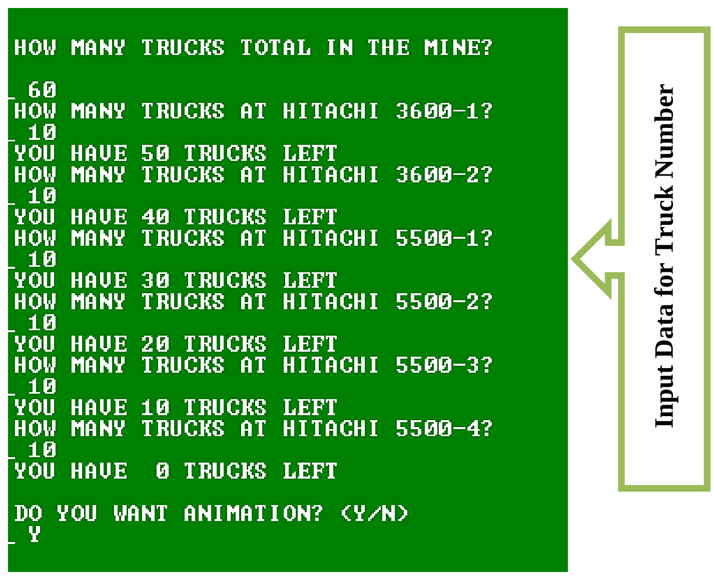


Figure 7.2: The Input Parameters of the Coal Mine Simulation Model

The output of the computer simulation includes the following:

- number of loads from each excavator
- loads per truck
- excavator utilization
- number of trucks in excavator and waste area queues
- number of loads arriving at each waste area
- total waste production

The process logic of the mine's overburden removal is as follows: empty trucks are loaded by the excavators; loaded trucks haul waste to the assigned areas; after dumping, they return to the excavators assigned by a Dispatch fleet management system. This system decides at each of the four intersections which excavator a truck is assigned to by looking at the number of trucks at each excavator and the estimated wait and load time. It also takes into account the time to travel from the intersection to the excavator. Only one truck can dump at a time in both waste areas owing to a constrained dumping area.

The simulation model consists of 270 separate paths/travel segments with generic statistical distributions. Each segment has a separate normal distribution including a mean with a standard deviation. A built-in function that sample from the normal (Gaussian) distribution is featured into GPSS/H® simulation language. In fact, GPSS/H® includes more than 20 built-in functions that enable modeler(s) to use a variety of distributions and sample from them (Sturgul, 2000). Examples of the GPSS/H® built-in function for normal distribution code used in the simulation model are illustrated in Figure 7.3.

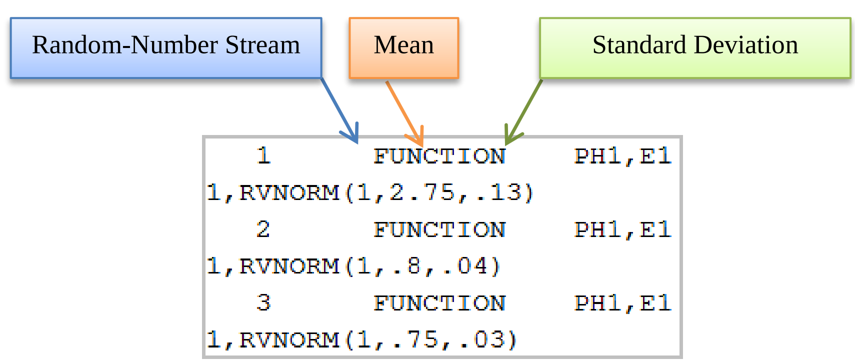


Figure 7.3: Normal Distribution Function Examples in GPSS/H®

Loading and spotting were modeled using a normal distribution, and breakdowns were modeled using an exponential distribution. Appendix D includes the source code of the developed simulation and animation model and additional data analysis.

The simulation and animation model of the mine operation was uploaded on a secured website (with a username and password) as a part of WEB-based simulation project, which is in its infancy. An interactive secure content management website was designed and launched for this purpose. If the simulation model and its animation utility can be posted on a website so that a remote user/mining engineer will be able to easily interact with the model and pose the “what if?” questions, it will add greatly to the applicability of a simulation program. This has not been implemented before for a mining simulation. WEB-based simulation for mining is a new and unique area (Karimi-Tarshizi, 2012). A snapshot of a secured online management website that was designed and developed for better communications during mining system simulation projects implementation and as a secure archive place is presented in Figure 7.4.

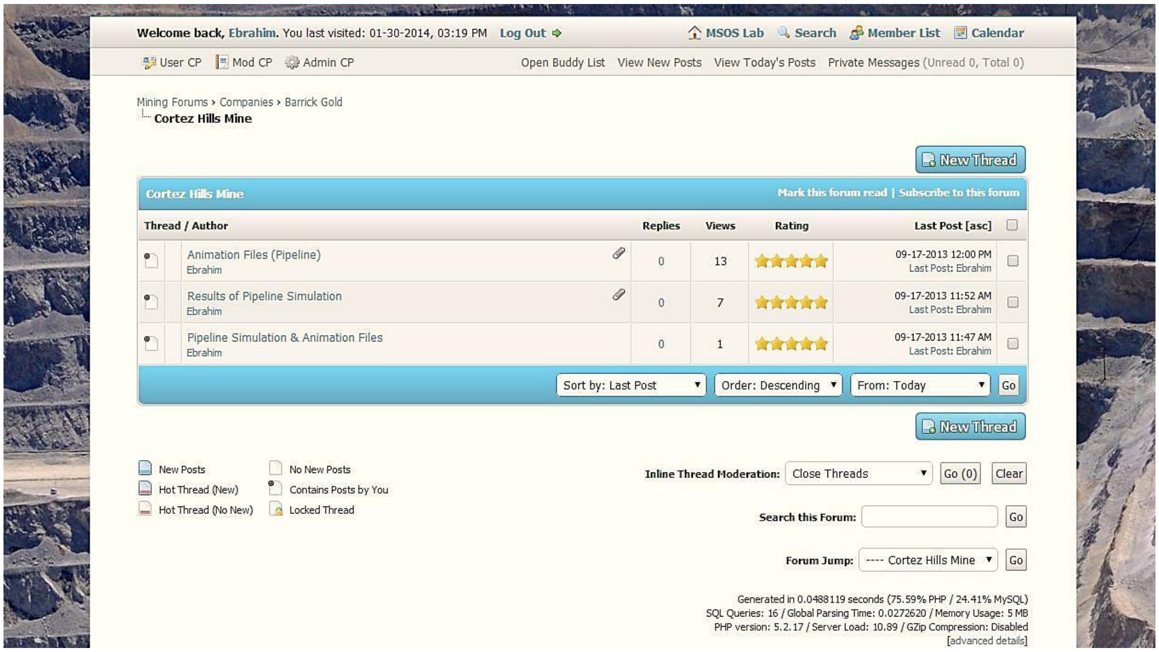


Figure 7.4: Screen capture of the Interactive Secure Content Management Website

7.3. Coal Mine Simulation Results and Analysis

Different scenarios were assessed that involved changing the number of trucks assigned to each excavator. Several scenarios in combination were run using 13 to 20 trucks in pit 1 and 40 to 44 trucks in pit 2, in order to compare results. Figures 7.5 and 7.6 illustrate the number of loads when the number of trucks was increased in pit 1 and pit 2. In both pit 1 and pit 2, the largest rate of increase in loads occurred in the beginning when one truck was added. Gradually the rate of change decreased, and eventually, the number of loads decreased when pit 1 operated with 20 trucks.

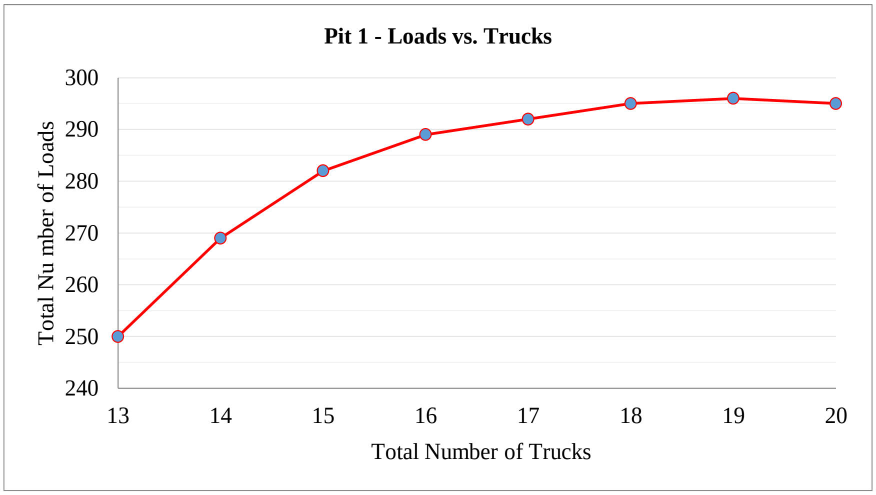


Figure 7.5: Number of Loads vs. Number of Trucks (Pit 1)

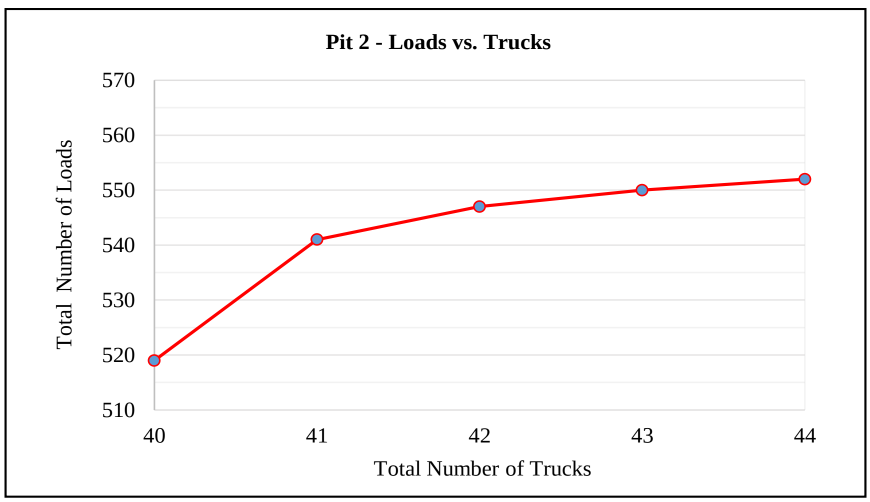


Figure 7.6: Number of Loads vs. Number of Trucks (Pit 2)

Figures 7.7 and 7.8 demonstrate the utilization of each excavator when the number of operating trucks was increased in pit 1 and pit 2, respectively. The utilization of excavators was mathematically calculated according to the following definition:

Utilization (%) = Excavator's Operation Hours / (Total Hours - Standby Hours/Idle Time) × 100 (eq. 7.1)

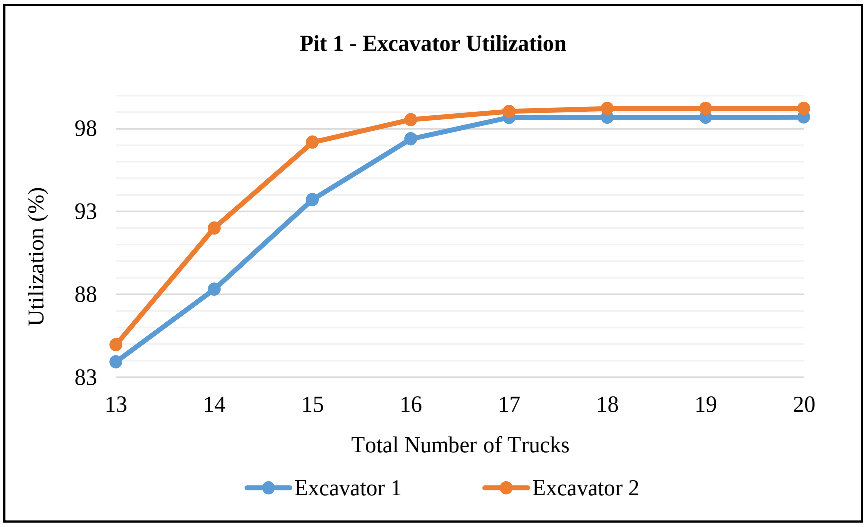


Figure 7.7: Utilization of the Excavators vs. Number of Trucks (Pit 1)

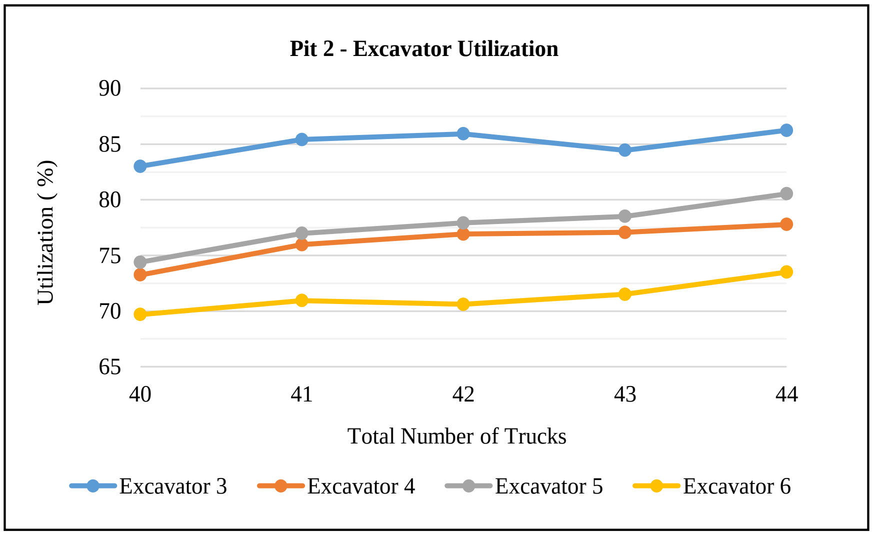


Figure 7.8: Utilization of the Excavators vs. Number of Trucks (Pit 2)

In pit 1, the rate of increase (slope) in utilization was high for the first three trucks added, after which the rate of change was marginal. On the other hand, the rate of increase in pit 2 was minimal.

Figures 7.9 and 7.10 show the change in production as trucks were added to each pit. As expected, in pit 1, the largest gain in production occurs with the increase from 13 to 16 trucks. From 16 to 20 trucks, the rate of change becomes gradual until it reaches 19 trucks when production starts to decrease. In pit 2, mine production increased when more trucks were added.

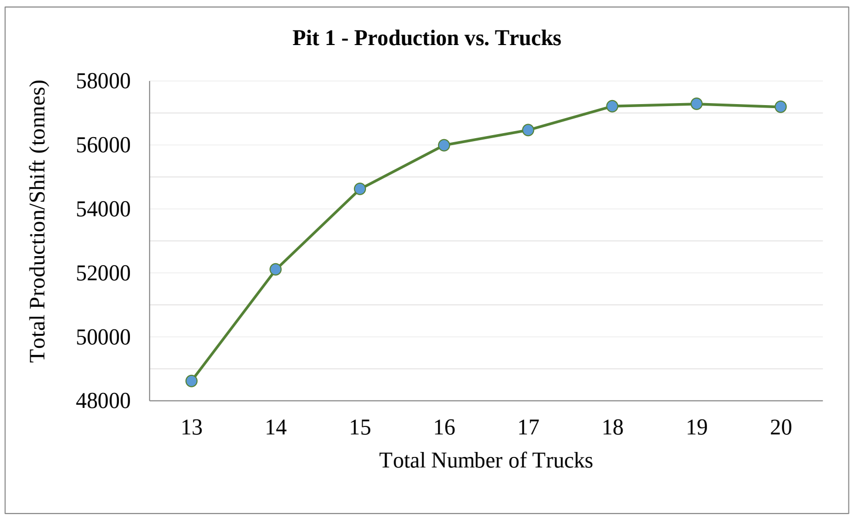


Figure 7.9: Production vs. Number of Trucks (Pit 1)

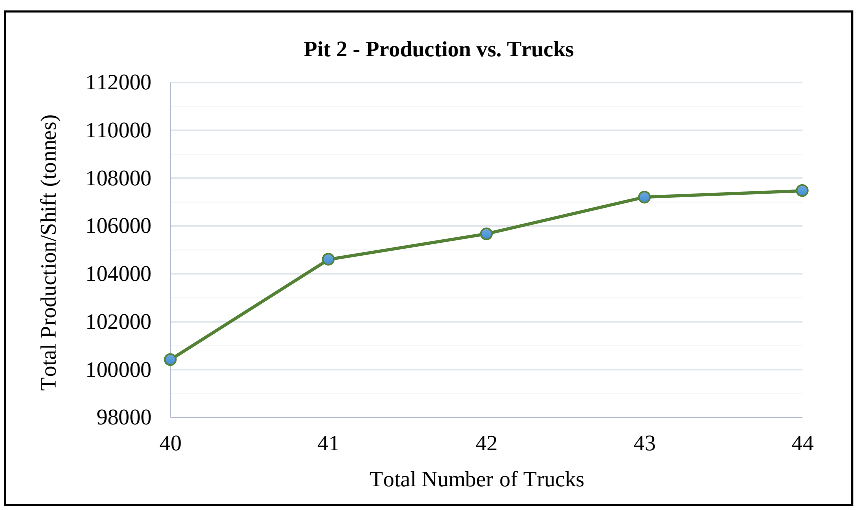


Figure 7.10: Production vs. Number of Trucks (Pit 2)

7.4. Economic Analysis

In general, trucks and excavators represent approximately half of the total operating cost of a surface mine (Nel et al., 2011). The initial mine operation set-up was pit 1 with 20 trucks and pit 2 with 40 trucks. Based on the model output and comparing the simulation results, the optimum number of trucks at pit 1 was 17 trucks. In fact, with 17 trucks, three more trucks were sent to pit 2 to resolve the need for more trucks in that pit (Figure 7.11).

The total number of trucks used in the operation did not change; rather, 3 trucks were moved from pit 1 to pit 2. With the proposed plan, the operating costs were assumed to be constant; however, this will not be the case in practice but will be adequate for this analysis.

Assuming $600/hour (U.S. Dollar) as the cost of running a truck, the total operating cost for the different number of trucks per shift can be calculated. There is a direct correlation between the number of trucks in an operation and the total operating cost of the mine. As the number of trucks increases, the mine operating cost increases. Figures 7.12 and 7.13 show the total operating costs and total production per number of trucks. The increase in the total operating costs is more extreme than the gradual increase in the total production.

Table 7.1 summarizes the results of the multiple-pit coal mine simulation and animation model. The mine production rate can be increased by 3.8% with a potential for reducing capital and operating costs. Determination of the proper truck-excavator allocation in the mine improves equipment utilization.

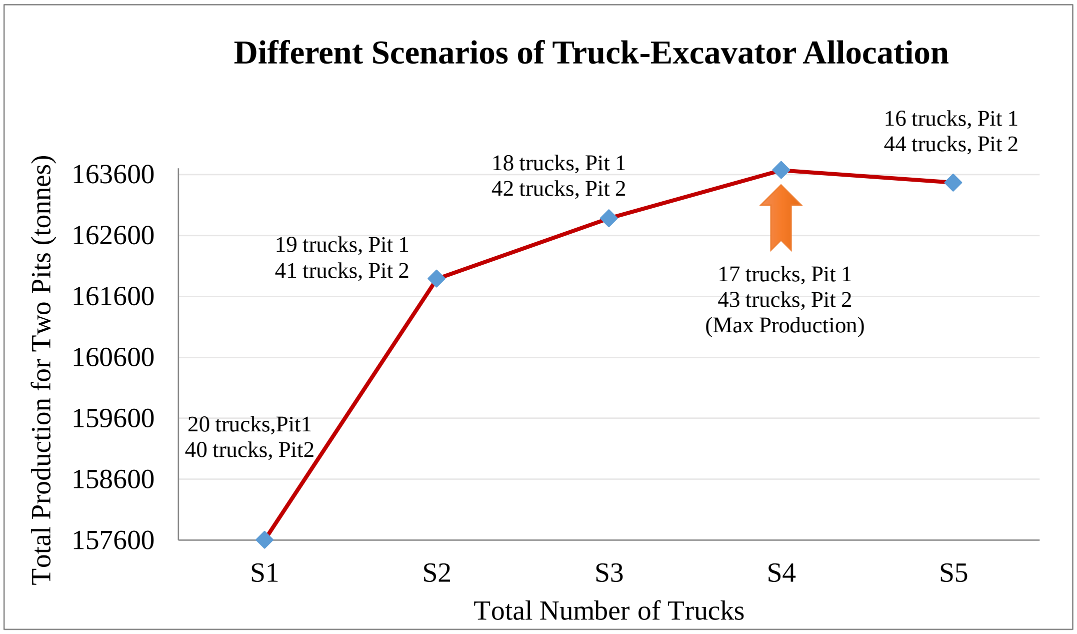


Figure 7.11: Comparison of Truck-Excavator Allocation Scenarios vs. Total Production

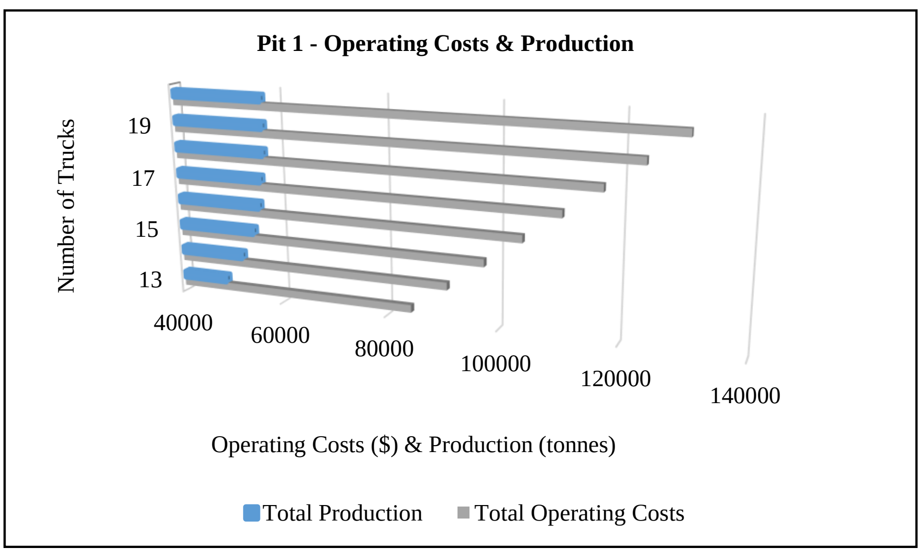


Figure 7.12: Comparison of Production and Truck Operating Costs (Pit 1)

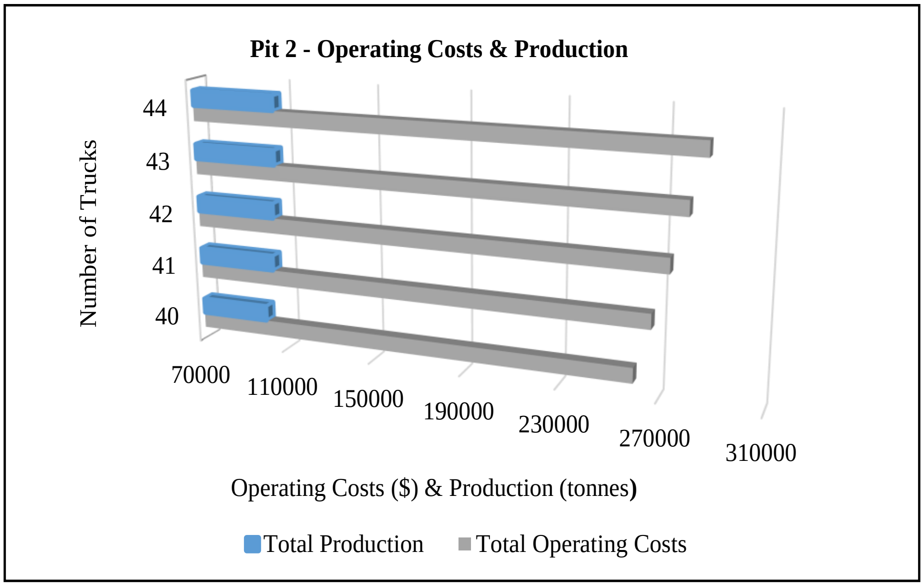


Figure 7.13: Comparison of Production and Truck Operating Costs (Pit 2)

Table 7.1: Truck-Excavator Allocation Analysis in the Coal Mine; before and after simulation results implementation

Coal Mine Simulation	Pit 1		Pit 2		Total
	# of trucks	production (tonnes)	# of trucks	production (tonnes)	Production (tonnes)
Before Implementation of Simulation Results	20	57,194	40	100,411	157,605
After Implementation of Simulation Results	17	56,466	43	107,206	163,672 ▲ **3.8%**

7.5. Environmental Impact Assessment

In mining operations, three areas of concern for a mine environment are noise pollution, exhaust emissions, and dust emissions from the loading and the moving equipment. It is important to reduce these environmental issues because of their impact on individuals working at the mine and/or living or working nearby. In particular, high levels of noise are detrimental to hearing and being exposed to this could result in hearing loss that is irreversible; hence, allocating fewer trucks in a mine operation will result in noise reduction. In fact, any type of dust emissions, especially respirable dust can be generated by heavy equipment, mainly haul trucks in surface mines, causing serious lung diseases for the operators and others who might be exposed to dust.

Truck emissions also include carbon monoxide (CO), carbon dioxide (CO2), nitrogen oxide (NOx), sulfur oxide (SOx), and Diesel Particulate Matter (DPM), all of which are health hazards (Lashgari and Kecojevic, 2013). Dust emissions result from “mechanical disturbance of granular material exposed to the air” (Environmental Protection Agency (EPA), 1995), such as material loading and dumping and traveling along haul roads. Dust control management may include, but is not limited to, watering, chemical stabilization, windbreaks, and source enclosures (Environmental Protection Agency (EPA), 1995).

If the mine initial total production of 157,605 tonnes per shift was assumed as the target production, the total required appropriate truck/shovel allocation to reach that target was determined to be 58 trucks rather than the assigned 60 trucks according to the simulation results (see Table 7.1). Consequently, operating fewer trucks in the operation not only leads to reduced operating and capital costs but also to a decrease in noise pollution and exhaust and dust emissions.

One of the applications of mine system simulation and animation can be studying and evaluating mining haulage performance to solve over-trucked situation, which increase mining total cost and environmental impact of the operations. This can be a new approach to use discrete-event system simulation and animation to model complex mines with multi-pit operations.

7.6. Summary and Conclusions

Discrete-event system simulation and animation studies were conducted for a surface coal mine operating two pits. A hypothetical layout of a surface coal mine with two pit operations was used for the simulation and animation model.

The initial equipment assignment was 20 trucks with 2 excavators in pit 1 and 40 trucks with 4 excavators in pit 2. After modeling the mine operation using discrete-event simulation and analyzing the results to optimize production and reduce environmental impact, it was found to be best to move 3 haul trucks (CAT 789C) from pit 1 to pit 2. Hence, 17 trucks should be assigned to Pit 1 and 43 trucks to Pit 2 to increase the mine's productivity rate by 3.8% without purchasing any new haul truck.

Such a simulation and animation model can assist mining engineers by providing an accurate decision-making tool to not only increase productivity with the potential to reduce capital and operating costs but also to operate the mine in a more eco-friendly manner. This all can lead to reduce the environmental impact of surface mine operations by utilizing heavy mining equipment more effectively and efficiently.

An interactive secure content management website was designed and created during this mine simulation project to investigate the potential applications of WEB-based simulation in mining projects.

In closing, once again, the simulation and animation modeling technique of mines proved its capability, flexibility, and application for studying mining systems, equipment efficiency, and their harmful and hazardous impact on the environment of mines. In addition, if a mine simulation program is written using several segments can be easily changed and updated according to mine operational needs.

Chapter 8. Innovative Approach to Assess and Improve Underground Mine Evacuation Operation Using Discrete-Event Simulation and Animation

An innovative approach to use discrete-event system simulation for a better evaluation of various possible configurations for emergency evacuation plans in an underground mine is described in this chapter. In addition, in this chapter Mine System Rescue Simulation Models (MSRS) are introduced and demonstrated as a convenient and powerful tool for planning mine rescue equipment and emergency response protocols in underground mines.

These simulation and animation models can also assist mine rescue teams, workers, and mining engineers in designing, training, and investigating a wide range of "what if?" scenarios and situations of rescue operations and evacuation plans in underground mines in case of underground disasters or emergency situations. For this purpose, an MSRS model of an unground mine with an animation interface was developed using GPSS/H® and PROOF Professional® discrete-event system simulation and animation software packages to assess and improve the mine refuge chamber locations, miners' evacuation operations, and their responses during mine emergencies.

8.1. Introduction to the Mine System Rescue Simulation Models

Generally, mine operators and managers desire an increased level of confidence in mine rescue teams to save lives during an underground emergency situation. It is, therefore, extremely important that rescue team members are trained and provided with advanced technology and modern simulation programs that are conducted in a realistic manner (Conti et al., 1999). To develop an emergency response program at an underground mine a discrete-event system simulation model along with an animation interface can be very useful and powerful. In fact, a discrete-event model can also be used to train min rescue teams and mining engineers (Sturgul and Tecsa, 1997).

There is a considerable need for engineers in underground mines to have a simulation tool able to investigate various scenarios and options in mine rescue and evacuation operations based upon their particular mine layouts, rescue equipment, and operating characteristics. Such a system is called “MSRS,” which stands for “Mine System Rescue Simulation.” The MSRS models can be distinguished from general simulation programs and packages in mine safety and training, which are generally continuous system simulation or virtual reality type. Besides the underground openings and excavations, the MSRS models include all rescue infrastructures and systems such as dedicated escapeways, routes/passageways, escape ladders, location of mine rescue/refuge chambers/alternatives, first aid supplies/stations, emergency equipment, travel times for teams in vehicles or on foot, etc. The MSRS models allow mining engineers and rescue team members to study and analyze different alternatives and disaster management scenarios on a computer model well before a potential disaster occurs. The output data generated by the MSRS models and the animation interface can be used with confidence for training of underground mining work force, planning rescue operations, and identifying the optimum/effective locations of rescue equipment and alternatives in mines.

The MSRS models can be part of modern underground mine planning and design to help engineers consider the correct and accurate locations of mine rescue equipment (e.g. refuge stations/chambers) and improve effectiveness in solving problem and emergency response protocols. This would considerably reduce risks in mine safety and health and also avoid rescue equipment redundancy that imposes additional costs to mining operations. The MSRS models can answer the mining engineers' need for a flexible simulation tool to enable them to investigate various scenarios and options for mine rescue operations concerning their particular mine layouts and operating characteristics. The MSRS models can also be used as a strong, efficient, and cost-effective technique for training and preparing mining workers, mine rescue teams, and mine engineers for mine rescue operations and (rapid) evacuation. Such a discrete-event system simulation and animation model, particularly for planning and evaluating underground mining emergency and safety equipment has not previously been built and implemented in the mining industry.

8.2. Methodology and Applications of the Mine System Rescue Simulation Models

Safety and rescue operation have long been a concern and critical subject in mining engineering. A mine manager never wants to let his mine site become a historic statistic for mine disasters. An emergency situation in an underground mine can be defined as "any unplanned event that causes serious injuries or loss of life; causes extensive property damage; shuts down or disrupts the mining operations; or threatens the operation's financial standing or public image" (West Virginia Office of Miners' Health, Safety and Training, 2008). Any mine safety studies and research in this area by all means are essential and valuable to mines (Emergency Management, 2014).

Many uncertainties and unpredicted variables are involved during mine emergency situations or disasters. The MSRS models of mining operations can be applied efficiently to make estimates of the various configurations of possible rescue missions in the underground mines. The models can help mining engineers to study the suitability of a proposed emergency evacuation strategy and rescue system with a range of feasible conditions. These computer simulation models (MSRS) are built to demonstrate the effects of various evacuation criteria on the overall evacuation plan of the mines.

The MSRS models, along with animation utilities that verify the simulation models, can increase the confidence of underground workers to use rescue options when they observe and test different scenarios on a computer display. Mining companies can also eliminate and reduce workforce psychological issues, stress response, and the level of anxiety during underground mine disasters as the miners would become more familiar with how to rapidly select the best possible option in various emergency situations. Rescue trainers can also use the graphic interface function of these simulation models for work force training.

These models can be designed and developed as either deterministic, without access to actual data, or probabilistic (stochastic), based upon real data availability, for underground rescue operations. As a part of a modern underground mine design tool, the MSRS models, with built-in statistical distributions, can assist mine engineers to consider and model the effect of various mining accidents, rescue/emergency equipment, mine rescue/refuge chambers, first aid supplies/stations, travel times for miners, and rescue teams in vehicles or on foot, etc. upon mine emergency evacuation and rescue operations.

8.3. Why Using Discrete-Event System Simulation for Modeling Mine Rescue Operations?

Analyzing and modeling a system, such as a mine evacuation and/or rescue operation, by numerical methods rather than analytical methods assist modelers/engineers in running various scenarios instead of single identified solution. Uncertainties are typically inherent in mine emergencies and response time of miners, from the type of disasters (ignition, explosion, fire, spontaneous combustion, fall of ground/wind blast/entrapment, outburst, inrush, flooding, and unidentified accidents), miners' fitness, physiological conditions and locations, transportation systems, ventilation systems, visibility issues, information and communication systems, type and level of gases, the life support of the self-contained self-rescuer, primary and secondary escapeways, and the condition of pathways, etc., affect mine escape and rescue operations during disasters (Mines Rescue Services, 2014). Furthermore, it can be extremely difficult and complex to obtain and calculate the travel times of miners to the surface or to the refuge chambers/safe places in case of an emergency situation. This is why modeling such a system requires a stochastic simulation approach in order to enable the system to generate one or more random variables as inputs.

Discrete-event system simulation can be selected for this type of modeling as this technique is a powerful and flexible tool to run a wide variety of scenarios using different statistical distributions to examine and investigate various situations. This can assist the modeler(s) in evaluating and improving the performance of changes and miners' emergency responses, in the modeled mine operations. Hence, discrete-event system simulation can be easily utilized as a convenient "what if?" model for decision-making and associated likely risks in underground accidents and emergencies.

Adding animation utilities to these discrete-event system simulation models for mine evacuation and rescue operations significantly enhances the effectiveness of the developed models. A combination of the visual power of animation with simulation displays a comprehensive evacuation and rescue operations on a screen. Animation can also be used for verifying and debugging the correctness of simulation models. The calibration and validation of the simulation can be carried out by imitating and representing the actual system behavior and performance with reasonable accuracy (Banks et al., 2010).

Using discrete-event system simulation is not only a cost-effective approach in underground mines to investigate the efficiency of mine rescue procedures/operations, but is also of great help to study and establish optimum rescue solutions for the life of the mine. The models are constructed using discrete-event system simulation platforms to be fast, flexible, and powerful and to include all new phases as mining operations change.

The required data to construct the MSRS models can be obtained from actual mine emergency evacuation and rescue practices. After obtaining the logic of mining operations and analyzing collected/measured data the distribution functions of miners' travel times can be created for the simulation models. However, due to uncertain parameters during the event of a mine emergency, miners' responses and travel times can be difficult and complex to estimate, but appropriate assumptions can be made for use in the models.

Integration of the web with simulation programs, known as web-based simulation, is achievable for modeling mine rescue and evacuation operations and rescue planning. A web-based simulation environment/framework can be used for creating, saving, executing, and evaluating discrete-event system simulation as well as supporting e-learning technology of the developed models for engineers and miners (Despotovic-Zrakic et al., 2012).

8.4. The Uniqueness and Efficacy of the Mine System Rescue Simulation (MSRS) Models

Emergency evacuation and rescue operation planning are among the most important preparations in underground mines (West Virginia Office of Miners' Health, Safety and Training, 2008). Emergency procedures must be regularly performed for the benefit of the managers, engineers, and work force. However, most of the practice evacuation situations occur under circumstances where there is no danger or threat involved (Mould, 2001). An actual emergency operation obviously takes place in adverse conditions which affect the capabilities of rescue efforts. This is why simulation-based studies for mining evacuation and rescue operations can play an important role to promote safety. Figure 8.1 illustrates various vital factors that should be integrated with the simulation-based analyses to improve and organize rescue and evacuation plans and strategies in modern mines.

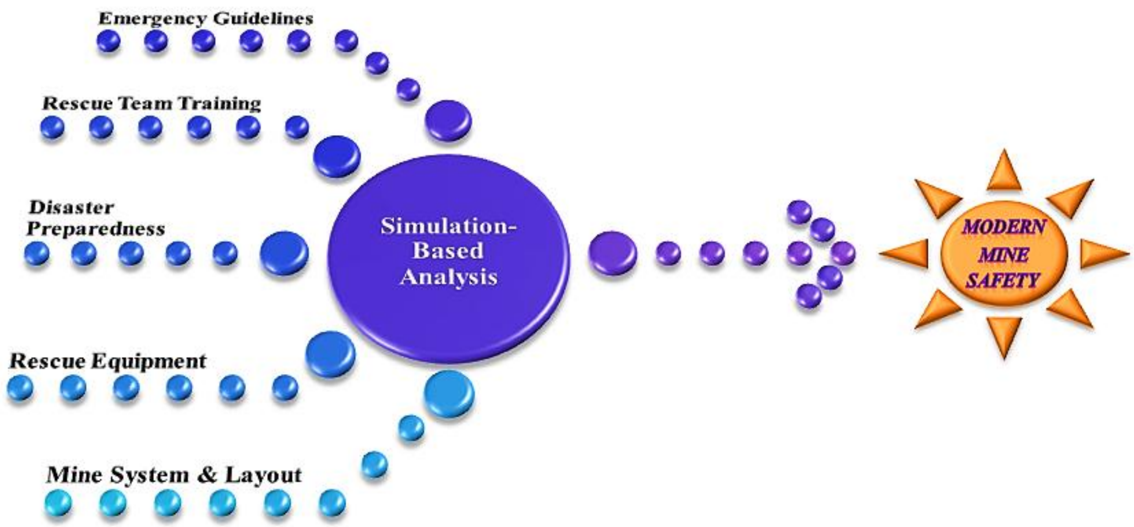


Figure 8.1: Discrete-Event System Simulation Analysis in Modern Underground Mining Safety

Presently, there is a lack of a strong, efficient, cost-effective, and flexible computer simulation tool to assist mine engineers and rescue teams in designing and assessing the effectiveness and usefulness of evacuation and rescue options in underground mines considering mining systems, ventilation (fire and gas inflow), slope and ground control issues, ground water inundation, and others.

Having a comprehensive simulation (discrete-event system) and animation model such as the MSRS models is enormously valuable and practical in underground mines to design and plan rescue operations and equipment selection. It helps to study and improve the emergency management, which is "collective arrangement of personnel to plan for, mitigate/control, respond to and recover from an emergency" (West Virginia Office of Miners' Health, Safety and Training, 2008). As a result, it is extremely important to equip mining engineers and rescue teams with a "what if?" simulation tool, similar to the developed simulation and animation model in this study, to review and investigate many types of rescue and evacuation possibilities. This approach provides an effective set of tools for better decision-making process for the first responders in mine emergency situations based on the mine layouts and characteristics.

8.5. Mine System Rescue Simulation (MSRS) Model and Analysis – A Case Study

An MSRS model of an underground metal mine using GPSS/H® was constructed to investigate and analyze the evacuation plans under emergency situations and the effectiveness of the rescue equipment locations and sizes in the case study. The model was flexibly designed and programmed by hundreds of independent segments to quickly run several proposed scenarios.

This simulation model included a detailed and comprehensive animation by PROOF Professional® to display miners' responses and movements to the nearest refuge chambers or safe locations after a warning alarm was raised (evacuation notification) in the mine. Figure 8.2 shows the screen grab of the developed MSRS model of the mine layout and rescue evacuation. The animation also included a digital clock that illustrates the rescue simulation time in minutes and hours (as absolute clock). Appendix E includes the source code of the simulation and animation model.

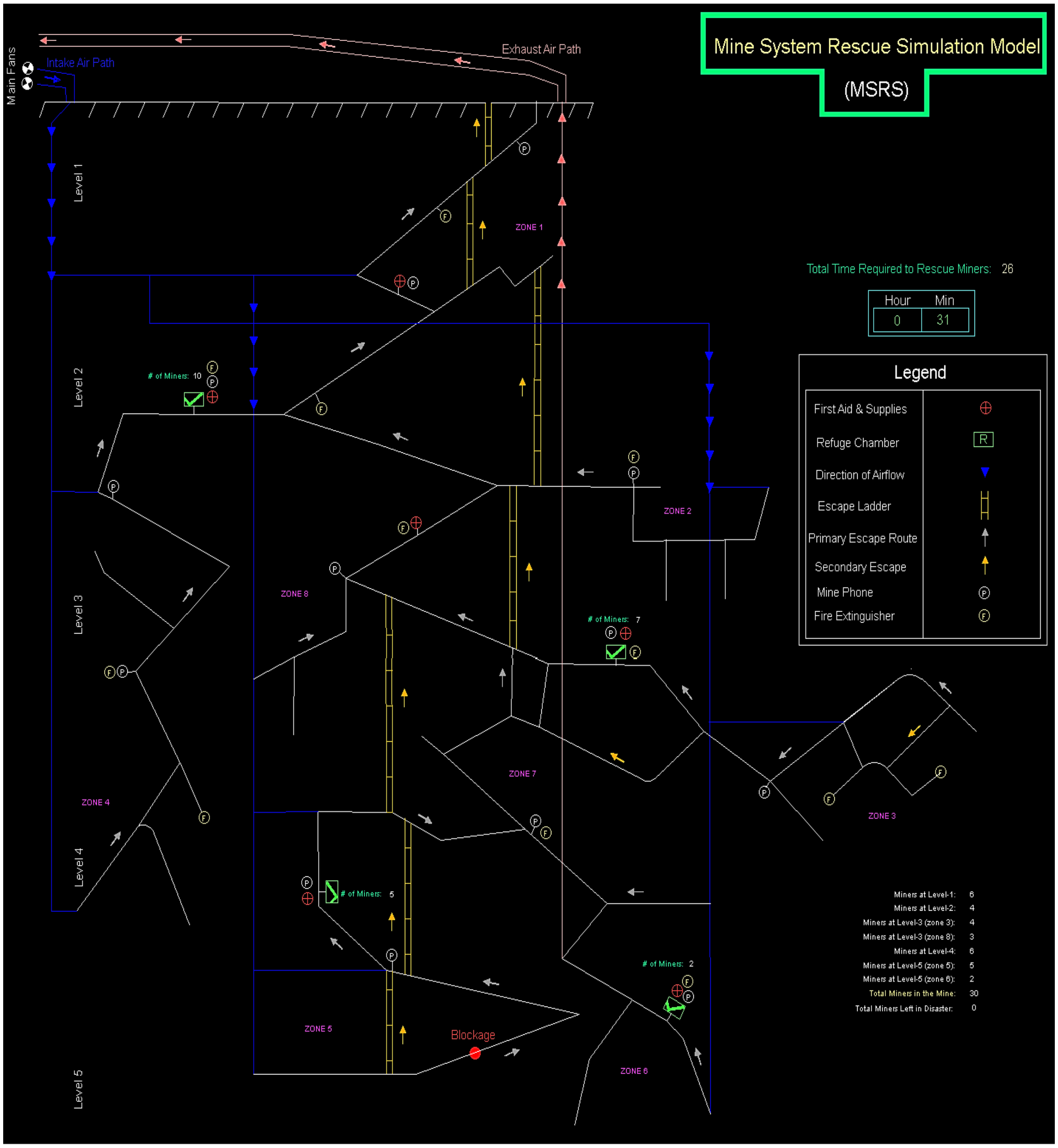


Figure 8.2: Screenshot of the Developed MSRS Model of the Mine Evacuation System

The mine operates at 5 different levels and in 7 zones/work areas. Simulation allows the user(s) to enter the number of miners and support personnel on each production level or working area as inputs. The program also requests an estimation time for an evacuation operation in the mine to compare with the simulated evacuation time. Based on the assumed rescue scenarios or situations, the model output on the simulation screen (GPSS/H® display) and the associated XLS file (Excel® spreadsheet) include the following:

- total number of miners at different levels and zones
- total number of rescued miners
- total number of miners with unknown condition/situation

In addition to the model output, a screenshot of the simulation input parameters is presented in Figure 8.3.

Figure 8.3: The Input of the Developed MSRS Model

Furthermore, the simulation model takes into account possible blockages along the escape routes generated by an unplanned event to examine other escape alternatives. As a proposed study, a blockage was created in the mine's zone 5 to investigate the miners' reaction and the possibility of using a ladder as a secondary escapeway. Obviously, other potential blockages can be easily assumed and added to the model to investigate their impacts upon the evacuation operations and the response time of the miners. The MSRS model of the case study was run for the first scenario using constant travel times and the second scenario using triangle distribution travel times for 30 miners in the mine working in the production and development areas on different levels. The reason for using the triangular distribution as the second scenario is that this type of distribution is most commonly used for modeling systems considering expert opinions or a rough approximation about some unknown random variable in the systems (Model Assist, 2014). However, in case of access to the actual data of the mine emergency practices, it would be feasible to create different distribution functions for the measured data.

Table 8.1 summarizes the results of the simulation analysis for the case study's evacuation operation. The model allowed the investigators to test the effects of various changes on the movements and response of the miners and evaluate the implementation for the overall evacuation time in different scenarios. As a result, assuming only constant travel times in the model, it took 23 minutes for the miners to reach the assigned refuge chambers or the surface. But the problem is more complicated when it is accepted that assuming constant travel times for the miners is not the case in real life. Therefore, running the simulation model using the triangular distribution for the miners' travel times showed that they would need 29 minutes to get into to the assigned or proposed mine refuge chambers. However, the initial rescue time estimation by the mining engineers and managers was approximately 20 minutes under the same circumstances. The results obviously demonstrated that considering unpredicted parameters (mentioned uncertainties) that can certainly affect the miners' travel times by using the triangular distribution (or sampling from statistical distributions) would need 9 more minutes for the miners to reach the assigned safe places or refuge chambers. A 9-minute difference in emergency evacuation response time estimation by the miners can lead to significant consequences in any underground mining operations.

Table 8.1: Results of the MSRS Model Investigation for the Case Study

Number of Miners Working in Level 1	6	Number of Miners Working in Level 2	4
Number of Miners Working in Level 3 (zone 3)	4	Number of Miners Working in Level 4	6
Number of Miners Working in Level 3 (zone 8)	3	Number of Miners Working in Level 5 (zone 6)	2
Number of Miners Working in Level 5 (zone 5)	5	Total Number of Miners Working in the Mine	30
Mine Evacuation Time Estimation/Prediction			**20 (min)**
Simulated Escape Operation by Constant Travel Times	***23 (min)***	***Simulated Evacuation Operation Using Triangular Distribution Travel Times***	***29 (min)***

8.5.1. Mine Refuge Chamber Location Analysis

In case of mining emergency events, particularly fire or explosion that may occur in underground mines, a miner needs to seek safety in a refuge chamber. Refuge chambers are used in many underground mines; however, there is a huge disagreement on the use of them (Gurtunca, 2008). However, using mine refuge chambers could save the lives of the trapped miners in the Soma Coal Mine in Turkey, but sadly, 301 workers totally were killed during this mine disaster in May, 2014 (Toppo, 2014) and (Tuysuz et al., 2014).

Due to the chaos and confusion during an event of this magnitude, a miner may choose to seek a refuge chamber due to its proximity rather than exiting the mine. When choosing to use refuge chambers, there are a number of items that must properly be studied and analyzed, including the size, design, efficiency, types and locations of the refuge chambers, as well as training miners to maintain the chambers (Gurtunca, 2008).

To locate a mine refuge chamber appropriately in an underground operation, there are a few important regulations and procedures to take into consideration. In particular, the refuge chambers should be installed close to the mine active workface and be accessible to all miners and personnel. Additionally, they need to be located with enough distance to possible threat in the area. The physical fitness of the personnel and time that takes a fit miner to access to the chamber at moderate walking pace using 50% of the SCSR (nominal length) for considering the maximum distance (not more than 750m or 2460.6 ft.) is also critical to study in this context (Department of Industry and Resources, 2005).

By studying the simulation and animation results, it was observed that the mine refuge chamber (Ch. 1) located on level 2 would need to accommodate a minimum capacity of 12 persons or more, since it is positioned in a critical and more accessible place in the mine, see Figure 8.4. However, considering the current mine layout and operation, for the refuge chamber (Ch. 4) that is located in the zone 6 of the level 5, the smaller models can be utilized due to its route and accessibility by the miners or mine visitors (see Figure 8.5).

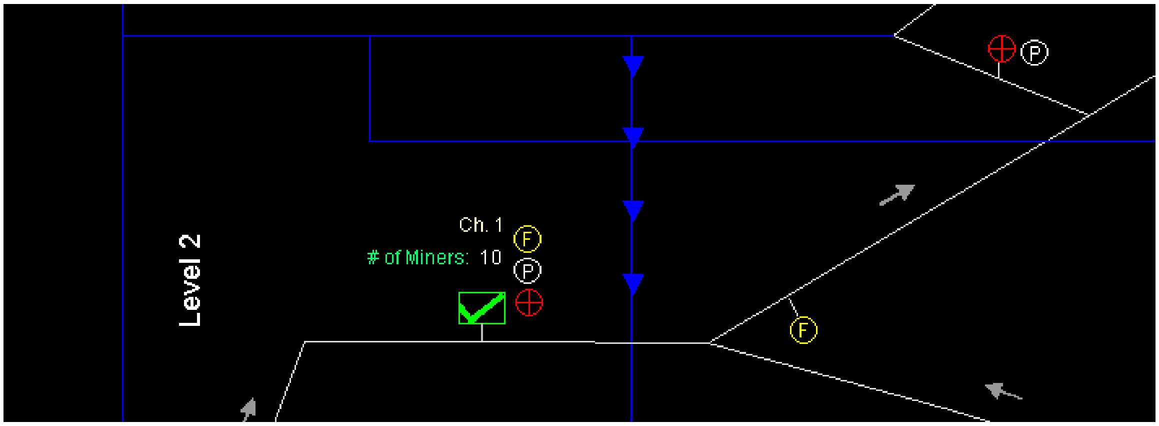


Figure 8.4: Detail View of the Refuge Chamber (Ch. 1) in Level 2

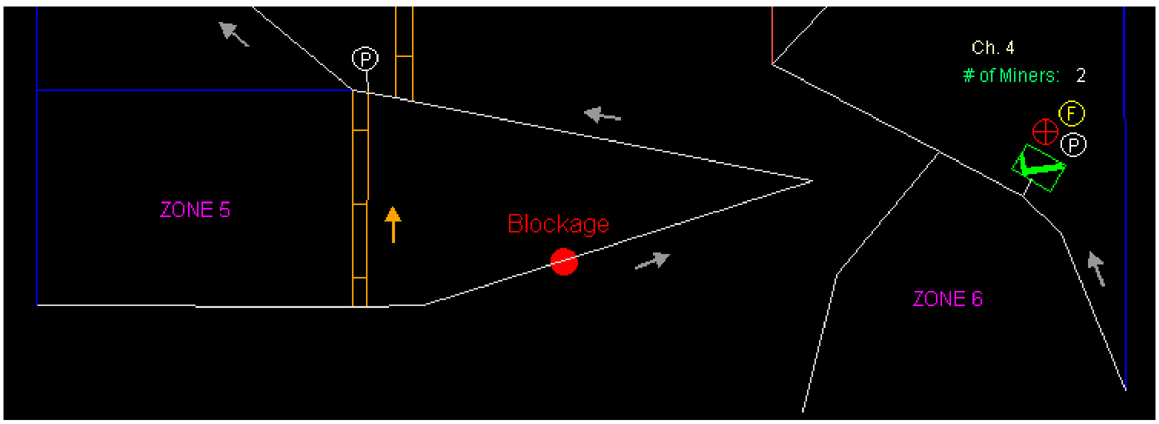


Figure 8.5: Detail View of the Refuge Chamber (Ch. 4) in Level 5 (zone 6)

In additional scenarios, the simulation model, using the triangular distribution for 30 miners on the different levels, were modified and executed for assessing the new locations of the refuge chambers and their 'network' to analyze and compare this new configuration to the previous case. Animation, once again, was modified and run for debugging and visualizing the simulation code, see Figure 8.6. The detailed throughput of the simulation results for additional scenarios, including two different configurations of the mine refuge chamber positioning, considering the various numbers of anticipated blockages and using alternative escape routes during the evacuation operation is shown in

Table 8.2. Consequently, the new proposed locations and numbers of the mine refuge chambers increased (28.57%) the miners' evacuation time and put their lives at a higher risk.

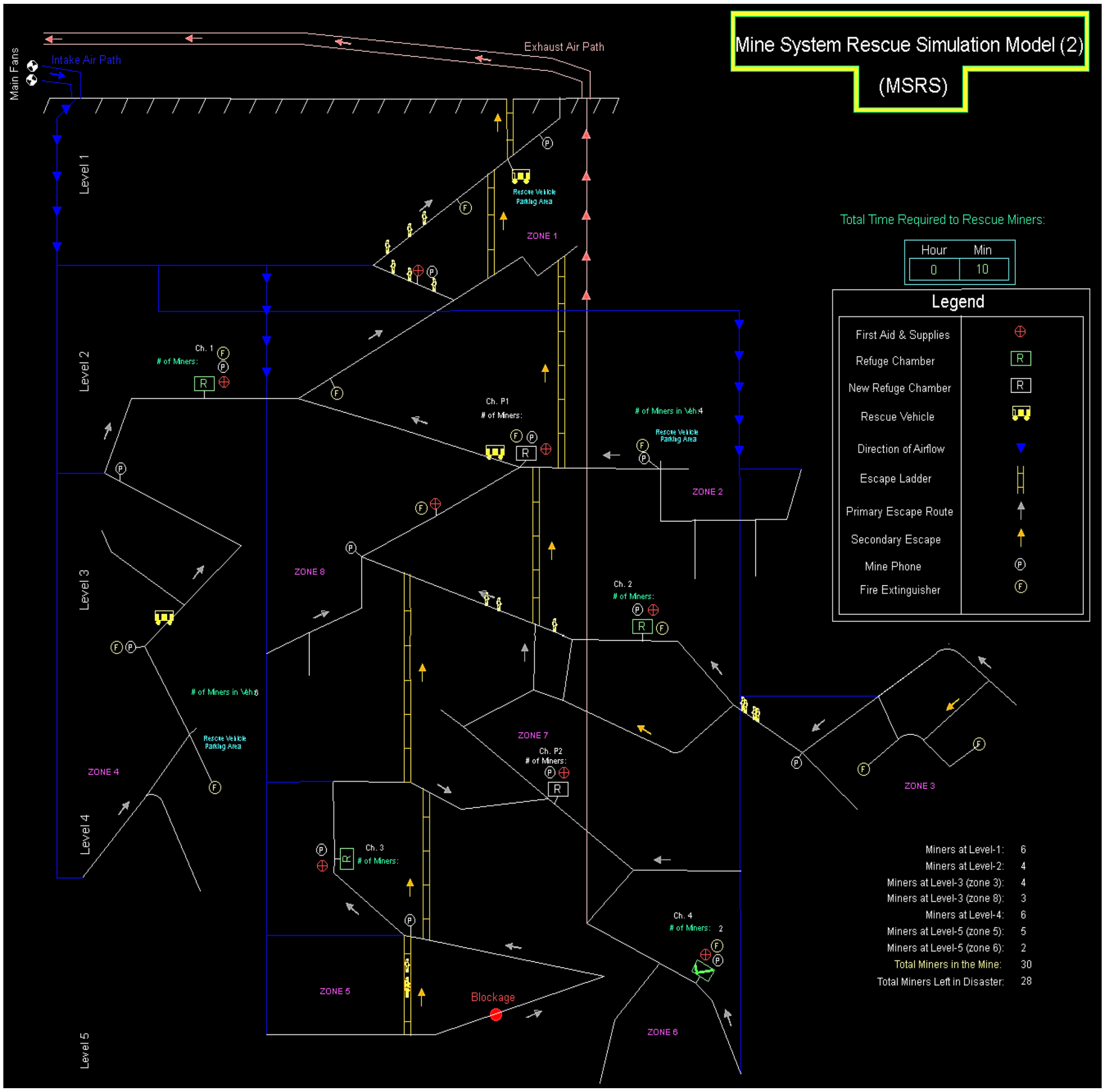


Figure 8.6: Screen Capture of the Animation Model of the Mine Refuge Chambers Investigation

Table 8.2: Simulation Analysis for the Mine Refuge Chamber for Different Scenarios

Scenario (1)	No. of Blockages	Surface	Ch. #1	Ch. #2	Ch. #3	Ch. #4	Total evacuation time
30 miners	N/A	6 miners	10 miners	7 miners	5 miners	2 miners	28 min
Scenario (1.1)	No. of Blockages	Surface	Ch. #1	Ch. #2	Ch. #3	Ch. #4	Total evacuation time
30 miners	1 (level 5)	6 miners	10 miners	7 miners	5 miners	2 miners	29 min
Scenario (1.2)	No. of Blockages	Surface	Ch. #1	Ch. #2	Ch. #3	Ch. #4	Total evacuation time
30 miners	2 (levels 5&2)	6 miners	13 miners	4 miners	5 miners	2 miners	29 min
Scenario (2)	No. of Blockages	Surface	Ch. #1	Ch. #P1	Ch. #P2	Ch. #4 Ch. #3	Total evacuation time
30 miners	N/A	6 miners	6 miners	11 miners	7 miners	N/A	36 min
Scenario (2.1)	No. of Blockages	Surface	Ch. #1	Ch. #P1	Ch. #P2	Ch. #4 Ch. #3	Total evacuation time
30 miners	1 (level 5)	6 miners	6 miners	11 miners	7 miners	N/A	36 min
Scenario (2.2)	No. of Blockages	Surface	Ch. #1	Ch. #P1	Ch. #P2	Ch. #4 Ch. #3	Total evacuation time
30 miners	2 (levels 5&3)	6 miners	6 miners	11 miners	7 miners	N/A	38 min

Several scenarios were studied using the simulation and animation model with generic data to analyze the effectiveness and accessibility of two mine refuge chambers positioning configurations or ‘network’. As can be seen in Table 8.2., the results from the simulation suggested that the first configuration of the refuge chambers can be more effectual in order to minimize the mine emergency evacuation time taking into account the proposed number of possible blockages in different areas. A series of additional what-ifs can be certainly modeled, evaluated, and documented.

8.5.2. Underground Mine Rescue Vehicles

The simulation and animation model was modified and programmed to include two proposed mine rescue/evacuation vehicles in the developed MSRS Model, considering scenario 1.1, to study the effects of using these vehicles to improve the total mine evacuation time during mine emergencies. Three parking areas for the mine rescue/evacuation vehicles were designated and added into the model. A close-up view of the animation of the mine rescue vehicle in the case study is shown in Figure 8.7.

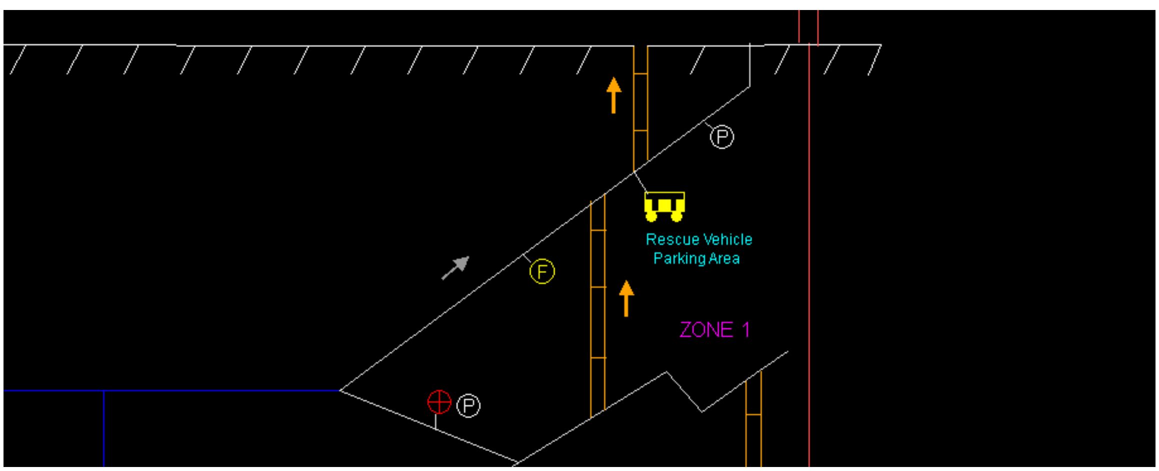


Figure 8.7: A Zoomed-in View of the Mine Recue Vehicle and Parking Area Using PROOF Professional®

The results from the model indicated that using these mine rescue vehicles by the personnel during the evacuation operation can reduce and improve the total evacuation time by 20.69%. In fact, the total mine evacuation time, in this scenario, was achieved at 23 minutes during the simulation model execution and analysis. Figure 8.8 illustrates the mine emergency evacuation time considering different conducted and analyzed scenarios.

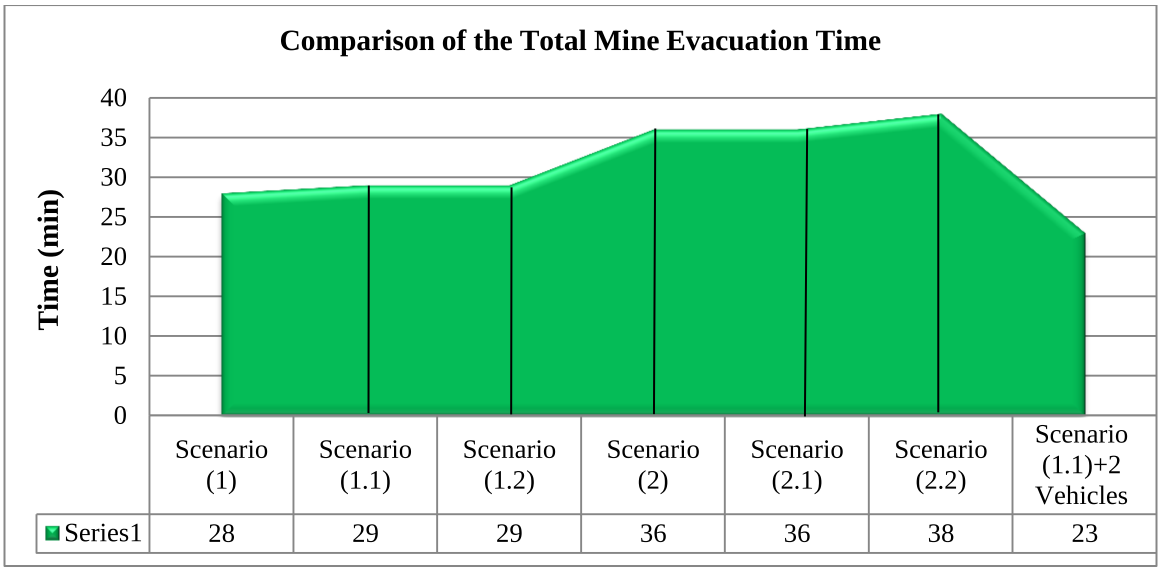


Figure 8.8: A Comparison of the Total Mine Evacuation Time in Several Situations

In summary, using discrete-event system simulation for analyzing such a complex situation indicated that models of this situation and its complexity are virtually impossible to be solved mathematically/analytically. By acquiring more accurate mine evacuation and response time considering additional scenarios, new plans can be prepared to improve the mine evacuation protocols and emergency response plan and time. The effectiveness of these plans can be analyzed and tested by utilizing the developed simulation and animation model and prevent any traditional guesswork before they actually will be implemented.

The developed MSRS model demonstrated that it is flexible and capable to include potential blockages in the different escape routes such as primary and secondary as well as various statistical distributions for travel times of the miners on foot and vehicles in the mine. The model also included the number of miners assigned to different levels and the number and location of mine rescue equipment, such as escape ladders and refuge chambers. The animation of the simulation displayed the locations of first aid and supplies, mine refuge chambers in two configurations (empty or in-use), both primary and secondary escape routes, mine phones, fire extinguishers, and the intake and exhaust air flows/ventilation plans.

8.6. Study Conclusions and Future Studies

The main objective of this project was to model, simulate, and animate evacuation operations and safety equipment of an underground mine to quickly assess and improve escape alternatives, emergency response strategies, evacuation procedures, and the effectiveness of the mine refuge chambers 'network' during an emergency situation. One of the great lessons learned from this study was investigating the capability and applicability of discrete-event system simulation and animation techniques, for the first time, in mine rescue and evacuation operations in modern underground mines. This innovative approach was used to implement discrete-event system simulation due to many uncertainties and variables involving mining emergencies for planning and designing mine rescue operations and equipment selection. The developed simulation model could ultimately assist the engineers in studying and evaluating emergency situations/accidents and rescue equipment efficiency in the case study.

This method was called “Mine Systems Rescue Simulation.” GPSS/H® and PROOF Professional® were the software platforms used for the investigation. The MSRS model can be used to develop emergency response protocols, improve the evacuation procedures and limits/barriers in the mine rescue guidelines, and design a well-planned emergency management program for the mine.

During mining rescue emergency operations, every second is critically important. The specific results of the developed model indicated that the mine evacuation time can take more than what the mining engineers and managers predicted/estimated under certain circumstances. The developed MSRS model can be easily altered and utilized to help the mine engineers and rescue teams to pose reasonable “what if?” questions/scenarios in respect to mine emergency response and then test them in the computer model in a few minutes. This practical method can avoid pricey analog modeling techniques and remove the guesswork inherent in such vital decision-making process in underground mines. In addition, more accurate analyses and studies can obviously enhance confidence in making decisions.

Along with the simulation analysis, the animation was applied to display the mine rescue scenarios to assist the engineers and rescue team in viewing a clear picture of different situations. This animation can also be helpful in planning training exercises for the underground work force to act rapidly, effectively and appropriately in the event of a mine emergency.

In future studies, many parameters and factors that can certainly impact on mine evacuation and rescue operations, such as the type of disasters, the fitness of personnel, transportation and ventilation systems, miners' emergency response, visibility, the life support of the self-contained self-rescuer, and pathways' condition, etc., should be carefully considered and studied for modeling such a system.

Additional investigations can be performed to examine the efficiency and usefulness of rescue and safety equipment locations and their positions in the underground mines using the MSRS models. Further different criteria for improving emergency evacuation plans and operations in both small and large-scale underground mines can be conducted. These powerful, flexible, and cost-effective simulation models can be part of mining engineering future and modern mines rescue planning and should be used practically to help engineers and rescue teams to better understand various situations, including:

- test and study the rescue and evacuation time that is needed for underground workers to reach the refuge chambers or the surface from various underground locations
- assess the evacuation sequence in emergency situations in the mine
- establish the fastest and safest access to the hazard areas for rescue efforts
- study the rapid evacuation of the mine via normal channels
- evaluate different possible configurations for rescue activities in the mine as determined by the mine rescue team and engineers
- use 3D interface animation for these simulation models for a better, high-quality, and detailed visualization

- other possible “what if?” scenarios/questions in mine evacuation and rescue operations

Chapter 9. Summary, Conclusions and Future Research

This chapter presents a summary of the mine system simulation applications, performed research projects, and their main conclusions. Contributed results and future research recommendations of this dissertation are also included.

9.1. Mine Simulation – A Brief Summary

Mine system simulation and its applications are acknowledged by mining engineers as a powerful and appropriate "what if?" tool for investigating the output of different approaches in mining design, planning, and optimization. In general, these computer simulations can be helpful for modeling proposed plans and strategies for accurate decision-making. In today's modern mining, technical issues of surface mines involving many uncertainties in all parts, such as correct equipment mix, right number of spare parts, optimum location of in-pit crushers, haulage roads, number and location of fuel stations, etc. are critical for mining engineers. Discrete-event system simulation studies can be also used for modeling the typical haulage issues that mining engineers are often faced with: using truck fleet haulage, conveyor belts, or a combination of both.

By using simulation programs, a practical method to model such systems and/or sub-systems, which take into consideration the stochastic nature of mining systems, engineers can answer those problems correctly. This evidently enables mine operations to save a great deal of operating and capital budgets. Discrete-event system simulation can be applied to mining operations of any size, type, and complexity. Mine simulation can be technically considered as a powerful and low-cost tool to evaluate complex scenarios and alternatives in mine design, planning, and optimization.

9.2. Summary and Conclusions of the Research

Chapter 1 contains the research investigation introduction, the problem statement and research objectives. In Chapter 2, an extensive overview is given of literature on mine system simulation. This chapter also presents and details published mine simulation projects, considering the modeled mining systems and simulation languages/software packages used from 2008 to 2014. Chapter 3 covers broad information about simulation techniques, with emphasis on the discrete-event system simulation implementation. Advantages and disadvantages of using animation approach with simulation modeling are detailed. The chapter also gives detailed information about the verification and validation of mine simulation models and the computer simulation tools classification. Chapter 4 presents two simulation models of a large gold open-pit mine operation with multiple dump and ore locations, a case study in Nevada. The simulation programs were run with full animations. A detailed discussion on the conducted mine simulation models and data analysis are included. Chapter 5 discusses a mine simulation and animation model of Cortez Hills' Gap Pit gold mine operation and the detailed implemented methodology. The developed simulation program was used by the mine's engineers in analyzing the impact of several proposed cases and scenarios in the mine plan before implementing them. Chapter 6 includes a simulation and animation model of a haulage operation (haul truck vs. conveyor belt) in an aggregate mine system. A detailed comparison of these materials handling systems and their standard economic analysis are explained. The simulation results indicated a combination of the haul truck working with a conveyer belt would be the best option for the mine. Chapter 7 outlines an investigation and applied methodology on modeling a large-scale surface coal mine with two separate pit operations to assess and maximize the operation productivity and study the possibility of reducing the mine haulage heavy equipment, using discrete-event system simulation and animation. The results aided the engineers to obtain the most optimum truck-excavator allocation in both pit operations. A mine evacuation operation simulation and animation model is set up in Chapter 8 to consider and study the possibility and capability of using the discrete-event system simulation technique for modeling these complex systems. Required sizes and proposed locations of the mine refuge chambers were analyzed and obtained using the simulation and animation results.

Overall, a detailed literature review of mine simulation projects and a number of simulation and animation models of different highly-mechanized mining methods and operations with various investigation scenarios were conducted to achieve the research objectives of the dissertation.

The key conclusions drawn from this study to answer and cover the research objectives/inquiries are as follows:

- During the large-scale gold mine simulation project, Chapter 4, the conclusion was obtained that general haul truck cycle times (mean times) given by the Dispatch fleet management system is typically too general and has technical limitations to accurately validate and calibrate a stochastic mine simulation and animation model. The results indicated that this issue can cause more severe technical problems in modeling large and complex operations, technically mentions "Garbage In, Garbage Out." However, if the data would be provided in the statistical form for different haul segments, it would be potentially beneficial to be used in a simulation model development. Other data from the Dispatch® system, including loading times and dumping times should be carefully reviewed and filtered, in case equipment operators' errors can be involved in the collected data stored on the system databases.

- In Chapter 5, during the Gap Pit simulation and animation project, several critical (technically and economical) scenarios were investigated, including the effects of appropriate truck/shovel allocation/matching, the tailings facility expansion project (bridge design simulation), and loading units' downtime analysis. The simulation output was precisely validated with less than 1% difference of the actual mine production rate. The technical results and reports were used by the mine's engineers and managers to drive the decision-making process more efficient in planning the operation. The numerical analysis from the simulation results clearly implied that a discrete-event system simulation model of a mine operation can be quickly and practically used for modeling several scenarios, small or large, simple or complex, in mine deign, planning, and management. Furthermore, it is entirely valuable to perform economic investigations and incorporate the analysis with the simulation results to economically assess and study the effects of changes upon the performance of the mining operations.
- Chapter 6 discussed that in spite of the fact that mine simulation study is incorrectly believed as an expensive and costly technique for very small and/or aggregate mines, the simulation results showed how beneficial a mine system

simulation modeling can be for these types of mines. In fact, the workload, allocated time and effort for modeling the small and medium-sized mine projects can be quite less compared with the large and complex mine simulation models. Additionally, investigations were carried out to examine the effects of changing a range of truck number scenarios comparing with a combination of this system with a conveyor belt in the aggregate mine simulation project. Advantages and disadvantages of both haulage systems were discussed and detailed in this chapter.

- A discrete-event system simulation and animation model of a large-scale surface coal mine was carried out to assess a series of scenarios to improve the mine production and reduce the negative environmental impact of the operation in Chapter 7. In one scenario, the simulation results suggested how the mine can reduce the environmental impact of the haulage operation or improve the production rate without incurring any additional cost and purchasing new equipment. The constructed mine simulation and animation model was also presented as a modern and cutting-edge tool that could be used to reduce the risk of mining environmental damage by providing an optimum truck/shovel system allocation.
- The capability and applicability of the discrete-event system simulation technique in modeling and studying underground mine evacuation operations and rescue equipment were examined by conducting a simulation and animation model in Chapter 8. The results presented that the simulation model was effectively utilized to analytically evaluate the time required to accomplish an underground

mine evacuation in an emergency situation. Moreover, the simulation analysis demonstrated investigations on the locations and sized of the mine refuge chambers, considering several scenarios using the constructed MSRS model (Mine System Rescue Simulation). In fact, the developed simulation model practically could be used to assist the mine engineers and rescue teams in studying and evaluating emergencies situations/accidents and rescue equipment efficiency, particularly mine refigure chambers. Actual statistical data analysis of the mine evacuation practices can be implemented into the MSRS models to validate the outputs of the programs. However, with no access to real data, deterministic MSRS models can be designed and developed to help the engineers and mining personnel to execute different "what if?" scenarios and achieve appropriate results.

- The interactive secure content management website proved its effectiveness and convenience for the users during the entire investigation. This advanced technique significantly could improve the effective communication between the modelers and mining engineers, which is very critical for implementing a mine simulation project.
- During the entire research investigation, GPSS/H® was used for simulating and running a wide range of "what if?" analyses, which proved its high execution-speed, re-usability, flexibility, and capability to model complex systems. PROOF Professional® was applied to graphically animate and visualized the developed simulation programs for debugging and verification process.

Consequently, this research provided a fine and elite library or collection of different mine simulation and animation projects, which could benefit (technically and economically) the mine modern and well-mechanized operations through implementing the results and analyses.

9.3. Contributions of the Research to Mining Engineering

This research represents original work by conducting mine simulation models, involving different surface mining methods, including open-pit, quarrying, and open-cast (strip) mining. In addition to those, a unique simulation and animation model of an underground mine's evacuation operation was conducted to examine and prove the flexibility and possibility of using discrete-event system simulation and animation in analyzing mine rescue operations for the first time in the mining industry.

Another relevant contribution of this work is to develop a fine collection of different mine simulation models with various "what if?" scenarios in mine design, planning, optimization, and equipment selection, using GPSS/H® and PROOF Professional® simulation package. A quite comprehensive literature survey of mine simulation projects that have been carried out and published was conducted and gathered during the investigation.

Furthermore, the investigation was the first to utilize an interactive secure content management website for the convenience of the mines' engineers. This approach was one of a kind to improve the communication through an online discussion between researchers/modelers and mine site engineers during the implementation of the simulation projects. The technique and technology showed that it is a worthwhile and effective tool that can help increasing the quality of communication and the ease of the accessibility of mine simulation files/programs for the engineers.

This research study contributed to the mine system simulation by applying this technology to model a very small mine/aggregate operation. The results indicated that mine simulation modeling can also be a great and valuable tool for these types of operations in a better and accurate decision making in mine planning and design.

It was pioneered that mine system simulation was also used for modeling a haulage system in a large surface coal mine to study and reduce the operational environmental impact. This cutting-edge approach should be used for any mine operation, particularly large-scale mines to decrease the negative and harmful impact of mining heavy equipment and machinery, through improving the appropriate use of the equipment as well as assisting mining eco-friendly or green practices.

As a thoughtful and valuable contribution of the conducted research, discrete-event system simulation and animation approach was applied, for one of the first times in the field, to investigate the applications of this modeling technique for planning and identifying underground mine rescue and evacuation plans and equipment.

9.4. Recommendations for Future Studies

Attempting to conduct a simulation model for a mine operation and use and generalize it for another different mine is almost impossible due to the many uncertainties and operational characteristics involved with each mine system and equipment. However, it is recommended to apply and re-use some parts of the developed simulation program for modeling other mining operations with similar mine methods, systems, and logics, if the identical simulation language or software is used in the future. This can significantly reduce the cost, time, effort, and labor intensity associated with developing simulation models/programs for the relatively similar mine operations in characteristics. An excellent diverse collection of mine system simulation models/projects can be valuable to the subject matter.

Reducing the environmental footprint of mines currently is one of the most critical concerns by the mineral and mining industry and other organizations (government and non-profit). Although concurrently with increasing these concerns related to the negative environmental impact associated with mining activities, the environmental issues can be significantly decreased using modern equipment, technologies, and well-deigned operations. The discrete-event system simulation modeling that was innovatively used for modeling a surface coal mine in this research can be clearly recognized as an advanced tool to be applied to reduce the environmental problems inherent with mining operations and to improve environmentally friendly mining practices. This application of mine system simulation was studied and presented for the first time in the field. In fact, mine simulation is one of the practical techniques that can help mining engineers to study and reduce the negative effects due to mining equipment, particularly heavy equipment misused in the operations. Generally, this approach should be used to effectively minimize the environmental impact of mining through operating optimum matches of equipment, appropriate design for repair/maintenance bays, waste rock and overburden areas, ore stockpiles, heap leaches, etc. regardless of the size and type of operations. In addition, since large-scale mining operations with heavy equipment and machinery can generate much more air and noise pollution and exhaust emissions, the mine simulation should be an essential and in-side tool for the mines' engineers to efficiently design and plan these operations in the future.

In underground mines, the most optimum locations, as well as required number of refuge chambers can be difficult and complicated to determine. It is necessary to install mine refuge chambers close to the active workface to minimize the required time and effort of the miners to access to them. However, this can increase the risk of locating the refuge chambers nearby the source of dangers during underground mine disasters. Furthermore, the costs associated with mine refuge chambers, including purchase, installation, training, maintenance, and relocation, are quite considerable. Therefore, additional in-depth investigations should be conducted for large and complex underground mines to evaluate the optimum sizes and the most favorable locations of the refuge chambers (stationary and portable) and other safety and emergency equipment using the discrete-event system simulation and animation technique. Moreover, attempts can be carried out to generalize the mine rescue simulation models to be used in mining operations with similar size, system, method, and operation.

Using discrete simulation to model mine rescue operations and emergency response plans can assist mining engineers and mine rescue trainers in assessing this complex system computationally, by taking into account the possible uncertainties that affect miners' travel times, using statistical distribution analysis during. In addition, it is highly recommended to use discrete-event system simulation and animation modeling in planning of both mine evacuation and rescue operations with details as well as designing rescue equipment applying SLX® and PROOF 3D® animation. SLX®, Simulation Language with Extensibility and using a C-like syntax, has only been utilized for modeling a few underground mining operations for the production evaluation and equipment assessment. SLX® simulation is more powerful, flexible, and quicker in performance comparing with GPSS/H® simulation language. Moreover, creating three-dimensional (3D) animation and visualization of the underground rescue simulation models, very complex systems, can be immensely valuable in this context. Overall, 3D animation allows the miners and engineers to achieve further and realistic detailed simulation results through having better and clear visual scenarios of mine rescue and evacuation operations with great complexity.

References

Anani, A. and Awuah-Offei, K., 2013, "Incorporating Cycle Time Dependency in Truck-Shovel Modeling," Society for Mining, Metallurgy and Exploration Annual Meeting, Denver, CO, USA, p. 5.

Arroyo Ortiz, C. E., Curi, A. and Campos, P. H., 2013, "The Use of Simulation in Fleet Selection and Equipment Sizing in Mining," Mine Planning and Equipment Selection (MPES), Proceedings of the 22nd MPES Conference, Dresden, Germany, pp. 869-877.

Awuah-Offei, K., Osei, B. A. and Askari-Nasab, H., 2011, "Modeling Truck/Shovel Energy Efficiency under Uncertainty," Transactions of the Society for Mining, Metallurgy, and Exploration, Vol. 330, pp. 573-584.

Awuah-Offei, K., Osei, B. A. and Askari-Nasab, H., 2012, "Improving Truck-Shovel Energy Efficiency through Discrete Event Modeling," Society for Mining, Metallurgy and Exploration Annual Meeting, Seattle, WA, USA, p. 6.

Baafi, E. Y. and Porter, I., 2010, "Computer Simulation of Roadway Development to Support Longwall Mining," Mine Planning and Equipment Selection (MPES) Conference, Fremantle, WA, Australia, pp. 561-566.

Banks, J., Carson, J. S., Nelson, B. L. and Nicol, D. M., 2010, "Discrete-event System Simulation," 5th edition, Upper Saddle River, NJ: Prentice Hall, p. 622.

Barrick Gold Corporation, 2013, http://www.barrick.com/, Accessed, 12/22/13.

Barrick Gold Corporation, 2014, http://www.barrick.com/, Accessed, 9/6/14.

Basu, A. and Baafi, E., 1999, "Discrete Event Simulation of Mining Systems: Current Practice in Australia," International Journal of Surface Mining, Reclamation and Environment, Vol. 13, Issue 2, pp. 79-84.

Bearman, R. and Munro, S., 2010, "A simulation Approach for the Comparison of In-Pit Crushing and Conveying and Truck-Shovel Mining Methods," Mine Planning and Equipment Selection (MPES) Conference, Fremantle, WA, Australia, pp. 33-41.

Belt Benefits, 2010, Infomine, International Mining, http://www.infomine.com/library/publications/docs/InternationalMining/IMOct2010b.pdf Accessed, 9/15/2013.

Boden P., Fricke C., Sandeman T. and C. Stanford, 2011, "Modeling the Mining Supply Chain from Mine to Port: A Combined Optimization and Simulation Approach," Journal of Mining Science, Vol. 47, No. 2, pp. 202-211.

Botha, J., Nichol, S. and Swarts, S., 2009, "Rapid Underground Development Optimisation at Cullinan Diamond Mine Using Computer Simulation," Diamonds - Source to use 2009, Gaborone, Botswana, p. 13.

Botha, J., Watson, S., Arkadius, T. and Samosir, E., 2008, "Simulation Applications at PT Freeport Indonesia's DOZ/ESZ Block Cave Mine," In Proceedings MassMin 2008, Lulea, Sweden: Lulea University of Technology Press, p. 10.

Burt, C., 2008, "An Optimisation Approach to Materials Handling in Surface Mines," PhD Thesis, Department of Mathematics and Statistics, Curtin University of Technology, Perth, Australia., p. 155.

Burt, C., Caccetta, L., Hill, S. and Welgama, P., 2005, "Models for Mining Equipment Selection," International Congress on Modeling and Simulation (MODSIM 05), Modelling and Simulation Society of Australia and New Zealand, Melbourne, Australia, pp. 1730-1736.

Cai, D., Baafi, E. and Porter, I., 2014, "Shuttle Car Network for Roadway Development," Society for Mining, Metallurgy and Exploration Annual Meeting, Salt Lake City, UT, USA, p. 4.

Cai, D., Baafi, E. and Porter, I., 2012, "Modelling a Longwall Production System Using Flexsim 3D Simulation Software," Mine Planning and Equipment Selection (MPES), New Delhi, India, pp. 107-114.

Caterpillar Performance Handbook (PHB), 2012, Edition 42, Published by Caterpillar Inc., Peoria, Illinois, USA, http://www.cashmanequipment.com/UserFiles/PDF/CaterpillarPerformanceHandbook42.pdf, Accessed, 11/10/2014.

Cetin N., 2004, "Open-pit Truck/Shovel Haulage System Simulation," PhD Thesis, Middle East: Graduate School of Natural and Sciences, Department of Mining Engineering, Middle East Technical University, p.116.

Chinbat, U., 2009, "Using Simulation for Reducing Risk of a Mining Optimization Project," International Journal of Simulation Modelling, Vol. 8, No. 3, pp. 166-177.

Chinbat, U. and Takakuwa, S., 2009, "Using Simulation Analysis for Mining Project Risk Management," Proceedings of the 2009 Winter Simulation Conference, Austin, Texas, USA, pp. 2612-2623.

Choi, Y. and Nieto, A., 2011, "Software for Simulating Open-pit Truck/Shovel Haulage Systems Using Google Earth and GPSS/H," Journal of the Korean Society for Geosystem Engineering, Vol. 48, No. 6, pp. 734-743.

Crain, R., 1997, "Simulation Using GPSS/H," Proceedings of the 1997 Winter Simulation Conference, Atlanta, GA, USA, pp. 567-573.

Conti, R., Chasko, L. and Cool, J., 1999, "An Overview of Technology and Training Simulations for Mine Rescue Teams," National Institute for Occupational Safety and Health, Pittsburgh Research Laboratory, Pittsburgh, PA, USA, p. 18.

Denver Gold Forum, 2013, http://www.denvergoldforum.org/dgf13/company-webcast/ABX:US, Accessed, 10/30/2013.

Department of Industry and Resources, 2005, "Refuge Chambers in Underground Metalliferous Mines - Guideline: Safety and Health Division," Department of Industry and Resources, Western Australia, p. 32, http://www.infomine.com/library/publications/docs/RefugeChambers2005.pdf, Accessed, 10/8/2014.

Despotovic-Zrakic, M., Barac, D., Bogdanovic, Z., Jovanic, B. and Radenkovic, B., 2012, "Integration of Web Based Environment for Learning Discrete Simulation in E-learning System," Simulation Modelling Practice and Theory, Vol. 27, pp. 17-30

EIP Associates and Sharrah, Dunlap, Sawyer, Inc., 2005, "Shasta Ranch Aggregates Project Mining and Reclamation Plan," http://www.cvfpb.ca.gov/meetings/2011/052611Item7A_18017_RecPlan.pdf, Accessed, 9/9/2014.

Environmental Protection Agency (EPA), 1995, "Emission Factors," http://www.epa.gov/ttnchie1/ap42/ch13/final/c13s02.pdf, Accessed, 9/15/2013.

Fjellström, N., 2011, "Simulation of an Underground Haulage System, Renström Mine, Boliden Mineral," Master's Thesis in Civil Engineering, Luleå University of Technology, Sweden, p. 76.

Frizzell, E. and Martin, T., 1992, "In-Pit Crushing and Conveying," SME Mining Engineering Handbook 2nd Edition, Ch. 13.5. pp. 1343-1351.

Galiyev, S. Zh., Boyandinova, A. A. and Adilkhanova, Zh., A, 2010, "Information and Methodical Base of Simulation Modelling of Excavator-Truck-Conveyor Complex Operation," Proceedings of Mine Planning and Equipment Selection (MPES) Conference, Fremantle, WA, Australia, pp. 567-575.

Gurtunca, R. G., 2008, "Possible Impact of New Safety Technology Developments on the Future of the United States Mining Industry," National Institute for Occupational Safety and Health (NIOSH), Proceedings of the 1st International Future Mining Conference and Exhibition, Sydney, New South Wales, Australia, Australasian Institute of Mining and Metallurgy, pp. 3-9, http://www.cdc.gov/niosh/mining/userfiles/works/pdfs/pions.pdf, Accessed, 9/25/2014.

Govinda Raj, M., Vardhan, H. and Rao, Y. V., 2009, "Productions Optimisation Using Simulation Models in Mine: A Critical Review," International Journal of Operational Research, Vol. 6, No. 3, pp. 330-359.

Gray, G., Baafi, E., Porter, I. and Rojas, O., A., 2009, "Simulation Model for Roadway Development to Support Longwall Mining," Proceedings of the 2009 Coal Operators' Conference, University of Wollongong and the Australasian Institute of Mining and Metallurgy, Australia, pp.103-107.

Greberg, J. and Sundqvist, F., 2011, "Simulation as a Tool for Mine Planning," Second International Future Mining Conference, Sydney, New South Wales, Australia, 22-23 November 2011, pp. 273-278.

Hartman, L. H. and Mutmansky, M. J., 2002, "Introductory Mining Engineering," John Wiley and Sons, Inc., 2nd Edition, Hoboken, New Jersey, USA, p. 570.

Henriksen, J., 2000, "GPSS/H: A 23-Year Retrospective View," Proceedings of the 2000 Winter Simulation Conference, Orlando, FL, USA, pp. 177-182.

Henriksen, J., 2000, "SLX: The X is for Extensibility," Proceedings of the 2000 Winter Simulation Conference, Orlando, FL, USA, pp. 183-190.

Henriksen, J., 2000, "Adding Animation to a Simulation Using PROOF" Proceedings of the 2000 Winter Simulation Conference, Orlando, FL, USA, pp. 191-196.

Hindle, K. and Limmer, V., 2009, "The Application of Discrete-Event Simulation in the Design of Underground Mines and Logistics," Process Control Applications in Mining and Metallurgical Plants - COM 2009, Sudbury, Canada, August 26 , pp. 213-224.

Hindle, K. and Limmer, V., 2010, "Understanding Underground Ore Handling and Shifting Bottleneck Identification Using Discrete-Event Simulation," SME International Conference on Hoisting and Haulage 2010 (Hoist and Haul 2010), September 15, 2010, Las Vegas, Nevada, USA, pp. 267-276.

Hodkiewicz, M., Richardson, S. and Durham, R., 2010, "Challenges and Opportunities for Simulation Modeling Integrating Mine Haulage and Truck Shop Operations," 2010 Australian Mining Technology Conference, 13-15 September 2010, pp. 163-172.

Hopkins, S. and Labrecque, P., 2008, "Production Simulation Overview and Case Study: Coleman 170 Orebody," Proceedings of CIM Edmonton 2008, Alberta, Canada, p. 7.

Jingxia, D., 2009, "Study on Mine Equipment Systems Combined with a Reliability Assessment Model," NSWCTC '09 Proceedings of the 2009 International Conference on Networks Security, Wireless Communications and Trusted Computing, Vol. 02, Wuhan, China, pp. 744-747.

Jacobsen, W. L., Sturgul, J., Ritter, K-C. and Fliess, T., 1995, "A Simulation Model of the Waste Handling System Proposed for the Lihir Project in Papua New Guinea," Proceedings of APCOM 95 Symposium, Brisbane, Australia, pp. 333-343.

Karimi-Tarshizi, Ebrahim, 2012, "Simulation and Animation Model of Fabero Coal Mine Operation," Master's Thesis, Mackay School of Earth Sciences and Engineering, Department of Mining Engineering, University of Nevada, Reno, p.139.

Kecojevic, V. and Komljenovic, 2012, "Haul Truck Fuel Consumption and CO_2 Emission Under Various Engine Load Conditions," SME Mining Engineering Magazine, Vol. 62, Issue 12, pp. 44-48.

Knights, P. F. and Bonates, E. J. L., 1999, "Applications of Discrete Mine Simulation Modeling in South America," International Journal of Surface Mining, Reclamation and Environment, Vol. 13, Issue 2, pp. 69-72.

Knights, P. F. and Paton, S., 2010, "Payload Variance Effects on Truck Bunching," Seventh Large Open Pit Mining Conference, Perth, WA, Australia, 27-28 July 2010, pp. 111-114.

Konyukh, V., Galiyev, S. and Li, Z., 1999, "Mine Simulation in Asia," International Journal of Surface Mining, Reclamation and Environment, Vol. 13, Issue 2, pp. 57-69.

Labrecque, P., Newman, T. and Jo-Anne, D., 2012, "The Use of ARENA® Simulation to Estimate Drawpoint Construction Rate, Production Rate and Costs for the Hugo North Lift 1 Panel Cave," MassMin 2012: 6th International Conference and Exhibition on Mass Mining, Sudbury, Ontario, Canada, p. 9.

Lashgari A. and Kecojevic V., 2013, "Environmental Impact of Digging and Loading Equipment in Surface Coal Mining," Society for Mining, Metallurgy and Exploration Annual Meeting, Denver, CO, USA, p. 5.

Li, Z., 2012, "Application of Simulation Techniques in Development Planning for Caving Methods," Master of Applied Science, Mining Engineering, The University of British Colombia, Canada, p. 199.

Maria, A., 1997, "Introduction to Modeling and Simulation," Proceedings of the 1997 Winter Simulation Conference, Atlanta, Georgia, USA, pp. 7-13.

Marsh, D., Peppin, C. and Ross, I., 2010, "Design Optimization of Grasberg Block Cave Haulage," Society for Mining, Metallurgy and Exploration Annual Meeting, Phoenix, AZ, USA, p. 3.

McHaney, R., 2009, "Understanding Computer Simulation (E-book)," Roger McHaney and Ventus Publishing, p. 172.

Metzger, D., 2007, "Long Distance Conveying-Long Term Savings, Conveyor vs. Haul Trucks," Superior Technical Bulletin, Superior Industries, LLC. http://superior-ind.com/wp-content/uploads/2009/03/Conveyor-vs-Haul-Truck.pdf, Accessed, 9/25/2013.

Mitchell, J.J. and Albertson, D.W., 1985, "High Angle Conveyor Offers Mine Haulage Savings," presented at International Materials, Handling Conference, Beltcon 3, Johannesburg, South Africa.

Mines Rescue Services, Emergency Preparedness and Mines Rescue Guidelines/Incident Management, Revised July 2011, Issue No. 13, http://www.minesrescueservices.com/MessageForceWebsite/Sites/311/Files/Guidelines%20March%202012%20final.pdf, Accessed, 05/10/2014.

Minerals Education Coalition, http://www.mineralseducationcoalition.org/minerals/sand-and-gravel, Accessed, 9/8/2014.

Mining Topic: Emergency Management, NIOSH Office of Mine Safety and Health Research Topic, http://www.cdc.gov/niosh/mining/topics/EmergencyManagement.html, Accessed, 05/20/2014.

Mission 2016: Strategic Mineral Management, Environmentally sensitive "Green" Mining, http://web.mit.edu/12.000/www/m2016/finalwebsite/solutions/greenmining.html, Accessed, 05/28/2014.

Model Assist, Modeling Export Opinions, Triangular Distribution, http://www.epixanalytics.com/modelassist/CrystalBall/Model_Assist.htm#Modeling_expert_opinions/Triangular_distribution.htm, Accessed, 05/28/2014.

Modular Mining, 2014, http://modularmining.com/product/dispatch/, Accessed, 8/25/14.

Morgan, W. C. and Peterson, L. L., 1968, "Determining Shovel-Truck Productivity," Mining Engineering, Society for Mining, Metallurgy and Exploration, pp. 76-80.

Mould, GI., 2001, "Assessing Systems for Offshore Emergency Evacuation," Journal of the Operational Research Society, Vol. 52, No. 4, pp. 401-408.

Nance, R. E., 1993, "A History of Discrete Event Simulation Programming Languages," Technical Report TR 93-21, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, USA, p. 52.

Nekoufar, S., 2014, "Trucks vs. Pocket Belt Conveyors," Australian Bulk Handling Review: January/February 2014, Vol. 18, No.7, pp. 68, http://www.scott.co.nz/news/pdf/2014_Trucks_vs._pocket_belt_conveyors.br_Source_Australian_Bulk_Handling_Review_Magazine_-_Issue_JanFeb_2014.pdf. Accessed, 12/9/2014.

Nel S., Kizil M. and Knights P., 2011, "Improving Truck-shovel Matching," Proceedings 35th APCOM Symposium, Wollongong, NSW, Australia, pp. 381-391.

Nordell, L., 2011, "Mining with Trucks vs. Belt Conveyors," Bulk-online Forum, http://forum.bulk-online.com/showthread.php?23552-Mining%20%E2%80%93with-Trucks-vs-Belt-Conveyors, Accessed, 9/25/2013.

O'Connell, T. and Sturgul, J.R., 2010, "Simulation and Animation Model for the Millerton Coal Mine (New Zealand)," Proceedings of Mine Planning and Equipment Selection (MPES) Conference, Fremantle, WA, Australia, pp. 577-580.

Panagiotou, G. N., 1999, "Discrete Mine System Simulation in Europe," International Journal of Surface Mining, Reclamation and Environment, Vol.13, Issue 2, pp. 43-46.

Parreira, J. and Meech, J., 2010, "Autonomous vs. Manual Haulage Trucks-How Mine Simulation Contributes to Future Haulage System Developments," Proceedings of CIM Meeting, Vancouver, BC, Canada, p. 13.

Pegden, C. D., Shannon, R. E. and Sadowski, R. P., 1995, "Introduction to Simulation Using SIMAN," 2nd edition, McGrew-Hill, New York, USA, p. 640.

Pereira, S. P., Costa, J.F.C.L, Salvadoretti, P. and Koppe, J., 2012, "Mining Simulation for Room and Pillar Coal Operation," The Journal of The Southern African Institute of Mining and Metallurgy, Vol. 112, pp. 473-476.

Pop-Andonov, G., Mirakovski, D. and Despotov, Z., 2012, "Simulation Modeling and Analyzing in Underground Haulage Systems with Arena Simulation Software," International Virtual Journal for Science, Technics and Innovations for the Industry-Machines, Technologies, Materials, Issue 6, pp. 48-50.

Raghavendra Rao, S., Cook, C., Baafi, E. and Porteous, R., 2010, "Design and Simulation of Roadway Development Operations to Improve Productivity," Transactions of the Institutions of Mining and Metallurgy, Section A: Mining Technology, 119 (2), pp. 79-87.

Rasche, T. and Sturgul, J., 1991, "A Simulation to Assist a Small Mine: A Case Study," International Journal of Surface Mining and Reclamation, Vol. 5, pp. 123-128.

Saiang, D., 2008, "Simulation of Truck Haulage Queue System at an Open Mine Using SIMAN," MassMine 2008: Proceedings of the 5th International Conference and Exhibition on Mass Mining, Lulea, Sweden, pp. 607-616.

Salama, A. and Greberg, J., 2012, "Optimization of Truck-Loader Haulage System in an Underground Mine: A Simulation Approach Using SimMine," MassMin 2012: 6th International Conference and Exhibition on Mass Mining, Sudbury, Canada, p. 10.

Salama, A., Greberg, J. and Schunnesson, H., 2014, "The Use of Discrete Event Simulation for Underground Haulage Mining Equipment Selection," International Journal of Mining and Mineral Engineering, Vol. 5, No. 3, pp. 256-271.

Salama, A., Nehring, M. and Greberg, J., 2014, "Operating Value Optimization Using Simulation and Mixed Integer Programming," International Journal of Mining, Reclamation and Environment, Vol. 28, Issue 1, pp. 25-46.

Sandeman, T., Fricke, C., Bodon, P. and Stanford, C., 2010, "Integrating Optimization and Simulation - A Comparison of Two Case Studies in Mine Planning," Proceedings of the 2010 Winter Simulation Conference, Baltimore, MD, USA, pp. 1898-1910.

Shogan, A.W., 1988, "Management Science," Englewood Cliffs, NJ: Prentice Hall, p. 823.

Shelswell, K., Fitzgerald, J. and Labrecque, P., 2013, "Discrete Event Simulation Modelling versus TKM Analysis of a Mine Operating with a Hybrid Material Movement Practice Consisting of Truck Haulage and Skipping," CIM Toronto 2013, Ontario, Canada, Proceedings, p. 9.

Shelswell, K. and Labrecque, P., 2014, "Discrete Simulations Quantifying the Effects of Material Handling Conveyors in Series or Parallel Oreflow Streams," Society for Mining, Metallurgy and Exploration Annual Meeting, Salt Lake City, Utah, USA, p. 7.

Skawina, B., Greberg, J., Salama, A. and Schunnesson, H., 2014, "Mechanical Excavation and Drilling and Blasting - A Comparison Using Discrete Event Simulation," Mine Planning and Equipment Selection: Proceedings of the 22nd MPES Conference, Dresden, Germany, 14th-19th October 2013, Vol. 1, pp. 367-377.

Stahl, I., Henriksen, J., Born, R. and Herper, H., 2011, "GPSS 50 Years Old, But Still Young," Proceedings of the 2011 Winter Simulation Conference, Phoenix, AZ, USA, pp. 3952-3962.

Stout, C., E., Conrad, P., W., Todd, C., S., Rosenthal, S. and Knudsen, H., P., 2013, “Simulation of a Large Multiple Pit Mining Operation Using GPSS/H,” International Journal of Mining and Mineral Engineering, Vol. 4, No. 4, pp. 278-295.

Sturgul, J., 1992. “Using Exact Statistical Distribution for Truck Shovel Simulation Studies,” International Journal of Surface Mining and Reclamation, Vol. 6, pp. 137-139.

Sturgul, J., 1993, “Animation Models of Mines to Assist in Mine Planning and Production,” Society for Mining, Metallurgy and Exploration Annual Meeting, Reno, NV, pp. 350-351.

Sturgul, J., 1997, “Annotated Bibliography of Mine System Simulation (1961-1995),” Proceedings of MineSim96, 1st International Symposium of Mine Simulation via the Internet, Moscow, Idaho, USA, p. 47.

Sturgul, J., 1997, “Simulation Languages for Mining Engineers,” Proceedings of MineSim96, 1st International Symposium of Mine Simulation via the Internet, Moscow, Idaho, USA, p. 11.

Sturgul, J. R., 1999, “Discrete Mine System Simulation in the United States,” International Journal of Surface Mining, Reclamation and Environment, Vol. 13, Issue 2, pp. 37-41.

Sturgul, J. R., 2000, “Mine Design: Examples Using Simulation,” Society for Mining, Metallurgy and Exploration Engineering, Littleton, CO, USA, p. 366.

Sturgul, J., Burvill, D., Mroczek, C. and Gray, D., 2014, “A Simulation and Animation Model of a Mine Port Facility,” Australian Simulation Society Conference Annual Meeting, August 2014, Adelaide, Australia, p. 5.

Sturgul, J., Lorenz, P., Shulze, T. and Silverton, T., 2014, “A Simulation and Animation Model for a Complex Underground Mine,” Australian Simulation Society Conference Annual Meeting, August 2014, Adelaide, Australia.

Sturgul, J. R. and Tecsa, T. L., 1997 “How Simulation and Animation Can Assist in Studying the Rapid Evacuation of a Mine under Emergency Conditions,” Regional APCOM, Moscow, Idaho, p. 7.

Tan, Y., 2012, “Enhancing Simulation Models for Open Pit Copper Mining Using Visual Basic for Applications,” 2012 JSPS ASIAN CORE PROGRAM Conference, Hanoi, Vietnam, p. 10.

Tan, Y., Chinbat, U., Miwa, K. and Takakuwa, S., 2012, “Operations Modeling and Analysis of Open Pit Copper Mining Using GPS Tracking Data,” Proceedings of the 2012 Winter Simulation Conference, Berlin, Germany, pp. 1309-1320.

Toppo, G., 2014, May 17, "'Refugee Chamber' Key to Surviving Mine Disaster," USATODAY, http://www.usatoday.com/story/news/world/2014/05/14/turkey-mine-rescue/9078279/, Accessed, 10/8/2014.

Torkamani E., 2013, "Linkage of Truck-and-shovel Operations to Short-term Mine Plans Using Discrete Event Simulation," Thesis of Master of Science in Mining Engineering, Department of Civil and Environmental Engineering, University of Alberta, Canada, p. 179.

Turner, R. J., 1999, "Simulation in the Mining industry of South Africa," International Journal of Surface Mining, Reclamation and Environment, Vol. 13, Issue 2, pp. 47-56.

Tuysuz, G., Watson, I. and Smith-Spark L., 2014, May 17, "Turkey Mine Search Ends with 301 Confirmed Victims of Fire," CNN World, http://www.cnn.com/2014/05/17/world/europe/turkey-mine-accident/, Accessed, 10/8/2014.

Upadhyay S., Suglo R., Lin Z., Sundararajan Z. and J. Szymanski, 2013, "Simulation Analysis Model and Equipment Selection in Continuous Surface Mining Systems," The Canadian Institute of Mining, Metallurgy and Petroleum Journal, Vol. 4, No. 2, pp. 87-94.

Vagenas, N., 1999, "Applications of Discrete-event Simulation in Canadian Mining Operations in the Nineties," International Journal of Surface Mining, Reclamation and Environment, Vol. 13, Issue 2, pp. 77-78.

Vasquez-Coronado, P. P., 2014, "Optimization of the Haulage Cycle Model for Open Pit Mining Using a Discrete-Event Simulator and a Context-Based Alert System," Master's Thesis in Mining Engineering, Department of Mining, Geological, and Geophysical Engineering, University of Arizona, p. 156.

Visual Capitalist, 2013, http://www.visualcapitalist.com/what-is-the-cost-of-mining-gold, Accessed, 12/22/2013.

West Virginia Office of Miners' Health, Safety and Training, and West Virginia University-Mining Extension Service , 2008, "Developing a Comprehensive Emergency Preparedness Planning Manual for Undergraduate Mining Operations," Final Report, http://www.wvminesafety.org/PDFs/Emergency%20Preparedness%20Plan-Final.pdf, Accessed, 04/15/2014.

Winter Simulation Conference 2014, http://wintersim.org/2014/program.html, Accessed, 8/12/2014.

Wolverine Software Company, http://www.wolverinesoftware.com/, Accessed, 8/12/2014.

Xu, L., Ye, S., Lu, G. and Zhang, Z., 2011, "Underground Mining Transportation System," Proceedings of Advanced Research on Computer Education, Simulation and Modeling; International Conference, CESM 2011, Wuhan, China, June 18-19, pp. 116-121.

Yuriy, G. and Vayenas, N., 2008, "Discrete-event Simulation of Mine Equipment Systems Combined with a Reliability Assessment Model Based on Genetic Algorithms," International Journal of Mining, Reclamation and Environment, Vol. 22, Issue 1, pp. 70-83.

Zaharis, L., 2011, Mining with Trucks vs. Belt Conveyors, Bulk-online Forum, http://forum.bulk-online.com/showthread.php?23552-Mining%20%E2%80%93with-Trucks-vs-Belt-Conveyors, Accessed, 9/25/2013.

Zhou, J., 2010, "Analysis of a Mine-Mill Production System Using Simulation and Integer Programming," Master's Thesis in Applied Science, Dalhousie University, Halifax, Nova Scotia, p. 128.

Appendices

Appendix A: Preliminary and secondary simulation and animation programs of the gold open pit mine using GPSS/H® and PROOF Animation®.

Preliminary Gold Mine Simulation and Animation Program:

- This code was written by the guidance and assistance of Dr. John Sturgul, Professor of Mining Engineering, at the University of Adelaide, Australia.

```
***************************************************************
*  SIMULATION AND ANIMATION OF A GOLD MINE                    *
*   PROGRAMMED IN GPSS/H                                      *
*   BY JOHN R. STURGUL                                        *
*   EBRAHIM KARIMI TARSHIZI                                   *
***************************************************************
         SIMULATE
         RMULT      12345
         REALLOCATE  COM,1000000
 ATF     FILEDEF    'GOLDMINE.ATF'
         INTEGER    &NT793,&NT789,&NT789B,&NT789C,&N789TOT
         REAL       &X,&Y,&Z,&R,&S,&T,&U,&V,&W,&XX,&YY,&XXX,&YYY
         REAL       &ZZZ,&RRR,&SSS,&TTT,&UUU,&VVV,&WWW
         REAL       &AAA,&BBB,&CCC,&DDD,&EEE,&FFF,&GGG,&HHH
         REAL       &III,&JJJ,&KKK,&LLL,&MMM,&NNN,&PPP,&QQQ
         REAL       &XX1,&XX2,&XX3,&ABC1,&ABC2,&ABC3,&ABC4
         REAL       &WW1,&WW2,&WW3,&YYZZ,&YYUU
         REAL       &SUN1,&SUN2,&SUN3,&SUN4
         REAL       &MUN1,&MUN2
         REAL       &TUN1,&TUN2
         REAL       &ABC5,&ABC6,&ABC7,&ABC8
         REAL       &XYZ1,&XYZ2,&XYZ3,&XYZ4,&XYZ5,&XYZ6,&XYZ7,&XYZ8
         REAL       &XYZ9,&XYZ10,&XYZ11,&XYZ12,&XYZ13
         REAL       &XYZ14,&XYZ15,&XYZ16
         REAL       &XYZ17,&XYZ18,&XYZ19,&XYZ20
         INTEGER    &LL793A,&LL793B,&LL793C,&LL793D
         INTEGER    &LL789A,&LL789B,&LL789C,&LL789D
         REAL       &XX793A,&XX793B,&XX793C,&XX793D
         REAL       &XX789A,&XX789B,&XX789C,&XX789D
         REAL       &O793D1,&O789D1,&TOD1,&AAAA
         INTEGER    &O793A,&O789A
         REAL       &TOTORE,&TOTWAS
```

```
  1     FUNCTION    PH1,E2
1,RVNORM(1,3,.2)/2,RVNORM(1,2.5,.1)
  AA1A   FUNCTION    PH1,E2
1,RVNORM(1,2,.1)/2,RVNORM(1,1.5,.05)
  2     FUNCTION    PH1,E2
1,RVNORM(1,4.1,.3)/2,RVNORM(1,3.75,.2)
  3     FUNCTION    PH1,E2
1,RVNORM(1,5,.2)/2,RVNORM(1,4,.1)
  AA4A   FUNCTION    PH1,E2
1,RVNORM(1,1,.05)/2,RVNORM(1,1,.05)
  AA4B   FUNCTION    PH1,E2
1,RVNORM(1,5,.2)/2,RVNORM(1,4,.1)
  AA5A   FUNCTION    PH1,E2
1,RVNORM(1,1,.05)/2,RVNORM(1,1,.02)
  AA5B    FUNCTION    PH1,E2
1,RVNORM(1,5,.1)/2,RVNORM(1,4,.1)
  AA6A   FUNCTION    PH1,E2
1,RVNORM(1,4,.1)/2,RVNORM(1,3,.1)
  AA6B   FUNCTION    PH1,E2
1,RVNORM(1,1,.1)/2,RVNORM(1,1,.1)
  7     FUNCTION    PH1,E2
1,RVNORM(1,6,.3)/2,RVNORM(1,5,.1)
  8     FUNCTION    PH1,E2
1,RVNORM(1,5,.1)/2,RVNORM(1,4,.5)
  AA8A   FUNCTION    PH1,E2
1,RVNORM(1,1,.05)/2,RVNORM(1,.8,.02)
  AA9A   FUNCTION    PH1,E2
1,RVNORM(1,1,.05)/2,RVNORM(1,.8,.03)
  9     FUNCTION    PH1,E2
1,RVNORM(1,3,.2)/2,RVNORM(1,2.5,.08)
  10     FUNCTION    PH1,E2
1,RVNORM(1,5,.1)/2,RVNORM(1,4,.05)
  13     FUNCTION    PH1,E2
1,RVNORM(1,2,.1)/2,RVNORM(1,1.5,.1)
  12     FUNCTION    PH1,E2
1,RVNORM(1,2,.05)/2,RVNORM(1,1.5,.05)
  AA11A  FUNCTION    PH1,E2
1,RVNORM(1,2,.1)/2,RVNORM(1,1.5,.1)
  AA11B  FUNCTION    PH1,E2
1,RVNORM(1,2,.1)/2,RVNORM(1,1.5,.08)
  15     FUNCTION    PH1,E2
1,RVNORM(1,2,.1)/2,RVNORM(1,1.5,.08)
  16     FUNCTION    PH1,E2
1,RVNORM(1,1.8,.1)/2,RVNORM(1,1.4,.05)
 AA16A   FUNCTION    PH1,E2
```

```
1,RVNORM(1,1.5,.1)/2,RVNORM(1,1.2,.08)
 AA3A    FUNCTION    PH1,E2
1,RVNORM(1,1.5,.1)/2,RVNORM(1,1.2,.07)
 23      FUNCTION    PH1,E2
1,RVNORM(1,1,.05)/2,RVNORM(1,.8,.03)
 24      FUNCTION    PH1,E2
1,RVNORM(1,5,.1)/2,RVNORM(1,4.5,.1)
 25      FUNCTION    PH1,E2
1,RVNORM(1,5,.1)/2,RVNORM(1,4.5,.1)
 AA25A   FUNCTION    PH1,E2
1,RVNORM(1,1,.1)/2,RVNORM(1,.8,.1)
 20      FUNCTION    PH1,E2
1,RVNORM(1,6,.5)/2,RVNORM(1,5,.35)
 21      FUNCTION    PH1,E2
1,RVNORM(1,4,.4)/2,RVNORM(1,3,.3)
 22      FUNCTION    PH1,E2
1,RVNORM(1,1,.1)/2,RVNORM(1,.8,.08)
 30      FUNCTION    PH1,E2
1,RVNORM(1,3.9,.3)/2,RVNORM(1,3.1,.2)
 31      FUNCTION    PH1,E2
1,RVNORM(1,1,.05)/2,RVNORM(1,.8,.06)
 50      FUNCTION    PH1,E2
1,RVNORM(1,5.5,.3)/2,RVNORM(1,4,.2)
 49      FUNCTION    PH1,E2
1,RVNORM(1,4,.2)/2,RVNORM(1,3.2,.2)
 47      FUNCTION    PH1,E2
1,RVNORM(1,1,.08)/2,RVNORM(1,.8,.03)
 46      FUNCTION    PH1,E2
1,RVNORM(1,3.5,.2)/2,RVNORM(1,3.2,.1)
 62      FUNCTION    PH1,E2
1,RVNORM(1,1,.05)/2,RVNORM(1,.75,.02)
 63      FUNCTION    PH1,E2
1,RVNORM(1,1.5,.03)/2,RVNORM(1,1,.03)
 64      FUNCTION    PH1,E2
1,RVNORM(1,1.5,.1)/2,RVNORM(1,1,.05)
 59      FUNCTION    PH1,E2
1,RVNORM(1,3.2,.3)/2,RVNORM(1,3,.1)
 60      FUNCTION    PH1,E2
1,RVNORM(1,1.,.01)/2,RVNORM(1,.9,.01)
 61      FUNCTION    PH1,E2
1,RVNORM(1,.8,.01)/2,RVNORM(1,.8,.01)
 55      FUNCTION    PH1,E2
1,RVNORM(1,2,.2)/2,RVNORM(1,1.6,.05)
 56      FUNCTION    PH1,E2
1,RVNORM(1,2.1,.2)/2,RVNORM(1,2,.08)
```

```
  57     FUNCTION    PH1,E2
1,RVNORM(1,4,.1)/2,RVNORM(1,3.8,.3)
  58     FUNCTION    PH1,E2
1,RVNORM(1,.8,.01)/2,RVNORM(1,.7,.01)
  53     FUNCTION    PH1,E2
1,RVNORM(1,4,.1)/2,RVNORM(1,3.8,.3)
  54     FUNCTION    PH1,E2
1,RVNORM(1,.8,.01)/2,RVNORM(1,.7,.01)
  51     FUNCTION    PH1,E2
1,RVNORM(1,4,.1)/2,RVNORM(1,3.8,.3)
  52     FUNCTION    PH1,E2
1,RVNORM(1,.8,.01)/2,RVNORM(1,.7,.01)
  32      FUNCTION   PH1,E2
1,RVNORM(1,.9,.01)/2,RVNORM(1,.8,.01)
  33     FUNCTION    PH1,E2
1,RVNORM(1,2,.1)/2,RVNORM(1,1.8,.1)
  34     FUNCTION    PH1,E2
1,RVNORM(1,2,.1)/2,RVNORM(1,1.8,.1)
  35     FUNCTION    PH1,E2
1,RVNORM(1,4,.2)/2,RVNORM(1,3.7,.15)
  36      FUNCTION    PH1,E2
1,RVNORM(1,.8,.01)/2,RVNORM(1,.7,.01)
  37     FUNCTION    PH1,E2
1,RVNORM(1,1,.05)/2,RVNORM(1,.8,.05)
  38     FUNCTION    PH1,E2
1,RVNORM(1,4,.2)/2,RVNORM(1,3.7,.15)
  39     FUNCTION    PH1,E2
1,RVNORM(1,5,.2)/2,RVNORM(1,4,.1)
  45     FUNCTION    PH1,E2
1,RVNORM(1,1,.1)/2,RVNORM(1,.8,.08)
  40      FUNCTION    PH1,E2
1,RVNORM(1,1.2,.01)/2,RVNORM(1,1,.01)
  41     FUNCTION    PH1,E2
1,RVNORM(1,4.2,.5)/2,RVNORM(1,4,.5)
  42     FUNCTION    PH1,E2
1,RVNORM(1,3.8,.2)/2,RVNORM(1,3.5,.15)
  43     FUNCTION    PH1,E2
1,RVNORM(1,1.7,.1)/2,RVNORM(1,1.4,.1)
  44     FUNCTION    PH1,E2
1,RVNORM(1,2.5,.08)/2,RVNORM(1,2.2,.08)
  65     FUNCTION    PH1,E2
1,RVNORM(1,1.8,.2)/2,RVNORM(1,1.5,.15)
  66     FUNCTION    PH1,E2
1,RVNORM(1,1.6,.1)/2,RVNORM(1,1.4,.1)
  67     FUNCTION    PH1,E2
```

```
1,RVNORM(1,1.4,.08)/2,RVNORM(1,1.2,.08)
  132      FUNCTION   PH1,E2
1,RVNORM(1,.9,.01)/2,RVNORM(1,.8,.01)
  133     FUNCTION    PH1,E2
1,RVNORM(1,2,.1)/2,RVNORM(1,1.8,.1)
  134     FUNCTION    PH1,E2
1,RVNORM(1,2,.1)/2,RVNORM(1,1.8,.1)
  135     FUNCTION    PH1,E2
1,RVNORM(1,4,.2)/2,RVNORM(1,3.7,.15)
  SPOTL1  FUNCTION    PH1,E2            SPOT LOADER 1
1,RVNORM(1,.8,.02)/2,RVNORM(1,.7,.02)
  SPOTL2  FUNCTION    PH1,E2            SPOT LOADER 2
1,RVNORM(1,.5,.02)/2,RVNORM(1,.4,.02)
  SPOTS1   FUNCTION   PH1,E2            SPOT SHOVEL 1
1,RVNORM(1,.4,.02)/2,RVNORM(1,3.8,.02)
  SPOTS2   FUNCTION   PH1,E2            SPOT SHOVEL 2
1,RVNORM(1,.4,.02)/2,RVNORM(1,3.8,.02)

*   &NT793   NUMBER OF 793 TRUCKS IN THE MINE
*   &NT789   NUMBER OF 789 TRUCKS IN THE MINE
          INTEGER     &I
*    I IS A DUMMMY VARIABLE
***********************************
*  START MACRO DEFINITIONS         *
***********************************
 TRAVEL  STARTMACRO
        BLET         #A=FN(#B)
        TRANSFER     SBR,ANIM,3PH
        BPUTPIC      FILE=ATF,LINES=3,AC1,XID1,XID1,#A
TIME *.****
PLACE T* ON P#C
SET T* TRAVEL **.**
PAT#D    ADVANCE     #A
        ENDMACRO
******************************
*  END OF MACRO DEFINITIONS   *
******************************
        DO    &I=1,80
        PUTSTRING   ('  ')
        ENDDO
        PUTSTRING    ('  ')
        PUTSTRING    ('                  *** SIMULATION MODEL ***')
        PUTSTRING    ('  ')
        PUTSTRING    ('  ')
```

```
AGAIN   PUTSTRING   ('  INPUT THE NUMBER OF 793 TRUCKS AT TIME 0 AT
SHOVEL 1')
        PUTSTRING   ('  ')
        GETLIST     &NT793
        PUTSTRING   ('  ')
        PUTSTRING   ('  INPUT THE NUMBER OF 789 TRUCKS AT TIME 0 AT
SHOVEL 2')
        PUTSTRING   ('  ')
        GETLIST     &NT789
        PUTSTRING   ('  INPUT THE NUMBER OF 789 TRUCKS AT TIME 0 AT
LOADER 1')
        PUTSTRING   ('  ')
        GETLIST     &NT789B
        PUTSTRING   ('  ')
        PUTSTRING   ('  INPUT THE NUMBER OF 789 TRUCKS AT TIME 0 AT
LOADER 2')
        PUTSTRING   ('  ')
        GETLIST     &NT789C
        PUTPIC      LINES=4,&NT793,&NT789,&NT789B,&NT789C
  NUMBER OF 793 TRUCKS  AT SHOVEL 1 **   (ONLY AT TIME T = 0)
  NUMBER OF 789 TRUCKS  AT SHOVEL 2 **   (ONLY AT TIME T = 0)
  NUMBER OF 789 TRUCKS  AT LOADER 1 **   (ONLY AT TIME T = 0)
  NUMBER OF 789 TRUCKS  AT LOADER 2 **   (ONLY AT TIME T = 0)
        PUTSTRING   ('  ')
        CHAR*1      &ANS
        PUTSTRING   ('  ARE YOU HAPPY WITH THESE VALUES? (Y/N)')
        PUTSTRING   ('  ')
        GETLIST     &ANS
        IF          &ANS'NE"Y'
          GOTO   AGAIN
        ENDIF
        PUTSTRING   ('  ')
        PUTSTRING   ('  DO YOU WANT ANIMATION? (Y/N)')
        CHAR*1      &YES
        GETLIST     &YES
ANIM    TEST E      &YES,'Y',PH3+2
        TRANSFER    ,PH3+1
        LET         &N789TOT=&NT789+&NT789B+&NT789C
        IF          &YES'E"Y'
        PUTPIC      FILE=ATF,LINES=3,AC1,&NT793,&N789TOT
TIME *.****
WRITE MA1 **
WRITE MA2 **
        ENDIF
        PUTSTRING   ('  ')
```

```
        PUTSTRING    ('  ')
        PUTSTRING    ('  ** SIMULATION RESULTS **')
        PUTSTRING    ('  ')
        PUTSTRING    ('  ')
*****************************************
*  START WITH 793 TRUCKS IN THE MINE     *
*****************************************
        GENERATE     3,,0,&NT793,,12PH,12PL
        ASSIGN       1,1,PH     793 TRUCKS ARE NUMBER 1 TRUCKS
        TRANSFER     ,FIRSTA
*****************************************
*  START WITH 789 TRUCKS IN THE MINE     *
*****************************************
        GENERATE     3,,0,&NT789,,12PH,12PL
        ASSIGN       1,2,PH      THESE ARE NUMBER TWO TRUCKS
        TRANSFER     ,FIRSTB     789 TRUCKS AT SHOVEL 1
        GENERATE     3,,0,&NT789B,,12PH,12PL  NUMBER 789 AT LOADER1 AT
TIME 0
        ASSIGN       1,2,PH
        TRANSFER     ,FIRSTC
        GENERATE     3,,0,&NT789C,,12PH,12PL  NUMBER 789 AT LOADER 2 AT
TIME 0
        ASSIGN       1,2,PH    NUMBER THESE AS 2
        TRANSFER     SBR,ANIM,3PH
        BPUTPIC      FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE T789 T*
PLACE T* AT 48.21 20.54
        SEIZE        LOADER2    USE THE LOADER
        ADVANCE      RVNORM(1,2,.1)  LOAD A TRUCK
        RELEASE      LOADER2     FREE THE LOADER
        ASSIGN       1,RVNORM(1,195,4.5),PL   AMOUNT DUMPED
        BLET         &LL789D=&LL789D+1
        BLET         &XX789D=&XX789D+PL1
        TRANSFER     SBR,ANIM,3PH
        BPUTPIC
FILE=ATF,LINES=4,AC1,&LL789D,&XX789D,FR(LOADER2)/10.
TIME *.****
WRITE MESS114 ***
WRITE MESS115 *****.**
WRITE MESS119   **.**%
         ADVANCE     0

        TRANSFER     SBR,ANIM,3PH
        BPUTPIC      FILE=ATF,LINES=2,AC1,XID1
```

```
TIME *.****
SET T* CLASS T789L
 PLACEZZ  SEIZE        INTERAA    CHECK TO SEE IF WAY CLEAR
 TRAVEL   MACRO        &EEE,23,23,23    TRAVEL ON PATH 22
          RELEASE      INTERAA
 PLACE24  ADVANCE      0
 TRAVEL   MACRO        &FFF,24,24,24
 TRAVEL   MACRO        &GGG,25,25,25
          SEIZE        INTERA
 TRAVEL   MACRO        &HHH,AA25A,25A,25A
          RELEASE      INTERA
          TRANSFER     ,INTERB
********************************************
*  TRUCKS AT LOADER 1 AT START OF PROGRAM *
********************************************
 FIRSTC   TRANSFER     SBR,ANIM,3PH
          BPUTPIC      FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE T789 T*
PLACE T* AT 60.73 23.85
          SEIZE        LOADER1    USE THE LOADER
          ADVANCE      RVNORM(1,2,.1)  LOAD A TRUCK
          RELEASE      LOADER1    FREE THE LOADER
          ASSIGN       1,RVNORM(1,195,4.5),PL   AMOUNT DUMPED  IN 789 (TIME 0)
          BLET         &LL789C=&LL789C+1
          BLET         &XX789C=&XX789C+PL1
          TRANSFER     SBR,ANIM,3PH
          BPUTPIC
FILE=ATF,LINES=4,AC1,&LL789C,&XX789C,FR(LOADER1)/10.
TIME *.****
WRITE MESS108 ***
WRITE MESS109 *****.**
WRITE MESS118   **.**%
          ADVANCE      0

          TRANSFER     SBR,ANIM,3PH
          BPUTPIC      FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS T789L
 PATH20  ADVANCE      0
 TRAVEL  MACRO        &III,20,20,20    TRAVEL ON PATH 20

 TRAVEL   MACRO       &JJJ,21,21,21    TRAVEL ON PATH 21
          SEIZE       INTERAA         CHECK IF NO TRUCK COMING FROM LOADER
2
```

```
 TRAVEL   MACRO      &KKK,22,22,22    TRAVEL TO INTERSECTION AT
LOADER 2
         RELEASE     INTERAA         FREE THE INTERSECTION

         TRANSFER    ,PLACE24        GO ON ROAD SEGMENT 24

 FIRSTB   SEIZE      SHOVEL2
         TRANSFER    SBR,ANIM,3PH
         BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE T789  T*
PLACE T* AT 37.17 27.30
         ADVANCE     RVNORM(1,2.,.1)   ONLY FOR THE FIRST LOAD OF THE
DAY
         RELEASE     SHOVEL2       FREE THE SHOVEL
         ASSIGN      1,RVNORM(1,195,4.5),PL   LOAD A 798 AT START (ONLY)
         BLET        &LL789B=&LL789B+1   COUNT THE LOADS
         BLET        &XX789B=&XX789B+PL1
         TRANSFER    SBR,ANIM,3PH
         BPUTPIC     FILE=ATF,LINES=4,AC1,&LL789B,&XX789B,FR(SHOVEL2)/10.
TIME *.****
WRITE MESS104 ***
WRITE MESS105 *****.**
WRITE MESS117  **.**%
         ADVANCE    0
         TRANSFER    SBR,ANIM,3PH
         BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS T789L
 PATHP15  ADVANCE     0
 TRAVEL   MACRO      &AAA,15,15,15
 TRAVEL   MACRO      &BBB,16,16,16
         SEIZE       INTERA    CHECK FOR TRUCKS COMING FROM SHOVEL 1
 TRAVEL   MACRO      &CCC,AA16A,16A,16A
         RELEASE     INTERA    FREE INTERSECTION FOR TRUCKS FROM
SHOVEL 1
         TRANSFER    ,INTERB

 FIRSTA   SEIZE      SHOVEL1
         TRANSFER    SBR,ANIM,3PH
         BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE T793  T*
PLACE T* AT 20.45 8.67
```

```
        ADVANCE    RVNORM(1,1.2,.1)   ONLY FOR THE FIRST LOAD OF THE
DAY
        RELEASE    SHOVEL1       FREE THE SHOVEL
        ASSIGN     1,RVNORM(1,240,2.4),PL   AMOUNT DUMPED
        BLET       &LL793A=&LL793A+1
        BLET       &XX793A=&XX793A+PL1
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=4,AC1,&LL793A,&XX793A,FR(SHOVEL1)/10.
TIME *.****
WRITE MESS100 ***
WRITE MESS101 *****.**
WRITE MESS116   **.**%
        ADVANCE    0
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS T793L
*   LOADED TRUCK TRAVELS FROM POINT1 TO POINT 2
 PATHP1   ADVANCE    0
 TRAVEL   MACRO      &X,1,1,1
 TRAVEL   MACRO      &XXX,AA1A,1A,1A
 TRAVEL   MACRO      &Y,2,2,2
 TRAVEL   MACRO      &Z,3,3,3
        SEIZE      INTERA    ARE THERE TRUCKS FROM SHOVEL 2?
 TRAVEL   MACRO      &DDD,AA3A,3A,3A   TRAVEL TO OUR POINT 4
        RELEASE    INTERA
 INTERB   TRANSFER    .666,,WASTE
        TRANSFER   SBR,ANIM,3PH
        BLET       &TOTORE=&TOTORE+PL1   ADD TO TOTAL ORE
        BPUTPIC    FILE=ATF,LINES=2,AC1,&TOTORE
TIME *.****
WRITE M300 *****.**
        ADVANCE    0
        SEIZE      DUMMY1
 TRAVEL   MACRO      &R,AA5A,5A,5A
        RELEASE    DUMMY1
 TRAVEL   MACRO      &S,AA5B,5B,5B
        TRANSFER   .8,,TOPADS
 TRAVEL   MACRO      &T,AA6A,6A,6A
        SEIZE      LIME1      READY FOR LIME
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS TLIME
        ADVANCE    .5    WAIT A HALF MINUTE
```

```
         RELEASE     LIME1
 TRAVEL   MACRO      &U,AA6B,6B,6B
         SEIZE       LEACH1
         ADVANCE     .33    DUMP ONTO LEACH PADS
         RELEASE     LEACH1
         TEST E      PH1,1,NEXT2
         BLET        &O793D1=&O793D1+PL1
         BLET        &O793A=&O793A+1      COUNT THE LOADS
         BLET        &TOD1=&TOD1+PL1
         TRANSFER    SBR,ANIM,3PH
         BPUTPIC     FILE=ATF,LINES=5,AC1,&O793D1,&O793A,&TOD1,XID1
TIME *.****
WRITE MESS10 *****.**
WRITE MESS11    **
WRITE MESS12 *****.**
SET T* CLASS T793
  PLACELT ADVANCE     0
  TRAVEL  MACRO      &V,7,7,7        GO GET FUEL
         ADVANCE     RVNORM(1,10,1)    FUEL A TRUCK  - CHECK ON THIS!!
 TRAVEL   MACRO      &NNN,50,50,50  RETURN  TO LEACH PADS
 TRAVEL   MACRO      &PPP,49,49,49  TRAVEL TO INTERSECTION
         SEIZE       INTERC
 TRAVEL   MACRO      &QQQ,47,47,47
         RELEASE     INTERC
 PATH46   ADVANCE     0
 TRAVEL   MACRO      &RRR,46,46,46
         SEIZE       INTERB
 TRAVEL   MACRO      &XYZ8,45,45,45    TRAVEL TO INTERSECTION
         RELEASE     INTERB
         TRANSFER    ,INTERJ
 NEXT2    BLET       &AAAA=RVNORM(1,195,1.95)   AMOUNT DUMPED BY 789

         BLET        &O789D1=&O789D1+&AAAA
         BLET        &O789A=&O789A+1      COUNT THE LOADS
         BLET        &TOD1=&TOD1+&AAAA
         TRANSFER     SBR,ANIM,3PH
         BPUTPIC     FILE=ATF,LINES=5,AC1,&O789D1,&O789A,&TOD1,XID1
TIME *.****
WRITE MESS13 *****.**
WRITE MESS14    **
WRITE MESS12 *****.**
SET T* CLASS T789
         TRANSFER    ,PLACELT
  TOPADS  ADVANCE     0
  TRAVEL  MACRO      &W,8,8,8
```

```
        TRANSFER    .5,,LEACHP         50% OF THE TRUCKS GO TO THE ORE
CRUSHER
 TRAVEL  MACRO      &YYY,AA8A,8A,8A
        QUEUE      CRUSHER             TRUCKS AT CRUSHER
        SEIZE      CRUSHER
        DEPART     CRUSHER
        ADVANCE    .5      DUMP INTO CRUSHER
        RELEASE    CRUSHER
        TEST E     PH1,1,NEXT3
        REAL       &ORECA,&OTOTCA,&ORECB
        INTEGER    &LORECA,&LORECB

        BLET       &ABC1=RVNORM(1,240,2.4)   AMOUNT DUMPED

        BLET       &ORECA=&ORECA+&ABC1
        BLET       &LORECA=&LORECA+1      COUNT THE LOADS
        BLET       &OTOTCA=&OTOTCA+&ABC1
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=5,AC1,&ORECA,&LORECA,&OTOTCA,XID1
TIME *.****
WRITE MESS20 *****.**
WRITE MESS21    **
WRITE MESS22 *****.**
SET T* CLASS T793
        SEIZE      INTERD
 PLACEQQ ADVANCE     0
 TRAVEL  MACRO      &XX1,62,62,62      LEAVE CRUSHER
        RELEASE    INTERD
 PATH63  ADVANCE     0
 TRAVEL  MACRO      &XX2,63,63,63
        SEIZE      INTERC     CHECK FOR OTHER TRUCKS
 TRAVEL  MACRO      &XX3,64,64,64
        RELEASE    INTERC
        TRANSFER   ,PATH46

 NEXT3    BLET       &ABC2=RVNORM(1,195,2.4)   AMOUNT DUMPED

        BLET       &ORECB=&ORECB+&ABC2
        BLET       &LORECB=&LORECB+1      COUNT THE LOADS
        BLET       &OTOTCA=&OTOTCA+&ABC2
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=5,AC1,&ORECB,&LORECB,&OTOTCA,XID1
TIME *.****
WRITE MESS23 *****.**
WRITE MESS24    **
```

```
WRITE MESS22 *****.**
SET T* CLASS T789
        SEIZE      INTERD
        TRANSFER    ,PLACEQQ
 LEACHP  ADVANCE    0
 TRAVEL  MACRO      &ZZZ,AA9A,9A,9A
        TRANSFER    .75,,PADS3      25% GO TO FIRST LEACH PADS (C)
 TRAVEL  MACRO      &RRR,9,9,9       TRAVEL TO LEACH PAD AT OUR POINT
C
        QUEUE      LEACHC     JUST IN CASE MULTIPLE TRUCKS AT PADS
        SEIZE      LEACHC     HAVE ONLY ONE TRUCK DUMP
        DEPART     LEACHC
        ADVANCE    .5         DUMP ONTO LEACH PADS
        RELEASE    LEACHC     FREE THE LEACH C AREA
        TEST E     PH1,1,NEXT4

        REAL       &LP793,&LP789,&LPTOT
        INTEGER    &LP793I,&LP789I
        BLET       &YYZZ=RVNORM(1,240,2.4)   AMOUNT DUMPED

        BLET       &LP793=&LP793+&YYZZ
        BLET       &LP793I=&LP793I+1     COUNT THE LOADS
        BLET       &LPTOT=&LPTOT+&YYZZ
        BPUTPIC    FILE=ATF,LINES=5,AC1,&LP793,&LP793I,&LPTOT,XID1
TIME *.****
WRITE MESS30 *****.**
WRITE MESS31    **
WRITE MESS32 *****.**
SET T* CLASS T793
 PLACERR  ADVANCE    0
 TRAVEL  MACRO      &WW1,59,59,59       BACNK ON PATH 59
        SEIZE      INTERD
 TRAVEL  MACRO      &WW2,60,60,60
        RELEASE    INTERD
 PATH61  ADVANCE    0
 TRAVEL  MACRO      &WW3,61,61,61
        TRANSFER    ,PATH63

 NEXT4   BLET       &YYUU=RVNORM(1,195,2.4)   AMOUNT DUMPED

        BLET       &LP789=&LP789+&YYUU
        BLET       &LP789I=&LP789I+1     COUNT THE LOADS
        BLET       &LPTOT=&LPTOT+&YYUU
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=5,AC1,&LP789,&LP789I,&LPTOT,XID1
```

```
TIME *.****
WRITE MESS33 *****.**
WRITE MESS34    **
WRITE MESS32 *****.**
SET T* CLASS T789
        TRANSFER    ,PLACERR

 PADS3    ADVANCE     0        DUMMY ADVANCE BLOCKS TO 3 PADS
 TRAVEL   MACRO        &SSS,10,10,10        TO INTERSETCION OF THREE WAY
SPLIT
*******************************************************
*   TRUCKS ARE AT INTERSECTION.  THREE WAYS TO GO      *
*******************************************************
        TRANSFER    .666,,BLOCKA    GO TO ONE OF THREE PADS AREAS
 TRAVEL   MACRO      &TTT,13,13,13
        QUEUE      LEACHD    CALL IT LEACH D PADS
        SEIZE      LEACHD    PREPARE TO DUMP
        DEPART     LEACHD
        ADVANCE    .5       DUMP
        RELEASE    LEACHD

        TEST E     PH1,1,NEXT5
        REAL       &P793B,&PTOTB,&P789B
        INTEGER    &PT793B,&PT789B

        BLET       &ABC3=RVNORM(1,240,2.4)   AMOUNT DUMPED

        BLET       &P793B=&P793B+&ABC3
        BLET       &PT793B=&PT793B+1      COUNT THE LOADS
        BLET       &PTOTB=&PTOTB+&ABC3
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=5,AC1,&P793B,&PT793B,&PTOTB,XID1
TIME *.****
WRITE MESS40 *****.**
WRITE MESS41    **
WRITE MESS42 *****.**
SET T* CLASS T793
  PLACEVV ADVANCE     0
  TRAVEL  MACRO      &SUN1,55,55,55      LEAVE CRUSHER
        SEIZE      INTERE     CHECK FOR TRUCKS
  TRAVEL  MACRO      &SUN2,56,56,56
        RELEASE    INTERE
  PATH57  ADVANCE     0
  TRAVEL  MACRO      &SUN3,57,57,57
        SEIZE      INTERD     ARE THERE TRUCKS?
```

```
 TRAVEL  MACRO      &SUN4,58,58,58
        RELEASE     INTERD
        TRANSFER    ,PATH61

 NEXT5   BLET        &ABC4=RVNORM(1,195,2.4)   AMOUNT DUMPED

        BLET       &P789B=&P789B+&ABC4
        BLET       &PT789B=&PT789B+1      COUNT THE LOADS
        BLET       &PTOTB=&PTOTB+&ABC4
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=5,AC1,&P789B,&PT789B,&PTOTB,XID1
TIME *.****
WRITE MESS40 *****.**
WRITE MESS41    **
WRITE MESS42 *****.**
SET T* CLASS T789
        TRANSFER    ,PLACEVV

 BLOCKA   TRANSFER    .5,,BLOCKB
 TRAVEL   MACRO      &UUU,12,12,12
        QUEUE       LEACHE    CALL IT LEACH E PADS
        SEIZE       LEACHE    PREPARE TO DUMP
        DEPART      LEACHE
        ADVANCE     .5        DUMP
        RELEASE     LEACHE
        TEST E      PH1,1,NEXT6
        REAL        &P793C,&PTOTC,&P789C
        INTEGER     &PT793C,&PT789C

        BLET       &ABC5=RVNORM(1,240,2.4)   AMOUNT DUMPED

        BLET       &P793C=&P793C+&ABC5
        BLET       &PT793C=&PT793C+1      COUNT THE LOADS
        BLET       &PTOTC=&PTOTC+&ABC5
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=5,AC1,&PT793C,&PT793C,&PTOTC,XID1
TIME *.****
WRITE MESS60 *****.**
WRITE MESS61    **
WRITE MESS62 *****.**
SET T* CLASS T793
 PLACETT ADVANCE     0
 TRAVEL  MACRO      &MUN1,53,53,53      LEAVE CRUSHER
        SEIZE       INTERE
 TRAVEL  MACRO      &MUN2,54,54,54
```

```
         RELEASE     INTERE
         TRANSFER    ,PATH57

 NEXT6    BLET       &ABC6=RVNORM(1,195,2.4)   AMOUNT DUMPED

         BLET       &P789C=&P789C+&ABC6
         BLET       &PT789C=&PT789C+1      COUNT THE LOADS
         BLET       &PTOTC=&PTOTC+&ABC6
         TRANSFER    SBR,ANIM,3PH
         BPUTPIC     FILE=ATF,LINES=5,AC1,&P789C,&PT789C,&PTOTC,XID1
TIME *.****
WRITE MESS63 *****.**
WRITE MESS64    **
WRITE MESS62 *****.**
SET T* CLASS T789
         TRANSFER    ,PLACETT
 BLOCKB   ADVANCE     0
 TRAVEL   MACRO      &VVV,AA11A,11A,11A
         SEIZE      LIME2
         ADVANCE     .5     ADD LIME
         RELEASE     LIME2
         TRANSFER    SBR,ANIM,3PH
         BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS TLIME
 TRAVEL   MACRO      &WWW,AA11B,11B,11B
         QUEUE      LEACHF
         SEIZE      LEACHF
         DEPART     LEACHF
         ADVANCE     .5     DUMP A LOAD ONTO LEACH (WE CALL IT F)
         RELEASE     LEACHF
         TEST E      PH1,1,NEXT7
         REAL       &P793D,&PTOTD,&P789D
         INTEGER     &PT793D,&PT789D

         BLET       &ABC7=RVNORM(1,240,2.4)   AMOUNT DUMPED

         BLET       &P793D=&P793D+&ABC7
         BLET       &PT793D=&PT793D+1      COUNT THE LOADS
         BLET       &PTOTD=&PTOTD+&ABC7
         TRANSFER    SBR,ANIM,3PH
         BPUTPIC     FILE=ATF,LINES=5,AC1,&P793D,&PT793D,&PTOTD,XID1
TIME *.****
WRITE MESS50 *****.**
WRITE MESS51    **
```

```
WRITE MESS52 *****.**
SET T* CLASS T793
 PLACECC ADVANCE     0
 TRAVEL  MACRO       &TUN1,51,51,51      LEAVE CRUSHER
        SEIZE       INTERE      CHECK FOR TRUCKS
 TRAVEL  MACRO       &TUN2,52,52,52
        RELEASE     INTERE
        TRANSFER    ,PATH57
 NEXT7   BLET        &ABC8=RVNORM(1,195,2.4)   AMOUNT DUMPED

        BLET        &P789D=&P789D+&ABC8
        BLET        &PT789D=&PT789D+1      COUNT THE LOADS
        BLET        &PTOTD=&PTOTD+&ABC8
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=5,AC1,&P789D,&PT789D,&PTOTD,XID1
TIME *.****
WRITE MESS53 *****.**
WRITE MESS54    **
WRITE MESS52 *****.**
SET T* CLASS T789
        TRANSFER    ,PLACECC

 WASTE    SEIZE       DUMMY2
        BLET        &TOTWAS=&TOTWAS+PL1     ADD TO TOTAL WASTE
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1,&TOTWAS
TIME *.****
WRITE M301 ******.**
        ADVANCE     0
 TRAVEL   MACRO      &XX,AA4A,4A,4A
        RELEASE     DUMMY2
 TRAVEL   MACRO      &YY,AA4B,4B,4B
        TEST E      PH1,1,NEXT1
        ADVANCE     RVNORM(1,.5,.02)     793 DUMPS A LOAD OF WASTE
        REAL        &WST793,&WST789,&TOTWST,&XXXX,&YYYY
        INTEGER     &LOADW793,&LOADW789
        BLET        &XXXX=RVNORM(1,240,2.4)   ASSUME LOAD OF 793 IS THIS
        BLET        &TOTWST=&TOTWST+&XXXX    ADD TO TOTAL WASTE
        BLET        &WST793=&WST793+&XXXX    ADD TO WASTE FROM 793
        BLET        &LOADW793=&LOADW793+1    COUNT LOADS OF 793
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC
FILE=ATF,LINES=5,AC1,&WST793,&LOADW793,&TOTWST,XID1
TIME *.****
WRITE MESS1  *****.**
```

```
WRITE MESS2    ***
WRITE MESS3  *****.**
SET T* CLASS T793
 PATH30   ADVANCE    0
 TRAVEL   MACRO     &LLL,30,30,30   TRAVEL BACK TO INTERSECTION
          SEIZE     INTERB    IS INTERSECTION CLEAR
 TRAVEL   MACRO     &MMM,31,31,31   TRAVEL TO INTERSECTION
          RELEASE    INTERB      FREE THE INTERSECTION
**************************************************
*  READY FOR THE DISPATCHER                        *
*  COUNT THE TRUCKS GOING TO EACH PLACE            *
**************************************************
          INTEGER    &COUNT1,&COUNT2,&COUNT3,&COUNT4
 INTERJ   BLET
&COUNT1=W(PAT32)+W(PAT33)+W(PAT34)+W(PAT35)+W(PAT36)_
                +Q(LOADER2)+F(LOADER2)+F(SPOTL2)
          BLET      &COUNT2=W(PAT132)+W(PAT133)+W(PAT134)+W(PAT135)_
                +W(PAT37)+W(PAT38)+W(PAT39)+Q(LOADER1)+F(LOADER1)_
                +F(SPOTL1)
          BLET
&COUNT3=W(PAT40)+W(PAT41)+W(PAT42)+W(PAT43)+W(PAT44)_
                +Q(SHOVEL1)+F(SHOVEL1)+F(SPOTS1)
          BLET      &COUNT4=W(PAT65)+W(PAT66)+W(PAT67)+Q(SHOVEL2)_
                +F(SHOVEL2)+F(SPOTS2)
          TEST LE    &COUNT1,&COUNT2,LLOAD2
          TEST LE    &COUNT1,&COUNT3,LLOAD3
          TEST LE    &COUNT1,&COUNT4,LLOAD4
          TRANSFER   ,AREA2
   LLOAD2 TEST LE    &COUNT2,&COUNT3,LLOAD5
          TEST LE    &COUNT2,&COUNT4,LLOAD4
          TRANSFER   ,AREA1   TRUCKS TO TO LOADER 1
   LLOAD3 TEST LE    &COUNT3,&COUNT4,LLOAD4
          TRANSFER   ,AREA3     GO TO SHOVEL 1
   LLOAD4 TRANSFER   ,AREA4     GO TO SHOVEL 2
   LLOAD5 TEST LE    &COUNT3,&COUNT4,LLOAD6
          TRANSFER   ,AREA3
   LLOAD6 TRANSFER   ,AREA4
   AREA2  ADVANCE    0       TRUCKS GO TO LOADER 2
******************************************
*  SEND TRUCKS TO LOADER 2               *
 TRAVEL   MACRO      &XYZ1,32,32,32   RETURN ON PATH 32
 TRAVEL   MACRO      &XYZ2,33,33,33   TRAVEL ON PATH 33
 TRAVEL   MACRO      &XYZ3,34,34,34   TRAVEL ON PATH 34
 TRAVEL   MACRO      &XYZ4,35,35,35   TRAVEL ON PATH 35
 TRAVEL   MACRO      &XYZ5,36,36,36   TRAVEL TO LOADER 2
```

```
        QUEUE      LOADER2     JOIN QUEUE LOADER 2
        SEIZE      SPOTL2
        ADVANCE    FN(SPOTL2)
        RELEASE    SPOTL2
        SEIZE      LOADER2     SEE IF LOADER 2 IS FREE
        DEPART     LOADER2     LEAVE THE QUEUE
        TEST E     PH1,1,WWAIT1   SEE IF IT IS TRUCK 793
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=2,AC1,XID1
TIME *.****
PLACE T* AT 48.21 20.54
        ADVANCE    RVNORM(1,1.5,.1)    LOAD A T793
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS T793L
        RELEASE    LOADER2
        ASSIGN     1,RVNORM(1,240,2.4),PL   AMOUNT DUMPED
        BLET       &LL793D=&LL793D+1
        BLET       &XX793D=&XX793D+PL1
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC
FILE=ATF,LINES=4,AC1,&LL793D,&XX793D,FR(LOADER2)/10.
TIME *.****
WRITE MESS112 ***
WRITE MESS113 *****.**
WRITE MESS119   **.**%
        ADVANCE    0

        TRANSFER   ,PLACEZZ
 WWAIT1   TRANSFER    SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=2,AC1,XID1
TIME *.****
PLACE T* AT 48.59 20.19
        ADVANCE    RVNORM(1,1.1,.1)    LOAD A T793
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS T789L
        RELEASE    LOADER2
        ASSIGN     1,RVNORM(1,195,4.5),PL   AMOUNT DUMPED
        BLET       &LL789D=&LL789D+1
        BLET       &XX789D=&XX789D+PL1
        TRANSFER   SBR,ANIM,3PH
```

```
        BPUTPIC
FILE=ATF,LINES=4,AC1,&LL789D,&XX789D,FR(LOADER2)/10.
TIME *.****
WRITE MESS114 ***
WRITE MESS115 *****.**
WRITE MESS119   **.**%
        ADVANCE     0

        TRANSFER    ,PLACEZZ

 AREA1   ADVANCE    0
 TRAVEL  MACRO      &XYZ17,132,132,132
 TRAVEL  MACRO      &XYZ18,133,133,133
 TRAVEL  MACRO      &XYZ19,134,134,134
 TRAVEL  MACRO      &XYZ20,135,135,135
 TRAVEL  MACRO      &XYZ5,37,37,37
 TRAVEL  MACRO      &XYZ6,38,38,38
 TRAVEL  MACRO      &XYZ7,39,39,39
        QUEUE      LOADER1
        SEIZE      SPOTL1
        DEPART     LOADER1
        ADVANCE    FN(SPOTL1)    SPOT AT LOADER 2
        RELEASE    SPOTL1
        SEIZE      LOADER1
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=2,AC1,XID1
TIME *.****
PLACE T* AT 60.73 23.85
        TEST E     PH1,1,NEXT50     SEE WHAT TRUCK IT IS
        ADVANCE    RVNORM(1,1,.08)    LOAD AT 793
        RELEASE    LOADER1

        ASSIGN     1,RVNORM(1,240,4.5),PL   AMOUNT DUMPED
        BLET       &LL793C=&LL793C+1
        BLET       &XX793C=&XX793C+PL1
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC
FILE=ATF,LINES=4,AC1,&LL793C,&XX793C,FR(LOADER1)/10.
TIME *.****
WRITE MESS106 ***
WRITE MESS107 *****.**
WRITE MESS118   **.**%
        ADVANCE     0

        TRANSFER   SBR,ANIM,3PH
```

```
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS T793L
        TRANSFER    ,PATH20
 NEXT50   ADVANCE     RVNORM(1,.8,.1)  LOAD A 789
        RELEASE     LOADER1
        ASSIGN      1,RVNORM(1,195,4.5),PL   AMOUNT DUMPED
        BLET        &LL789C=&LL789C+1
        BLET        &XX789C=&XX789C+PL1
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC
FILE=ATF,LINES=4,AC1,&LL789C,&XX789C,FR(LOADER1)/10.
TIME *.****
WRITE MESS108 ***
WRITE MESS109 *****.**
WRITE MESS118   **.**%
        ADVANCE     0

        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS T789L
        TRANSFER    ,PATH20
 AREA3    ADVANCE     0
 TRAVEL   MACRO      &XYZ9,40,40,40
 TRAVEL   MACRO      &XYZ10,41,41,41
 TRAVEL   MACRO      &XYZ11,42,42,42
 TRAVEL   MACRO      &XYZ12,43,43,43
 TRAVEL   MACRO      &XYZ13,44,44,44
        QUEUE       SHOVEL1     TRUCKS ARE AT SHOVEL 1
        SEIZE       SPOTS1      SPOT
        DEPART      SHOVEL1     LEAVE THE QUEUE
        ADVANCE     FN(SPOTS1)   SPOT
        RELEASE     SPOTS1
        SEIZE       SHOVEL1     USE SHOVEL 1
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
PLACE T* AT  20.45 8.67
        TEST E      PH1,1,SMALL1
        ADVANCE     RVNORM(1,1.,.1)  LOAD A 793
        RELEASE     SHOVEL1
        ASSIGN      1,RVNORM(1,240,2.5),PL   AMOUNT LOADED INTO 793
        BLET        &LL793A=&LL793A+1       COUNT LOADS
        BLET        &XX793A=&XX793A+PL1     INCREMENT AMOUNT
```

```
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=4,AC1,&LL793A,&XX793A,FR(SHOVEL1)/10.
TIME *.****
WRITE MESS100 ***
WRITE MESS101 *****.**
WRITE MESS116   **.**%
        ADVANCE     0

        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS T793L
        TRANSFER    ,PATHP1
 SMALL1   ADVANCE     RVNORM(1,.8,.09)   LOAD AT 789 TRUCK
        RELEASE     SHOVEL1   FREE THE SHOVEL
        ASSIGN      1,RVNORM(1,195,4.5),PL   LOAD AT 195 TON TRUCK
        BLET        &LL789A=&LL789A+1
        BLET        &XX789A=&XX789A+PL1
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=4,AC1,&LL789A,&XX789A,FR(SHOVEL1)/10.
TIME *.****
WRITE MESS102 ***
WRITE MESS103 *****.**
WRITE MESS116  **.**%
        ADVANCE     0
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS T789L
        ADVANCE     0
        TRANSFER    ,PATHP1
  AREA4   ADVANCE     0
  TRAVEL  MACRO       &XYZ14,65,65,65
  TRAVEL  MACRO       &XYZ15,66,66,66
  TRAVEL  MACRO       &XYZ16,67,67,67
        QUEUE       SHOVEL2
        SEIZE       SPOTS2
        DEPART      SHOVEL2
        ADVANCE     FN(SPOTS2)     SPOT
        RELEASE     SPOTS2
        SEIZE       SHOVEL2
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
PLACE T* AT 37.17 27.30
```

```
        TEST E     PH1,1,SMALL2   CHECK FOR TRUCK TYPE
        ADVANCE     RVNORM(1,1,.08)    LOAD AT 793 TRUCK
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS T793L
        RELEASE     SHOVEL2
        ASSIGN      1,RVNORM(1,240,2.4),PL   AMOUNT DUMPED
        BLET        &LL793B=&LL793B+1
        BLET        &XX793B=&XX793B+PL1
        TRANSFER     SBR,ANIM,3PH
        BPUTPIC
FILE=ATF,LINES=4,AC1,&LL793B,&XX793B,FR(SHOVEL2)/10.
TIME *.****
WRITE MESS104 ***
WRITE MESS105 *****.**
WRITE MESS117   **.**%
        ADVANCE     0
        TRANSFER    ,PATHP15
 SMALL2   ADVANCE     RVNORM(1,.8,.07)   LOAD A 789 TRUCK
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS T789L
        RELEASE     SHOVEL2
        ASSIGN      1,RVNORM(1,195,4.5),PL   AMOUNT LOADED IN 789
        BLET        &LL789B=&LL789B+1
        BLET        &XX789B=&XX789B+PL1
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=4,AC1,&LL789B,&XX789B,FR(SHOVEL2)/10.
TIME *.****
WRITE MESS104 ***
WRITE MESS105 *****.**
WRITE MESS117   **.**%

        TRANSFER    ,PATHP15
*****************************************
 NEXT1    ADVANCE     RVNORM(1,.48,.02)     789 DUMPS A LOAD OF WASTE
        BLET        &YYYY=RVNORM(1,195,2.2)   ASSUME LOAD OF 789 IS THIS
        BLET        &TOTWST=&TOTWST+&YYYY   ADD TO TOTAL WASTE
        BLET        &WST789=&WST789+&YYYY    ADD TO WASTE FROM 789
        BLET        &LOADW789=&LOADW789+1    COUNT LOADS OF 789
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC
FILE=ATF,LINES=5,AC1,&WST789,&LOADW789,&TOTWST,XID1
```

```
TIME *.****
WRITE MESS4  *****.**
WRITE MESS5    ***
WRITE MESS3  *****.**
SET T* CLASS T789
          TRANSFER    ,PATH30

          TERMINATE

***********************************************
*   SEGMENT FOR SHOVEL 1 LOADING               *
***********************************************
          GENERATE    ,,,1,10      DUMMY TRANSACTION
 WAIT1    TEST E      F(SHOVEL1),1
          TRANSFER    SBR,ANIM,3PH
 WAIT2    BPUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
ROTATE BB1 45 STEP 3 TIME .25
          ADVANCE     .25
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
ROTATE BB1 -45 STEP 3 TIME .25
          ADVANCE     .25
          TEST E      F(SHOVEL1),1,WAIT1
          TRANSFER    ,WAIT2

***********************************************
*   SEGMENT FOR SHOVEL 2 LOADING               *
***********************************************
          GENERATE    ,,,1,10      DUMMY TRANSACTION
 WAIT3    TEST E      F(SHOVEL2),1
 WAIT4    TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
ROTATE BB2 45 STEP 3 TIME .25
          ADVANCE     .25
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
ROTATE BB2 -45 STEP 3 TIME .25
          ADVANCE     .25
          TEST E      F(SHOVEL2),1,WAIT3
          TRANSFER    ,WAIT4
***********************************************
```

```
*   SEGMENT FOR HYD. LOADER 2 MOVING          *
**********************************************
        GENERATE    ,,,1,10      DUMMY TRANSACTION
 WAIT5    TEST E      F(LOADER2),1
 WAIT6    TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
ROTATE SCOOP2 -45 STEP 3 TIME .25
        ADVANCE     .25
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
ROTATE SCOOP2 45 STEP 3 TIME .25
        ADVANCE     .25
        TEST E      F(LOADER2),1,WAIT5
        TRANSFER    ,WAIT6
**********************************************
*   SEGMENT FOR HYD. LOADER 1 MOVING          *
**********************************************
        GENERATE    ,,,1,10      DUMMY TRANSACTION
 WAIT7    TEST E      F(LOADER1),1
 WAIT8    TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
ROTATE SCOOP1 -45 STEP 3 TIME .25
        ADVANCE     .25
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
ROTATE SCOOP1 45 STEP 3 TIME .25
        ADVANCE     .25
        TEST E      F(LOADER1),1,WAIT7
        TRANSFER    ,WAIT8


*******************************************
*   CLOCK SEGMENT                        *
*******************************************
        INTEGER     &TIME,&DAYNO,&WKDAYNO,&WEEKNO,&HOUR
        GENERATE    ,,,1,150,12PL,12PH   DUMMY TRANSACTION FOR CLOCK
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1
TIME *.****
ROTATE MHAND1 SPEED -6 STEP 6
ROTATE HHAND1 SPEED -.5 STEP 6
```

```
        BLET       &HOUR=0
        BLET       &WKDAYNO=1
        BLET       &WEEKNO=1
NEXTMIN   ADVANCE     1      ADVANCE THE CLOCK ONE MINUTE
        BLET       &TIME=&TIME+1
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC
FILE=ATF,LINES=5,AC1,&TIME,&HOUR,&WKDAYNO,&WEEKNO
TIME *.****
WRITE MT1 **
WRITE MT2 **
WRITE MT3 **
WRITE MT4 **
        TEST E     &TIME@60,0,NEXTMIN
        BLET       &TIME=0
        BLET       &HOUR=&HOUR+1
        TEST E     &HOUR,24,NEXTMIN   24 HOURS PAST?
        BLET       &TIME=0
        BLET       &HOUR=0
        BLET       &DAYNO=&DAYNO+1
        BLET       &WKDAYNO=&WKDAYNO+1
        TEST E     &WKDAYNO,8,NEXTMIN  NEW WEEK?
        BLET       &WKDAYNO=1
        BLET       &WEEKNO=&WEEKNO+1
        TRANSFER    ,NEXTMIN
**************************************************
*            END CLOCK SEGMENT                  *
**************************************************
**************************************************
*  TIMER TRANSACTION COMES NEXT                  *
**************************************************
        GENERATE    ,,,1
*   ADVANCE   &DAYS*24*60*(23./24.)   23/24 AS FRACTION OF DAY
ACTUALLY WORKED)
        ADVANCE     1000
        TERMINATE   1
        START      1
***************************************************
*         SIMULATION RESULT DESPLAY              *
***************************************************
        PUTPIC
LINES=12,FR(SHOVEL1)/10,FR(SHOVEL2)/10,FR(LOADER1)/10,FR(LOADER2)/1
0,&TOTORE,&TOTWAS
UTILIZATION OF SHOVEL 1:  **.**%
```

```
UTILIZATION OF SHOVEL 2:  **.**%

UTILIZATION OF LOADER 1:  **.**%

UTILIZATION OF LOADER 2:  **.**%

TOTAL OF  ORE:  *****
TOTAL OF WASTE:  *****

************************************
        IF          &YES'E"Y'
        PUTPIC      FILE=ATF,LINES=2,AC1
TIME *.****
END
        ENDIF
        END
**************************************************
**************************************************
```

Second Simulation and Animation Model of the Large Gold Mine:

```
***********************************************************
*   SECOND SIMULATION AND ANIMATION OF THE GOLD MINE    *
*   (SECOND VERSION)              *
*   PROGRAMMED IN GPSS/H  BY                              *
*   EBRAHIM KARIMI TARSHIZI                            *
*  JOHN R. STURGUL                                *
***********************************************************
        SIMULATE
        RMULT       12345
        REALLOCATE  COM,1000000
ATF       FILEDEF     'GOLD2.ATF'
        INTEGER     &NT793A,&NT789A,&NT789B,&NT793B,&I
        INTEGER     &NT793C,&NT789C,&NT789D,&NT793D,&NT789E,&NT793E

        REAL
&T1,&T2,&T3,&T4,&T3A,&T4A,&T5,&T6,&T7,&T8,&T9,&T10,&T11,&T12
        REAL
&T13,&T14,&T15,&T16,&T17,&T18,&T19,&T20,&T21,&T22,&T23,&T24,&T25,&T
24B,&T25B
        REAL
&T28,&T28B,&T29,&T30,&T31,&T32,&T33,&T31B,&T32B,&T33B,&T34,&T35,&T
36,&T37,&T38
```

```
        REAL
&T39,&T40,&T41,&T42,&T43,&T44,&T45,&T46,&T47,&T49,&T50,&T51,&T52,&T
53,&T54
        REAL
&T51A,&T52A,&T54B,&T55,&T55B,&T5A,&T6A,&T5B,&T35A,&T34A,&T34B,&T
33A,&T31A,&T31C
        REAL
&T55A,&T54A,&T54C,&T49A,&T49B,&T24A,&T23A,&T23B,&T19A,&T15A,&T14
A,&T13A,&T13B,&T12A
        REAL
&T52C,&T51B,&T45A,&T44A,&T43A,&T43B,&T38A,&T25A,&T18A,&T1A,&T36
A,&T3B,&T4B,&T3C,&T4C
        REAL
&T29A,&T28C,&T29B,&T28A,&T41A,&T40A,&T40B,&T21A,&T47A,&T21B,&T20
A,&T20B,&T22A,&T21C,&T53A
        REAL
&A789,&A793,&B789,&B793,&C1,&C2,&TOTWST,&TAC,&TOTGAS,&TA,&T22B
,&T22C,&T23D,&T29D,&T30D
        REAL     &T47B,&T21D,&T56,&T57
        REAL     &AA789,&AA793,&BB789,&BB793,&C11,&C22,&TOTWST2
        REAL     &CC789,&DD789,&CC793,&DD793,&D1,&D2,&TOTWST3
        REAL     &EE789,&FF789,&EE793,&FF793,&E1,&E2,&TOTWST4
        REAL     &GG789,&HH789,&GG793,&HH793,&F1,&F2,&TOTWST5
        REAL     &II789,&JJ789,&II793,&JJ793,&G1,&G2,&TOTWST6
        REAL     &LL789,&KK789,&LL793,&KK793,&H1,&H2,&TOTWST7
        REAL     &VV789,&WW789,&VV793,&WW793,&Z1,&Z2,&TOTWST8
        REAL
&A793F,&B793F,&A789F,&B789F,&ALL793F,&BLL793F,&ALL789F,&BLL789F
        REAL
&AW789F,&BW789F,&AW793F,&BW793F,&AP793F,&BP793F,&AP789F,&BP789F
        REAL     &AL789F,&BL789F,&AL793F,&BL793F,&TT793,&TT789
**********************************
*    FUNCTION FOR PATHS
**********************************
TRIP1    FUNCTION  PH1,M2
1,RVNORM(1,.64,.03)/2,RVNORM(1,.64,.03)
TRIP1A    FUNCTION  PH1,M2
1,RVNORM(1,1,.05)/2,RVNORM(1,1,.05)
TRIP2    FUNCTION  PH1,M2
1,RVNORM(1,.41,.02)/2,RVNORM(1,.41,.02)
TRIP3    FUNCTION  PH1,M2
1,RVNORM(1,.49,.02)/2,RVNORM(1,.49,.02)
TRIP4    FUNCTION  PH1,M2
1,RVNORM(1,.16,.008)/2,RVNORM(1,.16,.008)
```

```
TRIP3B    FUNCTION  PH1,M2
1,RVNORM(1,.49,.02)/2,RVNORM(1,.49,.02)
TRIP4B    FUNCTION  PH1,M2
1,RVNORM(1,.16,.008)/2,RVNORM(1,.16,.008)

TRIP3C    FUNCTION  PH1,M2
1,RVNORM(1,.35,.017)/2,RVNORM(1,.35,.017)
TRIP4C    FUNCTION  PH1,M2
1,RVNORM(1,.12,.006)/2,RVNORM(1,.12,.006)

TRIP3A   FUNCTION  PH1,M2
1,RVNORM(1,.35,.017)/2,RVNORM(1,.35,.017)
TRIP4A   FUNCTION  PH1,M2
1,RVNORM(1,.12,.006)/2,RVNORM(1,.12,.006)

TRIP5    FUNCTION  PH1,M2
1,RVNORM(1,2.65,.13)/2,RVNORM(1,2.65,.13)
TRIP6     FUNCTION  PH1,M2
1,RVNORM(1,1.35,.06)/2,RVNORM(1,1.35,.06)

TRIP5A    FUNCTION  PH1,M2
1,RVNORM(1,1.44,.07)/2,RVNORM(1,1.44,.07)
TRIP5B     FUNCTION  PH1,M2
1,RVNORM(1,.16,.008)/2,RVNORM(1,.16,.008)
TRIP6A     FUNCTION  PH1,M2
1,RVNORM(1,1.2,.06)/2,RVNORM(1,1.2,.06)

TRIP7     FUNCTION  PH1,M2
1,RVNORM(1,.3,.015)/2,RVNORM(1,.3,.015)
TRIP8     FUNCTION  PH1,M2
1,RVNORM(1,0.77,.038)/2,RVNORM(1,0.77,.038)
TRIP9     FUNCTION  PH1,M2
1,RVNORM(1,2.9,.14)/2,RVNORM(1,2.9,.14)
TRIP10    FUNCTION  PH1,M2
1,RVNORM(1,.41,.02)/2,RVNORM(1,.41,.02)

TRIP11     FUNCTION  PH1,M2
1,RVNORM(1,.19,.009)/2,RVNORM(1,.19,.009)
TRIP12    FUNCTION  PH1,M2
1,RVNORM(1,1.96,.09)/2,RVNORM(1,1.96,.09)

TRIP12A    FUNCTION  PH1,M2
1,RVNORM(1,.32,.016)/2,RVNORM(1,.32,.016)

TRIP13     FUNCTION  PH1,M2
```

```
1,RVNORM(1,4.45,.22)/2,RVNORM(1,4.45,.22)
TRIP14    FUNCTION  PH1,M2
1,RVNORM(1,5.22,.26)/2,RVNORM(1,5.22,.26)
TRIP15     FUNCTION  PH1,M2
1,RVNORM(1,2.49,.12)/2,RVNORM(1,2.49,.12)
TRIP16    FUNCTION  PH1,M2
1,RVNORM(1,.14,.007)/2,RVNORM(1,.14,.007)
TRIP17    FUNCTION  PH1,M2
1,RVNORM(1,.4,.02)/2,RVNORM(1,.4,.02)

TRIP19A     FUNCTION  PH1,M2
1,RVNORM(1,.35,.02)/2,RVNORM(1,.35,.02)
TRIP15A    FUNCTION  PH1,M2
1,RVNORM(1,2.03,.1)/2,RVNORM(1,2.03,.1)
TRIP14A     FUNCTION  PH1,M2
1,RVNORM(1,3.2,.16)/2,RVNORM(1,3.2,.16)
TRIP13A    FUNCTION  PH1,M2
1,RVNORM(1,2.51,.13)/2,RVNORM(1,2.51,.13)
TRIP13B    FUNCTION  PH1,M2
1,RVNORM(1,.31,.016)/2,RVNORM(1,.31,.016)

TRIP18     FUNCTION  PH1,M2
1,RVNORM(1,.21,.01)/2,RVNORM(1,.21,.01)
TRIP18A     FUNCTION  PH1,M2
1,RVNORM(1,.12,.006)/2,RVNORM(1,.12,.006)
TRIP19    FUNCTION  PH1,M2
1,RVNORM(1,.28,.014)/2,RVNORM(1,.28,.014)
TRIP20     FUNCTION  PH1,M2
1,RVNORM(1,1.62,.08)/2,RVNORM(1,1.62,.08)
TRIP20A     FUNCTION  PH1,M2
1,RVNORM(1,1.37,.07)/2,RVNORM(1,1.37,.07)
TRIP20B     FUNCTION  PH1,M2
1,RVNORM(1,.35,.02)/2,RVNORM(1,.35,.02)
TRIP21    FUNCTION  PH1,M2                  CHECK ? AND FIX
1,RVNORM(1,2.5,.1)/2,RVNORM(1,2.5,.1)
TRIP21A    FUNCTION  PH1,M2
1,RVNORM(1,.4,.02)/2,RVNORM(1,.4,.02)
TRIP21B    FUNCTION  PH1,M2
1,RVNORM(1,.43,.02)/2,RVNORM(1,.43,.02)
TRIP21C    FUNCTION  PH1,M2
1,RVNORM(1,.36,.02)/2,RVNORM(1,.36,.02)
TRIP21D    FUNCTION  PH1,M2
1,RVNORM(1,.43,.02)/2,RVNORM(1,.43,.02)
TRIP22    FUNCTION  PH1,M2
1,RVNORM(1,1.48,.07)/2,RVNORM(1,1.48,.07)
```

```
TRIP22A    FUNCTION  PH1,M2
1,RVNORM(1,1.76,.09)/2,RVNORM(1,1.76,.09)

TRIP22B    FUNCTION  PH1,M2
1,RVNORM(1,.48,.02)/2,RVNORM(1,.48,.02)

TRIP22C    FUNCTION  PH1,M2
1,RVNORM(1,1,.05)/2,RVNORM(1,1,.05)

TRIP23     FUNCTION  PH1,M2
1,RVNORM(1,1.77,.09)/2,RVNORM(1,1.77,.09)
TRIP24    FUNCTION  PH1,M2
1,RVNORM(1,4.19,.21)/2,RVNORM(1,4.19,.21)
TRIP23A     FUNCTION  PH1,M2
1,RVNORM(1,1.88,.09)/2,RVNORM(1,1.88,.09)
TRIP23B    FUNCTION  PH1,M2
1,RVNORM(1,.3,.015)/2,RVNORM(1,.3,.015)

TRIP23D     FUNCTION  PH1,M2
1,RVNORM(1,.83,.04)/2,RVNORM(1,.83,.04)

TRIP24A    FUNCTION  PH1,M2
1,RVNORM(1,3.77,.19)/2,RVNORM(1,3.77,.19)
TRIP24B    FUNCTION  PH1,M2
1,RVNORM(1,.5,.1)/2,RVNORM(1,.5,.1)
TRIP25     FUNCTION  PH1,M2
1,RVNORM(1,6,.3)/2,RVNORM(1,6,.3)
TRIP25A     FUNCTION  PH1,M2
1,RVNORM(1,3.76,.19)/2,RVNORM(1,3.76,.19)
TRIP25B     FUNCTION  PH1,M2
1,RVNORM(1,6,.3)/2,RVNORM(1,6,.3)

TRIP28     FUNCTION  PH1,M2
1,RVNORM(1,4.22,.21)/2,RVNORM(1,4.22,.21)
TRIP28A     FUNCTION  PH1,M2
1,RVNORM(1,3.08,.15)/2,RVNORM(1,3.08,.15)
TRIP28B     FUNCTION  PH1,M2
1,RVNORM(1,1,.1)/2,RVNORM(1,.9,.1)
TRIP28C     FUNCTION  PH1,M2
1,RVNORM(1,1,.1)/2,RVNORM(1,.9,.1)

TRIP29    FUNCTION  PH1,M2
1,RVNORM(1,1.05,.05)/2,RVNORM(1,1.05,.05)
TRIP29D   FUNCTION  PH1,M2
1,RVNORM(1,1.05,.05)/2,RVNORM(1,1.05,.05)
```

```
TRIP29A   FUNCTION  PH1,M2
1,RVNORM(1,.85,.04)/2,RVNORM(1,.85,.04)
TRIP29B   FUNCTION  PH1,M2
1,RVNORM(1,.85,.04)/2,RVNORM(1,.85,.04)
TRIP30   FUNCTION  PH1,M2
1,RVNORM(1,.25,.01)/2,RVNORM(1,.25,.01)
TRIP30D   FUNCTION  PH1,M2
1,RVNORM(1,.25,.01)/2,RVNORM(1,.25,.01)
TRIP31    FUNCTION  PH1,M2
1,RVNORM(1,1.73,.09)/2,RVNORM(1,1.73,.09)
TRIP31A    FUNCTION  PH1,M2
1,RVNORM(1,.98,.05)/2,RVNORM(1,.98,.05)
TRIP31C    FUNCTION  PH1,M2
1,RVNORM(1,1.15,.08)/2,RVNORM(1,1.15,.08)
TRIP32   FUNCTION  PH1,M2
1,RVNORM(1,.49,.025)/2,RVNORM(1,.49,.025)
TRIP33   FUNCTION  PH1,M2
1,RVNORM(1,.14,.007)/2,RVNORM(1,.14,.007)
TRIP33A   FUNCTION  PH1,M2
1,RVNORM(1,.65,.03)/2,RVNORM(1,.65,.03)
TRIP31B    FUNCTION  PH1,M2
1,RVNORM(1,1.73,.09)/2,RVNORM(1,1.73,.09)
TRIP32B   FUNCTION  PH1,M2
1,RVNORM(1,.49,.025)/2,RVNORM(1,.49,.025)
TRIP33B   FUNCTION  PH1,M2
1,RVNORM(1,.14,.007)/2,RVNORM(1,.14,.007)
TRIP34   FUNCTION  PH1,M2
1,RVNORM(1,2.83,.14)/2,RVNORM(1,2.83,.14)
TRIP34A   FUNCTION  PH1,M2
1,RVNORM(1,2.31,.12)/2,RVNORM(1,2.31,.12)
TRIP34B   FUNCTION  PH1,M2
1,RVNORM(1,1.11,.006)/2,RVNORM(1,1.11,.006)
TRIP35   FUNCTION  PH1,M2
1,RVNORM(1,1.27,.06)/2,RVNORM(1,1.27,.06)
TRIP35A   FUNCTION  PH1,M2
1,RVNORM(1,1.08,.05)/2,RVNORM(1,1.08,.05)

TRIP36   FUNCTION  PH1,M2
1,RVNORM(1,.64,.03)/2,RVNORM(1,.64,.03)
TRIP36A   FUNCTION  PH1,M2
1,RVNORM(1,.82,.04)/2,RVNORM(1,.82,.04)
TRIP37   FUNCTION  PH1,M2
1,RVNORM(1,.29,.015)/2,RVNORM(1,.64,.03)

TRIP38   FUNCTION  PH1,M2
```

```
1,RVNORM(1,5.51,.28)/2,RVNORM(1,5.51,.28)

TRIP39    FUNCTION  PH1,M2
1,RVNORM(1,0.14,.007)/2,RVNORM(1,0.14,.007)
TRIP40    FUNCTION  PH1,M2
1,RVNORM(1,5.5,.28)/2,RVNORM(1,5.5,.28)
TRIP41    FUNCTION  PH1,M2
1,RVNORM(1,6.66,.33)/2,RVNORM(1,6.66,.33)
TRIP41A   FUNCTION  PH1,M2
1,RVNORM(1,5.75,.29)/2,RVNORM(1,5.75,.29)
TRIP40A   FUNCTION  PH1,M2
1,RVNORM(1,4.48,.22)/2,RVNORM(1,4.48,.22)
TRIP40B   FUNCTION  PH1,M2
1,RVNORM(1,.14,.007)/2,RVNORM(1,.14,.007)

TRIP42    FUNCTION  PH1,M2
1,RVNORM(1,.39,.02)/2,RVNORM(1,.39,.02)
TRIP43    FUNCTION  PH1,M2
1,RVNORM(1,4.73,.24)/2,RVNORM(1,4.73,.24)
TRIP44    FUNCTION  PH1,M2
1,RVNORM(1,5.13,.26)/2,RVNORM(1,5.13,.26)
TRIP45    FUNCTION  PH1,M2
1,RVNORM(1,2.6,.13)/2,RVNORM(1,2.6,.13)
TRIP46    FUNCTION  PH1,M2
1,RVNORM(1,.32,.016)/2,RVNORM(1,.32,.016)
TRIP47    FUNCTION  PH1,M2
1,RVNORM(1,.45,.02)/2,RVNORM(1,.45,.02)
TRIP47A    FUNCTION  PH1,M2
1,RVNORM(1,.16,.008)/2,RVNORM(1,.16,.008)
TRIP47B    FUNCTION  PH1,M2
1,RVNORM(1,.19,.01)/2,RVNORM(1,.19,.01)

TRIP52C     FUNCTION  PH1,M2
1,RVNORM(1,1.75,.09)/2,RVNORM(1,1.75,.09)
TRIP51B    FUNCTION  PH1,M2
1,RVNORM(1,.15,.008)/2,RVNORM(1,.15,.008)
TRIP45A     FUNCTION  PH1,M2
1,RVNORM(1,2.28,.11)/2,RVNORM(1,2.28,.11)
TRIP44A    FUNCTION  PH1,M2
1,RVNORM(1,3.57,.18)/2,RVNORM(1,3.57,.18)
TRIP43A    FUNCTION  PH1,M2
1,RVNORM(1,3.38,.17)/2,RVNORM(1,3.38,.17)
TRIP43B    FUNCTION  PH1,M2
1,RVNORM(1,.4,.02)/2,RVNORM(1,.4,.02)
TRIP38A    FUNCTION  PH1,M2
```

```
1,RVNORM(1,5.65,.28)/2,RVNORM(1,5.65,.28)

TRIP49    FUNCTION  PH1,M2
1,RVNORM(1,1.98,.1)/2,RVNORM(1,1.98,.1)
TRIP49A    FUNCTION  PH1,M2
1,RVNORM(1,1.62,.08)/2,RVNORM(1,1.62,.08)
TRIP49B    FUNCTION  PH1,M2
1,RVNORM(1,.05,.003)/2,RVNORM(1,.05,.003)
TRIP50   FUNCTION  PH1,M2
1,RVNORM(1,.15,.008)/2,RVNORM(1,.15,.008)
*TRIP51    FUNCTION  PH1,M2
*1,RVNORM(1,1.67,.084)/2,RVNORM(1,1.67,.084)
TRIP51A    FUNCTION  PH1,M2
1,RVNORM(1,.15,.008)/2,RVNORM(1,.15,.008)
*TRIP52    FUNCTION  PH1,M2
*1,RVNORM(1,.18,.01)/2,RVNORM(1,.18,.01)
TRIP52A    FUNCTION  PH1,M2
1,RVNORM(1,1.75,.09)/2,RVNORM(1,1.75,.09)

TRIP53   FUNCTION  PH1,M2
1,RVNORM(1,2.5,.1)/2,RVNORM(1,3,.1)
TRIP53A   FUNCTION  PH1,M2
1,RVNORM(1,2.5,.1)/2,RVNORM(1,3,.1)
TRIP54    FUNCTION  PH1,M2
1,RVNORM(1,6.57,.33)/2,RVNORM(1,6.57,.33)
TRIP54B    FUNCTION  PH1,M2
1,RVNORM(1,2.5,.1)/2,RVNORM(1,3,.1)
TRIP55    FUNCTION  PH1,M2
1,RVNORM(1,4.3,.22)/2,RVNORM(1,4.3,.22)
TRIP55B    FUNCTION  PH1,M2
1,RVNORM(1,4.3,.22)/2,RVNORM(1,4.3,.22)

TRIP55A    FUNCTION  PH1,M2
1,RVNORM(1,1.6,.08)/2,RVNORM(1,1.6,.08)
TRIP54A    FUNCTION  PH1,M2
1,RVNORM(1,6.33,.32)/2,RVNORM(1,6.33,.32)
TRIP54C    FUNCTION  PH1,M2
1,RVNORM(1,.29,.015)/2,RVNORM(1,.29,.015)

TRIP56    FUNCTION  PH1,M2
1,RVNORM(1,4.22,.2)/2,RVNORM(1,4.22,.2)
TRIP57    FUNCTION  PH1,M2
1,RVNORM(1,.16,.008)/2,RVNORM(1,.16,.008)

***********************************
```

```
*         SHOVEL 341
***********************************
LOAD1   FUNCTION    PH1,M2
1,FN(L1793)/2,FN(L1789)
L1793   FUNCTION    RN1,D7
0,2.208/0.0834,2.292/0.417,2.458/0.5,2.542/0.667,2.625/0.834,2.708/1,2.792
L1789   FUNCTION    RN1,D9
0,1.708/0.059,1.792/0.118,1.875/0.353,1.958/0.529,2.042/0.824,2.125/0.882,2.208/0.941,
2.375/1,2.458

SPOT341 FUNCTION    PH1,M2
1,FN(FIRST)/2,FN(SECOND)
FIRST   FUNCTION    RN1,D10
0,0.375/0.074,0.458/0.463,0.542/0.667,0.625/0.815,0.708/0.870,0.792/0.907,0.875/0.944,
0.958/0.963,1.042/1,1.292
SECOND   FUNCTION    RN1,D10
0,0.375/0.074,0.458/0.463,0.542/0.667,0.625/0.815,0.708/0.870,0.792/0.907,0.875/0.944,
0.958/0.963,1.042/1,1.292

***********************************
*         SHOVEL 342
***********************************
LOAD2     FUNCTION    PH1,M2
1,FN(L2793)/2,FN(L2789)
L2793     FUNCTION    RN1,D9
0,2.375/0.0714,2.458/0.214,2.542/0.429,2.625/0.571,2.708/0.786,2.792/0.857,3.042/0.92
9,3.292/1,3.375
L2789     FUNCTION    RN1,D6
0,1.542/0.111,1.625/0.444,1.792/0.556,1.875/0.667,2.042/1,2.292

SPOT342   FUNCTION    PH1,M2
1,FN(FIRST2)/2,FN(SECOND2)
FIRST2    FUNCTION    RN1,D10
0,0.375/0.074,0.458/0.463,0.542/0.667,0.625/0.815,0.708/0.870,0.792/0.907,0.875/0.944,
0.958/0.963,1.042/1,1.292
SECOND2   FUNCTION    RN1,D10
0,0.375/0.074,0.458/0.463,0.542/0.667,0.625/0.815,0.708/0.870,0.792/0.907,0.875/0.944,
0.958/0.963,1.042/1,1.292

***********************************
*         SHOVEL 343
***********************************
LOAD3     FUNCTION    PH1,M2
1,FN(L3793)/2,FN(L3789)
L3793     FUNCTION    RN1,D9
```

```
0,1.792/0.0769,1.875/0.231,2.125/0.462,2.208/0.538,2.292/0.692,2.375/0.846,2.542/0.92
3,2.708/1,1.417
L3789     FUNCTION    RN1,D9
0,1.708/0.059,1.792/0.118,1.875/0.353,1.958/0.529,2.042/0.824,2.125/0.882,2.208/0.941,
2.375/1,2.458

SPOT343   FUNCTION    PH1,M2
1,FN(FIRST3)/2,FN(SECOND3)
FIRST3    FUNCTION    RN1,D10
0,0.375/0.074,0.458/0.463,0.542/0.667,0.625/0.815,0.708/0.870,0.792/0.907,0.875/0.944,
0.958/0.963,1.042/1,1.292
SECOND3   FUNCTION    RN1,D10
0,0.375/0.074,0.458/0.463,0.542/0.667,0.625/0.815,0.708/0.870,0.792/0.907,0.875/0.944,
0.958/0.963,1.042/1,1.292

************************************
*         LOADER 1
************************************
LOADER1   FUNCTION    PH1,M2
1,RVNORM(1,4,.1)/2,RVNORM(1,5.1,.1)

SPOTL1    FUNCTION    PH1,M2
1,FN(FIRST4)/2,FN(SECOND4)
FIRST4    FUNCTION    RN1,D10
0,0.375/0.074,0.458/0.463,0.542/0.667,0.625/0.815,0.708/0.870,0.792/0.907,0.875/0.944,
0.958/0.963,1.042/1,1.292
SECOND4   FUNCTION    RN1,D10
0,0.375/0.074,0.458/0.463,0.542/0.667,0.625/0.815,0.708/0.870,0.792/0.907,0.875/0.944,
0.958/0.963,1.042/1,1.292

************************************
*         LOADER 2
************************************
LOADER2   FUNCTION    PH1,M2
1,RVNORM(1,4,.1)/2,RVNORM(1,5.1,.1)

SPOTL2  FUNCTION    PH1,M2
1,FN(FIRST5)/2,FN(SECOND5)
FIRST5    FUNCTION    RN1,D10
0,0.375/0.074,0.458/0.463,0.542/0.667,0.625/0.815,0.708/0.870,0.792/0.907,0.875/0.944,
0.958/0.963,1.042/1,1.292
SECOND5   FUNCTION    RN1,D10
0,0.375/0.074,0.458/0.463,0.542/0.667,0.625/0.815,0.708/0.870,0.792/0.907,0.875/0.944,
0.958/0.963,1.042/1,1.292
```

```
***********************************
*     DUMP TIME AT DUMPS
***********************************
DUMP1     FUNCTION    PH1,M2
1,FN(FDUMP1)/2,FN(FDUMP2)
FDUMP1    FUNCTION    RN1,D12
0,0.83/0.03,0.92/0.06,1/0.11,1.08/0.25,1.17/0.44,1.25/0.69,1.33/0.81,1.42/0.89,1.5/0.92,1
.58/0.97,1.67/1,1.75
FDUMP2    FUNCTION    RN1,D8
0,1.042/0.068,1.125/0.182,1.208/0.5,1.292/0.841,1.375/0.932,1.458/0.977,1.542/1,1.625

DUMP2     FUNCTION    PH1,M2
1,FN(FDUMP3)/2,FN(FDUMP4)
FDUMP3    FUNCTION    RN1,D12
0,0.83/0.03,0.92/0.06,1/0.11,1.08/0.25,1.17/0.44,1.25/0.69,1.33/0.81,1.42/0.89,1.5/0.92,1
.58/0.97,1.67/1,1.75
FDUMP4    FUNCTION    RN1,D8
0,1.042/0.068,1.125/0.182,1.208/0.5,1.292/0.841,1.375/0.932,1.458/0.977,1.542/1,1.625

LDUMP     FUNCTION    PH1,M2
1,FN(FDUMP5)/2,FN(FDUMP6)
FDUMP5    FUNCTION    RN1,D12
0,0.83/0.03,0.92/0.06,1/0.11,1.08/0.25,1.17/0.44,1.25/0.69,1.33/0.81,1.42/0.89,1.5/0.92,1
.58/0.97,1.67/1,1.75
FDUMP6    FUNCTION    RN1,D8
0,1.042/0.068,1.125/0.182,1.208/0.5,1.292/0.841,1.375/0.932,1.458/0.977,1.542/1,1.625

***********************************
*     DUMP TIME AT STOCKPILES
***********************************
STOCK1     FUNCTION    PH1,M2
1,FN(FSTOCK1)/2,FN(FSTOCK2)
FSTOCK1    FUNCTION    RN1,D12
0,0.83/0.03,0.92/0.06,1/0.11,1.08/0.25,1.17/0.44,1.25/0.69,1.33/0.81,1.42/0.89,1.5/0.92,1
.58/0.97,1.67/1,1.75
FSTOCK2    FUNCTION    RN1,D8
0,1.042/0.068,1.125/0.182,1.208/0.5,1.292/0.841,1.375/0.932,1.458/0.977,1.542/1,1.625

STOCK2     FUNCTION    PH1,M2
1,FN(FSTOCK3)/2,FN(FSTOCK4)
FSTOCK3    FUNCTION    RN1,D12
0,0.83/0.03,0.92/0.06,1/0.11,1.08/0.25,1.17/0.44,1.25/0.69,1.33/0.81,1.42/0.89,1.5/0.92,1
.58/0.97,1.67/1,1.75
FSTOCK4    FUNCTION    RN1,D8
0,1.042/0.068,1.125/0.182,1.208/0.5,1.292/0.841,1.375/0.932,1.458/0.977,1.542/1,1.625
```

```
***********************************
*     DUMP TIME AT CRUSHER
***********************************
CRUSHER     FUNCTION    PH1,M2
1,FN(FCRU1)/2,FN(FCRU2)
FCRU1    FUNCTION    RN1,D12
0,0.83/0.03,0.92/0.06,1/0.11,1.08/0.25,1.17/0.44,1.25/0.69,1.33/0.81,1.42/0.89,1.5/0.92,1
.58/0.97,1.67/1,1.75
FCRU2    FUNCTION    RN1,D8
0,1.042/0.068,1.125/0.182,1.208/0.5,1.292/0.841,1.375/0.932,1.458/0.977,1.542/1,1.625

***********************************
*     DUMP TIME AT LEACHPADS
***********************************
LEACH1     FUNCTION    PH1,M2
1,FN(FLEACH1)/2,FN(FLEACH2)
FLEACH1    FUNCTION    RN1,D12
0,0.83/0.03,0.92/0.06,1/0.11,1.08/0.25,1.17/0.44,1.25/0.69,1.33/0.81,1.42/0.89,1.5/0.92,1
.58/0.97,1.67/1,1.75
FLEACH2    FUNCTION    RN1,D8
0,1.042/0.068,1.125/0.182,1.208/0.5,1.292/0.841,1.375/0.932,1.458/0.977,1.542/1,1.625

LEACH2     FUNCTION    PH1,M2
1,FN(FLEACH3)/2,FN(FLEACH4)
FLEACH3    FUNCTION    RN1,D12
0,0.83/0.03,0.92/0.06,1/0.11,1.08/0.25,1.17/0.44,1.25/0.69,1.33/0.81,1.42/0.89,1.5/0.92,1
.58/0.97,1.67/1,1.75
FLEACH4    FUNCTION    RN1,D8
0,1.042/0.068,1.125/0.182,1.208/0.5,1.292/0.841,1.375/0.932,1.458/0.977,1.542/1,1.625

*****************************************************
*        FUNCTION PART FOR DIVITION
*****************************************************
DIV1  FUNCTION  RN1,D2
.74,BLOCKA/1,BLOCKB                  74% OF TRUCKS GO TO DUPMS, 26% GO
TO CRUSHER, LEACH FROM 341      &
DIV1B  FUNCTION  RN1,D2
.72,BLOCKAB/1,BLOCKBB                 72% OF TRUCKS GO TO DUPMS, 28% GO
TO CRUSHER, LEACH FROM 341   &

DIVX  FUNCTION  RN1,D2
.05,BLOCKU1/1,BLOCKU2                  5% OF TRUCKS GO TO NORTH RAMP
(NEXT PIT), 95% GO DUMP1 &DUMP2    &
```

```
DIV2  FUNCTION  RN1,D2
.265,BLOCKC/1,BLOCKD                    26.5% OF TRUCKS GO TO DUPM1, 73.5%
GO TO DUMP2  &
DIV3  FUNCTION  RN1,D2
.189,BLOCKE1/1,BLOCKE2                18.9% OF TRUCKS GO TO OXID
STOCKPILE(2), 81.1% GO TO CRUSHER AND STOCK(1)  &
DIV4  FUNCTION  RN1,D2
.484,BLOCKF1/1,BLOCKF2                 48.4% OF TRUCKS GO TO LEACHPAD
SOUTH, 51.6% GO TO CRUSHER AND STOCK (1)                 &
DIV5  FUNCTION  RN1,D2
.834,BLOCKG1/1,BLOCKG2                 83.4% OF TRUCKS GO TO CRUSHER,
16.6% GO TO STOCK (1)                &
DIV5B  FUNCTION  RN1,D2
.78,BLOCKT1/1,BLOCKT2                  78% OF TRUCKS GO TO STOCK (1), 22%
GO LEACH SOUTH    &

DIV6  FUNCTION  RN1,D2
.75,BLOCKH1/1,BLOCKH2                  75% OF TRUCKS GO TO LIME, 25% GO TO
LEACH SOUTH   &
DIV7  FUNCTION  RN1,D2
.82,BLOCKI1/1,BLOCKI2                  82% OF TRUCKS GO TO NORTH RAMP, 18%
GO TO SOUTH RAMP  &
DIV8  FUNCTION  RN1,D2
.738,BLOCKJ1/1,BLOCKJ2                 73.8% OF TRUCKS GO TO LARGE DUMP,
26.2% GO TO LEACHPAD WEST (2)        & CRUSHER FROM 342 & LOADER 2
DIV10  FUNCTION  RN1,D2
.99,BLOCKP1/1,BLOCKP2                  99% GO TO LEACHPAD WEST , %1 GO TO
CRUSHER FROM NORTH RAMP     &
DIV10A  FUNCTION  RN1,D2
.538,BLOCKS1/1,BLOCKS2                 53.8% GO TO CRUSHER, %48.2 GO TO
STOCK 2 & LEACH SOUTH      &

DIV12  FUNCTION  RN1,D2
.75,BLOCKV1/1,BLOCKV2                      75% OF TRUCKS GO TO LIME THEN
LEACH, 25% GO TO LEACHPAD WEST (2) &


DIV13  FUNCTION  RN1,D3
.2,BLOCKR1/.6,BLOCKR2/1,BLOCKR3                  20% OF TRUCKS GO TO GAS,
40% OF TRUCKS GO NORTH RAMP, 40% GO TO SOUTH RAMP (SHOVEL 342)
DIV14  FUNCTION  RN1,D2
.5,BLOCKQ1/1,BLOCKQ2                   50% OF TURCKS COME BACK TO NORTH,
50% OF TRUCKS COME BACK TO 341, L2 FROM CRUSHER
DIV15  FUNCTION  RN1,D2
```

```
.5,BLOCKZ1/1,BLOCKZ2                    50% OF TURCKS COME BACK TO 342, 50%
OF TRUCKS COME BACK TO 341, L2 FROM STOCKPILE 1

DIVGAS FUNCTION  RN1,D2
.5,BLOCKY1/1,BLOCKY2                    50% OF TURCKS COME BACK TO NORTH,
50% OF TRUCKS COME BACK TO SOUTH

************************************
*  START MACRO DEFINITIONS         *
************************************
 TRAVEL  STARTMACRO
        BLET        #A=FN(#B)
        TRANSFER     SBR,ANIM,3PH
        BPUTPIC      FILE=ATF,LINES=3,AC1,XID1,XID1,#A
TIME *.****
PLACE T* ON P#C
SET T* TRAVEL **.**
PAT#D    ADVANCE     #A
        ENDMACRO
************************************
        DO        &I=1,80
        PUTSTRING   ('  ')
        ENDDO
        PUTSTRING    ('  ')
        PUTSTRING    ('                   *** SIMULATION MODEL ***')
        PUTSTRING    ('  ')
        PUTSTRING    ('  ')
AGAIN    PUTSTRING    ('   INPUT THE NUMBER OF 793 TRUCKS AT SHOVEL
341')
        PUTSTRING    ('  ')
        GETLIST      &NT793A
        PUTSTRING    ('  ')
        PUTSTRING    ('   INPUT THE NUMBER OF 789 TRUCKS AT SHOVEL 341')
        PUTSTRING    ('  ')
        GETLIST      &NT789A
        PUTSTRING    ('  ')
        PUTSTRING    ('   INPUT THE NUMBER OF 793 TRUCKS AT SHOVEL 342')
        PUTSTRING    ('  ')
        GETLIST      &NT793B
        PUTSTRING    ('  ')
        PUTSTRING    ('   INPUT THE NUMBER OF 789 TRUCKS AT SHOVEL 342')
        PUTSTRING    ('  ')
        GETLIST      &NT789B
        PUTSTRING    ('  ')
        PUTSTRING    ('   INPUT THE NUMBER OF 793 TRUCKS AT SHOVEL 343')
```

```
        PUTSTRING   ('  ')
        GETLIST     &NT793C
        PUTSTRING   ('  ')
        PUTSTRING   ('   INPUT THE NUMBER OF 789 TRUCKS AT SHOVEL 343')
        PUTSTRING   ('  ')
        GETLIST     &NT789C
        PUTSTRING   ('  ')
        PUTSTRING   ('   INPUT THE NUMBER OF 793 TRUCKS AT LOADER 1')
        PUTSTRING   ('  ')
        GETLIST     &NT793D
        PUTSTRING   ('  ')
        PUTSTRING   ('   INPUT THE NUMBER OF 789 TRUCKS AT LOADER 1')
        PUTSTRING   ('  ')
        GETLIST     &NT789D
        PUTSTRING   ('  ')
        PUTSTRING   ('   INPUT THE NUMBER OF 793 TRUCKS AT LOADER 2')
        PUTSTRING   ('  ')
        GETLIST     &NT793E
        PUTSTRING   ('  ')
        PUTSTRING   ('   INPUT THE NUMBER OF 789 TRUCKS AT LOADER 2')
        PUTSTRING   ('  ')
        GETLIST     &NT789E
        PUTSTRING   ('  ')
        CHAR*1      &ANS
*   &ANS IS CHAR*1     VARIABLE THAT IS YES OR NO
        PUTSTRING   ('   ARE YOU HAPPY WITH THESE VALUES? (Y/N)')
        PUTSTRING   ('  ')
        GETLIST     &ANS
        IF          &ANS'NE"Y'
        GOTO   AGAIN
        ENDIF
        PUTSTRING   ('  ')
        PUTSTRING   ('  DO YOU WANT ANIMATION? (Y/N)')
        CHAR*1      &YES
        GETLIST     &YES
ANIM     TEST E       &YES,'Y',PH3+2
        TRANSFER     ,PH3+1
        IF          &YES'E"Y'
        ENDIF
        PUTSTRING   ('  ')
        PUTSTRING   ('  ')
        PUTSTRING   ('  ** SIMULATION RESULTS **')
        PUTSTRING   ('  ')
        PUTSTRING   ('  ')
        LET         &TT793=&NT793A+&NT793B+&NT793C+&NT793D+&NT793E
```

```
        LET        &TT789=&NT789A+&NT789B+&NT789C+&NT789D+&NT789E
        PUTPIC     FILE=ATF,LINES=3,AC1,&TT793,&TT789
TIME *.****
WRITE NT1 **
WRITE NT2 **

***********************************************
*                 GENERATE TRUCKS AT SHOVEL 341
***********************************************
        GENERATE   1,,4,&NT793A,,12PL,12PH    TRUCKS
        ASSIGN     1,1,PH
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE F793 T*
PLACE T* AT 40.81 -22.49
        TRANSFER   ,POINTA1

***********************************************
        GENERATE   2,,5.2,&NT789A,,12PL,12PH
        ASSIGN     1,2,PH
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE F789 T*
PLACE T* AT 40.90 -23.81
POINTA1  ADVANCE    0
        SEIZE      SHOV341
        ADVANCE    FN(LOAD1)
        TEST E     PH1,1,TYPE2A
        ASSIGN     1,RVNORM(1,240,5),PL     AMOUNT LOAD BY SHOVEL 341-
TRUCK 793
        BLET       &A793F=&A793F+1
        BLET       &B793F=&B793F+PL1
        RELEASE    SHOV341
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=4,AC1,&A793F,&B793F,FR(SHOV341)/10.
TIME *.****
WRITE M1  ***
WRITE M2  *****.**
WRITE M3  **.**%
        TRANSFER   ,PATHP1

TYPE2A   ADVANCE    0
```

```
        ASSIGN      1,RVNORM(1,195,5),PL      AMOUNT LOAD BY SHOVEL 341-
TRUCK 789
        BLET       &A789F=&A789F+1
        BLET       &B789F=&B789F+PL1
        RELEASE     SHOV341
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=4,AC1,&A789F,&B789F,FR(SHOV341)/10.
TIME *.****
WRITE M4  ***
WRITE M5  *****.**
WRITE M3  **.**%
        TRANSFER    ,PATHP1

**********************************************
*           GENERATE TRUCKS AT LOADER 2
**********************************************
        GENERATE    1,,5.5,&NT793E,,12PL,12PH
        ASSIGN      1,1,PH
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE F793 T*
PLACE T* AT 38.06 -16.60
        TRANSFER    ,POINTA2

***********************************************
        GENERATE    2,,3,&NT789D,,12PL,12PH
        ASSIGN      1,2,PH
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE F789 T*
PLACE T* AT 38.06 -16.60
POINTA2   ADVANCE     0
        SEIZE       LOADER2
        ADVANCE     FN(LOADER2)
        TEST E      PH1,1,TYPE22L
        ASSIGN      1,RVNORM(1,240,5),PL      AMOUNT LOAD BY LOADER 2-
TRUCK 793
        BLET       &ALL793F=&ALL793F+1
        BLET       &BLL793F=&BLL793F+PL1
        RELEASE     LOADER2
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC
FILE=ATF,LINES=4,AC1,&ALL793F,&BLL793F,FR(LOADER2)/10.
```

```
TIME *.****
WRITE M6  ***
WRITE M7  *****.**
WRITE M8  **.**%
        TRANSFER    ,PATHP36

TYPE22L   ADVANCE     0
        ASSIGN      1,RVNORM(1,195,5),PL      AMOUNT LOAD BY LOADER2-
TRUCK 789
        BLET        &ALL789F=&ALL789F+1
        BLET        &BLL789F=&BLL789F+PL1
        RELEASE     LOADER2
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC
FILE=ATF,LINES=4,AC1,&ALL789F,&BLL789F,FR(LOADER2)/10.
TIME *.****
WRITE M9  ***
WRITE M10  *****.**
WRITE M8  **.**%
PATHP36   ADVANCE    0
TRAVEL    MACRO       &T36,TRIP36,36,36
        SEIZE       INTERF        CHECK IF NO TRUCK COMING
TRAVEL    MACRO       &T37,TRIP37,37,37
        RELEASE     INTERF        FREE THE INTERSECTION
        TRANSFER    ,FN(DIV1B)
********************************
PATHP1    ADVANCE     0
TRAVEL    MACRO       &T1,TRIP1,1,1
        SEIZE       INTERA        CHECK IF NO TRUCK COMING
TRAVEL    MACRO       &T2,TRIP2,2,2
        RELEASE     INTERA        FREE THE INTERSECTION
        TRANSFER    ,FN(DIV1)
BLOCKA    ADVANCE     0
TRAVEL    MACRO       &T3,TRIP3,3,3
        SEIZE       INTERB        CHECK IF NO TRUCK COMING
TRAVEL    MACRO       &T4,TRIP4,4,4
        RELEASE     INTERB        FREE THE INTERSECTION
BLOCKAB   ADVANCE     0
TRAVEL    MACRO       &T5,TRIP5,5,5
        TRANSFER    ,FN(DIVX)

BLOCKU1   ADVANCE     0
TRAVEL    MACRO       &T56,TRIP56,56,56
        SEIZE       INTERW        CHECK IF NO TRUCK COMING
TRAVEL    MACRO       &T57,TRIP57,57,57
```

```
        RELEASE     INTERW       FREE THE INTERSECTION
        TRANSFER    ,PATHP32B

BLOCKU2   ADVANCE     0
TRAVEL    MACRO      &T6,TRIP6,6,6
        SEIZE       INTERC       CHECK IF NO TRUCK COMING
TRAVEL    MACRO      &T7,TRIP7,7,7
        RELEASE     INTERC       FREE THE INTERSECTION
        TRANSFER    ,FN(DIV2)    FUNCTION FOR DUMP1 & DUMP2
BLOCKC    ADVANCE     0
TRAVEL    MACRO      &T8,TRIP8,8,8

*********************************
*        DUMP-1
*********************************
        SEIZE       DUMP1
        ADVANCE     FN(DUMP1)    DUMP TIMES AT DUMP1
        TEST E      PH1,1,TYPE2B
        BLET        &C1=RVNORM(1,240,5)   ASSUME LOAD OF 793 IS THIS
        ASSIGN      1,RVNORM(1,240,5),PL
        BLET        &A793=&A793+1
        BLET        &B793=&B793+PL1
        BLET        &TOTWST=&TOTWST+&C1    ADD TO TOTAL WASTE
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=4,AC1,&A793,&B793,&TOTWST
TIME *.****
WRITE MD1  ***
WRITE MD2  *****.**
WRITE MD3  ******.**
        RELEASE     DUMP1
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS E793
        TRANSFER    ,PATHP10
TYPE2B    ADVANCE     0
        BLET        &C2=RVNORM(1,195,5)   ASSUME LOAD OF 789 IS THIS
        ASSIGN      1,RVNORM(1,195,5),PL
        BLET        &A789=&A789+1
        BLET        &B789=&B789+PL1
        BLET        &TOTWST=&TOTWST+&C2    ADD TO TOTAL WASTE
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=4,AC1,&A789,&B789,&TOTWST
TIME *.****
WRITE MD4  ***
```

```
WRITE MD5  *****.**
WRITE MD3  ******.**

          RELEASE     DUMP1
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS E789
PATHP10   ADVANCE     0
TRAVEL    MACRO       &T10,TRIP10,10,10
          SEIZE       INTERD        CHECK IF NO TRUCK COMING
TRAVEL    MACRO       &T11,TRIP11,11,11
          RELEASE     INTERD        FREE THE INTERSECTION
PATHP6A   ADVANCE     0
TRAVEL    MACRO       &T6A,TRIP6A,6A,6A
TRAVEL    MACRO       &T5A,TRIP5A,5A,5A
          SEIZE       INTERF        CHECK IF NO TRUCK COMING
TRAVEL    MACRO       &T5B,TRIP5B,5B,5B
          RELEASE     INTERF        FREE THE INTERSECTION
****************************************************
*  READY FOR THE DISPATCHER LOADER2 & 341 (NORTH)   *
*  COUNT THE TRUCKS GOING TO EACH PLACE             *
****************************************************
          INTEGER     &COUNT3,&COUNT4
          BLET        &COUNT3=W(PAT13A)+Q(LOADER2)+F(LOADER2)+F(SPOTL2)
          BLET        &COUNT4=W(PAT1A)+W(PAT4C)+W(PAT3C)_
                  +Q(SHOV341)+F(SHOV341)+F(SPOT341)
          TEST LE     &COUNT3,&COUNT4,SHOV22
          TRANSFER    ,AREA3        GO TO LOADER 2
SHOV22    TRANSFER    ,AREA4        GO TO SHOVEL 341

AREA3     ADVANCE     0
TRAVEL    MACRO       &T36A,TRIP36A,36A,36A

***************************************************
*           LOADER  2
***************************************************
          QUEUE       LOADER2
          SEIZE       SPOTL2
          ADVANCE     FN(SPOTL2)
          RELEASE     SPOTL2
          SEIZE       LOADER2
          ADVANCE     FN(LOADER2)
          TEST E      PH1,1,TYPE2AE
          DEPART      LOADER2
```

```
        ASSIGN      1,RVNORM(1,240,5),PL      AMOUNT LOAD BY LOADER 2-
TRUCK 793
        BLET       &ALL793F=&ALL793F+1
        BLET       &BLL793F=&BLL793F+PL1
        RELEASE     LOADER2
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC
FILE=ATF,LINES=4,AC1,&ALL793F,&BLL793F,FR(LOADER2)/10.
TIME *.****
WRITE M6  ***
WRITE M7  *****.**
WRITE M8  **.**%
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS F793
        TRANSFER    ,PATHP36

TYPE2AE   ADVANCE     0
        DEPART      LOADER2
        ASSIGN      1,RVNORM(1,195,5),PL      AMOUNT LOAD BY LOADER2-
TRUCK 789
        BLET       &ALL789F=&ALL789F+1
        BLET       &BLL789F=&BLL789F+PL1
        RELEASE     LOADER2
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC
FILE=ATF,LINES=4,AC1,&ALL789F,&BLL789F,FR(LOADER2)/10.
TIME *.****
WRITE M9  ***
WRITE M10  *****.**
WRITE M8  **.**%
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS F789
        TRANSFER    ,PATHP36

AREA4     ADVANCE    0
TRAVEL    MACRO      &T4C,TRIP4C,4C,4C
        SEIZE      INTERA       CHECK IF NO TRUCK COMING
TRAVEL    MACRO      &T3C,TRIP3C,3C,3C
        RELEASE     INTERA       FREE THE INTERSECTION
        TRANSFER    ,AREA1
```

```
BLOCKD   ADVANCE    0
TRAVEL   MACRO      &T9,TRIP9,9,9

*********************************
*        DUMP-2
*********************************
         SEIZE      DUMP2
         ADVANCE    FN(DUMP2)    DUMP TIMES AT DUMP2
         TEST E     PH1,1,TYPE2BB
         BLET       &C11=RVNORM(1,240,5)   ASSUME LOAD OF 793 IS THIS
         ASSIGN     1,RVNORM(1,240,5),PL
         BLET       &AA793=&AA793+1
         BLET       &BB793=&BB793+PL1
         BLET       &TOTWST2=&TOTWST2+&C11    ADD TO TOTAL WASTE
         TRANSFER   SBR,ANIM,3PH
         BPUTPIC    FILE=ATF,LINES=4,AC1,&AA793,&BB793,&TOTWST2
TIME *.****
WRITE MD6  ***
WRITE MD7  *****.**
WRITE MD8  ******.**
         RELEASE    DUMP2
         TRANSFER   SBR,ANIM,3PH
         BPUTPIC    FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS E793
         TRANSFER   ,PATHP12
TYPE2BB  ADVANCE    0
         BLET       &C22=RVNORM(1,195,5)   ASSUME LOAD OF 789 IS THIS
         ASSIGN     1,RVNORM(1,195,5),PL
         BLET       &AA789=&AA789+1
         BLET       &BB789=&BB789+PL1
         BLET       &TOTWST2=&TOTWST2+&C22    ADD TO TOTAL WASTE
         TRANSFER   SBR,ANIM,3PH
         BPUTPIC    FILE=ATF,LINES=4,AC1,&AA789,&BB789,&TOTWST2
TIME *.****
WRITE MD9  ***
WRITE MD10  *****.**
WRITE MD8  ******.**

         RELEASE    DUMP2
         TRANSFER   SBR,ANIM,3PH
         BPUTPIC    FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS E789
PATHP12  ADVANCE    0
```

```
TRAVEL   MACRO      &T12,TRIP12,12,12
         SEIZE      INTERC      CHECK IF NO TRUCK COMING
TRAVEL   MACRO      &T12A,TRIP12A,12A,12A
         RELEASE    INTERC      FREE THE INTERSECTION
         TRANSFER   ,PATHP6A

BLOCKBB  ADVANCE    0
TRAVEL   MACRO      &T4A,TRIP4A,4A,4A
         SEIZE      INTERA      CHECK IF NO TRUCK COMING
TRAVEL   MACRO      &T3A,TRIP3A,3A,3A
         RELEASE    INTERA      FREE THE INTERSECTION
         TRANSFER   ,BLOCKB


BLOCKB   ADVANCE    0           WAY FROM SHOVEL 341 TO CRUSHER-LEACH
TRAVEL   MACRO      &T13,TRIP13,13,13
TRAVEL   MACRO      &T14,TRIP14,14,14
TRAVEL   MACRO      &T15,TRIP15,15,15
         SEIZE      INTERE      CHECK IF NO TRUCK COMING
TRAVEL   MACRO      &T16,TRIP16,16,16
         RELEASE    INTERE      FREE THE INTERSECTION
         TRANSFER   ,FN(DIV3)          STOCKPILE(2) & CRUSHER, LEACHPAD
BLOCKE1  ADVANCE    0
TRAVEL   MACRO      &T17,TRIP17,17,17
****************************************
*        DUMP-STOCKPILE 2
****************************************
         SEIZE      STOCK2
         ADVANCE    FN(STOCK2)     DUMP TIMES AT DUMP2
         TEST E     PH1,1,TYPE2C
         BLET       &D1=RVNORM(1,240,5)   ASSUME LOAD OF 793 IS THIS
         ASSIGN     1,RVNORM(1,240,5),PL
         BLET       &CC793=&CC793+1
         BLET       &DD793=&DD793+PL1
         BLET       &TOTWST3=&TOTWST3+&D1     ADD TO TOTAL WASTE
         TRANSFER   SBR,ANIM,3PH
         BPUTPIC    FILE=ATF,LINES=4,AC1,&CC793,&DD793,&TOTWST3
TIME *.****
WRITE MD11  ***
WRITE MD12  *****.**
WRITE MD13  ******.**
         RELEASE    STOCK2
         TRANSFER   SBR,ANIM,3PH
         BPUTPIC    FILE=ATF,LINES=2,AC1,XID1
TIME *.****
```

```
SET T* CLASS E793
         TRANSFER    ,PATHP18
TYPE2C   ADVANCE     0
          BLET       &D2=RVNORM(1,195,5)   ASSUME LOAD OF 789 IS THIS
          ASSIGN      1,RVNORM(1,195,5),PL
          BLET       &CC789=&CC789+1
          BLET       &DD789=&DD789+PL1
          BLET       &TOTWST3=&TOTWST3+&D2     ADD TO TOTAL WASTE
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=4,AC1,&CC789,&DD789,&TOTWST3
TIME *.****
WRITE MD14  ***
WRITE MD15  *****.**
WRITE MD13  ******.**

          RELEASE     STOCK2
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS E789
PATHP18   ADVANCE     0
TRAVEL    MACRO       &T18,TRIP18,18,18
          SEIZE       INTERE       CHECK IF NO TRUCK COMING
TRAVEL    MACRO       &T18A,TRIP18A,18A,18A
          RELEASE     INTERE       FREE THE INTERSECTION
          TRANSFER    ,PATHP15A

BLOCKE2   ADVANCE     0
          SEIZE       INTERW       CHECK IF NO TRUCK COMING
TRAVEL    MACRO       &T19,TRIP19,19,19
          RELEASE     INTERW       FREE THE INTERSECTION
          TRANSFER    ,FN(DIV4)            STOCKPILE(1), CRUSHER & LEACHPAD
BLOCKF2   ADVANCE     0
TRAVEL    MACRO       &T20,TRIP20,20,20
          TRANSFER    ,FN(DIV5)            STOCKPILE(1) & CRUSHER
BLOCKG1   ADVANCE     0             CRUSHER
TRAVEL    MACRO       &T21,TRIP21,21,21
WESTCR    ADVANCE     0
*****************************************
*        DUMP CRUSHER
*****************************************
          SEIZE       CRUSHER
          ADVANCE     FN(CRUSHER)     DUMP TIMES AT CRUSHER
          TEST E      PH1,1,TYPE2D
          BLET       &E1=RVNORM(1,240,5)   ASSUME LOAD OF 793 IS THIS
```

```
        ASSIGN      1,RVNORM(1,240,5),PL
        BLET        &EE793=&EE793+1
        BLET        &FF793=&FF793+PL1
        BLET        &TOTWST4=&TOTWST4+&E1     ADD TO TOTAL WASTE
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=4,AC1,&EE793,&FF793,&TOTWST4
TIME *.****
WRITE MD16  ***
WRITE MD17  *****.**
WRITE MD18  ******.**
        RELEASE     CRUSHER
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS E793
       TRANSFER     ,PATHP21A
TYPE2D   ADVANCE     0
        BLET        &E2=RVNORM(1,195,5)   ASSUME LOAD OF 789 IS THIS
        ASSIGN      1,RVNORM(1,195,5),PL
        BLET        &EE789=&EE789+1
        BLET        &FF789=&FF789+PL1
        BLET        &TOTWST4=&TOTWST4+&E2     ADD TO TOTAL WASTE
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=4,AC1,&EE789,&FF789,&TOTWST4
TIME *.****
WRITE MD19  ***
WRITE MD20  *****.**
WRITE MD18  ******.**

        RELEASE     CRUSHER
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS E789
PATHP21A  ADVANCE     0
TRAVEL    MACRO       &T21A,TRIP21A,21A,21A
        TRANSFER    ,FN(DIV14)
BLOCKQ1   ADVANCE     0
PATHP47A  ADVANCE     0
TRAVEL    MACRO       &T47A,TRIP47A,47A,47A
        TRANSFER    ,PATHP45A

BLOCKQ2   ADVANCE     0
TRAVEL    MACRO       &T21B,TRIP21B,21B,21B
BLOCKZ2   ADVANCE     0
```

```
TRAVEL    MACRO      &T20A,TRIP20A,20A,20A
          SEIZE      INTERW       CHECK IF NO TRUCK COMING
TRAVEL    MACRO      &T20B,TRIP20B,20B,20B
          RELEASE    INTERW       FREE THE INTERSECTION
          TRANSFER   ,PATHP19A

PATHP22   ADVANCE    0
BLOCKG2   ADVANCE    0            STOCK1
TRAVEL    MACRO      &T22,TRIP22,22,22
          TRANSFER   ,FN(DIV5B)
BLOCKT1   ADVANCE    0
TRAVEL    MACRO      &T22B,TRIP22B,22B,22B

****************************************
*         DUMP STOCKPILE 1
****************************************
          SEIZE      STOCK1
          ADVANCE    FN(STOCK1)    DUMP TIMES AT CRUSHER
          TEST E     PH1,1,TYPE2E
          BLET       &F1=RVNORM(1,240,5)   ASSUME LOAD OF 793 IS THIS
          ASSIGN     1,RVNORM(1,240,5),PL
          BLET       &GG793=&GG793+1
          BLET       &HH793=&HH793+PL1
          BLET       &TOTWST5=&TOTWST5+&F1    ADD TO TOTAL WASTE
          TRANSFER   SBR,ANIM,3PH
          BPUTPIC    FILE=ATF,LINES=4,AC1,&GG793,&HH793,&TOTWST5
TIME *.****
WRITE MD21  ***
WRITE MD22  *****.**
WRITE MD23  ******.**
          RELEASE    STOCK1
          TRANSFER   SBR,ANIM,3PH
          BPUTPIC    FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS E793
          TRANSFER   ,PATHP22A
TYPE2E    ADVANCE    0
          BLET       &F2=RVNORM(1,195,5)   ASSUME LOAD OF 789 IS THIS
          ASSIGN     1,RVNORM(1,195,5),PL
          BLET       &GG789=&GG789+1
          BLET       &HH789=&HH789+PL1
          BLET       &TOTWST5=&TOTWST5+&F2    ADD TO TOTAL WASTE
          TRANSFER   SBR,ANIM,3PH
          BPUTPIC    FILE=ATF,LINES=4,AC1,&GG789,&HH789,&TOTWST5
TIME *.****
```

```
WRITE MD24  ***
WRITE MD25  *****.**
WRITE MD23  ******.**

          RELEASE     STOCK1
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS E789
PATHP22A  ADVANCE     0
TRAVEL    MACRO       &T22A,TRIP22A,22A,22A
          TRANSFER    ,FN(DIV15)        RETURN FROM STOCKPILE 1 RO 342 AND
341-LOADER 2
BLOCKZ1   ADVANCE     0
TRAVEL    MACRO       &T21C,TRIP21C,21C,21C
          TRANSFER    ,PATHP47A

BLOCKF1   ADVANCE     0              LEACH SOUTH
TRAVEL    MACRO       &T23,TRIP23,23,23
          TRANSFER    ,PATHP23D

BLOCKT2   ADVANCE     0
TRAVEL    MACRO       &T22C,TRIP22C,22C,22C
PATHP23D  ADVANCE     0
TRAVEL    MACRO       &T23D,TRIP23D,23D,23D
TRAVEL    MACRO       &T24,TRIP24,24,24
          TRANSFER    ,FN(DIV6)           LIME
BLOCKH1   ADVANCE     0
TRAVEL    MACRO       &T24B,TRIP24B,24B,24B
*************************************
*         LIME1
*************************************
          SEIZE       LIME1
          ADVANCE     RVNORM(1,1,.2)
          TEST E      PH1,1,TYPE2L1
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,FC(LIME1)
TIME *.****
SET T* CLASS F793L
WRITE LIME1  ***
          RELEASE     LIME1
          TRANSFER    ,PATHP25
TYPE2L1   TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,FC(LIME1)
TIME *.****
```

```
SET T* CLASS F789L
WRITE LIME1  ***
        RELEASE     LIME1
PATHP25   ADVANCE     0
TRAVEL    MACRO       &T25,TRIP25,25,25
        TRANSFER    ,AWAYL1
BLOCKH2   ADVANCE     0
TRAVEL    MACRO       &T25B,TRIP25B,25B,25B
AWAYL1    ADVANCE     0
****************************************
*         DUMP LEACHPAD (SOUTH)
****************************************
        SEIZE       LEACH1
        ADVANCE     FN(LEACH1)     DUMP TIMES AT LEACHPAD (SOUTH)
        TEST E      PH1,1,TYPE2F
        BLET        &G1=RVNORM(1,240,5)   ASSUME LOAD OF 793 IS THIS
        ASSIGN      1,RVNORM(1,240,5),PL
        BLET        &II793=&II793+1
        BLET        &JJ793=&JJ793+PL1
        BLET        &TOTWST6=&TOTWST6+&G1     ADD TO TOTAL WASTE
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=4,AC1,&II793,&JJ793,&TOTWST6
TIME *.****
WRITE MD26  ***
WRITE MD27  *****.**
WRITE MD28  ******.**
        RELEASE     LEACH1
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS E793
        TRANSFER    ,PATHP25A
TYPE2F   ADVANCE     0
        BLET        &G2=RVNORM(1,195,5)   ASSUME LOAD OF 789 IS THIS
        ASSIGN      1,RVNORM(1,195,5),PL
        BLET        &II789=&II789+1
        BLET        &JJ789=&JJ789+PL1
        BLET        &TOTWST6=&TOTWST6+&G2     ADD TO TOTAL WASTE
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=4,AC1,&II789,&JJ789,&TOTWST6
TIME *.****
WRITE MD29  ***
WRITE MD30  *****.**
WRITE MD28  ******.**
```

```
         RELEASE     LEACH1
         TRANSFER    SBR,ANIM,3PH
         BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS E789
PATHP25A  ADVANCE     0
TRAVEL    MACRO      &T25A,TRIP25A,25A,25A
TRAVEL    MACRO      &T24A,TRIP24A,24A,24A
TRAVEL    MACRO      &T23A,TRIP23A,23A,23A
         SEIZE       INTERW       CHECK IF NO TRUCK COMING
TRAVEL    MACRO      &T23B,TRIP23B,23B,23B
         RELEASE     INTERW       FREE THE INTERSECTION
PATHP19A  ADVANCE     0
TRAVEL    MACRO      &T19A,TRIP19A,19A,19A
PATHP15A  ADVANCE     0
TRAVEL    MACRO      &T15A,TRIP15A,15A,15A
TRAVEL    MACRO      &T14A,TRIP14A,14A,14A
TRAVEL    MACRO      &T13A,TRIP13A,13A,13A
         SEIZE       INTERA       CHECK IF NO TRUCK COMING
TRAVEL    MACRO      &T13B,TRIP13B,13B,13B
         RELEASE     INTERA       FREE THE INTERSECTION
****************************************************
*  READY FOR THE DISPATCHER LOADER2 & 341          *
*  COUNT THE TRUCKS GOING TO EACH PLACE            *
****************************************************
         INTEGER     &COUNT1,&COUNT2
         BLET        &COUNT1=W(PAT1A)+Q(SHOV341)+F(SHOV341)+F(SPOT341)
         BLET
&COUNT2=W(PAT3)+W(PAT4)+W(PAT3B)+W(PAT4B)+W(PAT36A)_
               +Q(LOADER2)+F(LOADER2)+F(SPOTL2)
         TEST LE     &COUNT1,&COUNT2,LOAD22
         TRANSFER    ,AREA1       GO TO SHOVEL341
LOAD22    TRANSFER    ,AREA2       GO TO SHOVEL LOADER2

AREA1     ADVANCE     0
TRAVEL    MACRO      &T1A,TRIP1A,1A,1A
************************************************
*        SHOVEL 341
************************************************
         QUEUE       SHOV341
         TRANSFER    BOTH,,NEXT1
         SEIZE       SPOT341
         TRANSFER    SBR,ANIM,3PH
         BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
```

```
PLACE T* AT 40.81 -22.49
        ADVANCE    FN(SPOT341)
        RELEASE    SPOT341
        SEIZE      SHOV341
        ADVANCE    FN(LOAD1)
        TRANSFER   ,DUABLE2
NEXT1   SEIZE      SPOT341B
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=2,AC1,XID1
TIME *.****
PLACE T* AT 40.90 -23.81
        ADVANCE    FN(SPOT341)
        RELEASE    SPOT341B
        SEIZE      SHOV341
        ADVANCE    FN(LOAD1)
DUABLE2  ADVANCE    0
        TEST E     PH1,1,TYPE2AQ
        DEPART     SHOV341
        ASSIGN     1,RVNORM(1,240,5),PL     AMOUNT LOAD BY SHOVEL 341-
TRUCK 793
        BLET       &A793F=&A793F+1
        BLET       &B793F=&B793F+PL1
        RELEASE    SHOV341
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=4,AC1,&A793F,&B793F,FR(SHOV341)/10.
TIME *.****
WRITE M1  ***
WRITE M2  *****.**
WRITE M3  **.**%
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS F793
        TRANSFER   ,PATHP1

TYPE2AQ  ADVANCE    0
        DEPART     SHOV341
        ASSIGN     1,RVNORM(1,195,5),PL     AMOUNT LOAD BY SHOVEL 341-
TRUCK 789
        BLET       &A789F=&A789F+1
        BLET       &B789F=&B789F+PL1
        RELEASE    SHOV341
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=4,AC1,&A789F,&B789F,FR(SHOV341)/10.
TIME *.****
```

```
WRITE M4  ***
WRITE M5  *****.**
WRITE M3  **.**%
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS F789
        TRANSFER    ,PATHP1

AREA2     ADVANCE     0
TRAVEL    MACRO       &T3B,TRIP3B,3B,3B
        SEIZE       INTERF       CHECK IF NO TRUCK COMING
TRAVEL    MACRO       &T4B,TRIP4B,4B,4B
        RELEASE     INTERF       FREE THE INTERSECTION
        TRANSFER    ,AREA3

***********************************************
*           GENERATE TRUCKS AT LOADER 1
***********************************************
        GENERATE    1,,7,&NT793D,,12PL,12PH
        ASSIGN      1,1,PH
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE F793 T*
PLACE T* AT -20.22 -18.69
        TRANSFER    ,POINTA3

************************************************
        GENERATE    2,,3.2,&NT789D,,12PL,12PH
        ASSIGN      1,2,PH
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE F789 T*
PLACE T* AT -20.22 -18.69
POINTA3   ADVANCE     0
        SEIZE       LOADER1
        ADVANCE     FN(LOADER1)
        TEST E      PH1,1,TYPE2L
        ASSIGN      1,RVNORM(1,240,5),PL      AMOUNT LOAD BY LOADER 1-
TRUCK 793
        BLET        &AL793F=&AL793F+1
        BLET        &BL793F=&BL793F+PL1
        RELEASE     LOADER1
```

```
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=4,AC1,&AL793F,&BL793F,FR(LOADER1)/10.
TIME *.****
WRITE M11  ***
WRITE M12  *****.**
WRITE M13  **.**%
        TRANSFER    ,PATHP28

TYPE2L    ADVANCE     0
        ASSIGN      1,RVNORM(1,195,5),PL      AMOUNT LOAD BY LOADER 1-
TRUCK 789
        BLET        &AL789F=&AL789F+1
        BLET        &BL789F=&BL789F+PL1
        RELEASE     LOADER1
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=4,AC1,&AL789F,&BL789F,FR(LOADER1)/10.
TIME *.****
WRITE M14  ***
WRITE M15  *****.**
WRITE M13  **.**%
        TRANSFER    ,PATHP28

**********************************************
*           GENERATE TRUCKS AT SHOVEL 343
**********************************************
        GENERATE    1,,5,&NT793C,,12PL,12PH
        ASSIGN      1,1,PH
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE F793 T*
PLACE T* AT -22.64 -11.08
        TRANSFER    ,POINTA4

***********************************************
        GENERATE    2,,2,&NT789C,,12PL,12PH
        ASSIGN      1,2,PH
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE F789 T*
PLACE T* AT -20.22 -18.69
POINTA4   ADVANCE     0
        SEIZE       SHOV343
        ADVANCE     FN(LOAD3)
```

```
        TEST E      PH1,1,TYPE2P
        ASSIGN      1,RVNORM(1,240,5),PL      AMOUNT LOAD BY SHOVEL 343-
TRUCK 793
        BLET        &AP793F=&AP793F+1
        BLET        &BP793F=&BP793F+PL1
        RELEASE     SHOV343
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=4,AC1,&AP793F,&BP793F,FR(SHOV343)/10.
TIME *.****
WRITE M16  ***
WRITE M17  *****.**
WRITE M18  **.**%
        TRANSFER    ,PATHP28B

TYPE2P    ADVANCE     0
        ASSIGN      1,RVNORM(1,195,5),PL      AMOUNT LOAD BY SHOVEL 343-
TRUCK 789
        BLET        &AP789F=&AP789F+1
        BLET        &BP789F=&BP789F+PL1
        RELEASE     SHOV343
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=4,AC1,&AP789F,&BP789F,FR(SHOV343)/10.
TIME *.****
WRITE M19  ***
WRITE M20  *****.**
WRITE M18  **.**%
PATHP28B  ADVANCE    0
        SEIZE       INTERI       CHECK IF NO TRUCK COMING
TRAVEL    MACRO       &T28B,TRIP28B,28B,28B
        RELEASE     INTERI       FREE THE INTERSECTION
TRAVEL    MACRO       &T29D,TRIP29D,29D,29D
        SEIZE       INTERG       CHECK IF NO TRUCK COMING
TRAVEL    MACRO       &T30D,TRIP30D,30D,30D
        RELEASE     INTERG       FREE THE INTERSECTION
        TRANSFER    ,AWAY2

*********************************************
*           GENERATE TRUCKS AT SHOVEL 342
*********************************************
        GENERATE    1,,8,&NT793B,,12PL,12PH
        ASSIGN      1,1,PH
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE F793 T*
```

```
PLACE T* AT -5.14 -19.66
          TRANSFER    ,POINTA5

***********************************************
          GENERATE    2,,7,&NT789B,,12PL,12PH
          ASSIGN      1,2,PH
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE F789 T*
PLACE T* AT -5.14 -19.66
POINTA5   ADVANCE     0
          SEIZE       SHOV342
          ADVANCE     FN(LOAD2)
          TEST E      PH1,1,TYPE2R
          ASSIGN      1,RVNORM(1,240,5),PL      AMOUNT LOAD BY SHOVEL 342-
TRUCK 793
          BLET        &AW793F=&AW793F+1
          BLET        &BW793F=&BW793F+PL1
          RELEASE     SHOV342
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC
FILE=ATF,LINES=4,AC1,&AW793F,&BW793F,FR(SHOV342)/10.
TIME *.****
WRITE M21  ***
WRITE M22  *****.**
WRITE M23  **.**%
          TRANSFER    ,PATHP38

TYPE2R    ADVANCE     0
          ASSIGN      1,RVNORM(1,195,5),PL      AMOUNT LOAD BY SHOVEL 343-
TRUCK 789
          BLET        &AW789F=&AW789F+1
          BLET        &BW789F=&BW789F+PL1
          RELEASE     SHOV342
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC
FILE=ATF,LINES=4,AC1,&AW789F,&BW789F,FR(SHOV342)/10.
TIME *.****
WRITE M24  ***
WRITE M25  *****.**
WRITE M23  **.**%
PATHP38   ADVANCE     0
TRAVEL    MACRO       &T38,TRIP38,38,38
          SEIZE       INTERJ       CHECK IF NO TRUCK COMING
```

```
TRAVEL    MACRO      &T39,TRIP39,39,39
          RELEASE    INTERJ       FREE THE INTERSECTION
          TRANSFER   ,FN(DIV7)
BLOCKI1   ADVANCE    0            NORTH RAMP TO CRUSHER & LEACH
TRAVEL    MACRO      &T40,TRIP40,40,40
TRAVEL    MACRO      &T41,TRIP41,41,41
          SEIZE      INTERG       CHECK IF NO TRUCK COMING
TRAVEL    MACRO      &T42,TRIP42,42,42
          RELEASE    INTERG       FREE THE INTERSECTION
PATHP31B  ADVANCE    0
TRAVEL    MACRO      &T31B,TRIP31B,31B,31B
PATHP32B  ADVANCE    0
TRAVEL    MACRO      &T32B,TRIP32B,32B,32B
          SEIZE      INTERH       CHECK IF NO TRUCK COMING
TRAVEL    MACRO      &T33B,TRIP33B,33B,33B
          RELEASE    INTERH       FREE THE INTERSECTION
          TRANSFER   ,FN(DIV8)          DUMPS & LEACH-CRUSHER FROM 342 &
LOADER 1
BLOCKJ2   ADVANCE    0
TRAVEL    MACRO      &T49,TRIP49,49,49
          SEIZE      INTERT       CHECK IF NO TRUCK COMING
TRAVEL    MACRO      &T50,TRIP50,50,50
          RELEASE    INTERT       FREE THE INTERSECTION
          TRANSFER   ,FN(DIV10)    (LEACH, CRUSHER)

BLOCKR1   ADVANCE    0
TRAVEL    MACRO      &T53,TRIP53,53,53
*********************************
*            GAS STATION
*********************************
          SEIZE      GAS
          ADVANCE    RVNORM(1,20,4)   FUEL A TRUCK  - CHECK ON THIS!!
          BLET       &TAC=RVNORM(1,1285,50)    ASSUME AMOUNT OF FUELING
OF TRUCKS' AVERAGE (?)
          BLET       &TOTGAS=&TOTGAS+&TAC     ADD TO TOTAL GAS
          BLET       &TA=&TA+1              COUNT FUELING TRUCKS
          TRANSFER   SBR,ANIM,3PH
          BPUTPIC    FILE=ATF,LINES=3,AC1,&TA,&TOTGAS
TIME *.****
WRITE MGAS1 ***
WRITE MGAS2 ******Gal
          RELEASE    GAS
TRAVEL    MACRO      &T53A,TRIP53A,53A,53A
          TRANSFER   ,FN(DIVGAS)
*********************************
```

```
BLOCKP1   ADVANCE    0
LEACHW    ADVANCE    0
TRAVEL    MACRO      &T54,TRIP54,54,54
*********************************
*             GET LIME
*********************************
          TRANSFER    ,FN(DIV12)           LIME 2-WEST
BLOCKV1   ADVANCE    0
TRAVEL    MACRO      &T54B,TRIP54B,54B,54B

          SEIZE      LIME2
          ADVANCE    RVNORM(1,1,.2)
          TEST E     PH1,1,TYPE2LI
          TRANSFER   SBR,ANIM,3PH
          BPUTPIC    FILE=ATF,LINES=3,AC1,XID1,FC(LIME2)
TIME *.****
SET T* CLASS F793L
WRITE LIME2  ***
          RELEASE    LIME2
          TRANSFER   ,PATHP55
TYPE2LI   TRANSFER   SBR,ANIM,3PH
          BPUTPIC    FILE=ATF,LINES=3,AC1,XID1,FC(LIME2)
TIME *.****
SET T* CLASS F789L
WRITE LIME2  ***
          RELEASE    LIME2
PATHP55   ADVANCE    0
TRAVEL    MACRO      &T55,TRIP55,55,55
          TRANSFER   ,AWAYL2
BLOCKV2   ADVANCE    0
TRAVEL    MACRO      &T55B,TRIP55B,55B,55B
AWAYL2    ADVANCE    0

*********************************
*       DUMPING IN LEACH2-WEST
*********************************
          SEIZE      LEACH2
          ADVANCE    FN(LEACH2)     DUMP TIMES AT LEACHPAD (WEST)
          TEST E     PH1,1,TYPE2Y
          BLET       &Z1=RVNORM(1,240,5)   ASSUME LOAD OF 793 IS THIS
          ASSIGN     1,RVNORM(1,240,5),PL
          BLET       &VV793=&VV793+1
          BLET       &WW793=&WW793+PL1
          BLET       &TOTWST8=&TOTWST8+&Z1     ADD TO TOTAL WASTE
          TRANSFER   SBR,ANIM,3PH
```

```
          BPUTPIC     FILE=ATF,LINES=4,AC1,&VV793,&WW793,&TOTWST8
TIME *.****
WRITE MD36  ***
WRITE MD37  *****.**
WRITE MD38  ******.**
          RELEASE     LEACH2
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS E793
         TRANSFER    ,PATHP55A
TYPE2Y   ADVANCE     0
          BLET        &Z2=RVNORM(1,195,5)   ASSUME LOAD OF 789 IS THIS
          ASSIGN      1,RVNORM(1,195,5),PL
          BLET        &VV789=&VV789+1
          BLET        &WW789=&WW789+PL1
          BLET        &TOTWST8=&TOTWST8+&Z2     ADD TO TOTAL WASTE
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=4,AC1,&VV789,&WW789,&TOTWST8
TIME *.****
WRITE MD39  ***
WRITE MD40  *****.**
WRITE MD38  ******.**

          RELEASE     LEACH2
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS E789
PATHP55A  ADVANCE     0
TRAVEL    MACRO       &T55A,TRIP55A,55A,55A
TRAVEL    MACRO       &T54A,TRIP54A,54A,54A
          SEIZE       INTERT       CHECK IF NO TRUCK COMING
TRAVEL    MACRO       &T54C,TRIP54C,54C,54C
          RELEASE     INTERT       FREE THE INTERSECTION
          TRANSFER    ,FN(DIV13)      GAS, NORTH RAMP, SOUTH RAMP

BLOCKY1   ADVANCE     0
BLOCKR2   ADVANCE     0
TRAVEL    MACRO       &T49A,TRIP49A,49A,49A
          SEIZE       INTERH       CHECK IF NO TRUCK COMING
TRAVEL    MACRO       &T49B,TRIP49B,49B,49B
          RELEASE     INTERH       FREE THE INTERSECTION
          TRANSFER    ,BACKN
BLOCKY2   ADVANCE     0
```

```
BLOCKR3   ADVANCE     0
TRAVEL    MACRO      &T52C,TRIP52C,52C,52C
          SEIZE      INTERK       CHECK IF NO TRUCK COMING
TRAVEL    MACRO      &T51B,TRIP51B,51B,51B
          RELEASE    INTERK       FREE THE INTERSECTION
PATHP45A  ADVANCE     0
TRAVEL    MACRO      &T45A,TRIP45A,45A,45A
TRAVEL    MACRO      &T44A,TRIP44A,44A,44A
TRAVEL    MACRO      &T43A,TRIP43A,43A,43A
          SEIZE      INTERJ       CHECK IF NO TRUCK COMING
TRAVEL    MACRO      &T43B,TRIP43B,43B,43B
          RELEASE    INTERJ       FREE THE INTERSECTION
PATHP38A  ADVANCE     0
TRAVEL    MACRO      &T38A,TRIP38A,38A,38A

*******************************************
*            SHOVEL 342
*******************************************
          QUEUE      SHOV342
          SEIZE      SPOT342
          ADVANCE    FN(SPOT342)
          RELEASE    SPOT342
          SEIZE      SHOV342
          ADVANCE    FN(LOAD2)
          TEST E     PH1,1,TYPE2AT
          DEPART     SHOV342
          ASSIGN     1,RVNORM(1,240,5),PL      AMOUNT LOAD BY SHOVEL 342-
TRUCK 793
          BLET       &AW793F=&AW793F+1
          BLET       &BW793F=&BW793F+PL1
          RELEASE    SHOV342
          TRANSFER   SBR,ANIM,3PH
          BPUTPIC
FILE=ATF,LINES=4,AC1,&AW793F,&BW793F,FR(SHOV342)/10.
TIME *.****
WRITE M21  ***
WRITE M22  *****.**
WRITE M23  **.**%
          TRANSFER   SBR,ANIM,3PH
          BPUTPIC    FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS F793
          TRANSFER   ,PATHP38

TYPE2AT   ADVANCE     0
```

```
        DEPART     SHOV342
        ASSIGN     1,RVNORM(1,195,5),PL      AMOUNT LOAD BY SHOVEL 343-
TRUCK 789
        BLET       &AW789F=&AW789F+1
        BLET       &BW789F=&BW789F+PL1
        RELEASE    SHOV342
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC
FILE=ATF,LINES=4,AC1,&AW789F,&BW789F,FR(SHOV342)/10.
TIME *.****
WRITE M24  ***
WRITE M25  *****.**
WRITE M23  **.**%
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS F789
        TRANSFER   ,PATHP38

BLOCKP2   ADVANCE    0
TRAVEL    MACRO      &T52A,TRIP52A,52A,52A
        SEIZE      INTERK      CHECK IF NO TRUCK COMING
TRAVEL    MACRO      &T51A,TRIP51A,51A,51A
        RELEASE    INTERK      FREE THE INTERSECTION
PATHP47B  ADVANCE    0
TRAVEL    MACRO      &T47B,TRIP47B,47B,47B
        TRANSFER   ,FN(DIV10A)    CRUSHER & STOCK 2-LEACH SOUTH
BLOCKS1   ADVANCE    0
TRAVEL    MACRO      &T47,TRIP47,47,47
        TRANSFER   ,WESTCR
BLOCKS2   ADVANCE    0
TRAVEL    MACRO      &T21D,TRIP21D,21D,21D
        TRANSFER   ,PATHP22

BLOCKI2   ADVANCE    0
TRAVEL    MACRO      &T43,TRIP43,43,43
TRAVEL    MACRO      &T44,TRIP44,44,44
TRAVEL    MACRO      &T45,TRIP45,45,45
        SEIZE      INTERK      CHECK IF NO TRUCK COMING
TRAVEL    MACRO      &T46,TRIP46,46,46
        RELEASE    INTERK      FREE THE INTERSECTION
        TRANSFER   ,PATHP47B
```

```
*TRAVEL    MACRO      &T51,TRIP51,51,51
*          SEIZE      INTERT       CHECK IF NO TRUCK COMING
*TRAVEL    MACRO      &T52,TRIP52,52,52
*          RELEASE    INTERT       FREE THE INTERSECTION
*          TRANSFER   ,LEACHW



PATHP28   ADVANCE    0
TRAVEL    MACRO      &T28,TRIP28,28,28
TRAVEL    MACRO      &T29,TRIP29,29,29
          SEIZE      INTERG       CHECK IF NO TRUCK COMING
TRAVEL    MACRO      &T30,TRIP30,30,30
          RELEASE    INTERG       FREE THE INTERSECTION
          TRANSFER   ,PATHP31B

AWAY2     ADVANCE    0
TRAVEL    MACRO      &T31,TRIP31,31,31
TRAVEL    MACRO      &T32,TRIP32,32,32
          SEIZE      INTERH       CHECK IF NO TRUCK COMING
TRAVEL    MACRO      &T33,TRIP33,33,33
          RELEASE    INTERH       FREE THE INTERSECTION
BLOCKJ1   ADVANCE    0
TRAVEL    MACRO      &T34,TRIP34,34,34
TRAVEL    MACRO      &T35,TRIP35,35,35

****************************************
*          LARGE DUMP
****************************************
          SEIZE      LDUMP
          ADVANCE    FN(LDUMP)    DUMP TIMES AT LARGE DUMP
          TEST E     PH1,1,TYPE2G
          BLET       &H1=RVNORM(1,240,5)   ASSUME LOAD OF 793 IS THIS
          ASSIGN     1,RVNORM(1,240,5),PL
          BLET       &KK793=&KK793+1
          BLET       &LL793=&LL793+PL1
          BLET       &TOTWST7=&TOTWST7+&H1    ADD TO TOTAL WASTE
          TRANSFER   SBR,ANIM,3PH
          BPUTPIC    FILE=ATF,LINES=4,AC1,&KK793,&LL793,&TOTWST7
TIME *.****
WRITE MD31  ***
WRITE MD32  *****.**
WRITE MD33  ******.**
          RELEASE    LDUMP
```

```
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS E793
       TRANSFER    ,PATHP35A
TYPE2G   ADVANCE     0
        BLET       &H2=RVNORM(1,195,5)   ASSUME LOAD OF 789 IS THIS
        ASSIGN      1,RVNORM(1,195,5),PL
        BLET       &KK789=&KK789+1
        BLET       &LL789=&LL789+PL1
        BLET       &TOTWST7=&TOTWST7+&H2     ADD TO TOTAL WASTE
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=4,AC1,&KK789,&LL789,&TOTWST7
TIME *.****
WRITE MD34  ***
WRITE MD35  *****.**
WRITE MD33  ******.**

        RELEASE     LDUMP
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS E789
PATHP35A  ADVANCE    0
TRAVEL    MACRO      &T35A,TRIP35A,35A,35A
TRAVEL    MACRO      &T34A,TRIP34A,34A,34A
        SEIZE       INTERH       CHECK IF NO TRUCK COMING
TRAVEL    MACRO      &T34B,TRIP34B,34B,34B
        RELEASE     INTERH       FREE THE INTERSECTION
BACKN     ADVANCE     0
TRAVEL    MACRO      &T33A,TRIP33A,33A,33A
TRAVEL    MACRO      &T31A,TRIP31A,31A,31A
        SEIZE       INTERG       CHECK IF NO TRUCK COMING
TRAVEL    MACRO      &T31C,TRIP31C,31C,31C
        RELEASE     INTERG       FREE THE INTERSECTION

**********************************************
*            DISPATCH   WEST PIT
**********************************************
        INTEGER    &COUNT5,&COUNT6,&COUNT7
        BLET       &COUNT5=W(PAT29A)+W(PAT28C)_
                +Q(SHOV343)+F(SHOV343)+F(SPOT343)
        BLET       &COUNT6=W(PAT29B)+W(PAT28A)_
                +Q(LOADER1)+F(LOADER1)+F(SPOTL1)
        BLET       &COUNT7=W(PAT41A)+W(PAT40A)+W(PAT40B)+W(PAT38A)_
```

```
              +Q(SHOV342)+F(SHOV342)+F(SPOT342)
        TEST LE    &COUNT5,&COUNT6,ELOAD2
        TEST LE    &COUNT5,&COUNT7,ELOAD3
        TRANSFER   ,AREA343        GO TO SHOVEL 343
ELOAD2  TEST LE    &COUNT6,&COUNT7,ELOAD4
        TRANSFER   ,AREAL1       GO TO LOADER 1
ELOAD3  TRANSFER   ,AREA342      GO TO SHOVEL 342
ELOAD4  TRANSFER   ,AREA342      GO TO SHOVEL 342
**************************************************
AREA343  ADVANCE   0
TRAVEL   MACRO     &T29A,TRIP29A,29A,29A
TRAVEL   MACRO     &T28C,TRIP28C,28C,28C

*************************************************
*       SHOVEL 343
************************************************
        QUEUE      SHOV343
        TRANSFER   BOTH,,NEXT2
        SEIZE      SPOT343
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=2,AC1,XID1
TIME *.****
PLACE T* AT -22.64 -11.08
        ADVANCE    FN(SPOT343)
        RELEASE    SPOT343
        SEIZE      SHOV343
        ADVANCE    FN(LOAD3)
        TRANSFER   ,DUABLE3
NEXT2   SEIZE      SPOT343B
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=2,AC1,XID1
TIME *.****
PLACE T* AT -23.25 -12.29
        ADVANCE    FN(SPOT343)
        RELEASE    SPOT343B
        SEIZE      SHOV343
        ADVANCE    FN(LOAD3)
DUABLE3  ADVANCE   0
        TEST E     PH1,1,TYPE2AU
        DEPART     SHOV343
        ASSIGN     1,RVNORM(1,240,5),PL     AMOUNT LOAD BY SHOVEL 343-
TRUCK 793
        BLET       &AP793F=&AP793F+1
        BLET       &BP793F=&BP793F+PL1
        RELEASE    SHOV343
```

```
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=4,AC1,&AP793F,&BP793F,FR(SHOV343)/10.
TIME *.****
WRITE M16  ***
WRITE M17  *****.**
WRITE M18  **.**%
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS F793
        TRANSFER    ,PATHP28B

TYPE2AU   ADVANCE     0
        DEPART      SHOV343
        ASSIGN      1,RVNORM(1,195,5),PL      AMOUNT LOAD BY SHOVEL 343-
TRUCK 789
        BLET        &AP789F=&AP789F+1
        BLET        &BP789F=&BP789F+PL1
        RELEASE     SHOV343
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=4,AC1,&AP789F,&BP789F,FR(SHOV343)/10.
TIME *.****
WRITE M19  ***
WRITE M20  *****.**
WRITE M18  **.**%
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS F789
        TRANSFER    ,PATHP28B

AREAL1    ADVANCE     0
TRAVEL    MACRO       &T29B,TRIP29B,29B,29B
TRAVEL    MACRO       &T28A,TRIP28A,28A,28A
*************************************************
*                   LOADER 1
*************************************************
        QUEUE       LOADER1
        SEIZE       SPOTL1
        ADVANCE     FN(SPOTL1)
        RELEASE     SPOTL1
        SEIZE       LOADER1
        ADVANCE     FN(LOADER1)
        TEST E      PH1,1,TYPE2AY
        DEPART      LOADER1
```

```
        ASSIGN     1,RVNORM(1,240,5),PL      AMOUNT LOAD BY LOADER 1-
TRUCK 793
        BLET       &AL793F=&AL793F+1
        BLET       &BL793F=&BL793F+PL1
        RELEASE    LOADER1
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=4,AC1,&AL793F,&BL793F,FR(LOADER1)/10.
TIME *.****
WRITE M11  ***
WRITE M12  *****.**
WRITE M13  **.**%

        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS F793
        TRANSFER   ,PATHP28

TYPE2AY   ADVANCE    0
        DEPART     LOADER1
        ASSIGN     1,RVNORM(1,195,5),PL      AMOUNT LOAD BY LOADER 1-
TRUCK 789
        BLET       &AL789F=&AL789F+1
        BLET       &BL789F=&BL789F+PL1
        RELEASE    LOADER1
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=4,AC1,&AL789F,&BL789F,FR(LOADER1)/10.
TIME *.****
WRITE M14  ***
WRITE M15  *****.**
WRITE M13  **.**%
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS F789
        TRANSFER   ,PATHP28

AREA342   ADVANCE    0
TRAVEL    MACRO      &T41A,TRIP41A,41A,41A
TRAVEL    MACRO      &T40A,TRIP40A,40A,40A
        SEIZE      INTERJ       CHECK IF NO TRUCK COMING
TRAVEL    MACRO      &T40B,TRIP40B,40B,40B
        RELEASE    INTERJ       FREE THE INTERSECTION
        TRANSFER   ,PATHP38A
```

```
**********************************************
*   SEGMENT FOR SHOVEL 1 LOADING              *
**********************************************
        GENERATE    ,,,1,10      DUMMY TRANSACTION
WAIT1     TEST E      F(SHOV341),1
WAIT2     TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
ROTATE BB1 -45 STEP 3 TIME 2
        ADVANCE     2
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
ROTATE BB1 45 STEP 3 TIME 2
        ADVANCE     2
        TEST E      F(SHOV341),1,WAIT1
        TRANSFER    ,WAIT2

**********************************************
*   SEGMENT FOR SHOVEL 342 LOADING            *
**********************************************
        GENERATE    ,,,1,10      DUMMY TRANSACTION
WAIT3     TEST E      F(SHOV342),1
WAIT4     TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
ROTATE BB2 -45 STEP 3 TIME 1.5
        ADVANCE     .25
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
ROTATE BB2 45 STEP 3 TIME 1.5
        ADVANCE     .25
        TEST E      F(SHOV342),1,WAIT3
        TRANSFER    ,WAIT4

**********************************************
*   SEGMENT FOR SHOVEL 343 LOADING            *
**********************************************
        GENERATE    ,,,1,10      DUMMY TRANSACTION
WAIT5     TEST E      F(SHOV343),1
WAIT6     TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
ROTATE BB3 -45 STEP 3 TIME 1
```

```
        ADVANCE    .5
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=2,AC1
TIME *.****
ROTATE BB3 45 STEP 3 TIME 1
        ADVANCE    .5
        TEST E     F(SHOV343),1,WAIT5
        TRANSFER   ,WAIT6

***********************************************
*   SEGMENT FOR HYD. LOADER 1 MOVING          *
***********************************************
        GENERATE   ,,,1,10     DUMMY TRANSACTION
WAIT9   TEST E     F(LOADER1),1
WAIT10  TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=2,AC1
TIME *.****
ROTATE SCOOP1 -45 STEP 3 TIME 5
        ADVANCE    1
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=2,AC1
TIME *.****
ROTATE SCOOP1 45 STEP 3 TIME 5
        ADVANCE    1
        TEST E     F(LOADER1),1,WAIT9
        TRANSFER   ,WAIT10

***********************************************
*   SEGMENT FOR HYD. LOADER 2 MOVING          *
***********************************************
        GENERATE   ,,,1,10     DUMMY TRANSACTION
WAIT7   TEST E     F(LOADER2),1
WAIT8   TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=2,AC1
TIME *.****
ROTATE SCOOP2 -45 STEP 3 TIME .25
        ADVANCE    .25
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=2,AC1
TIME *.****
ROTATE SCOOP2 45 STEP 3 TIME .25
        ADVANCE    .25
        TEST E     F(LOADER2),1,WAIT7
        TRANSFER   ,WAIT8
```

```
*******************************************
*        CLOCK SEGMENT                *
*******************************************
         INTEGER     &TIME,&DAYNO,&WKDAYNO,&WEEKNO,&HOUR
         GENERATE    ,,,1,150,12PL,12PH   DUMMY TRANSACTION FOR CLOCK
         TRANSFER    SBR,ANIM,3PH
         BPUTPIC     FILE=ATF,LINES=3,AC1
TIME *.****
ROTATE MHAND1 SPEED -6 STEP 6
ROTATE HHAND1 SPEED -.5 STEP 6
         BLET        &HOUR=0
         BLET        &WKDAYNO=1
         BLET        &WEEKNO=1
NEXTMIN  ADVANCE     1      ADVANCE THE CLOCK ONE MINUTE
         BLET        &TIME=&TIME+1
         TRANSFER    SBR,ANIM,3PH
         BPUTPIC
FILE=ATF,LINES=5,AC1,&TIME,&HOUR,&WKDAYNO,&WEEKNO
TIME *.****
WRITE MT1 **
WRITE MT2 **
WRITE MT3 **
WRITE MT4 **
         TEST E      &TIME@60,0,NEXTMIN
         BLET        &TIME=0
         BLET        &HOUR=&HOUR+1
         TEST E      &HOUR,24,NEXTMIN   24 HOURS PAST?
         BLET        &TIME=0
         BLET        &HOUR=0
         BLET        &DAYNO=&DAYNO+1
         BLET        &WKDAYNO=&WKDAYNO+1
         TEST E      &WKDAYNO,8,NEXTMIN  NEW WEEK?
         BLET        &WKDAYNO=1
         BLET        &WEEKNO=&WEEKNO+1
         TRANSFER    ,NEXTMIN

*************************************************
*        TIMER TRANSACTION COMES NEXT           *
*************************************************
         GENERATE    ,,,1
         ADVANCE     43200
         TERMINATE   1
         START       1

**************************************************
```

```
*          SIMULATION RESULT DESPLAY              *
*************************************************
         PUTPIC
LINES=8,FC(SHOV341),FR(SHOV341)/10.,QM(SHOV341),FC(LOADER2),FR(LOA
DER2)/10.,QM(LOADER2)
================================================
NUMBER OF LOADS BY SHOVEL 341:    ***
UTILIZATION OF SHOVEL 341:    **.**%
MAXIMUM NUMBER OF QUEUE AT SHOVEL 341:    **
================================================
NUMBER OF LOADS BY LOADER 2:    ***
UTILIZATION OF LOADER 2:    **.**%
MAXIMUM NUMBER OF QUEUE AT LOADER 2:    **
         PUTPIC
LINES=8,FC(SHOV342),FR(SHOV342)/10.,QM(SHOV342),FC(SHOV343),FR(SHOV
343)/10.,QM(SHOV343)
================================================
NUMBER OF LOADS BY SHOVEL 342:    ***
UTILIZATION OF SHOVEL 342:    **.**%
MAXIMUM NUMBER OF QUEUE AT SHOVEL 342:    **
================================================
NUMBER OF LOADS BY SHOVEL 343:    ***
UTILIZATION OF SHOVEL 343:    **.**%
MAXIMUM NUMBER OF QUEUE AT SHOVEL 343:    **
         PUTPIC      LINES=6,FC(LOADER1),FR(LOADER1)/10.,QM(LOADER1)
================================================
NUMBER OF LOADS BY LOADER 1:    ***
UTILIZATION OF LOADER 1:    **.**%
MAXIMUM NUMBER OF QUEUE AT LOADER 1:    **
***********************************
          IF         &YES'E"Y'
          PUTPIC      FILE=ATF,LINES=2,AC1
TIME *.****
END
         ENDIF
         END
```

Appendix B: Source code and data analysis of the Gap Pit mine simulation and animation model.

Preliminary Gap Pit Simulation and Animation Program with Generic Data:

```
*************************************************************
*  SIMULATION AND ANIMATION MODEL OF PIPELINE PIT            *
*    (CORTEZ HILLS)-BARRICK GOLD CORP.                  *
*     PROGRAMMED IN GPSS/H                         *
*     BY                                *
*     EBRAHIM K. TARSHIZI                        *
*************************************************************

         SIMULATE
         RMULT       12345
         REALLOCATE  COM,1000000
ATF      FILEDEF     'PIPELINE.ATF'
         INTEGER     &NT830,&NT282,&NT795,&IA
         REAL        &A,&B,&C,&D,&F,&G,&H,&I,&J,&K,&L,&M,&N
         REAL        &O,&P,&Q,&R,&S,&W,&U,&V,&X,&Y,&Z,&AA,&BB
         REAL
&CC,&DD,&EE,&FF,&GG,&HH,&II,&XF,&JJ,&KK,&LL,&MM,&NN,&OO
         REAL
&A830E,&B830E,&A282B,&B282B,&A795F,&B795F,&AA830E,&BB830E,&TOTW
ST
         REAL
&AA282B,&BB282B,&CCC,&CCCC,&AA795F,&BB795F,&XOLD,&YOLD,&YNE
W
         REAL
&AAA830E,&BBB830E,&AAA282B,&BBB282B,&AAA795F,&BBB795F

   1     FUNCTION    PH1,M3
1,RVNORM(1,3,.2)/2,RVNORM(1,2,.1)/3,RVNORM(1,2.5,.1)
   2     FUNCTION    PH1,M3
1,RVNORM(1,3,.2)/2,RVNORM(1,2.5,.1)/3,RVNORM(1,2.5,.1)
   3     FUNCTION    PH1,M3
1,RVNORM(1,3,.2)/2,RVNORM(1,2.5,.1)/3,RVNORM(1,2.5,.1)
   4     FUNCTION    PH1,M3
1,RVNORM(1,3,.2)/2,RVNORM(1,2.5,.1)/3,RVNORM(1,2.5,.1)
   5     FUNCTION    PH1,M3
1,RVNORM(1,3,.2)/2,RVNORM(1,2.5,.1)/3,RVNORM(1,2.5,.1)
   6     FUNCTION    PH1,M3
1,RVNORM(1,3,.2)/2,RVNORM(1,2.5,.1)/3,RVNORM(1,2.5,.1)
   7     FUNCTION    PH1,M3
```

```
1,RVNORM(1,3,.2)/2,RVNORM(1,2.5,.1)/3,RVNORM(1,2.5,.1)
   8     FUNCTION    PH1,M3
1,RVNORM(1,3,.2)/2,RVNORM(1,2.5,.1)/3,RVNORM(1,2.5,.1)
   9     FUNCTION    PH1,M3
1,RVNORM(1,3,.2)/2,RVNORM(1,2.5,.1)/3,RVNORM(1,2.5,.1)
   A9A     FUNCTION    PH1,M3
1,RVNORM(1,2,.2)/2,RVNORM(1,2,.1)/3,RVNORM(1,2,.1)
   A9B     FUNCTION    PH1,M3
1,RVNORM(1,2,.2)/2,RVNORM(1,2,.1)/3,RVNORM(1,2,.1)
   10     FUNCTION    PH1,M3
1,RVNORM(1,3,.2)/2,RVNORM(1,2.5,.1)/3,RVNORM(1,2.5,.1)
   11     FUNCTION    PH1,M3
1,RVNORM(1,3,.2)/2,RVNORM(1,2.5,.1)/3,RVNORM(1,2.5,.1)
   12     FUNCTION    PH1,M3
1,RVNORM(1,3,.2)/2,RVNORM(1,2.5,.1)/3,RVNORM(1,2.5,.1)
   13     FUNCTION    PH1,M3
1,RVNORM(1,3,.2)/2,RVNORM(1,2.5,.1)/3,RVNORM(1,2.5,.1)
   14     FUNCTION    PH1,M3
1,RVNORM(1,3,.2)/2,RVNORM(1,2.5,.1)/3,RVNORM(1,2.5,.1)
   15     FUNCTION    PH1,M3
1,RVNORM(1,3,.2)/2,RVNORM(1,2.5,.1)/3,RVNORM(1,2.5,.1)
   16     FUNCTION    PH1,M3
1,RVNORM(1,3,.2)/2,RVNORM(1,2.5,.1)/3,RVNORM(1,2.5,.1)
   17     FUNCTION    PH1,M3
1,RVNORM(1,3,.2)/2,RVNORM(1,2.5,.1)/3,RVNORM(1,2.5,.1)
   18     FUNCTION    PH1,M3
1,RVNORM(1,3,.2)/2,RVNORM(1,2.5,.1)/3,RVNORM(1,2.5,.1)
   19     FUNCTION    PH1,M3
1,RVNORM(1,3,.2)/2,RVNORM(1,2.5,.1)/3,RVNORM(1,2.5,.1)
   20     FUNCTION    PH1,M3
1,RVNORM(1,3,.2)/2,RVNORM(1,2.5,.1)/3,RVNORM(1,2.5,.1)
   21     FUNCTION    PH1,M3
1,RVNORM(1,3,.2)/2,RVNORM(1,2.5,.1)/3,RVNORM(1,2.5,.1)
   22     FUNCTION    PH1,M3
1,RVNORM(1,3,.2)/2,RVNORM(1,2.5,.1)/3,RVNORM(1,2.5,.1)
   23     FUNCTION    PH1,M3
1,RVNORM(1,3,.2)/2,RVNORM(1,2.5,.1)/3,RVNORM(1,2.5,.1)
   24     FUNCTION    PH1,M3
1,RVNORM(1,3,.2)/2,RVNORM(1,2.5,.1)/3,RVNORM(1,2.5,.1)
   25     FUNCTION    PH1,M3
1,RVNORM(1,3,.2)/2,RVNORM(1,2.5,.1)/3,RVNORM(1,2.5,.1)
   26     FUNCTION    PH1,M3
1,RVNORM(1,3,.2)/2,RVNORM(1,2.5,.1)/3,RVNORM(1,2.5,.1)
   27     FUNCTION    PH1,M3
1,RVNORM(1,3,.2)/2,RVNORM(1,2.5,.1)/3,RVNORM(1,2.5,.1)
```

```
   28     FUNCTION    PH1,M3
1,RVNORM(1,3,.2)/2,RVNORM(1,2.5,.1)/3,RVNORM(1,2.5,.1)
   29     FUNCTION    PH1,M3
1,RVNORM(1,3,.2)/2,RVNORM(1,2.5,.1)/3,RVNORM(1,2.5,.1)
   30     FUNCTION    PH1,M3
1,RVNORM(1,3,.2)/2,RVNORM(1,2.5,.1)/3,RVNORM(1,2.5,.1)
   31     FUNCTION    PH1,M3
1,RVNORM(1,3,.2)/2,RVNORM(1,2.5,.1)/3,RVNORM(1,2.5,.1)

    32     FUNCTION    PH1,M3
1,RVNORM(1,3,.2)/2,RVNORM(1,2,.1)/3,RVNORM(1,2.5,.1)
    33     FUNCTION    PH1,M3
1,RVNORM(1,3,.2)/2,RVNORM(1,2,.1)/3,RVNORM(1,2.5,.1)
  A32A    FUNCTION    PH1,M3
1,RVNORM(1,3,.2)/2,RVNORM(1,2,.1)/3,RVNORM(1,2.5,.1)

    34     FUNCTION    PH1,M3
1,RVNORM(1,3,.2)/2,RVNORM(1,2,.1)/3,RVNORM(1,2.5,.1)
    35     FUNCTION    PH1,M3
1,RVNORM(1,3,.2)/2,RVNORM(1,2,.1)/3,RVNORM(1,2.5,.1)
   A34A    FUNCTION    PH1,M3
1,RVNORM(1,3,.2)/2,RVNORM(1,2,.1)/3,RVNORM(1,2.5,.1)

  SPOTSH1  FUNCTION    PH1,M3       SPOT AT SHOVEL 1
1,RVNORM(1,.8,.02)/2,RVNORM(1,.7,.02)/3,RVNORM(1,.7,.02)

  SPOTSH2  FUNCTION    PH1,M3       SPOT AT SHOVEL 2
1,RVNORM(1,.8,.02)/2,RVNORM(1,.7,.02)/3,RVNORM(1,.7,.02)

  SPOTD1  FUNCTION    PH1,M3       SPOT AT DUMP 1
1,RVNORM(1,.8,.02)/2,RVNORM(1,.7,.02)/3,RVNORM(1,.7,.02)

FIRST     BVARIABLE   (LR(STOPSH1))AND(&XF'E'0)
FIRST1    BVARIABLE   (LR(STOPSH2))AND(&XF'E'0)

************************************************
*              START MACRO DEFINITIONS         *
************************************************
 TRAVEL   STARTMACRO
         BLET       #A=FN(#B)
         TRANSFER    SBR,ANIM,3PH
         BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1,#A
 TIME *.****
 PLACE T* ON P#C
 SET T* TRAVEL **.**
```

```
 PAT#D  ADVANCE     #A
       ENDMACRO

*****************************************************
*              END OF MACRO DEFINITIONS       *
*****************************************************
        DO    &IA=1,80
        PUTSTRING   ('  ')
        ENDDO
        PUTSTRING    ('  ')
        PUTSTRING    ('                    *** PIPELINE SIMULATION MODEL ***')
        PUTSTRING    ('  ')
        PUTSTRING    ('  ')
        PUTSTRING    ('  INPUT THE NUMBER OF KOMATSU 830E TRUCKS IN
THE GAP PIT?')
        PUTSTRING    ('  ')
        GETLIST      &NT830
        PUTSTRING    ('  ')
        PUTSTRING    ('  INPUT THE NUMBER OF LIEBHERR 282B TRUCKS IN
THE GAP PIT?')
        PUTSTRING    ('  ')
        GETLIST      &NT282
        PUTSTRING    ('  ')
        PUTSTRING    ('  INPUT THE NUMBER OF CATERPILLAR 795F TRUCKS IN
THE GAP PIT?')
        PUTSTRING    ('  ')
        GETLIST      &NT795
        PUTPIC       FILE=ATF,LINES=4,AC1,&NT830,&NT282,&NT795
TIME *.****
WRITE NT1 **
WRITE NT2 **
WRITE NT3 **
        PUTSTRING    ('  ')
        PUTSTRING    ('  DO YOU WANT ANIMATION? (Y/N)')
        CHAR*1       &YES
        GETLIST      &YES
ANIM     TEST E       &YES,'Y',PH3+2
        TRANSFER     ,PH3+1
        PUTSTRING    ('  ')
        PUTSTRING    ('  ')
        PUTSTRING    ('  ** SIMULATION RESULTS **')
        PUTSTRING    ('  ')
        PUTSTRING    ('  ')

*******************************************
```

```
*  START WITH 830E TRUCKS IN THE MINE    *
*****************************************
        GENERATE     3,,0,&NT830,,12PH,12PL
        ASSIGN       1,1,PH     830E TRUCKS ARE NUMBER 1 TRUCKS
        TRANSFER     SBR,ANIM,3PH
        BPUTPIC      FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE T830E T*
PLACE T* AT -13.28 -34.18
        TRANSFER     ,FIRSTA

*****************************************
*  START WITH 282B TRUCKS IN THE MINE    *
*****************************************
        GENERATE     3,,5,&NT282,,12PH,12PL
        ASSIGN       1,2,PH      THESE ARE NUMBER 2 TRUCKS
        TRANSFER     SBR,ANIM,3PH
        BPUTPIC      FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE T282E T*
PLACE T* AT -13.28 -34.18
        TRANSFER     ,FIRSTA

*****************************************
*  START WITH 795F TRUCKS IN THE MINE    *
*****************************************
         GENERATE    3,,10,&NT795,,12PH,12PL
         ASSIGN      1,3,PH       795C TRUCKS ARE NUMBER 3 TRUCKS
         TRANSFER    SBR,ANIM,3PH
         BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE T795E T*
PLACE T* AT -13.28 -34.18
FIRSTA    ADVANCE     0
TRAVEL    MACRO       &A,1,1,1
PATHP2    ADVANCE     0
TRAVEL    MACRO       &B,2,2,2
TRAVEL    MACRO       &C,3,3,3
TRAVEL    MACRO       &D,4,4,4
TRAVEL    MACRO       &F,5,5,5
TRAVEL    MACRO       &G,6,6,6
TRAVEL    MACRO       &H,7,7,7
TRAVEL    MACRO       &I,8,8,8
TRAVEL    MACRO       &J,9,9,9
```

```
*****************************************
*        DISPATCH CODE GOES HERE        *
*****************************************
         INTEGER     &COUNT1,&COUNT2,&TEST1,&TEST2
         BLET        &TEST1=20/100
         BLET        &TEST2=80/100
         BLET
&COUNT1=W(PAT10)+Q(SHOVEL1)+F(SHOVEL1)+F(SPOTS1)+&TEST1
         BLET
&COUNT2=W(PAT9B)+Q(SHOVEL2)+F(SHOVEL2)+F(SPOTD1)+&TEST2
         TEST LE     &COUNT1,&COUNT2,SSHOV2
         TRANSFER    ,POINT1        GO TO SHOVEL1
SSHOV2   TRANSFER    ,SHOVEL2       GO TO SHOVEL2
****************************************************************
*        TRANSFER    .2,,SHOVEL2    20% GOES TO SHOVEL2

POINT1   ADVANCE     0
         TEST E      BV(FIRST),1,AREA2
AREA1    ADVANCE     0
TRAVEL   MACRO       &K,10,10,10
         QUEUE       SHOVEL1
         SEIZE       SPOTSH1        SPOT
         ADVANCE     FN(SPOTSH1)    SPOT
         RELEASE     SPOTSH1
         SEIZE       SHOVEL1        USE THE SHOVEL1
         GATE LR     STOPSH1
         BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
PLACE T* AT -64.68 -19.77
         TEST E      PH1,1,TYPE2   CHECK FOR TRUCK TYPE
         ADVANCE     RVNORM(1,1.8,.08)    LOAD AT 830E TRUCK
         DEPART      SHOVEL1        LEAVE THE QUEUE
         RELEASE     SHOVEL1
         ASSIGN      1,RVNORM(1,225,10),PL   AMOUNT LOAD BY SHOVEL 2800
         BLET        &A830E=&A830E+1
         BLET        &B830E=&B830E+PL1
         TRANSFER    SBR,ANIM,3PH
         BPUTPIC
FILE=ATF,LINES=8,AC1,&A830E,&B830E,QA(SHOVEL1),QM(SHOVEL1),XID1,F
R(SHOVEL1)/10.,FC(SHOVEL1)
TIME *.****
WRITE M1  ***
WRITE M2  *****.**
WRITE M3 **.**
WRITE M4 **
```

```
SET T* CLASS T830F
WRITE M5 **.**%
WRITE M19 ***
          ADVANCE     0
          BLET        &YNEW=FR(SHOVEL1)/10.
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=2,AC1,&XOLD,&YOLD,AC1,&YNEW
TIME *.****
PLOT PLOT  **.**  **.**   **.** **.**
          BLET        &XOLD=AC1
          BLET        &YOLD=&YNEW
          TRANSFER    ,PATHP11

TYPE2     ADVANCE     0
          BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
PLACE T* AT -64.68 -19.77
          TEST E      PH1,2,TYPE3   CHECK FOR TYPES
          ADVANCE     RVNORM(1,3,.07)   LOAD A 282 TRUCK
          DEPART      SHOVEL1       LEAVE THE QUEUE
          RELEASE     SHOVEL1
          ASSIGN      1,RVNORM(1,345,15),PL   AMOUNT LOAD BY SHOVEL 2800
          BLET        &A282B=&A282B+1
          BLET        &B282B=&B282B+PL1
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC
FILE=ATF,LINES=8,AC1,&A282B,&B282B,QA(SHOVEL1),QM(SHOVEL1),XID1,F
R(SHOVEL1)/10.,FC(SHOVEL1)
TIME *.****
WRITE M6  ***
WRITE M7  *****.**
WRITE M3 **.**
WRITE M4 **
SET T* CLASS T282F
WRITE M5 **.**%
WRITE M19 ***
          ADVANCE     0
          BLET        &YNEW=FR(SHOVEL1)/10.
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=2,AC1,&XOLD,&YOLD,AC1,&YNEW
TIME *.****
PLOT PLOT  **.**  **.**   **.** **.**
          BLET        &XOLD=AC1
          BLET        &YOLD=&YNEW
          TRANSFER    ,PATHP11
```

```
TYPE3     ADVANCE     0
          BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
PLACE T* AT -64.68 -19.77
          ADVANCE   RVNORM(1,2.5,.07)   LOAD A 795F TRUCK
          DEPART      SHOVEL1       LEAVE THE QUEUE
          RELEASE     SHOVEL1
          ASSIGN      1,RVNORM(1,345,15),PL   AMOUNT LOAD BY SHOVEL 2800
          BLET        &A795F=&A795F+1
          BLET        &B795F=&B795F+PL1
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC
FILE=ATF,LINES=8,AC1,&A795F,&B795F,QA(SHOVEL1),QM(SHOVEL1),XID1,F
R(SHOVEL1)/10.,FC(SHOVEL1)
TIME *.****
WRITE M8  ***
WRITE M9  *****.**
WRITE M3 **.**
WRITE M4 **
SET T* CLASS T795F
WRITE M5 **.**%
WRITE M19 ***
          BLET        &YNEW=FR(SHOVEL1)/10.
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=2,AC1,&XOLD,&YOLD,AC1,&YNEW
TIME *.****
PLOT PLOT  **.**  **.**   **.** **.**
          BLET        &XOLD=AC1
          BLET        &YOLD=&YNEW
          TRANSFER    ,PATHP11

******************************************
*      PARKING LOT FOR BLAST             *
******************************************
PARK3     ADVANCE     0
TRAVEL    MACRO       &JJ,34,34,34
*         SEIZE       BLAST1
          ADVANCE     RVNORM(1,70,5)
*         RELEASE     BLAST1
TRAVEL    MACRO       &KK,A34A,34A,34A
          TRANSFER    ,RETURN2
PARK4     ADVANCE     0
TRAVEL    MACRO       &LL,35,35,35
*         SEIZE       BLAST2
```

```
        ADVANCE    RVNORM(1,70,5)
*         RELEASE    BLAST2
        TRANSFER    ,FIRSTA

*******************************************
*     PARKING LOT FOR SHIFT CHANGE      *
*******************************************
PARK1    ADVANCE    0
TRAVEL    MACRO      &MM,32,32,32
*         SEIZE      SHIFT1
        ADVANCE    60
*         RELEASE    SHIFT1
TRAVEL    MACRO      &NN,A32A,32A,32A
        TRANSFER    ,RETURN2
PARK2    ADVANCE    0
TRAVEL    MACRO      &OO,33,33,33
*         SEIZE      SHIFT2
        ADVANCE    60
*         RELEASE    SHIFT2
        TRANSFER    ,FIRSTA

************************************
*  SEGMENT FOR SHOVEL 2
************************************
SHOVEL2   ADVANCE    0
        TEST E      BV(FIRST1),1,AREA1
AREA2    ADVANCE    0
TRAVEL    MACRO      &HH,A9A,9A,9A
        QUEUE      SHOVEL2
        SEIZE      SPOTSH2      SPOT
        ADVANCE    FN(SPOTSH2)    SPOT
        RELEASE    SPOTSH2
        SEIZE      SHOVEL2      USE THE SHOVEL2
        GATE LR    STOPSH2
        BPUTPIC    FILE=ATF,LINES=2,AC1,XID1
TIME *.****
PLACE T* AT -64.10 -4.85
        TEST E      PH1,1,TYPES2   CHECK FOR TRUCK TYPE
        ADVANCE    RVNORM(1,1.8,.08)    LOAD AT 830E TRUCK
        DEPART     SHOVEL2
        RELEASE    SHOVEL2
        ASSIGN     1,RVNORM(1,225,10),PL   AMOUNT LOAD BY SHOVEL2
        BLET       &AAA830E=&AAA830E+1
        BLET       &BBB830E=&BBB830E+PL1
        TRANSFER    SBR,ANIM,3PH
```

```
        BPUTPIC
FILE=ATF,LINES=8,AC1,&AAA830E,&BBB830E,QA(SHOVEL2),QM(SHOVEL2),
XID1,FR(SHOVEL2)/10.,FC(SHOVEL2)
TIME *.****
WRITE M25  ***
WRITE M20  *****.**
WRITE M21 **.**
WRITE M22 **
SET T* CLASS T830F
WRITE M23 **.**%
WRITE M24 ***
        ADVANCE     0
        REAL        &XOLD6,&YOLD6,&YNEW6
        BLET        &YNEW6=FR(SHOVEL2)/10.
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1,&XOLD6,&YOLD6,AC1,&YNEW6
TIME *.****
PLOT PLOT2  **.**  **.**   **.** **.**
        BLET        &XOLD6=AC1
        BLET        &YOLD6=&YNEW6
        TRANSFER    ,PATHP9B

TYPES2    ADVANCE     0
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
PLACE T* AT -64.10 -4.85
        TEST E      PH1,2,TYPES3   CHECK FOR TRUCKS TYPES
        ADVANCE     RVNORM(1,3,.07)   LOAD A 282 TRUCK
        DEPART      SHOVEL2
        RELEASE     SHOVEL2
        ASSIGN      1,RVNORM(1,345,15),PL   AMOUNT LOAD BY SHOVEL 2
        BLET        &AAA282B=&AAA282B+1
        BLET        &BBB282B=&BBB282B+PL1
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC
FILE=ATF,LINES=8,AC1,&AAA282B,&BBB282B,QA(SHOVEL2),QM(SHOVEL2),
XID1,FR(SHOVEL2)/10.,FC(SHOVEL2)
TIME *.****
WRITE M26  ***
WRITE M27  *****.**
WRITE M21 **.**
WRITE M22 **
SET T* CLASS T282F
WRITE M23 **.**%
WRITE M24 ***
```

```
        ADVANCE    0
        BLET       &YNEW6=FR(SHOVEL2)/10.
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=2,AC1,&XOLD6,&YOLD6,AC1,&YNEW6
TIME *.****
PLOT PLOT2  **.**  **.**   **.** **.**
        BLET       &XOLD6=AC1
        BLET       &YOLD6=&YNEW6
        TRANSFER   ,PATHP9B

TYPES3   ADVANCE    0
        BPUTPIC    FILE=ATF,LINES=2,AC1,XID1
TIME *.****
PLACE T* AT -64.10 -4.85
        ADVANCE    RVNORM(1,2.5,.07)   LOAD A 795F TRUCK
        DEPART     SHOVEL2
        RELEASE    SHOVEL2
        ASSIGN     1,RVNORM(1,345,15),PL   AMOUNT LOAD BY SHOVEL 2
        BLET       &AAA795F=&AAA795F+1
        BLET       &BBB795F=&BBB795F+PL1
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC
FILE=ATF,LINES=8,AC1,&AAA795F,&BBB795F,QA(SHOVEL2),QM(SHOVEL2),X
ID1,FR(SHOVEL2)/10.,FC(SHOVEL2)
TIME *.****
WRITE M28  ***
WRITE M29  *****.**
WRITE M21 **.**
WRITE M22 **
SET T* CLASS T795F
WRITE M23 **.**%
WRITE M24 ***
        ADVANCE    0
        BLET       &YNEW6=FR(SHOVEL2)/10.
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=2,AC1,&XOLD6,&YOLD6,AC1,&YNEW6
TIME *.****
PLOT PLOT2  **.**  **.**   **.** **.**
        BLET       &XOLD6=AC1
        BLET       &YOLD6=&YNEW6
PATHP9B   ADVANCE    0
TRAVEL    MACRO      &II,A9B,9B,9B
        TRANSFER   ,PATHP12
PATHP11   ADVANCE    0
TRAVEL    MACRO      &L,11,11,11
```

```
PATHP12   ADVANCE    0
TRAVEL    MACRO      &M,12,12,12
TRAVEL    MACRO      &N,13,13,13
TRAVEL    MACRO      &O,14,14,14
TRAVEL    MACRO      &P,15,15,15
TRAVEL    MACRO      &Q,16,16,16
TRAVEL    MACRO      &R,17,17,17
TRAVEL    MACRO      &S,18,18,18
TRAVEL    MACRO      &W,19,19,19
        GATE LR    BLAST,PARK3
        ADVANCE    0
        GATE LR    SHIFTCH,PARK1
RETURN2   ADVANCE    0
TRAVEL    MACRO      &U,20,20,20
TRAVEL    MACRO      &V,21,21,21
TRAVEL    MACRO      &X,22,22,22
TRAVEL    MACRO      &Y,23,23,23
TRAVEL    MACRO      &Z,24,24,24
TRAVEL    MACRO      &AA,25,25,25
        SEIZE      SPOTD1       SPOT
        ADVANCE    FN(SPOTD1)    SPOT
        RELEASE    SPOTD1
        TEST E     PH1,1,TYPE22   CHECK FOR TRUCK TYPES
        SEIZE      DUMP1
        ADVANCE    RVNORM(1,.7,.1)      DUMPC A LOAD OF WASTE
        RELEASE    DUMP1
        BLET       &CC=RVNORM(1,225,5)   ASSUME LOAD OF 830E IS THIS
        ASSIGN     1,RVNORM(1,225,5),PL
        BLET       &AA830E=&AA830E+1
        BLET       &BB830E=&BB830E+PL1
        BLET       &TOTWST=&TOTWST+&CC     ADD TO TOTAL WASTE
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=6,AC1,&AA830E,&BB830E,XID1,&TOTWST
TIME *.****
WRITE M10  ***
WRITE M11  *****.**
SET T* CLASS T830E
WRITE M12  ******.**
WRITE M13 !DUMPING!
        REAL       &XOLD3,&YOLD3,&YNEW3
        BLET       &YNEW3=&TOTWST
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=2,AC1,&XOLD3,&YOLD3,AC1,&YNEW3
TIME *.****
PLOT PLOT1  **.**  **.**   **.**  **.** COLOR F2
```

```
        BLET      &XOLD3=AC1
        BLET      &YOLD3=&YNEW3
        ADVANCE   .7,.1
        TRANSFER  SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=3,AC1,FC(DUMP1)
TIME *.****
WRITE M13
WRITE M18 ****
        TRANSFER  ,PATHP26

TYPE22  ADVANCE   0
        TEST E    PH1,2,TYPE33   CHECK FOR TRUCK TYPES
        SEIZE     DUMP1
        ADVANCE   RVNORM(1,1,.2)     DUMPS A LOAD OF WASTE
        RELEASE   DUMP1
        BLET      &CCC=RVNORM(1,345,10)   ASSUME LOAD OF 282B IS THIS
        ASSIGN    1,RVNORM(1,345,10),PL
        BLET      &AA282B=&AA282B+1
        BLET      &BB282B=&BB282B+PL1
        BLET      &TOTWST=&TOTWST+&CCC     ADD TO TOTAL WASTE
        TRANSFER  SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=6,AC1,&AA282B,&BB282B,XID1,&TOTWST
TIME *.****
WRITE M14  ***
WRITE M15  *****.**
SET T* CLASS T282E
WRITE M12  ******.**
WRITE M13 !DUMPING!
        ADVANCE   1,.2
        TRANSFER  SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=3,AC1,FC(DUMP1)
TIME *.****
WRITE M13
WRITE M18 ****
        REAL      &XOLD2,&YOLD2,&YNEW2
        BLET      &YNEW2=&TOTWST
        TRANSFER  SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1,&XOLD2,&YOLD2,AC1,&YNEW2
TIME *.****
PLOT PLOT1  **.**  **.**   **.**  **.** COLOR F3
        BLET      &XOLD2=AC1
        BLET      &YOLD2=&YNEW2
        TRANSFER  ,PATHP26

TYPE33  ADVANCE   0
```

```
          SEIZE      DUMP1
          ADVANCE    RVNORM(1,1,.2)     LOADING TIME A LOAD OF WASTE
          RELEASE    DUMP1
          BLET       &CCCC=RVNORM(1,345,10)   ASSUME LOAD OF 795F IS THIS
          ASSIGN     1,RVNORM(1,345,10),PL
          BLET       &AA795F=&AA795F+1
          BLET       &BB795F=&BB795F+PL1
          BLET       &TOTWST=&TOTWST+&CCCC     ADD TO TOTAL WASTE
          TRANSFER   SBR,ANIM,3PH
          BPUTPIC    FILE=ATF,LINES=6,AC1,&AA795F,&BB795F,XID1,&TOTWST
TIME *.****
WRITE M16  ***
WRITE M17  *****.**
SET T* CLASS T795E
WRITE M12  ******.**
WRITE M13 !DUMPING!
          ADVANCE    1,.2
          TRANSFER   SBR,ANIM,3PH
          BPUTPIC    FILE=ATF,LINES=3,AC1,FC(DUMP1)
TIME *.****
WRITE M13
WRITE M18 ****
          REAL       &XOLD1,&YOLD1,&YNEW1
          BLET       &YNEW1=&TOTWST
          TRANSFER   SBR,ANIM,3PH
          BPUTPIC    FILE=ATF,LINES=2,AC1,&XOLD1,&YOLD1,AC1,&YNEW1
TIME *.****
PLOT PLOT1  **.**  **.**   **.**  **.** COLOR F4
          BLET       &XOLD1=AC1
          BLET       &YOLD1=&YNEW1
PATHP26   ADVANCE    0
TRAVEL    MACRO      &BB,26,26,26
TRAVEL    MACRO      &CC,27,27,27
TRAVEL    MACRO      &DD,28,28,28
TRAVEL    MACRO      &EE,29,29,29
TRAVEL    MACRO      &FF,30,30,30
TRAVEL    MACRO      &GG,31,31,31
          GATE LR    BLAST,PARK4
          ADVANCE    0
          GATE LR    SHIFTCH,PARK2
          TRANSFER   ,PATHP2

**********************************************
*   SEGMENT FOR SHOVEL 1 LOADING             *
**********************************************
```

```
        GENERATE    ,,,1,10      DUMMY TRANSACTION
 WAIT1    TEST E      F(SHOVEL1),1
        TRANSFER    SBR,ANIM,3PH
 WAIT2    BPUTPIC     FILE=ATF,LINES=2,AC1
 TIME *.****
 ROTATE BB1 45 STEP 5 TIME .35
        GATE LR     STOPSH1
        ADVANCE     .35
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1
 TIME *.****
 ROTATE BB1 -45 STEP 5 TIME .35
        ADVANCE     .35
        TEST E      F(SHOVEL1),1,WAIT1
        TRANSFER    ,WAIT2

*********************************************
*   SEGMENT FOR SHOVEL 2 LOADING             *
*********************************************
        GENERATE    ,,,1,10      DUMMY TRANSACTION
WAIT3     TEST E      F(SHOVEL2),1
        TRANSFER    SBR,ANIM,3PH
WAIT4     BPUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
ROTATE BB2 45 STEP 5 TIME .35
        GATE LR     STOPSH2
        ADVANCE     .35
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
ROTATE BB2 -45 STEP 5 TIME .35
        ADVANCE     .35
        TEST E      F(SHOVEL2),1,WAIT3
        TRANSFER    ,WAIT4

*********************************************************
*  DOWN TIMES AND RAPAIR TIMES FOR SHOVELS COMES NEXT      *
*********************************************************
        GENERATE    ,,,1
UPSTOP1   ADVANCE     RVEXPO(1,2000)
        LOGIC S     STOPSH1
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
WRITE MDS1 SHOVEL 1 IS DOWN!!!
```

```
        ADVANCE    RVNORM(1,60,10)
        LOGIC R    STOPSH1
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=2,AC1
TIME *.****
WRITE MDS1
        TRANSFER   ,UPSTOP1
********************************************
        GENERATE   ,,,1
UPSTOP2  ADVANCE    RVEXPO(1,450)
        LOGIC S    STOPSH2
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=2,AC1
TIME *.****
WRITE MDS2 SHOVEL 2 IS DOWN!!!
        ADVANCE    RVNORM(1,30,5)
        LOGIC R    STOPSH2
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=2,AC1
TIME *.****
WRITE MDS2
        TRANSFER   ,UPSTOP2

*******************************************
*   CLOCK SEGMENT                        *
*******************************************
        INTEGER    &TIME,&DAYNO,&WKDAYNO,&WEEKNO,&HOUR
        GENERATE   ,,,1,150,12PL,12PH   DUMMY TRANSACTION FOR CLOCK
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=3,AC1
TIME *.****
ROTATE MHAND1 SPEED -6 STEP 6
ROTATE HHAND1 SPEED -.5 STEP 6
        BLET       &HOUR=0
        BLET       &WKDAYNO=1
        BLET       &WEEKNO=1
NEXTMIN  ADVANCE    1     ADVANCE THE CLOCK ONE MINUTE
        BLET       &TIME=&TIME+1
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC
FILE=ATF,LINES=5,AC1,&TIME,&HOUR,&WKDAYNO,&WEEKNO
TIME *.****
WRITE MT1 **
WRITE MT2 **
WRITE MT3 **
```

```
WRITE MT4 **
        TEST E     &TIME@60,0,NEXTMIN
        BLET       &TIME=0
        BLET       &HOUR=&HOUR+1
        TEST E     &HOUR,24,NEXTMIN   24 HOURS PAST?
        BLET       &TIME=0
        BLET       &HOUR=0
        BLET       &DAYNO=&DAYNO+1
        BLET       &WKDAYNO=&WKDAYNO+1
        TEST E     &WKDAYNO,8,NEXTMIN  NEW WEEK?
        BLET       &WKDAYNO=1
        BLET       &WEEKNO=&WEEKNO+1
        TRANSFER   ,NEXTMIN

*********************************************
*          BLAST ANIMATION PART            *
*********************************************
        GENERATE   ,,,1
WAITED1   ADVANCE    RVNORM(1,495,5)
        LOGIC S    BLAST
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=4,AC1,XID1,XID1,XID1
TIME *.****
CREAT BLAST P*
PLACE P* ON PA2
SET P* TRAVEL 60
        ADVANCE    RVNORM(1,60,5)
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=2,AC1
TIME *.****
WRITE MBLAST !BLASTING!
       ADVANCE     10
       TRANSFER    SBR,ANIM,3PH
       BPUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
WRITE MBLAST
        LOGIC R    BLAST
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=2,AC1,XID1
TIME *.****
DESTROY P*
        TRANSFER   ,WAITED1

*********************************************************
*     CHANGING SHIFT SIMULATION & ANIMATION PART      *
```

```
*********************************************************
        GENERATE    ,,,1
WAITED   ADVANCE    RVNORM(1,660,10)
        LOGIC S    SHIFTCH
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=5,AC1,XID1,XID1,XID1
TIME *.****
CREAT SHIFT P*
PLACE P* ON PA1
SET P* TRAVEL 60
WRITE MSHIFT !SHIFT CHANGING!
        ADVANCE    60
        LOGIC R    SHIFTCH
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=3,AC1,XID1
TIME *.****
DESTROY P*
WRITE MSHIFT
        TRANSFER   ,WAITED

***************************************************
*       TIMER TRANSACTION COMES NEXT          *
***************************************************
        GENERATE    ,,,1
*   ADVANCE   &DAYS*24*60*(23./24.)   23/24 AS FRACTION OF DAY
ACTUALLY WORKED)
        ADVANCE    1440
        TERMINATE  1
        START      1

****************************************************
*         SIMULATION RESULT DESPLAY              *
****************************************************
        PUTPIC
LINES=13,FC(SHOVEL1),FR(SHOVEL1)/10.,QM(SHOVEL1),FC(SHOVEL2),FR(SH
OVEL2)/10.,QM(SHOVEL2),FC(DUMP1),&TOTWST
==============================================
NUMBER OF LOADS BY SHOVEL 2800:    ***
UTILIZATION OF SHOVEL 2800:    **.**%
MAXIMUM NUMBER OF QUEUE AT SHOVEL 2800:    **
==============================================
NUMBER OF LOADS BY SHOVEL 2:    ***
UTILIZATION OF SHOVEL 2:    **.**%
MAXIMUM NUMBER OF QUEUE AT SHOVEL 2:    **
==============================================
```

```
TOTAL OF  LOADS INTO DUMP AREA:    ***
TOTAL OF WASTE:    ****

"BARRICK GOLD CORPORATION"
****************************************************

        IF         &YES'E"Y'
        PUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
END
        ENDIF
        END
****************************************************
****************************************************
```

Completed Gap Pit simulation and animation program, including the latest version and scenario:

- This simulation and animation code was reviewed and modified by the guidance of Dr. John Sturgul.

```
***************************************************************
*  SIMULATION AND ANIMATION MODEL OF PIPELINE PIT 13         *
*   (QUEUE FIXED + DOWN CODES ADDED) READY FOR NEW PROJECT   *
*    (CORTEZ HILLS)-BARRICK GOLD CORP.                   *
*     PROGRAMMED IN GPSS/H                          *
*     BY                                   *
*     EBRAHIM K. TARSHIZI
*     REVIWED BY JOHN STURGUL                          *
***************************************************************

        SIMULATE
        RMULT      12345
        REALLOCATE  COM,1000000
ATF      FILEDEF    'PIPELINE2.ATF'
MYOUT    FILEDEF    'PIPERST13.XLS'

        REAL       &A,&B,&C,&F,&G,&H,&I,&J,&K,&L,&M,&III,&LLL
        REAL       &P,&Q,&R,&S,&T,&U,&X,&Y,&Z,&AA
        REAL       &DD,&EE,&FF,&GG,&HH,&II,&KK,&MM,&NN
        REAL
&UA,&PP,&QQ,&RR,&SS,&TT,&UU,&WW,&XX,&ZZ,&TAC3,&TOTGAS
        REAL       &LL795F,&LB795F,&CRB795F,&ROS795F,&ROB795F,&TA3
        REAL       &A795F,&B795F,&OO,&W,&OPH,&AT795F,&BT795F
```

```
         REAL
&AA795F,&BB795F,&AAA,&BBB,&CCC,&DDD,&EEE,&FFF,&GGG,&HHH,&JJJ
         REAL       &AAA795F,&BBB795F,&RCB795F,&RC795F,&CR795F
         INTEGER    &COUNT1,&COUNT2,&SHIFTS,&WWW,&NT795,&IA


1       FUNCTION    PH1,E1      (?) PARKING
1,RVNORM(1,.33,.067)
2       FUNCTION    PH1,E1      (?) PARKING
1,RVNORM(1,.33,.067)

3       FUNCTION    RN1,C7
0,0.50/0.08,0.58/0.50,0.67/0.82,0.75/0.89,0.83/0.95,0.92/1,1
A3      FUNCTION    RN1,C2
0,.16/1,.18

5       FUNCTION    RN1,C8
0,1.67/0.02,1.83/0.22,2/0.56,2.17/0.82,2.33/0.94,2.67/0.98,2.83/1,3

6       FUNCTION    RN1,C6
0,0.67/0.10,0.83/0.38,1/0.72,1.17/0.9,1.33/1,1.5

7       FUNCTION    RN1,C4
0,0.25/0.13,0.42/0.75,0.58/1,0.75

8       FUNCTION    RN1,C6
0,0.5/0.08,0.67/0.13,0.83/0.71,1/0.88,1.17/1,1.33

A8      FUNCTION    RN1,C2
0,.16/1,.18

10      FUNCTION    RN1,C7
0,0.83/0.03,1/0.26,1.17/0.61,1.33/0.95,1.5/0.97,1.67/1,1.83

A10     FUNCTION    RN1,C2
0,.16/1,.18

11      FUNCTION    RN1,C6
0,3.67/0.28,4.00/0.74,4.33/0.84,4.67/0.98,5/1,5.33

12      FUNCTION    RN1,C2
0,.16/1,.18

13      FUNCTION    RN1,C5
0,3.67/0.50,3.83/0.75,4/0.88,4.17/1,4.33
```

```
16      FUNCTION    RN1,C4
0,0.67/0.69,0.83/0.91,1/1,1.17

17      FUNCTION    RN1,C5
0,0.17/0.24,0.25/0.88,0.33/0.95,0.42/1,0.50

18      FUNCTION    RN1,C2
0,.16/1,.18

19      FUNCTION    RN1,C4
0,1.17/0.25,1.25/0.75,1.42/1,1.50

20      FUNCTION    RN1,C4
0,4.67/0.5,5.17/0.75,5.42/1,5.67

21      FUNCTION    RN1,C5
0,0.25/0.44,0.33/0.91,0.42/0.98,0.50/1,0.58

A21     FUNCTION    RN1,C2
0,.16/1,.18

24      FUNCTION    RN1,C8
0,1.50/0.10,1.67/0.40,1.83/0.60,2/0.75,2.17/0.85,2.33/0.90,2.67/1,2.83

25      FUNCTION    RN1,C4
0,1.67/0.67,2/0.83,2.33/1,2.67

26      FUNCTION    RN1,C9
0,2.33/0.13,2.50/0.35,2.67/0.61,2.83/0.78,3.00/0.87,3.17/0.91,3.50/0.96,3.67/1,3.83

27      FUNCTION    PH1,E1      CALCULATED DISPATCH
1,RVNORM(1,.85,.08)
30      FUNCTION    PH1,E1    NOT  AVERAGE AND 20%
1,RVNORM(1,4.26,.85)

31      FUNCTION    RN1,C4
0,2.67/0.33,3/0.67,3.33/1,3.67

32      FUNCTION    RN1,C2
0,.16/1,.18

33      FUNCTION    PH1,E1      CALCULATED DISPATCH
1,RVNORM(1,.82,.08)
```

```
34       FUNCTION    RN1,C2
0,.16/1,.18

35       FUNCTION    RN1,C5
0,0.17/0.08,0.25/0.58,0.33/0.93,0.42/1,0.50

A35       FUNCTION    RN1,C2
0,.16/1,.18

37       FUNCTION    RN1,C6
0,0.17/0.26,0.20/0.74,0.23/0.84,0.27/0.97,0.30/1,0.33

39       FUNCTION    PH1,C6
0,1.50/0.27,1.67/0.73,2.00/0.82,2.33/0.91,2.50/1,2.67

40       FUNCTION    RN1,C9
0,1.00/0.05,1.33/0.16,1.50/0.37,1.83/0.58,2/0.79,2.17/0.89,2.33/0.95,2.5/1,2.67

B21      FUNCTION    RN1,C2
0,.16/1,.18

43       FUNCTION    RN1,C6
0,1.83/0.09,2/0.32,2.17/0.5,2.33/0.91,2.67/1,2.83

44       FUNCTION    RN1,C4
0,3.25/0.40,3.42/0.60,3.58/1,3.75

*45       FUNCTION    PH1,E1    NOT(?) GAS
*1,RVNORM(1,.33,.067)

*A45      FUNCTION    PH1,E1     NOT(?) GAS BACK
*1,RVNORM(1,.33,.067)

45      FUNCTION    PH1,E1     NOT(?) GAS BACK
1,RVNORM(1,.3,.067)
46       FUNCTION    RN1,C4
0,0.97/0.2,1.05/0.4,1.13/1,1.22

47       FUNCTION    RN1,C2
0,.16/1,.18

49       FUNCTION    RN1,C5
0,1.83/0.25,2.00/0.50,2.17/0.75,2.50/1,2.67

50       FUNCTION    RN1,C2
```

```
0,.16/1,.18

52       FUNCTION    RN1,C4
0,0.83/0.40,1/0.80,1.33/1,1.50

53       FUNCTION    RN1,C4
0,0.50/0.20,0.67/0.4,0.83/1,1

54       FUNCTION    RN1,C2
0,.16/1,.18

***********************************
*     SPOT TIME FUNCTIONS
***********************************
SPOTSH1    FUNCTION   RN1,C7       SPOT AT SHOVEL 4100-1
0,0.33/0.23,0.67/0.55,1.00/0.87,1.33/0.94,1.67/0.97,2/1,2.33

SPOTSH2    FUNCTION   RN1,C8       SPOT AT SHOVEL 2800-2
0,0.25/0.09,0.5/0.52,0.75/0.8,1/0.86,1.25/0.91,1.75/0.95,2.25/1,2.50

SPOTD1    FUNCTION    RN1,C7       SPOT AT DUMP 1
0,0.50/0.13,0.75/0.62,1/0.87,1.25/0.94,1.50/0.96,1.75/1,2

SPOTL    FUNCTION     RN1,C7       SPOT AT LEACH PADS
0,0.50/0.13,0.75/0.62,1/0.87,1.25/0.94,1.50/0.96,1.75/1,2

SPOTC    FUNCTION     RN1,C7       SPOT AT ORE CRUSHER
0,0.50/0.13,0.75/0.62,1/0.87,1.25/0.94,1.50/0.96,1.75/1,2

SPOTR    FUNCTION     RN1,C7       SPOT AT ROAST
0,0.50/0.13,0.75/0.62,1/0.87,1.25/0.94,1.50/0.96,1.75/1,2

SPOTRC   FUNCTION     RN1,C7       SPOT AT ROAST
0,0.50/0.13,0.75/0.62,1/0.87,1.25/0.94,1.50/0.96,1.75/1,2

*FIRST     BVARIABLE   (LR(STOPSH1))AND(&XF'E'0)
*FIRST1    BVARIABLE   (LR(STOPSH2))AND(&XF'E'0)

*************************************
*     DUMP TIME FUNCTIONS
*************************************
DUMP1     FUNCTION    RN1,C5        DUMP-1 TIME
0,0.33/0.02,0.67/0.14,0.83/0.94,1/1,1.17

DUMPRC     FUNCTION    RN1,C5        DUMP ROCK CRUSHER TIME
```

```
0,0.33/0.02,0.67/0.14,0.83/0.94,1/1,1.17

ROAST     FUNCTION    RN1,C5          DUMP TIME AT ROAST
0,0.33/0.02,0.67/0.14,0.83/0.94,1/1,1.17

LEACH     FUNCTION    RN1,C5          LEACH DUMP TIME
0,0.33/0.02,0.67/0.14,0.83/0.94,1/1,1.17

DUMPCR    FUNCTION    RN1,C5          ORE CRUSHER DUMP TIME
0,0.33/0.02,0.67/0.14,0.83/0.94,1/1,1.17

***********************************
*         FUNCTION PART
***********************************
DIV1  FUNCTION  PH1,L4            BLOCKB IS WASTE/BLOCKRC IS ROCK
CRUSHER/BLOCKA IS LEACH
1,BLOCKB/2,BLOCKRC/3,BLOCKA/4,BLOCKB

DIV2  FUNCTION  PH1,D2            BLOCKD IS WASTE DUMPS AND ROAST
AREAS,BLOCKC ORE CRUSHER
1,BLOCKD/4,BLOCKC

*DIV3  FUNCTION  RN1,D2           95% GOES BACK TO DUMP DOWN, 5% GOES
DUMP EAST AND ROAST AREAS
*.95,BLOCKE/1,BLOCKF

DIV4  FUNCTION  RN1,D2            77% GOES BACK TO LOWER DUMP, 23%
GOES DUMP HIGHER DUMP
.77,BLOCKG/1,BLOCKH

*DIV6  FUNCTION  RN1,D2           10% GOES TO FUEL, 90% GOES BACK TO
SHOVELS
*.1,BLOCKK/1,BLOCKL

***********************************
*     PUMPING GAS TIMES
***********************************
GAST      FUNCTION    RN1,C2
0,13/1,19

***********************************
*     SHOVEL SHOVEL1-4100
***********************************
LOADS1    FUNCTION    RN1,C8
```

```
0,1.17/0.02,1.5/0.31,1.83/0.54,2.17/0.73,2.5/0.87,2.83/0.94,3.5/1,3.83      SECOND-
MODIFIED

*0,1/0.11,1.17/0.45,1.33/0.57,1.5/0.64,1.67/0.70,1.83/0.84,2/0.89,2.17/0.91,2.33/0.93,2.5
/0.95,3/1,3.17      FIRST DATA COLLECTION

***********************************
*     SHOVEL SHOVEL2-2800
***********************************
LOADS2    FUNCTION    RN1,C12
0,1.83/.05,2.5/.08,2.83/.13,3.17/.33,3.5/.54,3.83/.72,4.17/.87,4.5/.90,4.83/.95,5.17/.97,5.8
3/1,6.17      SECOND-MODIFIED

*0,2.33/0.31,2.67/0.67,3/0.89,3.33/1,3.67        FIRST DATA COLLECTION

***********************************
*    TRUCK TONNAGE FUNCTION
***********************************
LOAD795   FUNCTION   RN1,C4
0,300/0.17,310/0.67,320/1,330

***********************************
*     FUNCTIONS FOR MATERIALS
***********************************
TYPE1   FUNCTION      RN1,D4
.945,1/.954,2/.996,3/1,4
*.8,1/.81,2/.96,3/1,4

TYPE2   FUNCTION      RN1,D2
.996,1/1,2

***********************************
*   FUNCTIONS FOR SHOVEL DOWN TIME
***********************************
*SHOVDU1   FUNCTION    RN1,C12
*0,0/0.41,100/0.59,200/0.64,300/0.70,400/0.71,500/0.79,600/0.82,700/0.84,1000/0.86,13
00/0.88,1400/1,1500        SHOVEL 342-4100 DOWN TIME-DURATION

*SHOVDU2   FUNCTION    RN1,C9
*0,0/0.63,100/0.71,200/0.76,400/0.79,500/0.84,600/0.89,700/0.97,1200/1,1300
SHOVEL 352-2800 DOWN TIME-DURATION


***********************************
*           INPUTS
```

```
************************************
        DO    &IA=1,80
        PUTSTRING    ('  ')
        ENDDO
        PUTSTRING    ('  ')
        PUTSTRING    ('                  *** PIPELINE SIMULATION MODEL 2013 ***')
AGAIN   PUTSTRING    ('  ')
        PUTSTRING    ('  ')
        PUTSTRING    ('  INPUT THE NUMBER OF CATERPILLAR 795F TRUCK IN
THE GAP PIT?')
        PUTSTRING    ('  ')
        GETLIST      &NT795
        PUTPIC       FILE=ATF,LINES=2,AC1,&NT795
TIME *.****
WRITE NT3 **
        PUTSTRING    ('  ')
        PUTSTRING    ('   HOW MANY SHIFTS TO SIMULATE FOR? (TWO SHIFTS
PER DAY)')
        GETLIST      &SHIFTS
        PUTSTRING    ('  ')
        PUTSTRING    ('  HOW MANY EFFECTIVE OPERATING HOURS PER
SHIFT?')
        GETLIST      &OPH
        PUTPIC       FILE=ATF,LINES=2,AC1,&OPH
TIME *.****
WRITE MEW **.**
        PUTSTRING    ('  ')
        PUTSTRING    ('  DO YOU WANT ANIMATION? (Y/N)')
        CHAR*1       &YES,&YY
MYBOOL   BVARIABLE    (&YES'E"Y')OR(&YES'E"y')
        GETLIST      &YES
        PUTSTRING    ('  ')
        PUTPIC       LINES=4,&NT795,&SHIFTS,&OPH
        INPUT DATA IS AS FOLLOWS:
    NUMBER OF 795 TRUCKS: **
    NUMBER OF SHIFTS TO SIMULATE FOR: **
    EFFECTIVE HOURS PER SHIFTS: **.**
        PUTSTRING    ('  ')
        PUTSTRING    ('  ARE YOU HAPPY WITH THESE VALUES? (Y/N)')
        GETLIST      &YY
        IF           (&YY'NE"Y')AND(&YY'NE"y')
        GOTO   AGAIN
        ENDIF
ANIM     TEST E       BV(MYBOOL),1,PH3+2
        TRANSFER     ,PH3+1
```

```
       PUTSTRING    ('  ')
       PUTSTRING    ('  ')
       PUTSTRING    ('         *** SIMULATION RESULTS IN PROGRESS ***')
       PUTSTRING    ('  ')

**********************************************
*            START MACRO DEFINITIONS        *
**********************************************
 TRAVEL   STARTMACRO
        BLET       #A=FN(#B)
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1,#A
 TIME *.****
 PLACE T* ON P#C
 SET T* TRAVEL **.**
 PAT#D  ADVANCE     #A
      ENDMACRO
**********************************************
*            END OF MACRO DEFINITIONS      *
**********************************************

FIRST     TABLE       MP6PL,10,1,20
SECOND    TABLE       MP6PL,10,1,20
THIRD     TABLE       MP7PL,1,.5,10
FOURTH    TABLE       MP7PL,1,.5,10
FIFTH     TABLE       MP8PL,2,1,10
SIXTH     TABLE       MP9PL,1,1,10
SEVEN     TABLE       MP10PL,1,1,10
EIGHT     TABLE       MP11PL,1,1,10

****************************************
*  START WITH 795F TRUCKS IN THE MINE    *
****************************************
        GENERATE    5,,8,&NT795,,12PH,12PL
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE T795E T*
PLACE T* AT -36.12 -63.30
TRAVEL    MACRO      &A,1,1,1
        SEIZE       INTERA       QUEUE-1 AREA
TRAVEL    MACRO      &B,2,2,2
        RELEASE     INTERA
PATHP3    ADVANCE     0
```

```
TRAVEL    MACRO      &C,3,3,3
        SEIZE      INTERB
TRAVEL    MACRO      &W,A3,A3,A3
        RELEASE    INTERB
PATHP5    ADVANCE    0
TRAVEL    MACRO      &F,5,5,5
        GATE LR    STOPSH2,AREA1
        GATE LR    STOPSH1,SSHOV2
*******************************************
*        DISPATCH CODE GOES HERE        *
*******************************************
        BLET
&COUNT1=W(PAT6)+Q(SHOVEL1)+F(SHOVEL1)+F(SPOT1S1)+F(SPOT2S1)
        BLET
&COUNT2=W(PAT7)+Q(SHOVEL2)+F(SHOVEL2)+F(SPOT1S2)+F(SPOT2S2)
        TEST LE    &COUNT1,&COUNT2,SSHOV2
*******************************************************************
AREA1     ADVANCE    0
TRAVEL    MACRO      &G,6,6,6
        MARK       7PL
*********************************************
*             SHOVEL-1 4100
*********************************************
        TABULATE   FIRST
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=3,AC1,TB(FIRST),MP6PL
TIME *.****
WRITE MTABLE1 **.**
WRITE MTABLE2 **.**
        QUEUE      SHOVEL1
        MARK       6PL
        TRANSFER   BOTH,,NEXT1
        SEIZE      SPOT1S1
*         ADVANCE    FN(SPOTSH1)        SPOT TIME AT SHOVEL 1-4100
        ADVANCE    RVEXPO(1,.988)           DISPATCH DATA USED
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=2,AC1,XID1
TIME *.****
PLACE T* AT -73.85 -31.97
        SEIZE      SHOVEL1           LOADING SHOVEL 1
        GATE LR    STOPSH1
        RELEASE    SPOT1S1           SPOT SHOVEL 1-4100
        DEPART     SHOVEL1
        ADVANCE    FN(LOADS1)
*         ADVANCE    RVEXPO(1,1.366)
```

```
        ASSIGN      1,FN(TYPE1),PH      ASSIGN MATERIALS
        RELEASE     SHOVEL1
        TRANSFER    ,POINT1

NEXT1    SEIZE      SPOT2S1
*         ADVANCE    FN(SPOTSH1)
        ADVANCE    RVEXPO(1,.988)            DISPATCH DATA USED
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
PLACE T* AT -73.32 -33.83
        SEIZE      SHOVEL1
        GATE LR     STOPSH1
        RELEASE     SPOT2S1
        DEPART      SHOVEL1
        ADVANCE    FN(LOADS1)
*         ADVANCE    RVEXPO(1,1.366)
        ASSIGN      1,FN(TYPE1),PH     ASSIGN MATERIALS FOR SHOVEL 1
        RELEASE     SHOVEL1
POINT1    ASSIGN      1,FN(LOAD795),PL   AMOUNT LOAD BY SHOVEL 4100
TRUCK 795F
        BLET       &A795F=&A795F+1
        BLET       &B795F=&B795F+PL1
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC
FILE=ATF,LINES=8,AC1,&A795F,&B795F,QA(SHOVEL1),QM(SHOVEL1),XID1,F
R(SHOVEL1)/10.,FC(SHOVEL1)
TIME *.****
WRITE M8  ***
WRITE M9  *****.**
WRITE M3 **.**
WRITE M4 **
SET T* CLASS T795F
WRITE M5 **.**%
WRITE M19 ***
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1,FR(SHOVEL1)/10.
TIME *.****
SET BAR   SHOVEL1 **.**
        TABULATE    THIRD
******************************
*    WAY BACK FROM SHOVEL 1
******************************
TRAVEL    MACRO      &I,10,10,10
        SEIZE      INTERF
```

```
TRAVEL    MACRO       &III,A10,A10,A10
          RELEASE     INTERF
PATHP11   ADVANCE     0
          MARK        8PL
TRAVEL    MACRO       &J,11,11,11
          SEIZE       INTERB        LEACH PAD
TRAVEL    MACRO       &K,12,12,12
          RELEASE     INTERB
          TABULATE    FIFTH         TABLE TRAVEL TIME FULL TRUCK P11 &P12
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=2,AC1,TB(FIFTH)
TIME *.****
WRITE TVAB **.**
          TRANSFER    ,FN(DIV1)
BLOCKRC   ADVANCE     0
TRAVEL    MACRO       &AAA,52,52,52
********************************
*         ROCK CRUSHER
********************************
          SEIZE       DUMPRC
          SEIZE       SPOTRC        SPOT AT ROCK CRUSHER
          ADVANCE     FN(SPOTRC)    SPOT
          RELEASE     SPOTRC
          ADVANCE     FN(DUMPRC)         DUMP TIME AT CRUSHER
          RELEASE     DUMPRC
          BLET        &RC795F=&RC795F+1
          BLET        &RCB795F=&RCB795F+PL1
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=4,AC1,&RC795F,&RCB795F,XID1
TIME *.****
WRITE M61  ***
WRITE M62  *****.**
SET T* CLASS T795E
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=2,AC1,FC(DUMPRC)
TIME *.****
WRITE M64 ****
TRAVEL    MACRO       &BBB,53,53,53
          SEIZE       INTERB
TRAVEL    MACRO       &CCC,54,54,54
          RELEASE     INTERB
          TRANSFER    ,PATHP5

BLOCKB    ADVANCE     0
          MARK        9PL
```

```
TRAVEL    MACRO      &P,16,16,16
TRAVEL    MACRO      &Q,17,17,17
          SEIZE      INTERC         CRUSHER
TRAVEL    MACRO      &R,18,18,18
          RELEASE    INTERC
          TABULATE   SIXTH          TABLE FOR TRAVEL FULL TRUCK FOR
P16,P17,P18
          TRANSFER   SBR,ANIM,3PH
          BPUTPIC    FILE=ATF,LINES=2,AC1,TB(SIXTH)
TIME *.****
WRITE TVBC **.**
          TRANSFER   ,FN(DIV2)

BLOCKC    ADVANCE    0      CRUSHER
TRAVEL    MACRO      &S,19,19,19
TRAVEL    MACRO      &T,20,20,20

*********************************
*      DUMP INTO CRUSHER
*********************************
          SEIZE      CRUSHER
          SEIZE      SPOTC       SPOT AT CRUSHER
          ADVANCE    FN(SPOTC)     SPOT TIME
          RELEASE    SPOTC
          ADVANCE    FN(DUMPCR)        DUMP TIME AT CRUSHER
          RELEASE    CRUSHER
          BLET       &CR795F=&CR795F+1
          BLET       &CRB795F=&CRB795F+PL1
          TRANSFER   SBR,ANIM,3PH
          BPUTPIC    FILE=ATF,LINES=4,AC1,&CR795F,&CRB795F,XID1
TIME *.****
WRITE M40  ***
WRITE M41  *****.**
SET T* CLASS T795E
          TRANSFER   SBR,ANIM,3PH
          BPUTPIC    FILE=ATF,LINES=2,AC1,FC(CRUSHER)
TIME *.****
WRITE M43 ***
TRAVEL    MACRO      &RR,44,44,44

*         TRANSFER   ,FN(DIV6)
*BLOCKK   ADVANCE    0
*TRAVEL   MACRO      &SS,45,45,45

*****************************
```

```
*       GET FUEL
*****************************
        SEIZE      GAS1
        BLET       &TAC3=RVNORM(1,1900,90)      ASSUME AMOUNT OF
FUELING OF 795F IS THIS
        BLET       &TOTGAS=&TOTGAS+&TAC3       ADD TO TOTAL GAS
        BLET       &TA3=&TA3+1                 COUNT FUELING TRUCKS
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=4,AC1,&TA3,&TOTGAS
TIME *.****
WRITE MGAS1 ***
WRITE MGAS2 ******Gal
WRITE MGAS3 "REFUELING!"
        ADVANCE     FN(GAST)
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
WRITE MGAS3
        RELEASE     GAS1
TRAVEL    MACRO      &ZZ,A45,A45,A45
BLOCKL    ADVANCE     0


TRAVEL    MACRO      &TT,46,46,46
        SEIZE      INTERC
TRAVEL    MACRO      &UU,47,47,47
        RELEASE     INTERC
        TRANSFER    ,PATHP37
BLOCKD    ADVANCE     0      DUMPS & ROAST
TRAVEL    MACRO      &U,21,21,21
*         TRANSFER    ,FN(DIV3)
BLOCKE    ADVANCE     0
TRAVEL    MACRO      &UA,A21,A21,A21
        TRANSFER    ,FN(DIV4)          DUMPS DOWN SIDE

BLOCKG    ADVANCE     0
        MARK       10PL
TRAVEL    MACRO      &X,24,24,24     DUMP LEFT SIDE
TRAVEL    MACRO      &Y,25,25,25
*****************************
*        DUMP-1 LEFT SIDE
*****************************
        ADVANCE     FN(SPOTD1)    SPOT
        ADVANCE     FN(DUMP1)         WASTE TIME
        BLET       &AA795F=&AA795F+1
```

```
        BLET       &BB795F=&BB795F+PL1
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=4,AC1,&AA795F,&BB795F,XID1
TIME *.****
WRITE M16  ***
WRITE M17  *****.**
SET T* CLASS T795E
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1,&AA795F
TIME *.****
WRITE M18 ****

TRAVEL    MACRO      &MM,39,39,39
TRAVEL    MACRO      &NN,40,40,40
        TABULATE    SEVEN
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1,TB(SEVEN)
TIME *.****
WRITE TVDE **.**
PATHPB21  ADVANCE     0
        SEIZE      INTERD
TRAVEL    MACRO      &PP,B21,B21,B21
        RELEASE     INTERD
        TRANSFER    ,PATHP35

BLOCKH    ADVANCE     0
        MARK       11PL
TRAVEL    MACRO      &Z,26,26,26        DUMP RIGHT SIDE
****************************
*     DUMP-1 RIGHT SIDE
****************************
        ADVANCE     FN(SPOTD1)    SPOT
        ADVANCE     FN(DUMP1)         DUMP TIME

        BLET       &AA795F=&AA795F+1
        BLET       &BB795F=&BB795F+PL1
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=4,AC1,&AA795F,&BB795F,XID1
TIME *.****
WRITE M16  ***
WRITE M17  *****.**
SET T* CLASS T795E
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1,&AA795F
TIME *.****
```

```
WRITE M18 ****
TRAVEL    MACRO      &QQ,43,43,43
          TABULATE   EIGHT
          TRANSFER   SBR,ANIM,3PH
          BPUTPIC    FILE=ATF,LINES=2,AC1,TB(EIGHT)
TIME *.****
WRITE TVDF **.**
          TRANSFER   ,PATHPB21

BLOCKF    ADVANCE    0              ROAST & DUMP RIGHT
TRAVEL    MACRO      &AA,27,27,27
TRAVEL    MACRO      &DD,30,30,30
*********************************
*         DUMP ROAST
*********************************
          ADVANCE    FN(SPOTR)    SPOT TIME
          ADVANCE    FN(ROAST)         DUMP TIME AT ROAST
          BLET       &ROS795F=&ROS795F+1
          BLET       &ROB795F=&ROB795F+PL1
          TRANSFER   SBR,ANIM,3PH
          BPUTPIC    FILE=ATF,LINES=4,AC1,&ROS795F,&ROB795F,XID1
TIME *.****
WRITE M50  ***
WRITE M51  *****.**
SET T* CLASS T795E
          TRANSFER   SBR,ANIM,3PH
          BPUTPIC    FILE=ATF,LINES=2,AC1,&ROS795F
TIME *.****
WRITE M53 ****
TRAVEL    MACRO      &EE,31,31,31
          SEIZE      INTERE
TRAVEL    MACRO      &FF,32,32,32
          RELEASE    INTERE
TRAVEL    MACRO      &GG,33,33,33
          SEIZE      INTERD
TRAVEL    MACRO      &HH,34,34,34
          RELEASE    INTERD

PATHP35   ADVANCE    0
TRAVEL    MACRO      &II,35,35,35
          SEIZE      INTERC
TRAVEL    MACRO      &OO,A35,A35,A35
          RELEASE    INTERC

PATHP37   ADVANCE    0
```

```
TRAVEL    MACRO      &KK,37,37,37
          TRANSFER    ,PATHP3

BLOCKA    ADVANCE     0
TRAVEL    MACRO      &M,13,13,13
********************************
*         DUMP LEACH
********************************
          ADVANCE     FN(SPOTL)     SPOT TIME
          ADVANCE     FN(LEACH)          DUMP TIME AT LEACH
          BLET        &LL795F=&LL795F+1
          BLET        &LB795F=&LB795F+PL1
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=4,AC1,&LL795F,&LB795F,XID1
TIME *.****
WRITE M30  ***
WRITE M31  *****.**
SET T* CLASS T795E
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=2,AC1,&LL795F
TIME *.****
WRITE M33 ****
TRAVEL    MACRO      &WW,49,49,49
          SEIZE       INTERB
TRAVEL    MACRO      &XX,50,50,50
          RELEASE     INTERB
          TRANSFER    ,PATHP5

********************************************
*              SHOVEL-2 2800
********************************************
SSHOV2    ADVANCE     0
TRAVEL    MACRO      &H,7,7,7
          MARK        7PL
          TABULATE    SECOND
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=3,AC1,TB(SECOND),MP6PL
TIME *.****
WRITE MTABLE3 **.**
WRITE MTABLE4 **.**
          QUEUE       SHOVEL2
          MARK        6PL
          TRANSFER    BOTH,,NEXT2
          SEIZE       SPOT1S2
*           ADVANCE     FN(SPOTSH2)        SPOT TIME AT SHOVEL 2
```

```
        ADVANCE    RVEXPO(1,1.204)          DISPATCH DATA USED
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=2,AC1,XID1
TIME *.****
PLACE T* AT -68.02 -12.78
        SEIZE      SHOVEL2
        GATE LR    STOPSH2
        RELEASE    SPOT1S2         SPOT SHOVEL 2
        DEPART     SHOVEL2
        ADVANCE    FN(LOADS2)
*       ADVANCE    RVEXPO(1,2.99)
        ASSIGN     1,FN(TYPE2),PH     ASSIGN THE TYPE OF MATERIALS
        RELEASE    SHOVEL2
        TRANSFER   ,POINT2

NEXT2   SEIZE      SPOT2S2
*       ADVANCE    FN(SPOTSH2)
        ADVANCE    RVEXPO(1,1.204)          DISPATCH DATA USED
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=2,AC1,XID1
TIME *.****
PLACE T* AT -68.69 -15.03
        SEIZE      SHOVEL2
        GATE LR    STOPSH2
        RELEASE    SPOT2S2
        DEPART     SHOVEL2
        ADVANCE    FN(LOADS2)
*       ADVANCE    RVEXPO(1,2.99)
        ASSIGN     1,FN(TYPE2),PH      ASSIGN THE TYPE OF MATERIALS
        RELEASE    SHOVEL2
POINT2  ADVANCE    0
        ASSIGN     1,FN(LOAD795),PL   AMOUNT LOAD BY SHOVEL 2 2800
        BLET       &AAA795F=&AAA795F+1
        BLET       &BBB795F=&BBB795F+PL1
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC
FILE=ATF,LINES=8,AC1,&AAA795F,&BBB795F,QA(SHOVEL2),QM(SHOVEL2),X
ID1,FR(SHOVEL2)/10.,FC(SHOVEL2)
TIME *.****
WRITE M28  ***
WRITE M29  *****.**
WRITE M21 **.**
WRITE M22 **
SET T* CLASS T795F
WRITE M23 **.**%
```

```
WRITE M24 ***
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=2,AC1,FR(SHOVEL2)/10.
TIME *.****
SET BAR   SHOVEL2 **.**
          TABULATE    FOURTH
TRAVEL    MACRO       &L,8,8,8
          SEIZE       INTERF
TRAVEL    MACRO       &LLL,A8,A8,A8
          RELEASE     INTERF
          TRANSFER    ,PATHP11

***********************************************
*   SEGMENT FOR SHOVEL 1 LOADING              *
***********************************************
          GENERATE    ,,,1,10      DUMMY TRANSACTION
WAIT1     TEST E      F(SHOVEL1),1
          TRANSFER    SBR,ANIM,3PH
WAIT2     BPUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
ROTATE BB1 45 STEP 5 TIME .3
          GATE LR     STOPSH1
          ADVANCE     .35
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
ROTATE BB1 -45 STEP 5 TIME .3
          ADVANCE     .35
          TEST E      F(SHOVEL1),1,WAIT1
          TRANSFER    ,WAIT2

***********************************************
*   SEGMENT FOR SHOVEL 2 LOADING              *
***********************************************
          GENERATE    ,,,1,10      DUMMY TRANSACTION
WAIT3     TEST E      F(SHOVEL2),1
          TRANSFER    SBR,ANIM,3PH
WAIT4     BPUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
ROTATE BB2 45 STEP 5 TIME .15
          GATE LR     STOPSH2
          ADVANCE     .35
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
```

```
ROTATE BB2 -45 STEP 5 TIME .15
          ADVANCE     .35
          TEST E      F(SHOVEL2),1,WAIT3
          TRANSFER    ,WAIT4

***********************************************
*   SEGMENT FOR ROCK CRUSHER ANIMATION        *
***********************************************
          GENERATE    ,,,1      DUMMY TRANSACTION
WAIT5     TEST E      F(DUMPRC),1
          TRANSFER    SBR,ANIM,3PH
WAIT6     BPUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
ROTATE CIR 800 SPEED  500
          ADVANCE     3
          TEST E      F(DUMPRC),1,WAIT5
          TRANSFER    ,WAIT6

****************************************************
*  DOWN TIMES AND RAPAIR TIMES FOR SHOVEL-1 (4100)  *
****************************************************
          GENERATE    ,,,1
UPSTOP1   ADVANCE     RVEXPO(1,100)
          LOGIC S     STOPSH1
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
WRITE MDS1 SHOVEL 1 IS DOWN!!!
          ADVANCE     FN(SHOVDU1)
          LOGIC R     STOPSH1
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
WRITE MDS1
          TRANSFER    ,UPSTOP1

****************************************************
*  DOWN TIMES AND RAPAIR TIMES FOR SHOVEL-2  (2800) *
****************************************************
          GENERATE    ,,,1
UPSTOP2   ADVANCE     1
         ADVANCE     RVEXPO(1,250)
          LOGIC S     STOPSH2
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=2,AC1
```

```
TIME *.****
WRITE MDS2 SHOVEL 2 IS DOWN!!!
        ADVANCE    85000
        ADVANCE    FN(SHOVDU2)
        LOGIC R    STOPSH2
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=2,AC1
TIME *.****
WRITE MDS2
        TRANSFER   ,UPSTOP2

*******************************************
*           CLOCK SEGMENT              *
*******************************************
        INTEGER    &TIME,&DAYNO,&WKDAYNO,&WEEKNO,&HOUR
        GENERATE   ,,,1,150,12PL,12PH   DUMMY TRANSACTION FOR CLOCK
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=3,AC1
TIME *.****
ROTATE MHAND1 SPEED -6 STEP 6
ROTATE HHAND1 SPEED -.5 STEP 6
        BLET       &HOUR=0
        BLET       &WKDAYNO=1
        BLET       &WEEKNO=1
NEXTMIN   ADVANCE     1      ADVANCE THE CLOCK ONE MINUTE
        BLET       &TIME=&TIME+1
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC
FILE=ATF,LINES=5,AC1,&TIME,&HOUR,&WKDAYNO,&WEEKNO
TIME *.****
WRITE MT1 **
WRITE MT2 **
WRITE MT3 **
WRITE MT4 **
        TEST E     &TIME@60,0,NEXTMIN
        BLET       &TIME=0
        BLET       &HOUR=&HOUR+1
        TEST E     &HOUR,24,NEXTMIN   24 HOURS PAST?
        BLET       &TIME=0
        BLET       &HOUR=0
        BLET       &DAYNO=&DAYNO+1
        BLET       &WKDAYNO=&WKDAYNO+1
        TEST E     &WKDAYNO,8,NEXTMIN  NEW WEEK?
        BLET       &WKDAYNO=1
        BLET       &WEEKNO=&WEEKNO+1
```

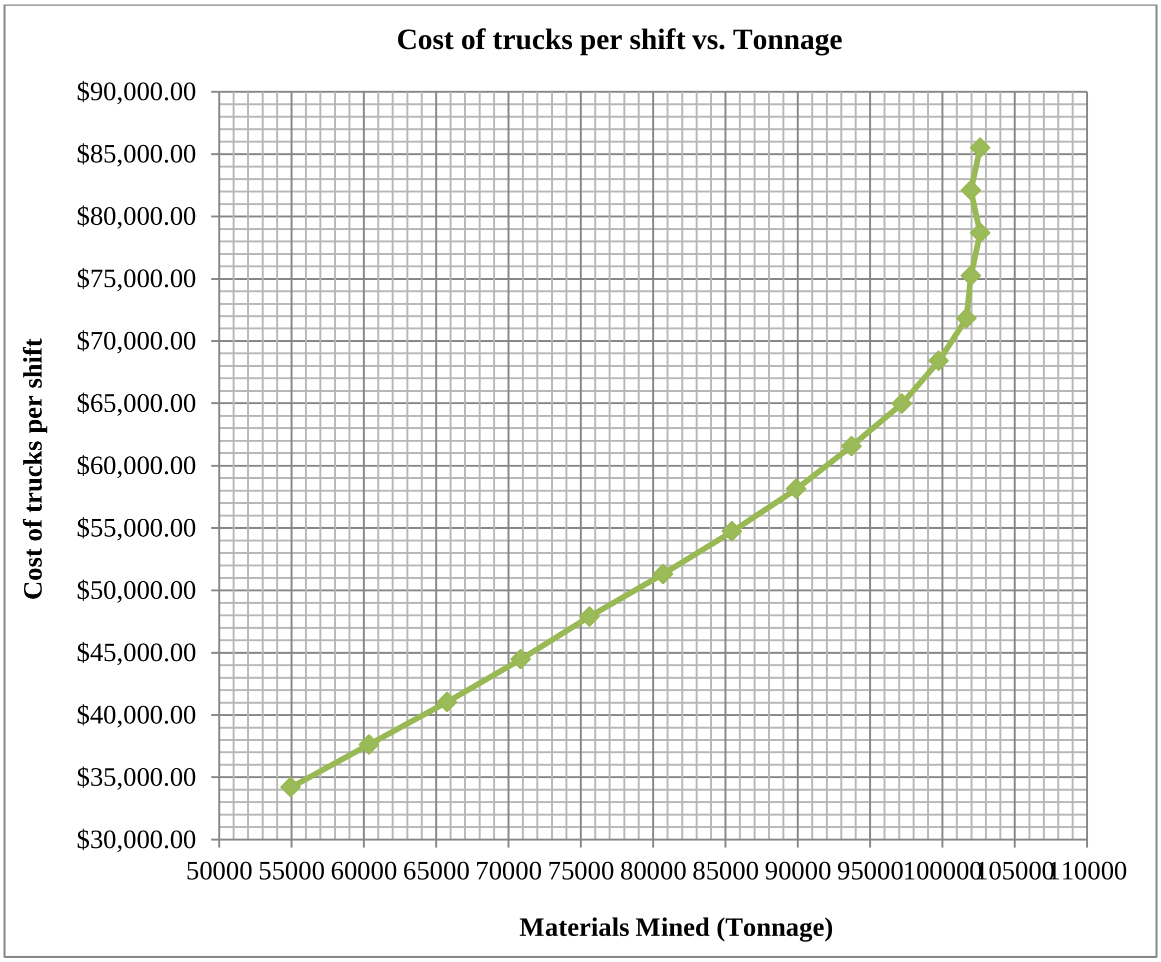
```
        TRANSFER    ,NEXTMIN

****************************************************
*        TIMER TRANSACTION COMES NEXT            *
****************************************************
        GENERATE    ,,,1
        ADVANCE     &SHIFTS*&OPH*60
        TERMINATE   1
        START       1

*****************************************************
*          SIMULATION RESULT DISPLAY              *
*****************************************************
        DO        &WWW=1,23
        PUTSTRING ('  ')
        ENDDO
        PUTPIC      LINES=4,&NT795,&SHIFTS,&OPH
        ---RESULTS OF SIMULATION PROGRAM---
          NUMBER OF TRUCKS: **
          SHIFTS TO SIMULATE FOR: ***
          HOURS OF ACTUAL WORK: **.**
        PUTSTRING ('  ')
        PUTSTRING ('  ')
        PUTPIC
LINES=18,FC(SHOVEL1)/&SHIFTS,FR(SHOVEL1)/10.,QA(SHOVEL1),QT(SHOVE
L1),TB(FIRST),TB(THIRD),FC(SHOVEL2)/&SHIFTS,_

FR(SHOVEL2)/10.,QA(SHOVEL2),QT(SHOVEL2),TB(SECOND),TB(FOURTH),&A
A795F/&SHIFTS,&BB795F/&SHIFTS
==============================================================
NUMBER OF LOADS PER SHIFT FROM SHOVEL 4100(342):    ***
UTILIZATION OF SHOVEL 4100(342):    **.**%
AVERAGE QUEUE AT SHOVEL 4100(342):    **.**
AVERAGE RESIDENCE TIME OF TRUCKS AT SHOVEL 4100(342):    **.**
CYCLE TIME FOR TRUCKS AT SHOVEL 4100(342):  **.**
AVERAGE TIME FOR TRUCKS AT SHOVEL 4100(342):  **.**
==============================================================
NUMBER OF LOADS PER SHIFT FROM SHOVEL 2800(352):    ***
UTILIZATION OF SHOVEL 2800(352):    **.**%
AVERAGE QUEUE AT SHOVEL 2800(352):    **.**
AVERAGE RESIDENCE TIME OF TRUCKS AT SHOVEL 2800(352):    **.**
CYCLE TIME FOR TRUCKS AT SHOVEL 2800(352):  **.**
AVERAGE TIME FOR TRUCKS AT SHOVEL 2800(352):  **.**
==============================================================
TOTAL NUMBER OF  LOADS PER SHIFT INTO DUMP SOUTH AREA:    ***
```

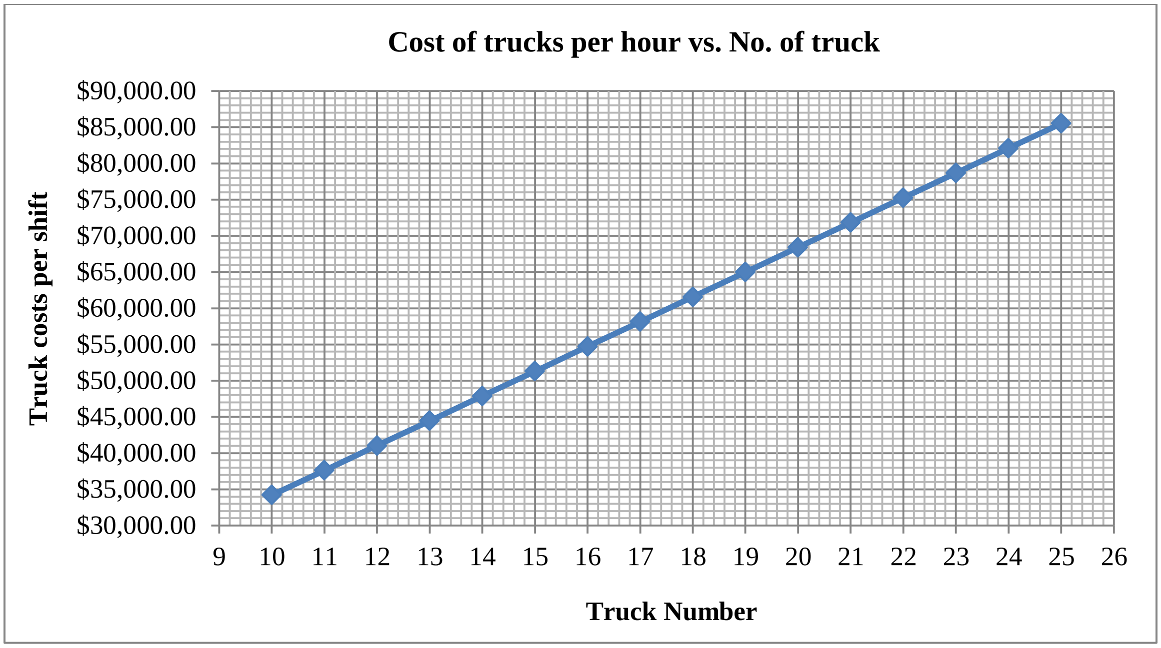
```
TOTAL OF WASTE PER SHIFT:    ****
===============================================================
        PUTPIC
LINES=22,FILE=MYOUT,&NT795,&SHIFTS,&OPH,FC(SHOVEL1)/&SHIFTS,FR(S
HOVEL1)/10.,QA(SHOVEL1),QT(SHOVEL1),_

TB(FIRST),TB(THIRD),FC(SHOVEL2)/&SHIFTS,FR(SHOVEL2)/10.,QA(SHOVEL2)
,QT(SHOVEL2),TB(SECOND),TB(FOURTH),_
        &AA795F/&SHIFTS,&BB795F/&SHIFTS
        --- RESULTS OF GAP PIT SIMULATION PROGRAM IN EXCEL FILE ---
           NUMBER OF TRUCKS: **
           SHIFTS TO SIMULATE FOR: ***
           HOURS OF ACTUAL WORK: **.**
===============================================================
NUMBER OF LOADS PER SHIFT FROM SHOVEL 4100(342):    ***
UTILIZATION OF SHOVEL 4100(342):    **.**%
AVERAGE QUEUE AT SHOVEL 4100(342):    **.**
AVERAGE RESIDENCE TIME OF TRUCKS AT SHOVEL 4100(342):    **.**
CYCLE TIME FOR TRUCKS AT SHOVEL 4100(342):  **.**
AVERAGE TIME FOR TRUCKS AT SHOVEL 4100(342):  **.**
===============================================================
NUMBER OF LOADS PER SHIFT FROM SHOVEL 2800(352):    ***
UTILIZATION OF SHOVEL 2800(352):    **.**%
AVERAGE QUEUE AT SHOVEL 2800(352):    **.**
AVERAGE RESIDENCE TIME OF TRUCKS AT SHOVEL 2800(352):    **.**
CYCLE TIME FOR TRUCKS AT SHOVEL 2800(352):  **.**
AVERAGE TIME FOR TRUCKS AT SHOVEL 2800(352):  **.**
===============================================================
TOTAL NUMBER OF  LOADS PER SHIFT INTO DUMP SOUTH AREA:    ***
TOTAL OF WASTE PER SHIFT:    ****
===============================================================
        PUTPIC
LINES=15,FC(CRUSHER)/&SHIFTS,&CRB795F/&SHIFTS,&RC795F/&SHIFTS,&R
CB795F/&SHIFTS,&ROS795F/&SHIFTS,_

&ROB795F/&SHIFTS,&LL795F/&SHIFTS,&LB795F/&SHIFTS,&AT795F/&SHIFTS,
&BT795F/&SHIFTS
TOTAL NUMBER OF  LOADS PER SHIFT INTO ORE CRUSHER:    ***
TOTAL ORE CRUSHER PER SHIFT:    *****
===============================================================
TOTAL NUMBER OF  LOADS PER SHIFT INTO ROCK CRUSHER:    ***
TOTAL ROCK CRUSHER PER SHIFT:    *****
===============================================================
TOTAL NUMBER OF  LOADS PER SHIFT INTO ROAST:    ***
TOTAL ROAST PER SHIFT:    ****
```

```
=============================================================
TOTAL NUMBER OF  LOADS PER SHIFT INTO LEACH PADS:    ***
TOTAL LEACH PADS PER SHIFT:    ****
=============================================================
TOTAL NUMBER OF  LOADS PER SHIFT INTO TAIL:    ***
TOTAL TAIL PER SHIFT:    ****
=============================================================
        PUTPIC
LINES=15,FILE=MYOUT,FC(CRUSHER)/&SHIFTS,&CRB795F/&SHIFTS,&RC795
F/&SHIFTS,&RCB795F/&SHIFTS,_

&ROS795F/&SHIFTS,&ROB795F/&SHIFTS,&LL795F/&SHIFTS,&LB795F/&SHIFT
S,&AT795F/&SHIFTS,&BT795F/&SHIFTS
TOTAL NUMBER OF  LOADS PER SHIFT INTO ORE CRUSHER:    ***
TOTAL ORE CRUSHER PER SHIFT:    *****
=============================================================
TOTAL NUMBER OF  LOADS PER SHIFT INTO ROCK CRUSHER:    ***
TOTAL ROCK CRUSHER PER SHIFT:    *****
=============================================================
TOTAL NUMBER OF  LOADS PER SHIFT INTO ROAST:    ***
TOTAL ROAST PER SHIFT:    ****
=============================================================
TOTAL NUMBER OF  LOADS PER SHIFT INTO LEACH PADS:    ***
TOTAL LEACH PADS PER SHIFT:    ****
=============================================================
TOTAL NUMBER OF  LOADS PER SHIFT INTO TAIL:    ***
TOTAL TAIL PER SHIFT:    ****
=============================================================

        PUTPIC      LINES=5,&TA3,&TOTGAS
TOTAL NUMBER OF  TRUCKS AT FUEL:    ***
TOTAL FUEL CINSUMPTION:    ******
=============================================================

"BARRICK GOLD CORPORATION"
        PUTPIC      LINES=4,FILE=MYOUT,&TA3,&TOTGAS
TOTAL NUMBER OF  TRUCKS AT FUEL:    ***
TOTAL FUEL CINSUMPTION:    ******
=============================================================
"BARRICK GOLD CORPORATION"
        PUTSTRING   ('  ')
        PUTSTRING   ('  RESULTS PLACED IN A FILE PIPERST.XLS (EXCEL FILE)
')
************************************************
```

```
        IF          &YES'E"Y'
        PUTPIC      FILE=ATF,LINES=2,AC1
TIME *.****
END
        ENDIF
        END
****************************************************
****************************************************
```

Additional Data Analysis of the Gap Pit Simulation Results:





Several examples of the outputs of the developed simulation and animation models are presented as following:

--- RESULTS OF GAP PIT SIMULATION PROGRAM IN EXCEL FILE ---
NUMBER OF TRUCKS: 23
SHIFTS TO SIMULATE FOR: 180
HOURS OF ACTUAL WORK: 7.60
==
NUMBER OF LOADS PER SHIFT FROM SHOVEL 4100: 204
UTILIZATION OF SHOVEL 4100: 99.79%
AVERAGE QUEUE AT SHOVEL 4100: 2.70
AVERAGE RESIDENCE TIME OF TRUCKS AT SHOVEL 4100: 6.01
CYCLE TIME FOR TRUCKS AT SHOVEL 4100 32.63
AVERAGE TIME FOR TRUCKS AT SHOVEL 4100: 8.23
==
NUMBER OF LOADS PER SHIFT FROM SHOVEL 2800: 119
UTILIZATION OF SHOVEL 2800: 99.91%
AVERAGE QUEUE AT SHOVEL 2800: 2.78
AVERAGE RESIDENCE TIME OF TRUCKS AT SHOVEL 2800: 10.63
CYCLE TIME FOR TRUCKS AT SHOVEL 2800 31.96
AVERAGE TIME FOR TRUCKS AT SHOVEL 2800: 14.46

==
TOTAL NUMBER OF LOADS PER SHIFT INTO DUMP SOUTH AREA: 312
TOTAL OF WASTE PER SHIFT: 98631
TOTAL NUMBER OF LOADS PER SHIFT INTO ORE CRUSHER: 0
TOTAL ORE CRUSHER PER SHIFT: 284
==
TOTAL NUMBER OF LOADS PER SHIFT INTO ROAST: 0
TOTAL ROAST PER SHIFT: 0
==
TOTAL NUMBER OF LOADS PER SHIFT INTO LEACH PADS: 9
TOTAL LEACH PADS PER SHIFT: 2818
==
TOTAL NUMBER OF TRUCKS AT FUEL: 0
TOTAL FUEL CINSUMPTION: 0
==
BARRICK GOLD CORPORATION

--- RESULTS OF GAP PIT SIMULATION PROGRAM IN EXCEL FILE ---
NUMBER OF TRUCKS: 24
SHIFTS TO SIMULATE FOR: 180
HOURS OF ACTUAL WORK: 7.60
==
NUMBER OF LOADS PER SHIFT FROM SHOVEL 4100: 203
UTILIZATION OF SHOVEL 4100: 99.88%
AVERAGE QUEUE AT SHOVEL 4100: 3.22
AVERAGE RESIDENCE TIME OF TRUCKS AT SHOVEL 4100: 7.21
CYCLE TIME FOR TRUCKS AT SHOVEL 4100 34.19
AVERAGE TIME FOR TRUCKS AT SHOVEL 4100: 9.45
==
NUMBER OF LOADS PER SHIFT FROM SHOVEL 2800: 118
UTILIZATION OF SHOVEL 2800: 99.93%
AVERAGE QUEUE AT SHOVEL 2800: 3.29
AVERAGE RESIDENCE TIME OF TRUCKS AT SHOVEL 2800: 12.60
CYCLE TIME FOR TRUCKS AT SHOVEL 2800 33.44
AVERAGE TIME FOR TRUCKS AT SHOVEL 2800: 16.44
==
TOTAL NUMBER OF LOADS PER SHIFT INTO DUMP SOUTH AREA: 311
TOTAL OF WASTE PER SHIFT: 98374
TOTAL NUMBER OF LOADS PER SHIFT INTO ORE CRUSHER: 0
TOTAL ORE CRUSHER PER SHIFT: 265
==
TOTAL NUMBER OF LOADS PER SHIFT INTO ROAST: 0
TOTAL ROAST PER SHIFT: 0
==
TOTAL NUMBER OF LOADS PER SHIFT INTO LEACH PADS: 9
TOTAL LEACH PADS PER SHIFT: 2735
==
TOTAL NUMBER OF TRUCKS AT FUEL: 0
TOTAL FUEL CINSUMPTION: 0
==
BARRICK GOLD CORPORATION

--- RESULTS OF GAP PIT SIMULATION PROGRAM IN EXCEL FILE ---
NUMBER OF TRUCKS: 12
SHIFTS TO SIMULATE FOR: 180
HOURS OF ACTUAL WORK: 7.60
==
NUMBER OF LOADS PER SHIFT FROM SHOVEL 4100: 0
UTILIZATION OF SHOVEL 4100: 0.00%
AVERAGE QUEUE AT SHOVEL 4100: 0.00
AVERAGE RESIDENCE TIME OF TRUCKS AT SHOVEL 4100: 0.00
CYCLE TIME FOR TRUCKS AT SHOVEL 4100 0.00
AVERAGE TIME FOR TRUCKS AT SHOVEL 4100: 0.00
==
NUMBER OF LOADS PER SHIFT FROM SHOVEL 2800: 118
UTILIZATION OF SHOVEL 2800: 99.98%
AVERAGE QUEUE AT SHOVEL 2800: 5.42
AVERAGE RESIDENCE TIME OF TRUCKS AT SHOVEL 2800: 20.78
CYCLE TIME FOR TRUCKS AT SHOVEL 2800 46.02
AVERAGE TIME FOR TRUCKS AT SHOVEL 2800: 24.62
==
TOTAL NUMBER OF LOADS PER SHIFT INTO DUMP SOUTH AREA: 118
TOTAL OF WASTE PER SHIFT: 37472
TOTAL NUMBER OF LOADS PER SHIFT INTO ORE CRUSHER: 0
TOTAL ORE CRUSHER PER SHIFT: 0
==
TOTAL NUMBER OF LOADS PER SHIFT INTO ROAST: 0
TOTAL ROAST PER SHIFT: 0
==
TOTAL NUMBER OF LOADS PER SHIFT INTO LEACH PADS: 0
TOTAL LEACH PADS PER SHIFT: 0
==
TOTAL NUMBER OF TRUCKS AT FUEL: 0
TOTAL FUEL CINSUMPTION: 0
==
BARRICK GOLD CORPORATION

--- RESULTS OF GAP PIT SIMULATION PROGRAM IN EXCEL FILE ---
NUMBER OF TRUCKS: 13
SHIFTS TO SIMULATE FOR: 180
HOURS OF ACTUAL WORK: 7.60
==
NUMBER OF LOADS PER SHIFT FROM SHOVEL 4100: 0
UTILIZATION OF SHOVEL 4100: 0.00%
AVERAGE QUEUE AT SHOVEL 4100: 0.00
AVERAGE RESIDENCE TIME OF TRUCKS AT SHOVEL 4100: 0.00
CYCLE TIME FOR TRUCKS AT SHOVEL 4100 0.00
AVERAGE TIME FOR TRUCKS AT SHOVEL 4100: 0.00
==
NUMBER OF LOADS PER SHIFT FROM SHOVEL 2800: 118
UTILIZATION OF SHOVEL 2800: 99.98%
AVERAGE QUEUE AT SHOVEL 2800: 6.41
AVERAGE RESIDENCE TIME OF TRUCKS AT SHOVEL 2800: 24.56
CYCLE TIME FOR TRUCKS AT SHOVEL 2800 49.81
AVERAGE TIME FOR TRUCKS AT SHOVEL 2800: 28.40
==
TOTAL NUMBER OF LOADS PER SHIFT INTO DUMP SOUTH AREA: 118
TOTAL OF WASTE PER SHIFT: 37462
TOTAL NUMBER OF LOADS PER SHIFT INTO ORE CRUSHER: 0
TOTAL ORE CRUSHER PER SHIFT: 0
==
TOTAL NUMBER OF LOADS PER SHIFT INTO ROAST: 0
TOTAL ROAST PER SHIFT: 0
==
TOTAL NUMBER OF LOADS PER SHIFT INTO LEACH PADS: 0
TOTAL LEACH PADS PER SHIFT: 0
==
TOTAL NUMBER OF TRUCKS AT FUEL: 0
TOTAL FUEL CINSUMPTION: 0
==
BARRICK GOLD CORPORATION

--- RESULTS OF GAP PIT SIMULATION PROGRAM IN EXCEL FILE ---
NUMBER OF TRUCKS: 13
SHIFTS TO SIMULATE FOR: 180
HOURS OF ACTUAL WORK: 7.60
==
NUMBER OF LOADS PER SHIFT FROM SHOVEL 4100: 202
UTILIZATION OF SHOVEL 4100: 98.63%
AVERAGE QUEUE AT SHOVEL 4100: 2.23
AVERAGE RESIDENCE TIME OF TRUCKS AT SHOVEL 4100: 5.03
CYCLE TIME FOR TRUCKS AT SHOVEL 4100 29.31
AVERAGE TIME FOR TRUCKS AT SHOVEL 4100: 7.25
==
NUMBER OF LOADS PER SHIFT FROM SHOVEL 2800: 0
UTILIZATION OF SHOVEL 2800: 0.00%
AVERAGE QUEUE AT SHOVEL 2800: 0.00
AVERAGE RESIDENCE TIME OF TRUCKS AT SHOVEL 2800: 0.00
CYCLE TIME FOR TRUCKS AT SHOVEL 2800 0.00
AVERAGE TIME FOR TRUCKS AT SHOVEL 2800: 0.00
==
TOTAL NUMBER OF LOADS PER SHIFT INTO DUMP SOUTH AREA: 191
TOTAL OF WASTE PER SHIFT: 60381
TOTAL NUMBER OF LOADS PER SHIFT INTO ORE CRUSHER: 0
TOTAL ORE CRUSHER PER SHIFT: 279
==
TOTAL NUMBER OF LOADS PER SHIFT INTO ROAST: 0
TOTAL ROAST PER SHIFT: 0
==
TOTAL NUMBER OF LOADS PER SHIFT INTO LEACH PADS: 9
TOTAL LEACH PADS PER SHIFT: 2752
==
TOTAL NUMBER OF TRUCKS AT FUEL: 0
TOTAL FUEL CINSUMPTION: 0
==
BARRICK GOLD CORPORATION

--- RESULTS OF GAP PIT SIMULATION PROGRAM IN EXCEL FILE ---
NUMBER OF TRUCKS: 14
SHIFTS TO SIMULATE FOR: 180
HOURS OF ACTUAL WORK: 7.60
==
NUMBER OF LOADS PER SHIFT FROM SHOVEL 4100:   204
UTILIZATION OF SHOVEL 4100:   99.75%
AVERAGE QUEUE AT SHOVEL 4100:   3.11
AVERAGE RESIDENCE TIME OF TRUCKS AT SHOVEL 4100:   6.95
CYCLE TIME FOR TRUCKS AT SHOVEL 4100 31.22
AVERAGE TIME FOR TRUCKS AT SHOVEL 4100:   9.17
==
NUMBER OF LOADS PER SHIFT FROM SHOVEL 2800:   0
UTILIZATION OF SHOVEL 2800:   0.00%
AVERAGE QUEUE AT SHOVEL 2800:   0.00
AVERAGE RESIDENCE TIME OF TRUCKS AT SHOVEL 2800:   0.00
CYCLE TIME FOR TRUCKS AT SHOVEL 2800   0.00
AVERAGE TIME FOR TRUCKS AT SHOVEL 2800:   0.00
==
TOTAL NUMBER OF LOADS PER SHIFT INTO DUMP SOUTH AREA: 193
TOTAL OF WASTE PER SHIFT: 61013
TOTAL NUMBER OF LOADS PER SHIFT INTO ORE CRUSHER: 0
TOTAL ORE CRUSHER PER SHIFT: 274
==
TOTAL NUMBER OF LOADS PER SHIFT INTO ROAST: 0
TOTAL ROAST PER SHIFT: 0
==
TOTAL NUMBER OF LOADS PER SHIFT INTO LEACH PADS: 9
TOTAL LEACH PADS PER SHIFT: 2841
==
TOTAL NUMBER OF TRUCKS AT FUEL: 0
TOTAL FUEL CINSUMPTION: 0
==
BARRICK GOLD CORPORATION

--- RESULTS OF GAP PIT SIMULATION PROGRAM IN EXCEL FILE ---
NUMBER OF TRUCKS: 23
SHIFTS TO SIMULATE FOR: 180
HOURS OF ACTUAL WORK: 7.60
==
NUMBER OF LOADS PER SHIFT FROM SHOVEL 4100(342): 167
UTILIZATION OF SHOVEL 4100(342): 81.27%
AVERAGE QUEUE AT SHOVEL 4100(342): 1.28
AVERAGE RESIDENCE TIME OF TRUCKS AT SHOVEL 4100(342): 3.44
==
NUMBER OF LOADS PER SHIFT FROM SHOVEL 2800(352): 101
UTILIZATION OF SHOVEL 2800(352): 83.91%
AVERAGE QUEUE AT SHOVEL 2800(352): 1.30
AVERAGE RESIDENCE TIME OF TRUCKS AT SHOVEL 2800(352): 5.72
==
TOTAL NUMBER OF LOADS PER SHIFT INTO DUMP SOUTH AREA: 91
TOTAL OF WASTE PER SHIFT: 28902
==
TOTAL NUMBER OF LOADS PER SHIFT INTO ORE CRUSHER: 0
TOTAL ORE CRUSHER PER SHIFT: 0
==
TOTAL NUMBER OF LOADS PER SHIFT INTO ROCK CRUSHER: 0
TOTAL ROCK CRUSHER PER SHIFT: 0
==
TOTAL NUMBER OF LOADS PER SHIFT INTO ROAST: 0
TOTAL ROAST PER SHIFT: 0
==
TOTAL NUMBER OF LOADS PER SHIFT INTO LEACH PADS: 0
TOTAL LEACH PADS PER SHIFT: 0
==
TOTAL NUMBER OF LOADS PER SHIFT INTO TAIL: 165
TOTAL TAIL PER SHIFT: 52243
==
BARRICK GOLD CORPORATION

--- RESULTS OF GAP PIT SIMULATION PROGRAM IN EXCEL FILE ---
NUMBER OF TRUCKS: 24
SHIFTS TO SIMULATE FOR: 180
HOURS OF ACTUAL WORK: 7.60
==
NUMBER OF LOADS PER SHIFT FROM SHOVEL 4100(342):   170
UTILIZATION OF SHOVEL 4100(342):   83.13%
AVERAGE QUEUE AT SHOVEL 4100(342):   1.51
AVERAGE RESIDENCE TIME OF TRUCKS AT SHOVEL 4100(342):   3.97
==
NUMBER OF LOADS PER SHIFT FROM SHOVEL 2800(352):   102
UTILIZATION OF SHOVEL 2800(352):   84.95%
AVERAGE QUEUE AT SHOVEL 2800(352):   1.54
AVERAGE RESIDENCE TIME OF TRUCKS AT SHOVEL 2800(352):   6.65
==
TOTAL NUMBER OF LOADS PER SHIFT INTO DUMP SOUTH AREA: 96
TOTAL OF WASTE PER SHIFT: 30275
==
TOTAL NUMBER OF LOADS PER SHIFT INTO ORE CRUSHER: 0
TOTAL ORE CRUSHER PER SHIFT: 0
==
TOTAL NUMBER OF LOADS PER SHIFT INTO ROCK CRUSHER: 0
TOTAL ROCK CRUSHER PER SHIFT: 0
==
TOTAL NUMBER OF LOADS PER SHIFT INTO ROAST: 0
TOTAL ROAST PER SHIFT: 0
==
TOTAL NUMBER OF LOADS PER SHIFT INTO LEACH PADS: 0
TOTAL LEACH PADS PER SHIFT: 0
==
TOTAL NUMBER OF LOADS PER SHIFT INTO TAIL: 165
TOTAL TAIL PER SHIFT: 52334
==
BARRICK GOLD CORPORATION

--- RESULTS OF GAP PIT SIMULATION PROGRAM IN EXCEL FILE ---
NUMBER OF TRUCKS: 23
SHIFTS TO SIMULATE FOR: 180
HOURS OF ACTUAL WORK: 7.60
==
NUMBER OF LOADS PER SHIFT FROM SHOVEL 4100(342):   167
UTILIZATION OF SHOVEL 4100(342):   81.20%
AVERAGE QUEUE AT SHOVEL 4100(342):   1.29
AVERAGE RESIDENCE TIME OF TRUCKS AT SHOVEL 4100(342):   3.45
==
NUMBER OF LOADS PER SHIFT FROM SHOVEL 2800(352):   101
UTILIZATION OF SHOVEL 2800(352):   84.02%
AVERAGE QUEUE AT SHOVEL 2800(352):   1.30
AVERAGE RESIDENCE TIME OF TRUCKS AT SHOVEL 2800(352):   5.73
==
TOTAL NUMBER OF LOADS PER SHIFT INTO DUMP SOUTH AREA: 91
TOTAL OF WASTE PER SHIFT: 28907
==
TOTAL NUMBER OF LOADS PER SHIFT INTO ORE CRUSHER: 0
TOTAL ORE CRUSHER PER SHIFT: 0
==
TOTAL NUMBER OF LOADS PER SHIFT INTO ROCK CRUSHER: 0
TOTAL ROCK CRUSHER PER SHIFT: 0
==
TOTAL NUMBER OF LOADS PER SHIFT INTO ROAST: 0
TOTAL ROAST PER SHIFT: 0
==
TOTAL NUMBER OF LOADS PER SHIFT INTO LEACH PADS: 0
TOTAL LEACH PADS PER SHIFT: 0
==
TOTAL NUMBER OF LOADS PER SHIFT INTO TAIL: 165
TOTAL TAIL PER SHIFT: 52275
==
BARRICK GOLD CORPORATION

--- RESULTS OF GAP PIT SIMULATION PROGRAM IN EXCEL FILE ---
NUMBER OF TRUCKS: 24
SHIFTS TO SIMULATE FOR: 180
HOURS OF ACTUAL WORK: 7.60
==
NUMBER OF LOADS PER SHIFT FROM SHOVEL 4100(342): 170
UTILIZATION OF SHOVEL 4100(342): 83.26%
AVERAGE QUEUE AT SHOVEL 4100(342): 1.51
AVERAGE RESIDENCE TIME OF TRUCKS AT SHOVEL 4100(342): 3.96
==
NUMBER OF LOADS PER SHIFT FROM SHOVEL 2800(352): 102
UTILIZATION OF SHOVEL 2800(352): 85.15%
AVERAGE QUEUE AT SHOVEL 2800(352): 1.54
AVERAGE RESIDENCE TIME OF TRUCKS AT SHOVEL 2800(352): 6.66
==
TOTAL NUMBER OF LOADS PER SHIFT INTO DUMP SOUTH AREA: 96
TOTAL OF WASTE PER SHIFT: 30359
==
TOTAL NUMBER OF LOADS PER SHIFT INTO ORE CRUSHER: 0
TOTAL ORE CRUSHER PER SHIFT: 0
==
TOTAL NUMBER OF LOADS PER SHIFT INTO ROCK CRUSHER: 0
TOTAL ROCK CRUSHER PER SHIFT: 0
==
TOTAL NUMBER OF LOADS PER SHIFT INTO ROAST: 0
TOTAL ROAST PER SHIFT: 0
==
TOTAL NUMBER OF LOADS PER SHIFT INTO LEACH PADS: 0
TOTAL LEACH PADS PER SHIFT: 0
==
TOTAL NUMBER OF LOADS PER SHIFT INTO TAIL: 165
TOTAL TAIL PER SHIFT: 52287
==
BARRICK GOLD CORPORATION

Appendix C: Simulation and animation program of the aggregate mine operation using GPSS/H® and PROOF Animation®.

Simulation and animation source code for the case study (aggregate mine) using both haul truck and conveyer belt systems:

```
*************************************************************
*    SIMULATION AND ANIMATION MODEL OF AGGREGATE           *
*        SAND & GRAVEL                                     *
*     PROGRAMMED IN GPSS/H                                 *
*     BY                                                   *
*     EBRAHIM K. TARSHIZI                                  *
*************************************************************
        SIMULATE
        RMULT      12345
        REALLOCATE  COM,1000000
ATF      FILEDEF    'SAND.ATF'
        INTEGER    &DAYS,&T772,&IA
        REAL       &A,&B,&C,&D,&E,&F,&G,&H,&I,&J,&K,&L,&M,&N
        REAL       &P,&Q,&R,&S,&T
        REAL       &B772,&A772,&D772,&DB772,&BB772,&AA772

***********************************
*     FUNCTIONS                  *
***********************************
1      FUNCTION    PH1,E1
1,RVNORM(1,2,.2)
2      FUNCTION    PH1,E1
1,RVNORM(1,2,.1)
3      FUNCTION    PH1,E1
1,RVNORM(1,3,.2)

4      FUNCTION    PH1,E1
1,RVNORM(1,2.5,.15)
5      FUNCTION    PH1,E1
1,RVNORM(1,2.5,.2)
6      FUNCTION    PH1,E1
1,RVNORM(1,2.5,.1)

7      FUNCTION    PH1,E1
1,RVNORM(1,2,.2)
A7      FUNCTION    PH1,E1
1,RVNORM(1,1.8,.1)
```

```
8      FUNCTION    PH1,E1
1,RVNORM(1,1.8,.1)
9      FUNCTION    PH1,E1
1,RVNORM(1,2.5,.3)
10      FUNCTION    PH1,E1
1,RVNORM(1,2.5,.2)

11      FUNCTION    PH1,E1
1,RVNORM(1,3,.2)
12      FUNCTION    PH1,E1
1,RVNORM(1,2.5,.1)
13      FUNCTION    PH1,E1
1,RVNORM(1,2.5,.2)
A13     FUNCTION    PH1,E1
1,RVNORM(1,1,.1)

14      FUNCTION    PH1,E1
1,RVNORM(1,1.5,.1)
15      FUNCTION    PH1,E1
1,RVNORM(1,1.5,.1)

***********************************
*           INPUTS              *
***********************************
       DO    &IA=1,80
       PUTSTRING    ('  ')
       ENDDO
       PUTSTRING    ('  ')
       PUTSTRING    (' --- SAND & GRAVEL MINE SIMULATION PROGRAM ---')
AGAIN    PUTSTRING    ('  ')
       PUTSTRING    ('  ')
       PUTSTRING    ('  INPUT THE NUMBER OF TRUCKS IN THE MINE
OPERATION?')
       GETLIST     &T772
       PUTPIC      FILE=ATF,LINES=2,AC1,&T772
TIME *.****
WRITE NT1 **
       PUTSTRING    ('  ')
       PUTSTRING    ('   HOW MANY DAYS TO SIMULATE MINE FOR?')
       GETLIST      &DAYS
       PUTSTRING    ('  ')
       PUTSTRING    ('  DO YOU WANT ANIMATION? (Y/N)')
       CHAR*1      &YES,&YY
MYBOOL   BVARIABLE    (&YES'E"Y')OR(&YES'E"y')
       GETLIST     &YES
```

```
        PUTSTRING    ('  ')
        PUTPIC       LINES=3,&T772,&DAYS
        INPUT DATA IS AS FOLLOWS:
    NUMBER OF TRUCKS: **
    NUMBER OF DAYS TO SIMULATE MINE FOR: **
        PUTSTRING    ('  ')
        PUTSTRING    ('  ARE YOU HAPPY WITH THESE VALUES? (Y/N)')
        GETLIST      &YY
        IF           (&YY'NE"Y')AND(&YY'NE"y')
        GOTO   AGAIN
        ENDIF
ANIM     TEST E       BV(MYBOOL),1,PH3+2
        TRANSFER     ,PH3+1
        PUTSTRING    ('  ')
        PUTSTRING    ('  ')
        PUTSTRING    ('  ')

*****************************************
*       START MACRO DEFINITIONS        *
*****************************************
 TRAVEL   STARTMACRO
         BLET        #A=FN(#B)
         TRANSFER    SBR,ANIM,3PH
         BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1,#A
 TIME *.****
 PLACE T* ON P#C
 SET T* TRAVEL **.**
 PAT#D  ADVANCE     #A
       ENDMACRO
******************************************
*         END OF MACRO DEFINITIONS      *
******************************************
*****************************************
*   START WITH 772 TRUCKS IN THE MINE    *
*****************************************
         GENERATE    5,,1,&T772,,12PH,12PL
         TRANSFER    SBR,ANIM,3PH
         BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE TRUCKE T*
PLACE T* AT 0.07 -5.56
PATHP1    ADVANCE     0

TRAVEL    MACRO      &A,1,1,1
TRAVEL    MACRO      &B,2,2,2
```

```
TRAVEL    MACRO       &C,3,3,3
******************************************
*       LOADER NO. 1 PROGRAM HERE       *
******************************************
          QUEUE       LOADER1
          SEIZE       SPOTL1
          GATE LR     STOPSH1
          ADVANCE     RVEXPO(1,1.5)     SPOT TIME AT LOADER-1
          DEPART      LOADER1
          SEIZE       LOADER1        USE THE LOADER-1
          RELEASE     SPOTL1
          ADVANCE     RVNORM(1,2.8,.2)     LOAD A TRUCK 772
          RELEASE     LOADER1         FREE THE LOADER
          ASSIGN      1,RVNORM(1,51,5),PL   AMOUNT LOAD BY LOADER 1
          BLET        &A772=&A772+1
          BLET        &B772=&B772+PL1
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=5,AC1,XID1,&A772,&B772,FR(LOADER1)/10.
TIME *.****
SET T* CLASS TRUCKF2
WRITE MS1 ***
WRITE MS2 *****.**
WRITE MS3   **.**%
          SPLIT       6,AWAY
TRAVEL    MACRO       &D,4,4,4
TRAVEL    MACRO       &E,5,5,5
TRAVEL    MACRO       &F,6,6,6
TRAVEL    MACRO       &G,7,7,7
************************************************
*           STORAGE AREA/DUMP                  *
************************************************
          QUEUE       DUMP       TRUCKS AT DUMP AREA
          SEIZE       DUMP
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M1 !DUMPING!
          ADVANCE     RVNORM(1,1.8,.2)      DUMPS A LOAD OF WASTE
          DEPART      DUMP
          BLET        &D772=&D772+1
          BLET        &DB772=&DB772+PL1
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC   FILE=ATF,LINES=5,AC1,XID1,&D772,&DB772
TIME *.****
SET T* CLASS TRUCKE
```

```
WRITE MS4 ***
WRITE MS5 *****.**
WRITE M1
        RELEASE    DUMP
TRAVEL    MACRO      &H,A7,A7,A7
        TRANSFER   ,PATHP1
***********************************************
*           BELT  CONVEYOR                    *
***********************************************
AWAY     QUEUE      CON1
        SEIZE      CONVEY
        BPUTPIC     FILE=ATF,LINES=4,AC1,XID1,XID1,XID1
TIME *.****
CREATE ORE O*
PLACE  O* ON P18
SET O* TRAVEL 25
        DEPART    CON1
        ADVANCE    1.4
        RELEASE    CONVEY
        ADVANCE    24
        BPUTPIC    FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
DESTROY O*
WRITE TEST  *****
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1,FC(CONVEY)
TIME *.****
SET BAR   BABAR ***
        TERMINATE
***********************************************
*   SEGMENT FOR BELT CIRCLE ANIMATION         *
***********************************************
        GENERATE    ,,,1      DUMMY TRANSACTION
WAIT5     TEST E      F(CONVEY),1
        TRANSFER    SBR,ANIM,3PH
WAIT6     BPUTPIC     FILE=ATF,LINES=6,AC1
TIME *.****
ROTATE CIR  -360 SPEED  120
ROTATE CIR1 -360 SPEED  120
ROTATE CIR2 -360 SPEED  120
ROTATE CIR3 -360 SPEED  120
ROTATE CIR4 -360 SPEED  120
        ADVANCE     1
        TEST E      F(CONVEY),1,WAIT5
        TRANSFER    ,WAIT6
```

```
**********************************************
*   SEGMENT FOR LOADER 1 LOADING             *
**********************************************
        GENERATE    ,,,1,10      DUMMY TRANSACTION
WAIT1     TEST E      F(LOADER1),1
        TRANSFER    SBR,ANIM,3PH
WAIT2    BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET LOAD1 CLASS LOADER2
        ADVANCE     .5
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET LOAD1 CLASS LOADER3
        ADVANCE     .5
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET LOAD1 CLASS LOADER4
        ADVANCE     .5
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET LOAD1 CLASS LOADER1
        ADVANCE     .5
        TEST E      F(LOADER1),1,WAIT1
        TRANSFER    ,WAIT2
**********************************************
*   SEGMENT FOR LOADER 2 LOADING             *
**********************************************
        GENERATE    ,,,1,10      DUMMY TRANSACTION
WAIT3     TEST E      F(CONVEY),1
        TRANSFER    SBR,ANIM,3PH
WAIT4    BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET LOAD2 CLASS LOADER22
        ADVANCE     .7
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET LOAD2 CLASS LOADER33
        ADVANCE     .7
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET LOAD2 CLASS LOADER44
        ADVANCE     .7
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
```

```
SET LOAD2 CLASS LOADER11
        ADVANCE    .7
        TEST E     F(CONVEY),1,WAIT3
        TRANSFER   ,WAIT4
*************************************************************
*  DOWN TIMES AND RAPAIR TIMES FOR LOADER-1 COMES NEXT      *
*************************************************************
        GENERATE   ,,,1
UPSTOP1  ADVANCE    RVEXPO(1,300)
        LOGIC S    STOPSH1
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=2,AC1
TIME *.****
WRITE MDS1 SHOVEL 1 IS DOWN!!
        ADVANCE    RVNORM(1,30,5)
        LOGIC R    STOPSH1
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=2,AC1
TIME *.****
WRITE MDS1
        TRANSFER   ,UPSTOP1
*********************************************
*          CLOCK SEGMENT                 *
*********************************************
        INTEGER    &TIME,&DAYNO,&WKDAYNO,&WEEKNO,&HOUR
        GENERATE   ,,,1,150,12PL,12PH   DUMMY TRANSACTION FOR CLOCK
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=3,AC1
TIME *.****
ROTATE MHAND1 SPEED -6 STEP 6
ROTATE HHAND1 SPEED -.5 STEP 6
        BLET       &HOUR=0
        BLET       &WKDAYNO=1
        BLET       &WEEKNO=1
NEXTMIN  ADVANCE    1     ADVANCE THE CLOCK ONE MINUTE
        BLET       &TIME=&TIME+1
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC
FILE=ATF,LINES=5,AC1,&TIME,&HOUR,&WKDAYNO,&WEEKNO
TIME *.****
WRITE MT8 **
WRITE MT7 **
WRITE MT6 **
WRITE MT5 **
        TEST E     &TIME@60,0,NEXTMIN
```

```
         BLET       &TIME=0
         BLET       &HOUR=&HOUR+1
         TEST E     &HOUR,24,NEXTMIN   24 HOURS PAST?
         BLET       &TIME=0
         BLET       &HOUR=0
         BLET       &DAYNO=&DAYNO+1
         BLET       &WKDAYNO=&WKDAYNO+1
         TEST E     &WKDAYNO,8,NEXTMIN  NEW WEEK?
         BLET       &WKDAYNO=1
         BLET       &WEEKNO=&WEEKNO+1
         TRANSFER    ,NEXTMIN
**************************************************
*           END CLOCK SEGMENT               *
**************************************************

**************************************************
*  TIMER TRANSACTION COMES NEXT                 *
**************************************************
         GENERATE    ,,,1
         ADVANCE     &DAYS*8*60
         TERMINATE   1
         START       1
         PUTPIC
LINES=14,&A772,&B772,FR(LOADER1)/10.,&AA772,&BB772,FR(LOADERA2)/10.
,&D772,&DB772
            ===SIMULATION RESULTS===
============================================================
TOTAL NUMBER OF  LOADS OF LOADER 1:    ***
AMOUNT OF LOADS OF LOADER 1:    *****
UTILIZATION OF LOADER 1: **.**%
============================================================
TOTAL NUMBER OF  LOADS OF LOADER 2:    ***
AMOUNT OF LOADS OF LOADER 2:    *****
UTILIZATION OF LOADER 2: **.**%
============================================================
TOTAL NUMBER OF  LOADS INTO STORAGE AREA:    ***
AMOUNT OF LOADS INTO STORAGE AREA:    *****
============================================================
"MINE SYSTEMS OPTIMIZATION AND SIMULATION LABORATORY"
         IF         (&YES'E"Y')OR(&YES'E"y')
         PUTPIC      FILE=ATF,LINES=2,AC1
TIME *.****
END
         ENDIF
         END
```

```
**************************************************
**************************************************
```

Simulation and animation program/code for the aggregate mine using only haul truck system:

```
*************************************************************
*    SIMULATION AND ANIMATION MODEL OF AGGREGATE            *
*       SAND & GRAVEL                                       *
*     PROGRAMMED IN GPSS/H                                  *
*     BY                                                    *
*     EBRAHIM K. TARSHIZI                                   *
*************************************************************
        SIMULATE
        RMULT       12345
        REALLOCATE  COM,1000000
ATF     FILEDEF     'SAND.ATF'
        INTEGER     &DAYS,&T772,&IA,&TOT
        REAL        &A,&B,&C,&D,&E,&F,&G,&H,&I,&J,&K,&L,&M,&N
        REAL        &P,&Q,&R,&S,&T
        REAL        &B772,&A772,&D772,&DB772,&BB772,&AA772

***********************************
*     FUNCTIONS                   *
***********************************

1       FUNCTION    PH1,E1
1,RVNORM(1,2,.2)
2       FUNCTION    PH1,E1
1,RVNORM(1,2,.1)
3       FUNCTION    PH1,E1
1,RVNORM(1,3,.2)

4       FUNCTION    PH1,E1
1,RVNORM(1,2.5,.15)
5       FUNCTION    PH1,E1
1,RVNORM(1,2.5,.2)
6       FUNCTION    PH1,E1
1,RVNORM(1,2.5,.1)

7       FUNCTION    PH1,E1
1,RVNORM(1,2,.2)
A7      FUNCTION    PH1,E1
1,RVNORM(1,1.8,.1)
```

```
8      FUNCTION    PH1,E1
1,RVNORM(1,1.8,.1)
9      FUNCTION    PH1,E1
1,RVNORM(1,2.5,.3)
10      FUNCTION    PH1,E1
1,RVNORM(1,2.5,.2)

11      FUNCTION    PH1,E1
1,RVNORM(1,3,.2)
12      FUNCTION    PH1,E1
1,RVNORM(1,2.5,.1)
13      FUNCTION    PH1,E1
1,RVNORM(1,2.5,.2)
A13     FUNCTION    PH1,E1
1,RVNORM(1,1,.1)

14      FUNCTION    PH1,E1
1,RVNORM(1,1.5,.1)
15      FUNCTION    PH1,E1
1,RVNORM(1,1.5,.1)

***********************************
*           INPUTS              *
***********************************
       DO    &IA=1,80
       PUTSTRING    ('  ')
       ENDDO
       PUTSTRING    ('  ')
       PUTSTRING    (' --- SAND & GRAVEL MINE SIMULATION PROGRAM ---')
AGAIN    PUTSTRING    ('  ')
       PUTSTRING    ('  ')
       PUTSTRING    ('  INPUT THE NUMBER OF TRUCKS IN THE MINE
OPERATION?')
       GETLIST     &T772
       PUTPIC      FILE=ATF,LINES=2,AC1,&T772
TIME *.****
WRITE NT1 **
       PUTSTRING    ('  ')
       PUTSTRING    ('   HOW MANY DAYS TO SIMULATE MINE FOR?')
       GETLIST      &DAYS
       PUTSTRING    ('  ')
       PUTSTRING    ('  DO YOU WANT ANIMATION? (Y/N)')
       CHAR*1      &YES,&YY
MYBOOL   BVARIABLE    (&YES'E"Y')OR(&YES'E"y')
       GETLIST     &YES
```

```
        PUTSTRING    ('  ')
        PUTPIC       LINES=3,&T772,&DAYS
        INPUT DATA IS AS FOLLOWS:
    NUMBER OF TRUCKS: **
    NUMBER OF DAYS TO SIMULATE MINE FOR: **
        PUTSTRING    ('  ')
        PUTSTRING    ('  ARE YOU HAPPY WITH THESE VALUES? (Y/N)')
        GETLIST      &YY
        IF           (&YY'NE"Y')AND(&YY'NE"y')
        GOTO   AGAIN
        ENDIF
ANIM     TEST E       BV(MYBOOL),1,PH3+2
        TRANSFER     ,PH3+1
        PUTSTRING    ('  ')
        PUTSTRING    ('  ')
        PUTSTRING    ('  ')

******************************************
*       START MACRO DEFINITIONS         *
******************************************
 TRAVEL   STARTMACRO
         BLET        #A=FN(#B)
         TRANSFER    SBR,ANIM,3PH
         BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1,#A
 TIME *.****
 PLACE T* ON P#C
 SET T* TRAVEL **.**
 PAT#D  ADVANCE     #A
       ENDMACRO
*******************************************
*         END OF MACRO DEFINITIONS       *
*******************************************

******************************************
*   START WITH 772 TRUCKS IN THE MINE    *
******************************************
         GENERATE    5,,1,&T772,,12PH,12PL
         TRANSFER    SBR,ANIM,3PH
         BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE TRUCKE T*
PLACE T* AT 0.07 -5.56
PATHP1    ADVANCE     0
TRAVEL    MACRO       &A,1,1,1
TRAVEL    MACRO       &B,2,2,2
```

```
TRAVEL   MACRO     &C,3,3,3
*****************************************
*      LOADER NO. 1 PROGRAM HERE      *
*****************************************
       QUEUE     LOADER1
       SEIZE     SPOTL1
       ADVANCE    RVEXPO(1,1.5)    SPOT TIME AT LOADER-1
       DEPART     LOADER1
       SEIZE      LOADER1        USE THE LOADER-1
       RELEASE    SPOTL1
       ADVANCE    RVNORM(1,2.8,.2)    LOAD A TRUCK 772
       RELEASE    LOADER1         FREE THE LOADER
       ASSIGN     1,RVNORM(1,51,5),PL   AMOUNT LOAD BY LOADER 1
       BLET       &A772=&A772+1
       BLET       &B772=&B772+PL1
       TRANSFER   SBR,ANIM,3PH
       BPUTPIC    FILE=ATF,LINES=5,AC1,XID1,&A772,&B772,FR(LOADER1)/10.
TIME *.****
SET T* CLASS TRUCKF2
WRITE MS1 ***
WRITE MS2 *****.**
WRITE MS3   **.**%

TRAVEL   MACRO     &D,4,4,4
TRAVEL   MACRO     &E,5,5,5
TRAVEL   MACRO     &F,6,6,6
TRAVEL   MACRO     &G,7,7,7
**********************************************
*          STORAGE AREA/DUMP              *
**********************************************
       QUEUE     DUMP       TRUCKS AT DUMP AREA
       SEIZE     DUMP
       TRANSFER   SBR,ANIM,3PH
       BPUTPIC    FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M1 !DUMPING!
       ADVANCE    RVNORM(1,1.8,.2)     DUMPS A LOAD OF WASTE
       DEPART     DUMP
       BLET       &D772=&D772+1
       BLET       &DB772=&DB772+PL1
       BLET       &TOT=FC(DUMP)+FC(DUMP2)
       TRANSFER   SBR,ANIM,3PH
       BPUTPIC   FILE=ATF,LINES=6,AC1,XID1,&D772,&DB772,&TOT
TIME *.****
SET T* CLASS TRUCKE
```

```
WRITE MS4 ***
WRITE MS5 *****.**
WRITE M1
SET BAR   BABAR ***
        RELEASE     DUMP
        TRANSFER    .5,,PATHP15         50% GOES TO LOADER-2
PATHPA7   ADVANCE     0
TRAVEL    MACRO      &H,A7,A7,A7
        TRANSFER    ,PATHP1
PATHP15   ADVANCE     0
        BPUTPIC   FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS TRUCKE2
        SEIZE      INTERM
TRAVEL    MACRO      &P,15,15,15
        RELEASE     INTERM
PATHP8    ADVANCE     0
TRAVEL    MACRO      &I,8,8,8
TRAVEL    MACRO      &J,9,9,9
TRAVEL    MACRO      &K,10,10,10
*****************************************
*       LOADER NO. 2 PROGRAM HERE       *
*****************************************
        QUEUE      LOADERA2
        SEIZE      SPOTA2
        ADVANCE     RVEXPO(1,1.5)     SPOT TIME AT LOADER-2
        DEPART     LOADERA2
        SEIZE      LOADERA2        USE THE LOADER-2
        RELEASE     SPOTA2
        ADVANCE     RVNORM(1,2.8,.2)     LOAD A TRUCK 772
        RELEASE     LOADERA2         FREE THE LOADER
        ASSIGN      1,RVNORM(1,51,5),PL   AMOUNT LOAD BY LOADER 2
        BLET       &AA772=&AA772+1
        BLET       &BB772=&BB772+PL1
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC
FILE=ATF,LINES=5,AC1,XID1,&AA772,&BB772,FR(LOADERA2)/10.
TIME *.****
SET T* CLASS TRUCKF
WRITE MS6 ***
WRITE MS7 *****.**
WRITE MS8   **.**%
TRAVEL    MACRO      &L,11,11,11
TRAVEL    MACRO      &M,12,12,12
TRAVEL    MACRO      &S,13,13,13
```

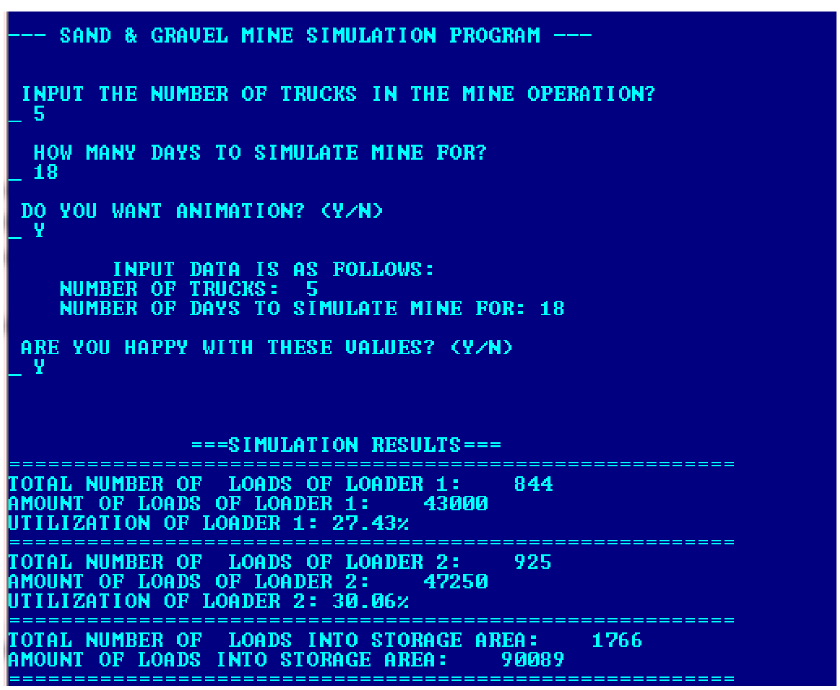
```
*************************************
*           DUMP 2- PROGRAM
*************************************
          QUEUE      DUMP2       TRUCKS AT DUMP AREA
          SEIZE      DUMP2
          TRANSFER   SBR,ANIM,3PH
          BPUTPIC    FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M1 !DUMPING!
          ADVANCE    RVNORM(1,1.8,.2)     DUMPS A LOAD OF WASTE
          DEPART     DUMP2
          BLET       &D772=&D772+1
          BLET       &DB772=&DB772+PL1
          BLET       &TOT=FC(DUMP)+FC(DUMP2)
          TRANSFER   SBR,ANIM,3PH
          BPUTPIC   FILE=ATF,LINES=6,AC1,XID1,&D772,&DB772,&TOT
TIME *.****
SET T* CLASS TRUCKE
WRITE MS4 ***
WRITE MS5 *****.**
WRITE M1
SET BAR   BABAR ***

          RELEASE    DUMP2
TRAVEL    MACRO      &N,A13,A13,A13
          TRANSFER   .5,,PATHP14        50% GOES TO LOADER-1
          BPUTPIC   FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS TRUCKE2
          TRANSFER    ,PATHP8

PATHP14   ADVANCE    0
          SEIZE      INTERM
TRAVEL    MACRO      &Q,14,14,14
          RELEASE    INTERM
          TRANSFER   ,PATHPA7

**********************************************
*   SEGMENT FOR LOADER 1 LOADING              *
**********************************************
          GENERATE   ,,,1,10     DUMMY TRANSACTION
WAIT1     TEST E     F(LOADER1),1
          TRANSFER   SBR,ANIM,3PH
WAIT2     BPUTPIC    FILE=ATF,LINES=2,AC1,XID1
TIME *.****
```

```
SET LOAD1 CLASS LOADER2
          ADVANCE     .5
          BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET LOAD1 CLASS LOADER3
          ADVANCE     .5
          BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET LOAD1 CLASS LOADER4
          ADVANCE     .5
          BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET LOAD1 CLASS LOADER1
          ADVANCE     .5
          TEST E      F(LOADER1),1,WAIT1
          TRANSFER    ,WAIT2
**********************************************
*   SEGMENT FOR LOADER 2 LOADING             *
**********************************************
          GENERATE    ,,,1,10      DUMMY TRANSACTION
WAIT3     TEST E      F(LOADERA2),1
          TRANSFER    SBR,ANIM,3PH
WAIT4     BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET LOAD2 CLASS LOADER22
          ADVANCE     .5
          BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET LOAD2 CLASS LOADER33
          ADVANCE     .5
          BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET LOAD2 CLASS LOADER44
          ADVANCE     .5
          BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET LOAD2 CLASS LOADER11
          ADVANCE     .5
          TEST E      F(LOADERA2),1,WAIT3
          TRANSFER    ,WAIT4
*******************************************
*          CLOCK SEGMENT                  *
*******************************************
          INTEGER     &TIME,&DAYNO,&WKDAYNO,&WEEKNO,&HOUR
          GENERATE    ,,,1,150,12PL,12PH   DUMMY TRANSACTION FOR CLOCK
```

```
         TRANSFER    SBR,ANIM,3PH
         BPUTPIC     FILE=ATF,LINES=3,AC1
TIME *.****
ROTATE MHAND1 SPEED -6 STEP 6
ROTATE HHAND1 SPEED -.5 STEP 6
         BLET       &HOUR=0
         BLET       &WKDAYNO=1
         BLET       &WEEKNO=1
NEXTMIN   ADVANCE     1      ADVANCE THE CLOCK ONE MINUTE
         BLET       &TIME=&TIME+1
         TRANSFER    SBR,ANIM,3PH
         BPUTPIC
FILE=ATF,LINES=5,AC1,&TIME,&HOUR,&WKDAYNO,&WEEKNO
TIME *.****
WRITE MT8 **
WRITE MT7 **
WRITE MT6 **
WRITE MT5 **
         TEST E      &TIME@60,0,NEXTMIN
         BLET       &TIME=0
         BLET       &HOUR=&HOUR+1
         TEST E      &HOUR,24,NEXTMIN   24 HOURS PAST?
         BLET       &TIME=0
         BLET       &HOUR=0
         BLET       &DAYNO=&DAYNO+1
         BLET       &WKDAYNO=&WKDAYNO+1
         TEST E      &WKDAYNO,8,NEXTMIN  NEW WEEK?
         BLET       &WKDAYNO=1
         BLET       &WEEKNO=&WEEKNO+1
         TRANSFER    ,NEXTMIN
****************************************************
*             END CLOCK SEGMENT                *
****************************************************

****************************************************
*  TIMER TRANSACTION COMES NEXT                    *
****************************************************
         GENERATE    ,,,1
         ADVANCE     &DAYS*8*60
         TERMINATE   1
         START       1
         PUTPIC
LINES=14,&A772,&B772,FR(LOADER1)/10.,&AA772,&BB772,FR(LOADERA2)/10.
,&D772,&DB772
              ===SIMULATION RESULTS===
```

```
==========================================================
TOTAL NUMBER OF  LOADS OF LOADER 1:     ***
AMOUNT OF LOADS OF LOADER 1:     *****
UTILIZATION OF LOADER 1: **.**%
==========================================================
TOTAL NUMBER OF  LOADS OF LOADER 2:     ***
AMOUNT OF LOADS OF LOADER 2:     *****
UTILIZATION OF LOADER 2: **.**%
==========================================================
TOTAL NUMBER OF  LOADS INTO STORAGE AREA:     ***
AMOUNT OF LOADS INTO STORAGE AREA:     *****
==========================================================
"MINE SYSTEMS OPTIMIZATION AND SIMULATION LABORATORY"

        IF          (&YES'E"Y')OR(&YES'E"y')
        PUTPIC      FILE=ATF,LINES=2,AC1
TIME *.****
END
        ENDIF
        END
***************************************************
***************************************************
```

The snapshot of the simulation input and output for the sand and gravel mine with dummy/generic data is provided as following:



Appendix D: GPSS/H® simulation and animation source code of the surface coal mine operation and data analysis.

- This simulation and animation program was revised and run by Ms. Virginia Ibarra:

```
**********************************************************************
*    SIMULATION AND ANIMATION MODEL OF THE SURFACE COAL MINE    *
*     PROGRAMMED IN GPSS/H                                        *
*     BY EBRAHIM K. TARSHIZI                                      *
*     REVISED By: VIRGINIA IBARRA, 9/19/13                        *
*                                                                 *
**********************************************************************
        SIMULATE
        RMULT      12345
        REALLOCATE  COM,1000000
 ATF     FILEDEF     'COALMINE.ATF'
        REAL  &X,&Y,&Z,&E,&G,&H,&I,&J,&K,&L,&M,&N,&O,&T
                    REAL
&P,&Q,&R,&S,&W,&U,&V,&XX,&WW,&ZZ,&AA,&YY,&BB
                    REAL
&CC,&DD,&EE,&FF,&GG,&HH,&II,&AA789C,&BB789C,&CC789C,&DD789C
        REAL
          &TOTWST,&CCC,&AAAA,&JJ,&KK,&LL,&MM,&NN,&OO,&PP,&QQ,&R
R,&SS
                    REAL
&TT,&UU,&VV,&AAA,&BBB,&DDD,&EEE,&FFF,&GGG,&HHH,&III,&JJJ
                    REAL
&KKK,&LLL,&MMM,&NNN,&OOO,&PPP,&QQQ,&RRR,&SSS,&TTT,&UUU,&V
VV
                    REAL
&WWW,&XXX,&YYY,&ZZZ,&BBBB,&CCCC,&DDDD,&EEEE,&FFFF,&GGGG,&
HHHH
                    REAL
&IIII,&JJJJ,&KKKK,&LLLL,&MMMM,&NNNN,&OOOO,&PPPP,&QQQQ,&RRRR,
&SSSS
                    REAL
&TTTT,&UUUU,&VVVV,&WWWW,&XXXX,&YYYY,&ZZZZ,&AAAAA,&BBBB
B,&CCCCC,&LLLLL,&IIIII,&FFFFF,&GGGGG
                    REAL
&DDDDD,&EEEEE,&TOTWST2,&AC789C,&BD789C,&ACC789C,&BDD789C,&A
CD789C,&BCD789C
```

```
                    REAL
&AF,&AG,&AH,&AK,&AL,&AZ,&AX,&AV,&AN,&AM,&AO,&AI,&TA,&TAC,&T
OTGAS,&TA2,&TAC2,&TOTGAS2
        REAL
&EEEE1,&FFFF1,&GGGG1,&WWWW1,&TTTT1,&UUUU1,&VVVV1,&XF
        INTEGER   &LOAD789C,&DUMP789C,&IA

  1      FUNCTION    PH1,E1
1,RVNORM(1,2.75,.13)
  2      FUNCTION    PH1,E1
1,RVNORM(1,.8,.04)
  3      FUNCTION    PH1,E1
1,RVNORM(1,.75,.03)
  4      FUNCTION    PH1,E1
1,RVNORM(1,.25,.01)
  6      FUNCTION    PH1,E1
1,RVNORM(1,1,.05)
 7       FUNCTION    PH1,E1
1,RVNORM(1,.5,.02)
 8       FUNCTION    PH1,E1
1,RVNORM(1,.4,.02)
 9       FUNCTION    PH1,E1
1,RVNORM(1,.9,.04)
 10      FUNCTION    PH1,E1
1,RVNORM(1,1.1,.05)
 11      FUNCTION    PH1,E1
1,RVNORM(1,.95,.04)
 12      FUNCTION    PH1,E1
1,RVNORM(1,.95,.04)
 AA12A   FUNCTION    PH1,E1
1,RVNORM(1,.15,.007)
 13      FUNCTION    PH1,E1
1,RVNORM(1,1.05,.05)
 14      FUNCTION    PH1,E1
1,RVNORM(1,.5,.02)
 15      FUNCTION    PH1,E1
1,RVNORM(1,.5,.02)
 16      FUNCTION    PH1,E1
1,RVNORM(1,.7,.03)
 17      FUNCTION    PH1,E1
1,RVNORM(1,1.6,.08)
 18      FUNCTION    PH1,E1
1,RVNORM(1,.15,.007)
 19      FUNCTION    PH1,E1
1,RVNORM(1,.35,.01)
```

```
 20     FUNCTION    PH1,E1
1,RVNORM(1,.6,.03)
 AA20A  FUNCTION    PH1,E1
1,RVNORM(1,.1,.005)
 21     FUNCTION    PH1,E1
1,RVNORM(1,.75,.03)
 22     FUNCTION    PH1,E1
1,RVNORM(1,.65,.03)
 23     FUNCTION    PH1,E1
1,RVNORM(1,.8,.04)
 24     FUNCTION    PH1,E1
1,RVNORM(1,.65,.03)
 25     FUNCTION    PH1,E1
1,RVNORM(1,.25,.01)
 26     FUNCTION    PH1,E1
1,RVNORM(1,.35,.01)
 27     FUNCTION    PH1,E1
1,RVNORM(1,.65,.03)
 AA27A  FUNCTION    PH1,E1
1,RVNORM(1,.05,.002)
 28     FUNCTION    PH1,E1
1,RVNORM(1,.2,.01)
 29     FUNCTION    PH1,E1
1,RVNORM(1,.8,.04)
 30     FUNCTION    PH1,E1
1,RVNORM(1,.45,.02)
 31     FUNCTION    PH1,E1
1,RVNORM(1,.3,.01)
 211    FUNCTION    PH1,E1
1,RVNORM(1,1.5,.07)
 212    FUNCTION    PH1,E1
1,RVNORM(1,1.75,.08)
 213    FUNCTION    PH1,E1
1,RVNORM(1,.5,.02)
 32     FUNCTION    PH1,E1
1,RVNORM(1,.2,.01)
 33     FUNCTION    PH1,E1
1,RVNORM(1,.55,.02)
 34     FUNCTION    PH1,E1
1,RVNORM(1,.6,.03)
 35     FUNCTION    PH1,E1
1,RVNORM(1,2.05,.1)

 36     FUNCTION    PH1,E1
1,RVNORM(1,.7,.03)
```

```
 37     FUNCTION    PH1,E1
1,RVNORM(1,.6,.03)
 38     FUNCTION    PH1,E1
1,RVNORM(1,.85,.04)
 39     FUNCTION    PH1,E1
1,RVNORM(1,.7,.03)
 40     FUNCTION    PH1,E1
1,RVNORM(1,.1,.005)
 41     FUNCTION    PH1,E1
1,RVNORM(1,1.05,.05)
 42     FUNCTION    PH1,E1
1,RVNORM(1,1.1,.05)
 43     FUNCTION    PH1,E1
1,RVNORM(1,.1,.005)

 44     FUNCTION    PH1,E1
1,RVNORM(1,3.4,.17)
 AA44A   FUNCTION    PH1,E1
1,RVNORM(1,.5,.02)
 AA44B   FUNCTION    PH1,E1
1,RVNORM(1,1,.05)
 45     FUNCTION    PH1,E1
1,RVNORM(1,.35,.01)
 46     FUNCTION    PH1,E1
1,RVNORM(1,1.15,.05)
 47     FUNCTION    PH1,E1
1,RVNORM(1,.95,.04)
 48     FUNCTION    PH1,E1
1,RVNORM(1,.65,.03)
 49     FUNCTION    PH1,E1
1,RVNORM(1,.7,.03)
 50     FUNCTION    PH1,E1
1,RVNORM(1,.95,.04)
 51     FUNCTION    PH1,E1
1,RVNORM(1,.1,.005)
 52     FUNCTION    PH1,E1
1,RVNORM(1,1.3,.06)
 53     FUNCTION    PH1,E1
1,RVNORM(1,2.3,.12)
 54     FUNCTION    PH1,E1
1,RVNORM(1,2.45,.12)
 55     FUNCTION    PH1,E1
1,RVNORM(1,2.45,.12)
 56     FUNCTION    PH1,E1
1,RVNORM(1,1.6,.08)
```

```
 57     FUNCTION    PH1,E1
1,RVNORM(1,1.2,.06)
 58     FUNCTION    PH1,E1
1,RVNORM(1,.65,.03)
 59     FUNCTION    PH1,E1
1,RVNORM(1,1.15,.05)
 60     FUNCTION    PH1,E1
1,RVNORM(1,.35,.01)
 61     FUNCTION    PH1,E1
1,RVNORM(1,.15,.007)
 62     FUNCTION    PH1,E1
1,RVNORM(1,1,.05)
 63     FUNCTION    PH1,E1
1,RVNORM(1,1.35,.07)
 64     FUNCTION    PH1,E1
1,RVNORM(1,1.2,.06)
 65     FUNCTION    PH1,E1
1,RVNORM(1,.2,.01)
 66     FUNCTION    PH1,E1
1,RVNORM(1,.8,.04)
 67     FUNCTION    PH1,E1
1,RVNORM(1,.6,.03)
 68     FUNCTION    PH1,E1
1,RVNORM(1,.8,.04)
 69     FUNCTION    PH1,E1
1,RVNORM(1,.7,.03)
 70     FUNCTION    PH1,E1
1,RVNORM(1,.2,.01)
 71     FUNCTION    PH1,E1
1,RVNORM(1,.75,.03)
 72     FUNCTION    PH1,E1
1,RVNORM(1,1,.05)
 73     FUNCTION    PH1,E1
1,RVNORM(1,1.35,.06)
 74     FUNCTION    PH1,E1
1,RVNORM(1,.2,.01)
 75     FUNCTION    PH1,E1
1,RVNORM(1,.4,.02)
 AA75A  FUNCTION    PH1,E1
1,RVNORM(1,.2,.01)
 AA75B  FUNCTION    PH1,E1
1,RVNORM(1,1.5,.07)
 76     FUNCTION    PH1,E1
1,RVNORM(1,.2,.01)
 77     FUNCTION    PH1,E1
```

```
1,RVNORM(1,1,.05)
 78     FUNCTION    PH1,E1
1,RVNORM(1,.75,.03)
 79     FUNCTION    PH1,E1
1,RVNORM(1,.1,.005)
 80     FUNCTION    PH1,E1
1,RVNORM(1,.5,.02)
 81     FUNCTION    PH1,E1
1,RVNORM(1,.55,.02)
 82     FUNCTION    PH1,E1
1,RVNORM(1,.4,.02)
 83     FUNCTION    PH1,E1
1,RVNORM(1,.45,.02)
 84     FUNCTION    PH1,E1
1,RVNORM(1,.8,.04)
 85     FUNCTION    PH1,E1
1,RVNORM(1,.55,.02)
 86     FUNCTION    PH1,E1
1,RVNORM(1,.5,.02)
 87     FUNCTION    PH1,E1
1,RVNORM(1,.7,.03)
 88     FUNCTION    PH1,E1
1,RVNORM(1,.85,.04)
 89     FUNCTION    PH1,E1
1,RVNORM(1,1.5,.07)
 90     FUNCTION    PH1,E1
1,RVNORM(1,2,.1)
 91     FUNCTION    PH1,E1
1,RVNORM(1,.2,.01)
 92     FUNCTION    PH1,E1
1,RVNORM(1,1,.05)
 93     FUNCTION    PH1,E1
1,RVNORM(1,.95,.02)
 94     FUNCTION    PH1,E1
1,RVNORM(1,.65,.03)
 95     FUNCTION    PH1,E1
1,RVNORM(1,.1,.005)
 96     FUNCTION    PH1,E1
1,RVNORM(1,.3,.01)
 97     FUNCTION    PH1,E1
1,RVNORM(1,.75,.03)
 98     FUNCTION    PH1,E1
1,RVNORM(1,.4,.02)
 99     FUNCTION    PH1,E1
1,RVNORM(1,.5,.02)
```

```
 100     FUNCTION    PH1,E1
1,RVNORM(1,.5,.02)
 101     FUNCTION    PH1,E1
1,RVNORM(1,.4,.02)
 102     FUNCTION    PH1,E1
1,RVNORM(1,.5,.02)
 103     FUNCTION    PH1,E1
1,RVNORM(1,1.5,.07)
 104     FUNCTION    PH1,E1
1,RVNORM(1,1.75,.08)
 105     FUNCTION    PH1,E1
1,RVNORM(1,.35,.01)

 177     FUNCTION    PH1,E1
1,RVNORM(1,1,.2)
 178     FUNCTION    PH1,E1
1,RVNORM(1,.75,.1)
 179     FUNCTION    PH1,E1
1,RVNORM(1,.1,.01)
 192     FUNCTION    PH1,E1
1,RVNORM(1,1,.3)
 193     FUNCTION    PH1,E1
1,RVNORM(1,.95,.2)
 194     FUNCTION    PH1,E1
1,RVNORM(1,.65,.2)
 195     FUNCTION    PH1,E1
1,RVNORM(1,.1,.01)

 201     FUNCTION    PH1,E1
1,RVNORM(1,1,.3)
 202     FUNCTION    PH1,E1
1,RVNORM(1,.95,.2)
 203     FUNCTION    PH1,E1
1,RVNORM(1,.65,.2)
 204     FUNCTION    PH1,E1
1,RVNORM(1,.1,.01)

 SPOTS1  FUNCTION    PH1,E1          SPOT SHOVEL1
1,RVNORM(1,.3,.02)
SPOTS2   FUNCTION    PH1,E1          SPOT SHOVEL2
1,RVNORM(1,.3,.02)
SPOTS3   FUNCTION    PH1,E1          SPOT SHOVEL3
1,RVNORM(1,.5,.03)
SPOTS4   FUNCTION    PH1,E1          SPOT SHOVEL4
1,RVNORM(1,.5,.02)
```

```
SPOTS5    FUNCTION    PH1,E1           SPOT SHOVEL5
1,RVNORM(1,.5,.01)
SPOTS6    FUNCTION    PH1,E1           SPOT SHOVEL6
1,RVNORM(1,.5,.04)

FIRST     BVARIABLE   (LR(STOPSH1))AND(&XF'E'0)
FIRST1    BVARIABLE   (LR(STOPSH2))AND(&XF'E'0)

FIRST3    BVARIABLE   (LR(STOPSH3))AND(&XF'E'0)
FIRST4    BVARIABLE   (LR(STOPSH4))AND(&XF'E'0)
FIRST5    BVARIABLE   (LR(STOPSH5))AND(&XF'E'0)

FIRST6    BVARIABLE   (LR(STOPSH6))AND(&XF'E'0)

FIRST7    BVARIABLE   (LR(STOPSH3))+(LR(STOPSH4))AND(&XF'E'0)
FIRST8    BVARIABLE   (LR(STOPSH5))+(LR(STOPSH6))AND(&XF'E'0)


**********************************************
*            START MACRO DEFINITIONS         *
**********************************************
 TRAVEL   STARTMACRO
         BLET       #A=FN(#B)
         TRANSFER    SBR,ANIM,3PH
         BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1,#A
 TIME *.****
 PLACE T* ON P#C
 SET T* TRAVEL **.**
 PAT#D  ADVANCE     #A
        ENDMACRO
**********************************************
*            END OF MACRO DEFINITIONS        *
**********************************************
         DO    &IA=1,80
         PUTSTRING   ('  ')
         ENDDO
         PUTSTRING    ('  ')
         PUTSTRING    ('                  *** COAL MINE SIMULATION MODEL ***')
         PUTSTRING    ('  ')
         PUTSTRING    ('  ')
         INTEGER
&TRUCK,&TRUCK1,&TRUCK2,&TRUCK3,&TRUCK4,&TRUCK5,&TRUCK6
         PUTSTRING   (' ')
         PUTSTRING   ('  TRUCKS MODEL: CAT 789C')
         PUTSTRING   ('  ')
```

```
        PUTPIC      FILE=ATF,LINES=2,AC1
TIME *.****
WRITE MCAT 789C
        PUTSTRING   (' ')
        PUTSTRING   ('  "DISPATCH SYSTEM"')
        PUTSTRING   ('  ')
        PUTPIC      FILE=ATF,LINES=2,AC1
TIME *.****
WRITE DIS DISPATCH SYSTEM
        PUTSTRING   (' ')
        PUTSTRING   ('  HOW MANY TRUCKS TOTAL IN THE MINE?')
        PUTSTRING   ('  ')
        GETLIST     &TRUCK
        PUTPIC    FILE=ATF,LINES=2,AC1,&TRUCK
TIME *.****
WRITE MT **
        PUTSTRING   ('  HOW MANY TRUCKS AT HITACHI 3600-1?')
        GETLIST     &TRUCK1
        PUTPIC    FILE=ATF,LINES=2,AC1,&TRUCK1
TIME *.****
WRITE MT11 **
        LET         &TRUCK=&TRUCK-&TRUCK1
        PUTPIC      &TRUCK
  YOU HAVE ** TRUCKS LEFT
        PUTSTRING   ('  HOW MANY TRUCKS AT HITACHI 3600-2?')
        GETLIST     &TRUCK2
        PUTPIC    FILE=ATF,LINES=2,AC1,&TRUCK2
TIME *.****
WRITE MT12 **
        LET         &TRUCK=&TRUCK-&TRUCK2
        PUTPIC      &TRUCK
  YOU HAVE ** TRUCKS LEFT
     PUTSTRING   ('  HOW MANY TRUCKS AT HITACHI 5500-1?')
        GETLIST     &TRUCK3
        PUTPIC    FILE=ATF,LINES=2,AC1,&TRUCK3
TIME *.****
WRITE MT13 **
        LET         &TRUCK=&TRUCK-&TRUCK3
        PUTPIC      &TRUCK
  YOU HAVE ** TRUCKS LEFT
      PUTSTRING   ('  HOW MANY TRUCKS AT HITACHI 5500-2?')
        GETLIST   &TRUCK4
        PUTPIC    FILE=ATF,LINES=2,AC1,&TRUCK4
TIME *.****
WRITE MT14 **
```

```
        LET      &TRUCK=&TRUCK-&TRUCK4
        PUTPIC   &TRUCK
  YOU HAVE ** TRUCKS LEFT
      PUTSTRING  ('  HOW MANY TRUCKS AT HITACHI 5500-3?')
                 GETLIST &TRUCK5
       PUTPIC    FILE=ATF,LINES=2,AC1,&TRUCK5
TIME *.****
WRITE MT15 **
                 LET     &TRUCK=&TRUCK-&TRUCK5
       PUTPIC  &TRUCK
  YOU HAVE ** TRUCKS LEFT
     PUTSTRING  ('  HOW MANY TRUCKS AT HITACHI 5500-4?')
                 GETLIST &TRUCK6
       PUTPIC    FILE=ATF,LINES=2,AC1,&TRUCK6
TIME *.****
WRITE MT16 **
                 LET     &TRUCK=&TRUCK-&TRUCK6
       PUTPIC  &TRUCK
  YOU HAVE ** TRUCKS LEFT
        PUTSTRING    ('  ')
        PUTSTRING    ('  DO YOU WANT ANIMATION? (Y/N)')
        CHAR*1       &YES
        GETLIST      &YES
ANIM    TEST E       &YES,'Y',PH3+2
        TRANSFER     ,PH3+1
        PUTSTRING    ('  ')
        PUTSTRING    ('  ')
        PUTSTRING    ('  ** SIMULATION RESULTS **')
        PUTSTRING    ('  ')
        PUTSTRING    ('  ')

*************************************************************
*       SEGMENT FOR SHOVEL 1                                *
*************************************************************
        GENERATE    3,,5,&TRUCK1,,12PH,12PL    TRUCKS AT SHOVEL1
        ASSIGN      1,2,PH
        TRANSFER    SBR,ANIM,3PH
        GATE LR     STOPSH1
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
 TIME *.****
 CREATE E789C T*
 PLACE T* AT 21.25 -33.81
        SEIZE       SHOVEL1        USE THE SHOVEL
        ADVANCE     RVNORM(1,3.5,.35)    LOAD A TRUCK 789C
        RELEASE     SHOVEL1        FREE THE SHOVEL
```

```
          ASSIGN      1,RVNORM(1,195,4.5),PL   AMOUNT LOAD BY HITACHI 3600
          BLET        &AA789C=&AA789C+1
          BLET        &BB789C=&BB789C+PL1
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC
FILE=ATF,LINES=5,AC1,XID1,&AA789C,&BB789C,FR(SHOVEL1)/10.
TIME *.****
SET T* CLASS F789C
WRITE MESS1 ***
WRITE MESS2 *****.**
WRITE MESS3   **.**%
          ADVANCE     0
          REAL       &XOLD,&YOLD,&YNEW
          BLET       &YNEW=&BB789C
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC   FILE=ATF,LINES=2,AC1,&XOLD,&YOLD,AC1,&YNEW
TIME *.****
PLOT MYPLOT  **.**  **.**   **.** **.** COLOR F4
          BLET       &XOLD=AC1
          BLET       &YOLD=&YNEW
PATHP1    ADVANCE     0
TRAVEL    MACRO       &X,1,1,1
TRAVEL          MACRO       &Y,2,2,2
TRAVEL    MACRO       &Z,3,3,3
          SEIZE       INTERA     CHECK TO SEE IF WAY CLEAR
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M1 STOP!
              RELEASE   INTERA
                  ADVANCE   .4,.08
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M1
TRAVEL          MACRO       &E,4,4,4   TRAVEL ON PATH4
 PLACE5   ADVANCE     0
 TRAVEL   MACRO       &G,6,6,6
 TRAVEL          MACRO       &H,7,7,7
 TRAVEL   MACRO       &I,8,8,8
 TRAVEL   MACRO       &J,9,9,9
 TRAVEL          MACRO       &K,10,10,10
 TRAVEL   MACRO       &L,11,11,11
 TRAVEL   MACRO       &M,12,12,12
          SEIZE       INTERGAS     CHECK TO SEE IF WAY CLEAR
```

```
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE MA1 STOP!
           RELEASE     INTERGAS
        ADVANCE   .4,.08
TRAVEL    MACRO       &AK,AA12A,12A,12A
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE MA1
 TRAVEL         MACRO       &N,13,13,13
 TRAVEL   MACRO       &O,14,14,14
        QUEUE     DUMP1       TRUCKS AT DUMP1
        GATE LR   BLAST
        SEIZE     DUMP1
        ADVANCE   RVNORM(1,.7,.1)     789C DUMPS A LOAD OF WASTE
        DEPART    DUMP1
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M13 !DUMPING!
        ADVANCE     .7,.1
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M13
        RELEASE   DUMP1
        BLET    &CCC=RVNORM(1,195,4.5)   ASSUME LOAD OF 789C IS THIS
        BLET    &TOTWST=&TOTWST+&CCC     ADD TO TOTAL WASTE
        BLET    &LOAD789C=&LOAD789C+1    COUNT LOADS OF 789C
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC
FILE=ATF,LINES=6,AC1,&LOAD789C,&TOTWST,QA(DUMP1),QM(DUMP1),XID
1
TIME *.****
WRITE MESS8    ***
WRITE MESS9  *****.**
WRITE MESS24 **.**
WRITE MESS27 **
SET T* CLASS E789C
TRAVEL    MACRO       &T,19,19,19
TRAVEL         MACRO       &U,20,20,20
        SEIZE       INTERGAS     CHECK TO SEE IF WAY CLEAR
        TRANSFER    SBR,ANIM,3PH
```

```
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE MA2 STOP!
          RELEASE    INTERGAS
        ADVANCE   .4,.08
TRAVEL    MACRO      &AL,AA20A,20A,20A
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE MA2
        TRANSFER    .00001,,GAS1       PERCENT FOR SENDING TRUCKS TO GAS
STATION1
PATHP21   ADVANCE    0
TRAVEL    MACRO      &V,21,21,21
TRAVEL    MACRO      &W,22,22,22
TRAVEL         MACRO      &XX,23,23,23
TRAVEL    MACRO      &YY,24,24,24
TRAVEL    MACRO      &ZZ,25,25,25
TRAVEL         MACRO      &WW,26,26,26
TRAVEL    MACRO      &AA,27,27,27
        SEIZE      INTERA     CHECK TO SEE IF WAY CLEAR
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M3 STOP!
          RELEASE    INTERA
             ADVANCE   .4,.08
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M3
TRAVEL    MACRO      &AAAA,AA27A,27A,27A  TRAVEL ON PATH27A

*************************************************
*  READY FOR THE DISPATCHER PIT-1                    *
*  COUNT THE TRUCKS GOING TO EACH PLACE              *
*************************************************
        INTEGER    &COUNT1,&COUNT2
        BLET       &COUNT1=W(PAT32)+W(PAT33)+W(PAT34)+W(PAT35)_
                 +Q(SHOVEL1)+F(SHOVEL1)+F(SPOTS1)
        BLET       &COUNT2=W(PAT28)+W(PAT29)+W(PAT30)+W(PAT31)_
                 +Q(SHOVEL2)+F(SHOVEL2)+F(SPOTS2)
        TEST LE    &COUNT1,&COUNT2,LLOAD2
        TRANSFER    ,AREA1       GO TO SHOVEL1
  LLOAD2 TRANSFER    ,AREA2       GO TO SHOVEL2
```

```
****************************************************
AREA2    ADVANCE    0
         TEST E     BV(FIRST1),1,AREA1
PATHP28  ADVANCE    0
TRAVEL   MACRO      &BB,28,28,28
TRAVEL   MACRO      &CC,29,29,29
TRAVEL   MACRO      &DD,30,30,30
TRAVEL   MACRO      &EE,31,31,31
         TRANSFER   ,SHOVE22

************************************************
*            DISPATCH POINTS                   *
************************************************
AREA1    ADVANCE    0
         TEST E     BV(FIRST),1,AREA2
TRAVEL   MACRO      &FF,32,32,32
TRAVEL   MACRO      &GG,33,33,33
TRAVEL   MACRO      &HH,34,34,34
TRAVEL   MACRO      &II,35,35,35
         QUEUE      SHOVEL1     TRUCKS ARE AT SHOVEL 1
         SEIZE      SPOTS1      SPOT
         ADVANCE    FN(SPOTS1)  SPOT
         RELEASE    SPOTS1
         GATE LR    STOPSH1,POINTA
         SEIZE      SHOVEL1     USE SHOVEL1
         DEPART     SHOVEL1     LEAVE THE QUEUE
         TRANSFER   SBR,ANIM,3PH
         BPUTPIC    FILE=ATF,LINES=4,AC1,QA(SHOVEL1),QM(SHOVEL1),XID1
TIME *.****
WRITE MESS28 **.**
WRITE MESS29 **
PLACE T* AT  21.25 -33.81
         ADVANCE    RVNORM(1,3.5,.35)
         TRANSFER   SBR,ANIM,3PH
         BPUTPIC    FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS F789C
         RELEASE    SHOVEL1
         ASSIGN     1,RVNORM(1,195,4.5),PL   AMOUNT DUMPED
         BLET       &AA789C=&AA789C+1
         BLET       &BB789C=&BB789C+PL1
         TRANSFER   SBR,ANIM,3PH
         BPUTPIC    FILE=ATF,LINES=4,AC1,&AA789C,&BB789C,FR(SHOVEL1)/10.
TIME *.****
```

```
WRITE MESS1 ***
WRITE MESS2 *****.**
WRITE MESS3   **.**%
        ADVANCE     0
        BLET      &YNEW=&BB789C
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1,&XOLD,&YOLD,AC1,&YNEW
TIME *.****
PLOT MYPLOT  **.**  **.**    **.** **.** COLOR F4
        BLET      &XOLD=AC1
        BLET      &YOLD=&YNEW
        TRANSFER    ,PATHP1
GAS1     ADVANCE    0
TRAVEL    MACRO       &AF,211,211,211
        SEIZE       GAS1
        ADVANCE     RVNORM(1,15,5)   PUMPING GUS TRUCK 789C
        BLET      &TAC=RVNORM(1,851,20)     ASSUME AMOUNT OF FUELING OF
789C IS THIS
        BLET      &TOTGAS=&TOTGAS+&TAC     ADD TO TOTAL GAS
        BLET      &TA=&TA+1                COUNT FUELING OF 789C
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=5,AC1,&TA,&TOTGAS,XID1
TIME *.****
WRITE MGAS1 ***
WRITE MGAS2 ******Gal
SET T* COLOR F31
WRITE MGAS5 "REFUELING"
        ADVANCE     RVNORM(1,15,5)    PUMPING GAS DURIATION
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1
TIME *.****
SET T* COLOR F4
WRITE MGAS5
        RELEASE     GAS1
        GATE LR     BLAST
TRAVEL    MACRO       &AG,212,212,212
        SEIZE       INTERGAS    CHECK TO SEE IF WAY CLEAR
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE MA3 STOP!
               ADVANCE   .4,.08
        RELEASE     INTERGAS
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
```

```
TIME *.****
WRITE MA3
TRAVEL    MACRO      &AH,213,213,213
          TRANSFER    ,PATHP21

*********************************************
*        DISPATCH OPTIMIZATION              *
*********************************************
POINTA    ADVANCE     0
TRAVEL    MACRO      &LLLLL,201,201,201
TRAVEL          MACRO      &IIIII,202,202,202
TRAVEL    MACRO      &FFFFF,203,203,203
TRAVEL    MACRO      &GGGGG,204,204,204
          TRANSFER    ,PATHP28

*********************************************
*         SEGMENT FOR SHOVEL2                  *
*********************************************
          GENERATE    3,,3,&TRUCK2,,12PH,12PL   TRUCKS AT SHOVEL2
          ASSIGN      1,2,PH
          TRANSFER    SBR,ANIM,3PH
          GATE LR     STOPSH2
          BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
 TIME *.****
 CREATE E789C T*
 PLACE T* AT 44.25 -33.16
          SEIZE       SHOVEL2         USE THE SHOVEL
          ADVANCE     RVNORM(1,3.5,.35)      LOAD A TRUCK 789C
          RELEASE     SHOVEL2         FREE THE SHOVEL
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
 TIME *.****
 SET T* CLASS F789C
          ASSIGN      1,RVNORM(1,195,4.5),PL   AMOUNT LOAD BY HITACHI 3600
          BLET        &CC789C=&CC789C+1
          BLET        &DD789C=&DD789C+PL1
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=4,AC1,&CC789C,&DD789C,FR(SHOVEL2)/10.
TIME *.****
WRITE MESS4 ***
WRITE MESS5 *****.**
WRITE MESS6   **.**%
          ADVANCE     0
          BLET      &YNEW=&DD789C
          TRANSFER    SBR,ANIM,3PH
```

```
        BPUTPIC   FILE=ATF,LINES=2,AC1,&XOLD,&YOLD,AC1,&YNEW
TIME *.****
PLOT MYPLOT  **.**  **.**   **.** **.** COLOR F2
        BLET     &XOLD=AC1
        BLET     &YOLD=&YNEW
PATHP2    ADVANCE     0
TRAVEL    MACRO      &P,15,15,15
TRAVEL         MACRO      &Q,16,16,16
TRAVEL    MACRO      &R,17,17,17
        SEIZE      INTERA     CHECK TO SEE IF WAY CLEAR
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M2 STOP!
           RELEASE     INTERA
              ADVANCE   .4,.08
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M2
TRAVEL         MACRO      &S,18,18,18   TRAVEL ON PATH18
        TRANSFER    ,PLACE5        GO ON ROAD SEGMENT 5
SHOVE22   ADVANCE     0
        QUEUE      SHOVEL2    TRUCKS ARE AT SHOVEL 2
        SEIZE      SPOTS2     SPOT
        ADVANCE    FN(SPOTS2)   SPOT
        RELEASE    SPOTS2
        SEIZE      SHOVEL2    USE SHOVEL2
        GATE LR    STOPSH2
        DEPART     SHOVEL2    LEAVE THE QUEUE
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=4,AC1,QA(SHOVEL2),QM(SHOVEL2),XID1
TIME *.****
WRITE MESS30 **.**
WRITE MESS31 **
PLACE T* AT  44.25 -33.16
        ADVANCE    RVNORM(1,3.5,.35)
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET T* CLASS F789C
        RELEASE    SHOVEL2
        ASSIGN     1,RVNORM(1,195,4.5),PL   AMOUNT LOAD BY HITACHI 3600
        BLET       &CC789C=&CC789C+1
        BLET       &DD789C=&DD789C+PL1
```

```
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=4,AC1,&CC789C,&DD789C,FR(SHOVEL2)/10.
TIME *.****
WRITE MESS4 ***
WRITE MESS5 *****.**
WRITE MESS6   **.**%
        BLET      &YNEW=&DD789C
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1,&XOLD,&YOLD,AC1,&YNEW
TIME *.****
PLOT MYPLOT  **.**  **.**   **.** **.** COLOR F2
        BLET      &XOLD=AC1
        BLET      &YOLD=&YNEW
        ADVANCE   0
        TRANSFER    ,PATHP2

*********************************************
*   SEGMENT FOR SHOVEL3                     *
*********************************************
        GENERATE    3,,5,&TRUCK3,,12PH,12PL   TRUCKS AT SHOVEL3
        ASSIGN      1,2,PH
        GATE LR     STOPSH3
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
 TIME *.****
 CREATE E789C T*
 PLACE T* AT -3.89 -22.54
        SEIZE       SHOVEL3         USE THE SHOVEL
        ADVANCE     RVNORM(1,3,.5)      LOAD A TRUCK
        RELEASE     SHOVEL3         FREE THE SHOVEL
        ASSIGN      1,RVNORM(1,195,4.5),PL   AMOUNT LOAD BY HITACHI 5500-1
        REAL        &AB789C,&BBB789C
        BLET        &AB789C=&AB789C+1
        BLET        &BBB789C=&BBB789C+PL1
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC
FILE=ATF,LINES=5,AC1,XID1,&AB789C,&BBB789C,FR(SHOVEL3)/10.
TIME *.****
SET T* CLASS F789C
WRITE MESS12 ***
WRITE MESS13 *****.**
WRITE MESS14   **.**%
        ADVANCE   0
        BLET      &YNEW=&BBB789C
        TRANSFER    SBR,ANIM,3PH
```

```
        BPUTPIC   FILE=ATF,LINES=2,AC1,&XOLD,&YOLD,AC1,&YNEW
TIME *.****
PLOT MYPLOT  **.**  **.**   **.** **.** COLOR F9
        BLET      &XOLD=AC1
        BLET      &YOLD=&YNEW
 PATHP36  ADVANCE    0
 TRAVEL   MACRO      &JJ,36,36,36
 TRAVEL   MACRO      &KK,37,37,37
 TRAVEL   MACRO      &LL,38,38,38
 TRAVEL   MACRO      &MM,39,39,39
        SEIZE     INTERB     CHECK TO SEE IF WAY CLEAR
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M4 STOP!
           RELEASE   INTERB
              ADVANCE   .4,.08
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M4
TRAVEL   MACRO      &NN,40,40,40
PATHP41  ADVANCE    0
TRAVEL   MACRO      &OO,41,41,41
TRAVEL        MACRO      &PP,42,42,42
       SEIZE     INTERC     CHECK TO SEE IF WAY CLEAR
       TRANSFER    SBR,ANIM,3PH
       BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M5 STOP!
           RELEASE   INTERC
              ADVANCE   .4,.08
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M5
TRAVEL   MACRO     &QQ,43,43,43
PATHP44   ADVANCE   0
TRAVEL    MACRO     &RR,44,44,44
        SEIZE     INTERGS2    CHECK TO SEE IF WAY CLEAR
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE MB3 STOP!
           RELEASE   INTERGS2
```

```
            ADVANCE   .4,.08
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE MB3
TRAVEL    MACRO     &AV,AA44A,44A,44A
TRAVEL    MACRO     &AN,AA44B,44B,44B
        SEIZE     INTERD     CHECK TO SEE IF WAY CLEAR
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M6 STOP!
           RELEASE   INTERD
            ADVANCE   .4,.08
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M6
TRAVEL    MACRO     &SS,45,45,45
        TRANSFER    .65,,DUMP2     65% GO BACK TO DUMP2
TRAVEL    MACRO      &EEE,52,52,52
TRAVEL    MACRO      &FFF,53,53,53
TRAVEL    MACRO      &GGG,54,54,54
        QUEUE     DUMPS2       TRUCKS AT DUMP1 SIDE 2
        GATE LR   BLAST
        SEIZE     DUMPS2
        ADVANCE   RVNORM(1,.7,.1)     789C DUMPS A LOAD OF WASTE
            DEPART    DUMPS2
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M14 !DUMPING!
        ADVANCE     .7,.1
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M14
        RELEASE   DUMPS2
        BLET    &CCC=RVNORM(1,195,4.5)   ASSUME LOAD OF 789C IS THIS
        BLET    &TOTWST=&TOTWST+&CCC     ADD TO TOTAL WASTE
        BLET    &LOAD789C=&LOAD789C+1    COUNT LOADS OF 789C
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC
FILE=ATF,LINES=6,AC1,&LOAD789C,&TOTWST,QA(DUMPS2),QM(DUMPS2),XI
D1
```

```
TIME *.****
WRITE MESS8    ***
WRITE MESS9  *****.**
WRITE MESS124 **.**
WRITE MESS127 **
SET T* CLASS E789C
TRAVEL    MACRO      &QQQQ,89,89,89
TRAVEL    MACRO      &RRRR,90,90,90
        SEIZE     INTERD     CHECK TO SEE IF WAY CLEAR
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M6 STOP!
           RELEASE   INTERD
              ADVANCE   .4,.08
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M6
TRAVEL    MACRO      &SSSS,91,91,91
        TRANSFER    ,PATHP75
DUMP2     ADVANCE     0
TRAVEL    MACRO      &HHH,55,55,55
TRAVEL    MACRO      &III,56,56,56
TRAVEL    MACRO      &JJJ,57,57,57
        QUEUE     DUMP2       TRUCKS AT DUMP2
        GATE LR   BLAST
        SEIZE     DUMP2
        ADVANCE   RVNORM(1,.7,.1)     789C DUMPS A LOAD OF WASTE
        DEPART    DUMP2
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M15 !DUMPING!
        ADVANCE    .7,.1
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M15
              RELEASE   DUMP2
        BLET    &EEEEE=RVNORM(1,195,4.5)   ASSUME LOAD OF 789C IS THIS
        BLET    &TOTWST2=&TOTWST2+&EEEEE     ADD TO TOTAL WASTE
        BLET    &DUMP789C=&DUMP789C+1    COUNT LOADS OF 789C
        TRANSFER    SBR,ANIM,3PH
```

```
        BPUTPIC
FILE=ATF,LINES=6,AC1,&DUMP789C,&TOTWST2,QA(DUMP2),QM(DUMP2),XI
D1
TIME *.****
WRITE MESS10    ***
WRITE MESS11  *****.**
WRITE MESS25  **.**
WRITE MESS26  **
SET T* CLASS E789C
        ADVANCE    0
TRAVEL    MACRO      &XXX,71,71,71
TRAVEL    MACRO      &YYY,72,72,72
TRAVEL    MACRO      &ZZZ,73,73,73
        SEIZE     INTERD     CHECK TO SEE IF WAY CLEAR
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M6 STOP!
           RELEASE   INTERD
              ADVANCE   .4,.08
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M6
TRAVEL    MACRO      &BBBB,74,74,74
PATHP75   ADVANCE    0
TRAVEL    MACRO      &CCCC,75,75,75
        SEIZE     INTERGS2
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE MB1 STOP!
           RELEASE   INTERGS2
              ADVANCE   .4,.08
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE MB1
TRAVEL    MACRO     &AZ,AA75A,75A,75A
        TRANSFER  .00001,,GAS2        PERCENT FOR SENDING TRUCKS TO GAS
STATION2
PATHP75B  ADVANCE   0
TRAVEL    MACRO     &AX,AA75B,75B,75B
        SEIZE     INTERC     CHECK TO SEE IF WAY CLEAR
        TRANSFER    SBR,ANIM,3PH
```

```
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M9 STOP!
           RELEASE   INTERC
              ADVANCE   .4,.08
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M9
TRAVEL    MACRO      &DDDD,76,76,76

*****************************************************
*  READY FOR THE DISPATCHER PIT-2                  *
*  COUNT THE TRUCKS GOING TO EACH PLACE            *
*****************************************************
        INTEGER     &COUNT3,&COUNT4,&COUNT5,&COUNT6
        BLET
&COUNT3=W(PAT77)+W(PAT78)+W(PAT79)+W(PAT80)+W(PAT81)+W(PAT82)+
W(PAT83)_
                 +Q(SHOVEL3)+F(SHOVEL3)+F(SPOTS3)
        BLET
&COUNT4=W(PAT177)+W(PAT178)+W(PAT179)+W(PAT84)+W(PAT85)+W(PAT8
6)+W(PAT87)_
                 +W(PAT88)+Q(SHOVEL4)+F(SHOVEL4)+F(SPOTS4)
        BLET
&COUNT5=W(PAT92)+W(PAT93)+W(PAT94)+W(PAT95)+W(PAT96)+W(PAT97)+
W(PAT98)_
                 +Q(SHOVEL5)+F(SHOVEL5)+F(SPOTS5)
        BLET
&COUNT6=W(PAT192)+W(PAT193)+W(PAT194)+W(PAT195)+W(PAT99)+W(PAT
100)+W(PAT101)+W(PAT102)_
                 +Q(SHOVEL6)+F(SHOVEL6)+F(SPOTS6)
        TEST LE     &COUNT3,&COUNT4,LLOAD4
        TEST LE     &COUNT3,&COUNT5,LLOAD5
        TEST LE     &COUNT3,&COUNT6,LLOAD6
        TRANSFER    ,AREA3         GO SHOVEL3
LLOAD4          TEST LE     &COUNT4,&COUNT5,LLOAD5
        TEST LE     &COUNT4,&COUNT6,LLOAD6
        TRANSFER    ,AREA4          GO SHOVEL4
LLOAD5    TEST LE     &COUNT5,&COUNT6,LLOAD6
        TRANSFER    ,AREA5          GO SHOVEL5
LLOAD6    TRANSFER    ,AREA6          GO SHOVEL6

**********************************************************************
AREA3     ADVANCE     0
```

```
        TEST E     BV(FIRST7),1,AREA5
TRAVEL   MACRO     &EEEE,77,77,77
TRAVEL   MACRO     &FFFF,78,78,78
        SEIZE     INTERB    CHECK TO SEE IF WAY CLEAR
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M10 STOP!
           RELEASE   INTERB
              ADVANCE   .4,.08
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M10
TRAVEL   MACRO     &GGGG,79,79,79
PATHP80  ADVANCE    0
        TEST E     BV(FIRST3),1,PATHP84
TRAVEL   MACRO     &HHHH,80,80,80
TRAVEL   MACRO     &IIII,81,81,81
TRAVEL   MACRO     &JJJJ,82,82,82
TRAVEL   MACRO     &KKKK,83,83,83
        GATE LR    STOPSH3
        QUEUE      SHOVEL3    TRUCKS 789C ARE AT SHOVEL 3
        SEIZE      SPOTS3     SPOT
        ADVANCE    FN(SPOTS3)   SPOT
        RELEASE    SPOTS3
        SEIZE      SHOVEL3    USE SHOVEL3
        ADVANCE    RVNORM(1,3,.5)      LOAD A TRUCK 789C
        GATE LR    STOPSH3
        DEPART     SHOVEL3    LEAVE THE QUEUE
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=4,AC1,QA(SHOVEL3),QM(SHOVEL3),XID1
TIME *.****
WRITE MESS32 **.**
WRITE MESS33 **
PLACE T* AT  -3.89 -22.54
        RELEASE    SHOVEL3
        BLET       &AB789C=&AB789C+1
        BLET       &BBB789C=&BBB789C+PL1
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC
FILE=ATF,LINES=5,AC1,XID1,&AB789C,&BBB789C,FR(SHOVEL3)/10.
TIME *.****
SET T* CLASS F789C
WRITE MESS12 ***
```

```
WRITE MESS13 *****.**
WRITE MESS14   **.**%
          BLET      &YNEW=&BBB789C
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC   FILE=ATF,LINES=2,AC1,&XOLD,&YOLD,AC1,&YNEW
TIME *.****
PLOT MYPLOT  **.**  **.**    **.** **.** COLOR F9
          BLET      &XOLD=AC1
          BLET      &YOLD=&YNEW
          ADVANCE     0
          TRANSFER    ,PATHP36

AREA4     ADVANCE     0
          TEST E      BV(FIRST7),1,AREA5
TRAVEL    MACRO       &EEEE1,177,177,177
TRAVEL    MACRO       &FFFF1,178,178,178
          SEIZE       INTERB     CHECK TO SEE IF WAY CLEAR
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M10 STOP!
              RELEASE   INTERB
                  ADVANCE   .4,.08
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M10
TRAVEL    MACRO       &GGGG1,179,179,179
PATHP84   ADVANCE     0
          TEST E      BV(FIRST4),1,PATHP80
TRAVEL    MACRO       &LLLL,84,84,84
TRAVEL    MACRO       &MMMM,85,85,85
TRAVEL    MACRO       &NNNN,86,86,86
TRAVEL    MACRO       &OOOO,87,87,87
TRAVEL    MACRO       &PPPP,88,88,88
          GATE LR     STOPSH4
          QUEUE       SHOVEL4     TRUCKS ARE AT SHOVEL 4
          SEIZE       SPOTS4      SPOT
          ADVANCE     FN(SPOTS4)   SPOT
          RELEASE     SPOTS4
          SEIZE       SHOVEL4     USE SHOVEL4
          ADVANCE     RVNORM(1,3,.5)      LOAD A TRUCK 789C
          GATE LR     STOPSH4
          DEPART      SHOVEL4     LEAVE THE QUEUE
          TRANSFER    SBR,ANIM,3PH
```

```
        BPUTPIC     FILE=ATF,LINES=4,AC1,QA(SHOVEL4),QM(SHOVEL4),XID1
TIME *.****
WRITE MESS36 **.**
WRITE MESS37 **
PLACE T* AT -3.43 -32.42
        RELEASE     SHOVEL4
        ASSIGN      1,RVNORM(1,195,4.5),PL   AMOUNT LOAD BY HITACHI 5500-2
        BLET        &AC789C=&AC789C+1
        BLET        &BD789C=&BD789C+PL1
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC
FILE=ATF,LINES=5,AC1,XID1,&AC789C,&BD789C,FR(SHOVEL4)/10.
TIME *.****
SET T* CLASS F789C
WRITE MESS15 ***
WRITE MESS16 *****.**
WRITE MESS17   **.**%
        BLET       &YNEW=&BD789C
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1,&XOLD,&YOLD,AC1,&YNEW
TIME *.****
PLOT MYPLOT  **.**  **.**   **.** **.** COLOR F16
        BLET       &XOLD=AC1
        BLET       &YOLD=&YNEW
        ADVANCE   0
        TRANSFER    ,PATHP46
AREA5    ADVANEC     0
        TEST E      BV(FIRST8),1,AREA3
TRAVEL    MACRO      &TTTT,92,92,92
TRAVEL    MACRO      &UUUU,93,93,93
TRAVEL    MACRO      &VVVV,94,94,94
        SEIZE     INTERE     CHECK TO SEE IF WAY CLEAR
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M11 STOP!
            RELEASE   INTERE
                ADVANCE   .4,.08
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M11
TRAVEL    MACRO      &WWWW,95,95,95
PATHP96   ADVANCE     0
        TEST E      BV(FIRST5),1,PATHP99
```

```
TRAVEL    MACRO      &XXXX,96,96,96
TRAVEL    MACRO      &YYYY,97,97,97
TRAVEL    MACRO      &ZZZZ,98,98,98
        GATE LR    STOPSH5
        QUEUE      SHOVEL5    TRUCKS ARE AT SHOVEL 5
        SEIZE      SPOTS5     SPOT
        ADVANCE    FN(SPOTS5)   SPOT
        RELEASE    SPOTS5
        SEIZE      SHOVEL5    USE SHOVEL5
        ADVANCE    RVNORM(1,3,.5)    LOAD A TRUCK 789C
        GATE LR    STOPSH5
        DEPART     SHOVEL5    LEAVE THE QUEUE
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=4,AC1,QA(SHOVEL5),QM(SHOVEL5),XID1
TIME *.****
WRITE MESS34 **.**
WRITE MESS35 **
PLACE T* AT -43.73 -21.82
        RELEASE    SHOVEL5
        ASSIGN     1,RVNORM(1,195,4.5),PL   AMOUNT LOAD BY HITACHI 5500-3
        BLET       &ACC789C=&ACC789C+1
        BLET       &BDD789C=&BDD789C+PL1
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC
FILE=ATF,LINES=5,AC1,XID1,&ACC789C,&BDD789C,FR(SHOVEL5)/10.
TIME *.****
SET T* CLASS F789C
WRITE MESS18 ***
WRITE MESS19 *****.**
WRITE MESS20   **.**%
        BLET      &YNEW=&BDD789C
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1,&XOLD,&YOLD,AC1,&YNEW
TIME *.****
PLOT MYPLOT  **.**  **.**   **.** **.** COLOR F7
        BLET      &XOLD=AC1
        BLET      &YOLD=&YNEW
        ADVANCE   0
        TRANSFER  ,PATHP58
AREA6    ADVANCE    0
        TEST E     BV(FIRST8),1,AREA3
TRAVEL    MACRO      &TTTT1,192,192,192
TRAVEL    MACRO      &UUUU1,193,193,193
TRAVEL    MACRO      &VVVV1,194,194,194
        SEIZE     INTERE     CHECK TO SEE IF WAY CLEAR
```

```
         TRANSFER    SBR,ANIM,3PH
         BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M11 STOP!
            RELEASE   INTERE
               ADVANCE   .4,.08
         TRANSFER    SBR,ANIM,3PH
         BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M11
TRAVEL    MACRO      &WWWW1,195,195,195
PATHP99   ADVANCE    0
         TEST E      BV(FIRST6),1,PATHP96
TRAVEL    MACRO      &AAAAA,99,99,99
TRAVEL    MACRO      &BBBBB,100,100,100
TRAVEL    MACRO      &CCCCC,101,101,101
TRAVEL    MACRO      &DDDDD,102,102,102
         GATE LR     STOPSH6
         QUEUE       SHOVEL6     TRUCKS ARE AT SHOVEL 6
         SEIZE       SPOTS6      SPOT
         ADVANCE     FN(SPOTS6)   SPOT
         RELEASE     SPOTS6
         SEIZE       SHOVEL6     USE SHOVEL6
         ADVANCE     RVNORM(1,3,.5)     LOAD A TRUCK
         GATE LR     STOPSH6
         DEPART      SHOVEL6     LEAVE THE QUEUE
         TRANSFER    SBR,ANIM,3PH
         BPUTPIC     FILE=ATF,LINES=4,AC1,QA(SHOVEL6),QM(SHOVEL6),XID1
TIME *.****
WRITE MESS38 **.**
WRITE MESS39 **
PLACE T* AT -42.71 -32.23
         RELEASE     SHOVEL6
         ASSIGN      1,RVNORM(1,195,4.5),PL   AMOUNT LOAD BY HITACHI 5500-4
         BLET        &ACD789C=&ACD789C+1
         BLET        &BCD789C=&BCD789C+PL1
         TRANSFER    SBR,ANIM,3PH
         BPUTPIC
FILE=ATF,LINES=5,AC1,XID1,&ACD789C,&BCD789C,FR(SHOVEL6)/10.
TIME *.****
SET T* CLASS F789C
WRITE MESS21 ***
WRITE MESS22 *****.**
WRITE MESS23   **.**%
         BLET      &YNEW=&BCD789C
```

```
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1,&XOLD,&YOLD,AC1,&YNEW
TIME *.****
PLOT MYPLOT  **.**  **.**   **.** **.** COLOR F31
        BLET      &XOLD=AC1
        BLET      &YOLD=&YNEW
        ADVANCE   0
        TRANSFER    ,PATHP66
GAS2      ADVANCE     0
TRAVEL    MACRO       &AM,103,103,103
        SEIZE       GAS2
        ADVANCE     RVNORM(1,20,3)   PUMPING GUS
        BLET      &TAC2=RVNORM(1,851,20)     ASSUME AMOUNT OF FUELING
OF 789C IS THIS
        BLET      &TOTGAS2=&TOTGAS2+&TAC2     ADD TO TOTAL GAS
        BLET      &TA2=&TA2+1                COUNT FUELING OF 789C
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=5,AC1,&TA2,&TOTGAS2,XID1
TIME *.****
WRITE MGAS3 ***
WRITE MGAS4 ******Gal
SET T* COLOR F31
WRITE MGAS6 "REFUELING"
        ADVANCE     RVNORM(1,20,3)
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1
TIME *.****
SET T* COLOR F4
WRITE MGAS6
        RELEASE     GAS2
        GATE LR     BLAST
TRAVEL    MACRO       &AO,104,104,104
        SEIZE       INTERGS2    CHECK TO SEE IF WAY CLEAR
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE MB2 STOP!
              ADVANCE   .4,.08
        RELEASE     INTERGS2
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE MB2
TRAVEL    MACRO       &AI,105,105,105
        TRANSFER    ,PATHP75B
```

```
***********************************************
*   SEGMENT FOR SHOVEL4                    *
***********************************************
        GENERATE    3,,6,&TRUCK4,,12PH,12PL   TRUCKS 789C AT SHOVEL4
        ASSIGN      1,2,PH
        GATE LR     STOPSH4
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
 TIME *.****
 CREATE E789C T*
 PLACE T* AT -3.43 -32.42
        SEIZE       SHOVEL4         USE THE SHOVEL 789C
        ADVANCE     RVNORM(1,3,.5)      LOAD A TRUCK
        RELEASE     SHOVEL4         FREE THE SHOVEL4
        ASSIGN      1,RVNORM(1,195,4.5),PL   AMOUNT LOAD BY HITACH 5500-2
        BLET        &AC789C=&AC789C+1
        BLET        &BD789C=&BD789C+PL1
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC
FILE=ATF,LINES=5,AC1,XID1,&AC789C,&BD789C,FR(SHOVEL4)/10.
TIME *.****
SET T* CLASS F789C
WRITE MESS15 ***
WRITE MESS16 *****.**
WRITE MESS17   **.**%
        BLET      &YNEW=&BD789C
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1,&XOLD,&YOLD,AC1,&YNEW
TIME *.****
PLOT MYPLOT  **.**  **.**   **.** **.** COLOR F16
        BLET      &XOLD=AC1
        BLET      &YOLD=&YNEW
        ADVANCE   0
 PATHP46  ADVANCE   0
 TRAVEL   MACRO      &TT,46,46,46
 TRAVEL   MACRO      &UU,47,47,47
 TRAVEL   MACRO      &VV,48,48,48
 TRAVEL   MACRO      &AAA,49,49,49
 TRAVEL   MACRO      &BBB,50,50,50
        SEIZE       INTERB    CHECK TO SEE IF WAY CLEAR
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M7 STOP!
           RELEASE   INTERB
              ADVANCE   .4,.08
```

```
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M7
TRAVEL   MACRO      &DDD,51,51,51
        TRANSFER  ,PATHP41
**********************************************
*   SEGMENT FOR SHOVEL5                    *
**********************************************
        GENERATE    3,,3,&TRUCK5,,12PH,12PL   TRUCKS AT SHOVEL5
        ASSIGN      1,2,PH
        TRANSFER    SBR,ANIM,3PH
        GATE LR     STOPSH5
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
 TIME *.****
 CREATE E789C T*
 PLACE T* AT -43.73 -21.82
        SEIZE       SHOVEL5         USE THE SHOVEL
        ADVANCE     RVNORM(1,3,.5)      LOAD A TRUCK 789C
        RELEASE     SHOVEL5         FREE THE SHOVEL
        ASSIGN      1,RVNORM(1,195,4.5),PL   AMOUNT LOAD BY HITACH 5500-3
        BLET        &ACC789C=&ACC789C+1
        BLET        &BDD789C=&BDD789C+PL1
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC
FILE=ATF,LINES=5,AC1,XID1,&ACC789C,&BDD789C,FR(SHOVEL5)/10.
TIME *.****
SET T* CLASS F789C
WRITE MESS18 ***
WRITE MESS19 *****.**
WRITE MESS20   **.**%
        BLET      &YNEW=&BDD789C
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1,&XOLD,&YOLD,AC1,&YNEW
TIME *.****
PLOT MYPLOT  **.**  **.**   **.** **.** COLOR F7
        BLET      &XOLD=AC1
        BLET      &YOLD=&YNEW
        ADVANCE   0
PATHP58   ADVANCE   0
TRAVEL    MACRO     &KKK,58,58,58
TRAVEL    MACRO     &LLL,59,59,59
TRAVEL    MACRO     &MMM,60,60,60
        SEIZE     INTERE     CHECK TO SEE IF WAY CLEAR
        TRANSFER    SBR,ANIM,3PH
```

```
         BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M8 STOP!
            RELEASE   INTERE
               ADVANCE   .4,.08
         TRANSFER    SBR,ANIM,3PH
         BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M8
TRAVEL    MACRO      &NNN,61,61,61
PATHP62   ADVANCE   0
TRAVEL    MACRO     &OOO,62,62,62
TRAVEL    MACRO     &PPP,63,63,63
TRAVEL    MACRO     &QQQ,64,64,64
         SEIZE     INTERC     CHECK TO SEE IF WAY CLEAR
         TRANSFER    SBR,ANIM,3PH
         BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M9 STOP!
            RELEASE   INTERC
         ADVANCE   .4,.08
         TRANSFER    SBR,ANIM,3PH
         BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M9
TRAVEL    MACRO     &RRR,65,65,65
         TRANSFER    ,PATHP44
************************************************
*         SEGMENT FOR SHOVEL6                  *
************************************************
         GENERATE    3,,4,&TRUCK6,,12PH,12PL   TRUCKS AT SHOVEL6
         ASSIGN      1,2,PH
         GATE LR     STOPSH6
         BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
 TIME *.****
 CREATE E789C T*
 PLACE T* AT -42.71 -32.23
         SEIZE      SHOVEL6         USE THE SHOVEL
         ADVANCE     RVNORM(1,3,.5)     LOAD A TRUCK 789C
         RELEASE     SHOVEL6         FREE THE SHOVEL
         ASSIGN      1,RVNORM(1,195,4.5),PL   AMOUNT LOAD BY HITACH 5500-4
         BLET       &ACD789C=&ACD789C+1
         BLET       &BCD789C=&BCD789C+PL1
         TRANSFER    SBR,ANIM,3PH
```

```
        BPUTPIC
FILE=ATF,LINES=5,AC1,XID1,&ACD789C,&BCD789C,FR(SHOVEL6)/10.
TIME *.****
SET T* CLASS F789C
WRITE MESS21 ***
WRITE MESS22 *****.**
WRITE MESS23   **.**%
        BLET      &YNEW=&BCD789C
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1,&XOLD,&YOLD,AC1,&YNEW
TIME *.****
PLOT MYPLOT  **.**  **.**   **.** **.** COLOR F31
        BLET      &XOLD=AC1
        BLET      &YOLD=&YNEW
        ADVANCE   0
PATHP66   ADVANCE   0
 TRAVEL   MACRO     &SSS,66,66,66
 TRAVEL        MACRO     &TTT,67,67,67
 TRAVEL   MACRO     &UUU,68,68,68
 TRAVEL   MACRO     &VVV,69,69,69
        SEIZE     INTERE     CHECK TO SEE IF WAY CLEAR
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M12 STOP!
           RELEASE   INTERE
              ADVANCE   .4,.08
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
WRITE M12
 TRAVEL        MACRO     &WWW,70,70,70
        TRANSFER  ,PATHP62

**********************************************
*   SEGMENT FOR SHOVEL 1 LOADING              *
**********************************************
        GENERATE    ,,,1,10     DUMMY TRANSACTION
 WAIT1    TEST E      F(SHOVEL1),1
        TRANSFER    SBR,ANIM,3PH
 WAIT2    BPUTPIC     FILE=ATF,LINES=2,AC1
 TIME *.****
 ROTATE BB1 +45 STEP 5 TIME .35
        GATE LR     STOPSH1
        ADVANCE     .35
```

```
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1
 TIME *.****
 ROTATE BB1 -45 STEP 5 TIME .35
        ADVANCE     .35
        TEST E      F(SHOVEL1),1,WAIT1
        TRANSFER    ,WAIT2

**********************************************
*   SEGMENT FOR SHOVEL 2 LOADING             *
**********************************************
        GENERATE    ,,,1,10     DUMMY TRANSACTION
WAIT3   TEST E      F(SHOVEL2),1
        TRANSFER    SBR,ANIM,3PH
WAIT4   BPUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
ROTATE BB2 -45 STEP 5 TIME .35
        GATE LR     STOPSH2
        ADVANCE     .35
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
ROTATE BB2 +45 STEP 5 TIME .35
        ADVANCE     .35
        TEST E      F(SHOVEL2),1,WAIT3
        TRANSFER    ,WAIT4

**********************************************
*   SEGMENT FOR SHOVEL 3 LOADING             *
**********************************************
        GENERATE    ,,,1,10     DUMMY TRANSACTION
WAIT5   TEST E      F(SHOVEL3),1
        TRANSFER    SBR,ANIM,3PH
WAIT6   BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
ROTATE BUCKET3 45 STEP 4 TIME .4
        GATE LR     STOPSH3
        ADVANCE     .4
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
ROTATE BUCKET3 -45 STEP 4 TIME .4
        ADVANCE     .4
        TEST E      F(SHOVEL3),1,WAIT5
        TRANSFER    ,WAIT6
```

```
**********************************************
*   SEGMENT FOR SHOVEL 4 LOADING             *
**********************************************
        GENERATE    ,,,1,10     DUMMY TRANSACTION
WAIT7     TEST E      F(SHOVEL4),1
        TRANSFER    SBR,ANIM,3PH
WAIT8     BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
ROTATE BUCKET4 45 STEP 4 TIME .4
        GATE LR     STOPSH4
        ADVANCE     .4
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
ROTATE BUCKET4 -45 STEP 4 TIME .4
        ADVANCE     .4
        TEST E      F(SHOVEL4),1,WAIT7
        TRANSFER    ,WAIT8

**********************************************
*   SEGMENT FOR SHOVEL 5 LOADING             *
**********************************************
        GENERATE    ,,,1,10     DUMMY TRANSACTION
WAIT9     TEST E      F(SHOVEL5),1
        TRANSFER    SBR,ANIM,3PH
WAIT10    BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
ROTATE BUCKET5 -45 STEP 4 TIME .4
        GATE LR     STOPSH5
        ADVANCE     .4
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
ROTATE BUCKET5 +45 STEP 4 TIME .4
        ADVANCE     .4
        TEST E      F(SHOVEL5),1,WAIT9
        TRANSFER    ,WAIT10

**********************************************
*   SEGMENT FOR SHOVEL 6 LOADING             *
**********************************************
        GENERATE    ,,,1,10     DUMMY TRANSACTION
WAIT11    TEST E      F(SHOVEL6),1
        TRANSFER    SBR,ANIM,3PH
```

```
WAIT12    BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
ROTATE BUCKET6 -45 STEP 4 TIME .4
        GATE LR     STOPSH6
        ADVANCE     .4
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC   FILE=ATF,LINES=2,AC1
TIME *.****
ROTATE BUCKET6 45 STEP 4 TIME .4
        ADVANCE     .4
        TEST E      F(SHOVEL6),1,WAIT11
        TRANSFER    ,WAIT12

*******************************************
*           CLOCK SEGMENT                 *
*******************************************
        INTEGER     &TIME,&DAYNO,&WKDAYNO,&WEEKNO,&HOUR
        GENERATE    ,,,1,150,12PL,12PH   DUMMY TRANSACTION FOR CLOCK
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1
TIME *.****
ROTATE MHAND1 SPEED -6 STEP 6
ROTATE HHAND1 SPEED -.5 STEP 6
        BLET       &HOUR=0
        BLET       &WKDAYNO=1
        BLET       &WEEKNO=1
NEXTMIN   ADVANCE     1      ADVANCE THE CLOCK ONE MINUTE
        BLET       &TIME=&TIME+1
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC
FILE=ATF,LINES=5,AC1,&TIME,&HOUR,&WKDAYNO,&WEEKNO
TIME *.****
WRITE MT1 **
WRITE MT2 **
WRITE MT3 **
WRITE MT4 **
        TEST E      &TIME@60,0,NEXTMIN
        BLET       &TIME=0
        BLET       &HOUR=&HOUR+1
        TEST E      &HOUR,24,NEXTMIN   24 HOURS PAST?
        BLET       &TIME=0
        BLET       &HOUR=0
        BLET       &DAYNO=&DAYNO+1
        BLET       &WKDAYNO=&WKDAYNO+1
        TEST E      &WKDAYNO,8,NEXTMIN  NEW WEEK?
```

```
        BLET      &WKDAYNO=1
        BLET      &WEEKNO=&WEEKNO+1
        TRANSFER   ,NEXTMIN
*****************************************************
*           SHIFT ANIMATION PART              *
*****************************************************
        INTEGER    &SHIFT
        LET        &SHIFT=1
        GENERATE   20,,0,,150
        TEST E     AC1@600,0,AWAY
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=2,AC1,&SHIFT
TIME *.****
WRITE MSH **
        BLET      &SHIFT=&SHIFT+1
AWAY     TERMINATE

**************************************************************
*  DOWN TIMES AND RAPAIR TIMES FOR SHOVELS COMES NEXT      *
**************************************************************
        GENERATE   ,,,1
UPSTOP1   ADVANCE    RVEXPO(1,200)
        LOGIC S    STOPSH1
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=2,AC1
TIME *.****
WRITE MDS1 SHOVEL 1 IS DOWN!!
        ADVANCE    RVNORM(1,30,5)
        LOGIC R    STOPSH1
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=2,AC1
TIME *.****
WRITE MDS1
        TRANSFER   ,UPSTOP1
*********************************************
        GENERATE   ,,,1
UPSTOP2   ADVANCE    RVEXPO(1,300)
        LOGIC S    STOPSH2
        TRANSFER   SBR,ANIM,3PH
        BPUTPIC    FILE=ATF,LINES=2,AC1
TIME *.****
WRITE MDS2 SHOVEL 2 IS DOWN!!
        ADVANCE    RVNORM(1,30,5)
        LOGIC R    STOPSH2
        TRANSFER   SBR,ANIM,3PH
```

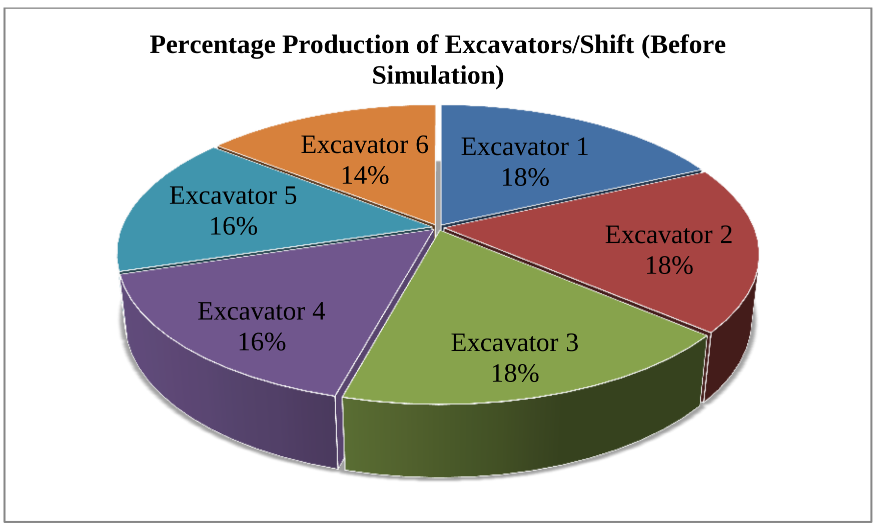
```
        BPUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
WRITE MDS2
        TRANSFER    ,UPSTOP2
*******************************************
        GENERATE    ,,,1
UPSTOP3   ADVANCE     RVEXPO(1,450)
        LOGIC S     STOPSH3
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
WRITE MDS3 SHOVEL 3 IS DOWN!!
        ADVANCE     RVNORM(1,60,5)
        LOGIC R     STOPSH3
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
WRITE MDS3
        TRANSFER    ,UPSTOP3
*******************************************
        GENERATE    ,,,1
UPSTOP4   ADVANCE     RVEXPO(1,550)
        LOGIC S     STOPSH4
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
WRITE MDS4 SHOVEL 4 IS DOWN!!
        ADVANCE     RVNORM(1,60,5)
        LOGIC R     STOPSH4
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
WRITE MDS4
        TRANSFER    ,UPSTOP4
*******************************************
        GENERATE    ,,,1
UPSTOP5   ADVANCE     RVEXPO(1,350)
        LOGIC S     STOPSH5
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
WRITE MDS5 SHOVEL 5 IS DOWN!!
        ADVANCE     RVNORM(1,60,15)
        LOGIC R     STOPSH5
        TRANSFER    SBR,ANIM,3PH
```

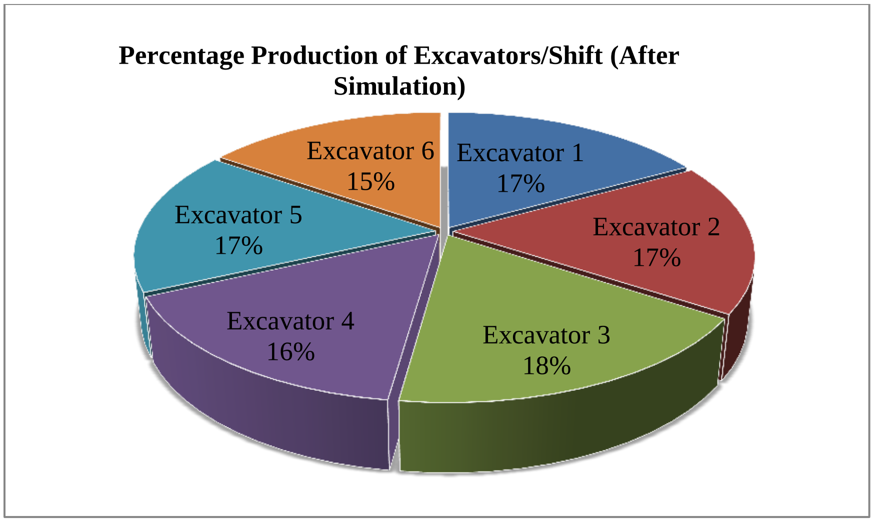
```
        BPUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
WRITE MDS5
        TRANSFER    ,UPSTOP5
*******************************************
        GENERATE    ,,,1
UPSTOP6   ADVANCE     RVEXPO(1,2000)
        LOGIC S     STOPSH6
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
WRITE MDS6 SHOVEL 6 IS DOWN!!
        ADVANCE     RVNORM(1,60,15)
        LOGIC R     STOPSH6
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
WRITE MDS6
        TRANSFER    ,UPSTOP6
*********************************************
*           BLAST ANIMATION PART            *
*********************************************
        GENERATE    ,,,1
WAITED    ADVANCE     360
        LOGIC S     BLAST
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=4,AC1,XID1,XID1,XID1
TIME *.****
CREAT BLAST P*
PLACE P* ON PB1
SET P* TRAVEL 90
        ADVANCE     60
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1
TIME *.****
WRITE MBLAST BLASTING!
WRITE MBLAST1 BLASTING!
        ADVANCE     30
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1
TIME *.****
WRITE MBLAST
WRITE MBLAST1
        LOGIC R     BLAST
        TRANSFER    SBR,ANIM,3PH
```

```
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
DESTROY P*
        TRANSFER    ,WAITED

**************************************************
*  TIMER TRANSACTION COMES NEXT                  *
**************************************************
        GENERATE    ,,,1
        ADVANCE     43200
        TERMINATE   1
        START       1

**************************************************
*           SIMULATION DISPLAY                   *
**************************************************
        PUTPIC
LINES=8,FC(SHOVEL1),FR(SHOVEL1)/10,QM(SHOVEL1),FC(SHOVEL2),FR(SHO
VEL2)/10,QM(SHOVEL2)
NUMBER OF LOADS BY SHOVEL 1:    ***
UTILIZATION OF SHOVEL 1:    **.**%
MAXIMUM NUMBER OF QUEUE AT SHOVEL 1:  **

NUMBER OF LOADS BY SHOVEL 2:    ***
UTILIZATION OF SHOVEL 2:    **.**%
MAXIMUM NUMBER OF QUEUE AT SHOVEL 2:  **

        PUTPIC
LINES=8,FC(SHOVEL3),FR(SHOVEL3)/10,QM(SHOVEL3),FC(SHOVEL4),FR(SHO
VEL4)/10,QM(SHOVEL4)
NUMBER OF LOADS BY SHOVEL 3:    ***
UTILIZATION OF SHOVEL 3:    **.**%
MAXIMUM NUMBER OF QUEUE AT SHOVEL 3:  **

NUMBER OF LOADS BY SHOVEL 4:    ***
UTILIZATION OF SHOVEL 4:    **.**%
MAXIMUM NUMBER OF QUEUE AT SHOVEL 4:  **

        PUTPIC
LINES=8,FC(SHOVEL5),FR(SHOVEL5)/10,QM(SHOVEL5),FC(SHOVEL6),FR(SHO
VEL6)/10,QM(SHOVEL6)
NUMBER OF LOADS BY SHOVEL 5:    ***
UTILIZATION OF SHOVEL 5:    **.**%
MAXIMUM NUMBER OF QUEUE AT SHOVEL 5:  **
```

```
NUMBER OF LOADS BY SHOVEL 6:    ***
UTILIZATION OF SHOVEL 6:    **.**%
MAXIMUM NUMBER OF QUEUE AT SHOVEL 6:  **

        PUTPIC      LINES=6,&TOTWST,&LOAD789C,&TOTWST2,&DUMP789C
TOTAL TONNAGE IN WASTE AREA #1:   *****
TOTAL LOADS IN WASTE AREA #1:    ***
TOTAL TONNAGE IN WASTE AREA #2:   *****
TOTAL LOADS IN WASTE AREA #2:    ***

***************************************************
        IF        &YES'E"Y'
        PUTPIC      FILE=ATF,LINES=2,AC1
TIME *.****
END
        ENDIF
        END

***************************************************
***************************************************
```

Additional Data Analysis of the Coal Mine Simulation and Animation Results:





- Pit 1 simulation and animation results:

#	SIMULATION									ANIMATION						COST		
of	Utilization		Loads				Queue Max			Utilization (Blast)			Tonnage (Shift)					
Trucks	Sh.1	Sh.2	Sh.1	Sh.2	Tot.Lds	Tot.Tng	Sh.1	Sh.2	Total	Shov.1	Shov.2	Avg.	Shov.1	Shov.2	Total	Oper/Hr	TotOp/Hr	TotOp/Shift
13	71.87	72.72	124	126	250	47387	1	2	3	83.93	84.97	84.45	24243	24376	48619	$800.00	$10,400.00	$104,000.00
14	75.7	78.23	132	137	269	50877	2	2	4	88.31	92	90.16	25570	26536	52106	$800.00	$11,200.00	$112,000.00
15	80.82	83.06	139	143	282	53127	2	2	4	93.72	97.18	95.45	26877	27747	54624	$800.00	$12,000.00	$120,000.00
16	83.65	84.65	143	146	289	54378	3	2	5	97.38	98.54	97.96	27681	28309	55991	$800.00	$12,800.00	$128,000.00
17	84.77	85.4	144	148	292	54907	3	3	6	98.67	99.04	98.86	27906	28560	56466	$800.00	$13,600.00	$136,000.00
18	85.24	86.17	147	148	295	55205	3	3	6	98.68	99.21	98.95	28517	28697	57213	$800.00	$14,400.00	$144,000.00
19	85.51	85.88	148	148	296	55577	3	4	7	98.68	99.21	98.95	28669	28616	57285	$800.00	$15,200.00	$152,000.00
20	86.23	85.76	147	148	295	55744	4	4	8	98.7	99.21	98.96	28504	28690	57194	$800.00	$16,000.00	$160,000.00

- Pit 2 simulation and animation results:

#	SIMULATION														COST		
of	Utilization				Loads					Queue Max							
trucks	Sh.3	Sh.4	Sh.5	Sh.6	Sh.3	Sh.4	Sh.5	Sh.6	Total	Sh.3	Sh.4	Sh.5	Sh.6	Total	Oper/Hr	TotOp/Hr	TotOp/Shift
40	70.94	63.44	63.97	58.94	146	130	126	117	519	5	4	4	4	17	$800.00	$32,000.00	$320,000.00
41	73.76	66.52	66.69	61.6	149	136	133	123	541	4	4	4	4	16	$800.00	$32,800.00	$328,000.00
42	74.55	66.65	67.8	60.4	150	135	137	125	547	4	4	4	4	16	$800.00	$33,600.00	$336,000.00
43	73.64	67.71	69	62.87	150	136	141	125	552	4	4	4	4	16	$800.00	$34,400.00	$344,000.00
44	76.41	68.35	70.45	63.94	152	134	140	130	556	4	5	4	4	17	$800.00	$35,200.00	$352,000.00
45	76.76	70.07	71.89	64.85	156	139	143	130	568	4	4	5	4	17	$800.00	$36,000.00	$360,000.00
46	78.25	69.47	71.73	66.61	155	142	144	133	574	4	4	4	4	16	$800.00	$36,800.00	$368,000.00
47	77.55	71.91	72.36	66.56	156	144	144	135	579	4	4	4	4	16	$800.00	$37,600.00	$376,000.00
48	81.22	75.1	77.29	69.81	163	147	157	137	604	4	4	4	3	15	$800.00	$38,400.00	$384,000.00

#	ANIMATION														
of	Utilization (Blast)					Loads (Shift)					Tonnage, tonnes (Shift)				
trucks	Sh.3	Sh.4	Sh.5	Sh.6	avg	Sh.3	Sh.4	Sh.5	Sh.6	Total	Sh.3	Sh.4	Sh.5	Sh.6	Total
40	83.01	73.25	74.39	69.7	75.09	146	130	126	117	519	28220	25202	24390	22598	100410.73
41	85.42	75.97	76.99	70.95	77.33	149	136	133	123	541	28812	26272	25724	23796	104605.00
42	85.93	76.93	77.93	70.61	77.85	150	135	137	125	547	28918	26110	26457	24184	105668.21
43	84.45	77.07	78.52	71.51	77.89	149	136	140	125	550	28969	26537	27247	24453	107206.01
44	86.24	77.79	80.54	73.5	79.52	151	133	139	129	552	29353	26015	27070	25036	107474.32
45	87.58	79.82	81.56	74.38	80.84	155	138	142	129	564	30202	26894	27691	25156	109943.74
46	87.82	78.38	80.86	74.93	80.5	155	141	144	132	572	30270	27192	27700	25546	110708.91
47	88.9	80.19	83.89	78.16	82.79	156	137	141	135	569	30560	26717	27595	26411	111282.93
48	91.46	84.53	87.68	77.91	85.4	162	146	156	136	600	31615	28546	30395	26550	117106.53

Appendix E: Simulation and animation code of the underground mine rescue operation using GPSS/H® and PROOF Animation®.

- First mine rescue/evacuation simulation and animation model:

```
*************************************************************
*        MINE RESCUE SIMULATION AND ANIMATION MODEL         *
*        PROGRAMMED IN GPSS/H                               *
*              BY                                           *
*        EBRAHIM K. TARSHIZI                                *
*************************************************************
         SIMULATE
         RMULT     12345
         REALLOCATE  COM,1000000
ATF      FILEDEF    'RESCUE2.ATF'
MYOUT    FILEDEF    'RESCUE-RESULTS.XLS'
         INSERT     FUNCRES5.DAT
         REAL       &A,&B,&C,&D,&F,&G,&H,&I,&J,&K,&L,&M,&N,&O
         REAL       &P,&Q,&R,&S,&T,&U,&V,&W,&X,&Y,&Z,&AA,&BB
         REAL       &TT,&UU,&VV,&WW,&XX,&AB,&ZZ,&CC,&DD,&EE,&FF
         REAL       &GG,&HH,&T1,&T2,&ETIME
         INTEGER    &ML1,&ML2,&ML3Z3,&ML3Z8,&ML4,&ML5Z5,&ML5Z6
         INTEGER    &TOTMIN,&IA,&RESMI,&LEFTMI

***********************************
*          INPUTS
***********************************
        DO    &IA=1,80
        PUTSTRING   ('  ')
        ENDDO
        PUTSTRING   ('  ')
        PUTSTRING   ('              *** MINE SYSTEM RESCUE SIMULATIOM
(MSRS) MODEL ***')
AGAIN   PUTSTRING   ('  ')
        PUTSTRING   ('  ')
        PUTSTRING   ('  INPUT THE NUMBER OF MINERS IN LEVEL 1?')
        GETLIST     &ML1
        PUTPIC      FILE=ATF,LINES=2,AC1,&ML1
TIME *.****
WRITE ML1 **
        PUTSTRING   ('  ')
        PUTSTRING   ('  ')
        PUTSTRING   ('  INPUT THE NUMBER OF MINERS IN LEVEL 2?')
        GETLIST     &ML2
```

```
        PUTPIC      FILE=ATF,LINES=2,AC1,&ML2
TIME *.****
WRITE ML2 **
        PUTSTRING   ('  ')
        PUTSTRING   ('  ')
        PUTSTRING   ('  ---INPUT THE NUMBER OF MINERS IN LEVEL 3 (ZONE
3)?')
        GETLIST     &ML3Z3
        PUTPIC      FILE=ATF,LINES=2,AC1,&ML3Z3
TIME *.****
WRITE ML3Z3 **
        PUTSTRING   ('  ')
        PUTSTRING   ('  ---INPUT THE NUMBER OF MINERS IN LEVEL 3 (ZONE
8)?')
        GETLIST     &ML3Z8
        PUTPIC      FILE=ATF,LINES=2,AC1,&ML3Z8
TIME *.****
WRITE ML3Z8 **
        PUTSTRING   ('  ')
        PUTSTRING   ('  ')
        PUTSTRING   ('  INPUT THE NUMBER OF MINERS IN LEVEL 4?')
        GETLIST     &ML4
        PUTPIC      FILE=ATF,LINES=2,AC1,&ML4
TIME *.****
WRITE ML4 **
        PUTSTRING   ('  ')
        PUTSTRING   ('  ')
        PUTSTRING   ('  ---INPUT THE NUMBER OF MINERS IN LEVEL 5 (ZONE
5)?')
        GETLIST     &ML5Z5
        PUTPIC      FILE=ATF,LINES=2,AC1,&ML5Z5
TIME *.****
WRITE ML5Z5 **
        PUTSTRING   ('  ')
        PUTSTRING   ('  ---INPUT THE NUMBER OF MINERS IN LEVEL 5 (ZONE
6)?')
        GETLIST     &ML5Z6
        PUTPIC      FILE=ATF,LINES=2,AC1,&ML5Z6
TIME *.****
WRITE ML5Z6 **
        PUTSTRING   ('  ')
        PUTSTRING   ('  ')
        PUTSTRING   ('  ESTIMATED RESCUE/EVACUATION TIME IN THE
MINE?')
        GETLIST     &ETIME
```

```
        PUTSTRING    ('  ')
        PUTSTRING    ('  ')
        PUTSTRING    ('  DO YOU WANT ANIMATION? (Y/N)')
        CHAR*1       &YES,&YY
MYBOOL   BVARIABLE    (&YES'E"Y')OR(&YES'E"y')
        GETLIST      &YES
        PUTSTRING    ('  ')
        PUTSTRING    ('  ')
        PUTSTRING    ('  ARE YOU HAPPY WITH THESE VALUES? (Y/N)')
        GETLIST      &YY
        IF           (&YY'NE"Y')AND(&YY'NE"y')
        GOTO   AGAIN
        ENDIF
ANIM     TEST E       BV(MYBOOL),1,PH3+2
        TRANSFER     ,PH3+1
        PUTSTRING    ('  ')
        PUTSTRING    ('  ')
        PUTSTRING    ('    *** RESCUE/EVACUATION SIMULATION RESULTS
HAVE BEEN PUT INTO EXCEL FILE ***')
        PUTSTRING    ('  ')
        PUTSTRING    ('  ')
        LET
&TOTMIN=&ML1+&ML2+&ML3Z3+&ML3Z8+&ML4+&ML5Z5+&ML5Z6
        PUTPIC       FILE=ATF,LINES=2,AC1,&TOTMIN
TIME *.****
WRITE TOTMIN ***
*********************************************************
*         START MACRO DEFINITIONS              *
*********************************************************
 TRAVEL   STARTMACRO
         BLET        #A=FN(#B)
         TRANSFER    SBR,ANIM,3PH
         BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1,#A
 TIME *.****
 PLACE T* ON P#C
 SET T* TRAVEL **.**
 PAT#D  ADVANCE     #A
       ENDMACRO
********************************************************
*          END OF MACRO DEFINITIONS          *
********************************************************
*************************************************************
         GENERATE    ,,,1
         BPUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
```

```
PLAY  ALARM.WAV
        TERMINATE

*******************************************
*     START WITH LEVEL-1 IN THE MINE     *
*******************************************
        GENERATE    .6,,.3,&ML1,,12PH,12PL
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE MINER T*
PLACE T* AT 22.94 17.06
        TRANSFER    ,PATHP33

*******************************************
*     START WITH LEVEL-2 IN THE MINE     *
*******************************************
        GENERATE    .6,,.3,&ML2,,12PH,12PL
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE MINER T*
PLACE T* AT 52.73 -29.86
        TRANSFER    ,PATHP1

*************************************************
*   START WITH LEVEL-3 (ZONE 3) IN THE MINE    *
*************************************************
        GENERATE    .6,,.3,&ML3Z3,,12PH,12PL
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE MINER T*
PLACE T* AT 93.24 -48.61
        TRANSFER    ,PATHP8

*************************************************
*   START WITH LEVEL-3 (ZONE 8) IN THE MINE    *
*************************************************
        GENERATE    .6,,.3,&ML3Z8,,12PH,12PL
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE MINER2 T*
PLACE T* AT -23.43 -41.14
```

```
        TRANSFER    ,PATHP26

*****************************************
*     START WITH LEVEL-4 IN THE MINE     *
*****************************************
        GENERATE    .6,,.3,&ML4,,12PH,12PL
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE MINER2 T*
PLACE T* AT -33.71 -75.89
        TRANSFER    ,PATHP12

***********************************************
*       START WITH LEVEL-5 IN THE MINE        *
***********************************************
***********************************************
*   START WITH LEVEL-5 (ZONE 5) IN THE MINE    *
***********************************************
        GENERATE    .6,,.3,&ML5Z5,,12PH,12PL
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE MINER2 T*
PLACE T* AT -23.40 -96.90
        TRANSFER    ,PATHP19

***********************************************
*   START WITH LEVEL-5 (ZONE 6) IN THE MINE    *
***********************************************
        GENERATE    .6,,.3,&ML5Z6,,12PH,12PL
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE MINER2 T*
PLACE T* AT 28.49 -104.08
        TRANSFER    ,PATHP24

*****************************************
*         LEVEL 1
*****************************************
PATHP33    ADVANCE     0
TRAVEL    MACRO       &EE,33,33,33
TRAVEL    MACRO       &FF,34,34,34
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
```

```
TIME *.****
SET  T* CLASS MINER2
TRAVEL    MACRO      &GG,35,35,35
TRAVEL    MACRO      &HH,36,36,36
          BLET       &RESMI=&RESMI+1
          BLET       &LEFTMI=&TOTMIN-&RESMI
          BPUTPIC    FILE=ATF,LINES=3,AC1,XID1,&LEFTMI
TIME *.****
DESTROY T*
WRITE TB  **
          TEST E     &LEFTMI,0
          BPUTPIC    FILE=ATF,LINES=2,AC1,AC1
TIME *.****
WRITE FTIME  **
          TERMINATE
****************************************
*         LEVEL 2
****************************************
PATHP1    ADVANCE    0
TRAVEL    MACRO      &A,1,1,1
TRAVEL    MACRO      &B,2,2,2
TRAVEL    MACRO      &C,3,3,3
TRAVEL    MACRO      &D,4,4,4
TRAVEL    MACRO      &F,5,5,5
TRAVEL    MACRO      &G,6,6,6
TRAVEL    MACRO      &H,7,7,7
          SEIZE      REFCH3
          TRANSFER   SBR,ANIM,3PH
          BPUTPIC    FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
SET  CH3 CLASS FRC
DESTROY T*
          BLET       &RESMI=&RESMI+1
          BLET       &LEFTMI=&TOTMIN-&RESMI
          BPUTPIC    FILE=ATF,LINES=3,AC1,FC(REFCH3),&LEFTMI
TIME *.****
WRITE  M1 **
WRITE TB  **
          RELEASE    REFCH3
          TEST E     &LEFTMI,0
          BPUTPIC    FILE=ATF,LINES=2,AC1,AC1
TIME *.****
WRITE FTIME  **
         TERMINATE
```

```
*****************************************
*         LEVEL 3
*****************************************
PATHP8    ADVANCE     0
TRAVEL    MACRO       &I,8,8,8
TRAVEL    MACRO       &J,9,9,9
TRAVEL    MACRO       &K,10,10,10
TRAVEL    MACRO       &L,11,11,11
          SEIZE       REFCH1
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
SET  CH1 CLASS FRC
DESTROY T*
          BLET        &RESMI=&RESMI+1
          BLET        &LEFTMI=&TOTMIN-&RESMI
          BPUTPIC     FILE=ATF,LINES=3,AC1,FC(REFCH1),&LEFTMI
TIME *.****
WRITE  M2 **
WRITE TB  **
          RELEASE     REFCH1
          TEST E      &LEFTMI,0
          BPUTPIC     FILE=ATF,LINES=2,AC1,AC1
TIME *.****
WRITE FTIME  **
          TERMINATE

PATHP26   ADVANCE     0
TRAVEL    MACRO       &VV,26,26,26
TRAVEL    MACRO       &WW,27,27,27
TRAVEL    MACRO       &XX,28,28,28
TRAVEL    MACRO       &AB,29,29,29
TRAVEL    MACRO       &ZZ,30,30,30
          SEIZE       REFCH1
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
SET  CH1 CLASS FRC
DESTROY T*
          BLET        &RESMI=&RESMI+1
          BLET        &LEFTMI=&TOTMIN-&RESMI
          BPUTPIC     FILE=ATF,LINES=3,AC1,FC(REFCH1),&LEFTMI
TIME *.****
WRITE  M2 **
WRITE TB  **
```

```
        RELEASE     REFCH1
        TEST E      &LEFTMI,0
        BPUTPIC     FILE=ATF,LINES=2,AC1,AC1
TIME *.****
WRITE FTIME  **
        TERMINATE
*****************************************
*       LEVEL 4
*****************************************
PATHP12   ADVANCE    0
TRAVEL    MACRO      &M,12,12,12
TRAVEL    MACRO      &N,13,13,13
TRAVEL    MACRO      &O,14,14,14
TRAVEL    MACRO      &P,15,15,15
TRAVEL    MACRO      &Q,16,16,16
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET  T* CLASS MINER
TRAVEL    MACRO      &R,17,17,17
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET  T* CLASS MINER2
TRAVEL    MACRO      &S,18,18,18
        SEIZE       REFCH3
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
SET  CH3 CLASS FRC
DESTROY T*
        BLET        &RESMI=&RESMI+1
        BLET        &LEFTMI=&TOTMIN-&RESMI
        BPUTPIC     FILE=ATF,LINES=3,AC1,FC(REFCH3),&LEFTMI
TIME *.****
WRITE  M1 **
WRITE TB  **
        RELEASE     REFCH3
        TEST E      &LEFTMI,0
        BPUTPIC     FILE=ATF,LINES=2,AC1,AC1
TIME *.****
WRITE FTIME  **
        TERMINATE

*****************************************
*         LEVEL 5
*****************************************
```

```
PATHP19   ADVANCE     0
TRAVEL    MACRO       &T,19,19,19
          BPUTPIC     FILE=ATF,LINES=3,AC1,XID1
TIME *.****
SET  AGE CLASS BLOCKAGE
WRITE BLOCK Blockage
TRAVEL    MACRO       &CC,31,31,31
          BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET  T* CLASS MINER
TRAVEL    MACRO       &DD,32,32,32
          SEIZE       REFCH2
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
SET  CH2 CLASS FRC
DESTROY T*
          BLET        &RESMI=&RESMI+1
          BLET        &LEFTMI=&TOTMIN-&RESMI
          BPUTPIC     FILE=ATF,LINES=3,AC1,FC(REFCH2),&LEFTMI
TIME *.****
WRITE  M3  **
WRITE TB  **
          RELEASE     REFCH2
          TEST E      &LEFTMI,0
          BPUTPIC     FILE=ATF,LINES=2,AC1,AC1
TIME *.****
WRITE FTIME  **
          TERMINATE
PATHP24   ADVANCE     0
TRAVEL    MACRO       &TT,24,24,24
TRAVEL    MACRO       &UU,25,25,25
          SEIZE       REFCH4
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
SET  CH4 CLASS FRC
DESTROY T*
          BLET        &RESMI=&RESMI+1
          BLET        &LEFTMI=&TOTMIN-&RESMI
          BPUTPIC     FILE=ATF,LINES=3,AC1,FC(REFCH4),&LEFTMI
TIME *.****
WRITE  M4 **
WRITE TB  **
          RELEASE     REFCH4
```

```
        TEST E     &LEFTMI,0
        BPUTPIC    FILE=ATF,LINES=2,AC1,AC1
TIME *.****
WRITE FTIME  **
        TERMINATE

*****************************************
*        INTAKE AIR FLOW
*****************************************
        GENERATE    .7,,,500
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE BLUEAF T*
PLACE T* AT -53.11 -39.99
TRAVEL    MACRO      &Y,50,50,50
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
DESTROY T*
        TERMINATE

        GENERATE    .7,,,500
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE BLUEAF T*
PLACE T* AT -23.42 15.69
TRAVEL    MACRO      &Z,52,52,52
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
DESTROY T*
        TERMINATE

        GENERATE    .7,,,500
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE BLUEAF T*
PLACE T* AT 50.14 8.96
TRAVEL    MACRO      &AA,53,53,53
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
DESTROY T*
        TERMINATE
```

```
        GENERATE    .7,,,500
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE REDAF T*
PLACE T* AT 26.52 15.61
TRAVEL    MACRO       &BB,54,54,54
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
DESTROY T*
        TERMINATE
********************************************
*         MAIN FANS ANIMATION              *
********************************************
        GENERATE    ,,,1      DUMMY TRANSACTION
WAIT      BPUTPIC     FILE=ATF,LINES=3,AC1
TIME *.****
ROTATE CIR 800 SPEED  700
ROTATE CIR2 -800 SPEED  700
        ADVANCE     .5
        TRANSFER    ,WAIT
********************************************
*           CLOCK SEGMENT                  *
********************************************
        INTEGER     &TIME,&HOUR
        GENERATE    ,,,1,150,12PL,12PH   DUMMY TRANSACTION FOR CLOCK
        TRANSFER    SBR,ANIM,3PH
        BLET        &HOUR=0
NEXTMIN   ADVANCE     1      ADVANCE THE CLOCK ONE MINUTE
        BLET        &TIME=&TIME+1
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1,&TIME,&HOUR
TIME *.****
WRITE MT1 **
WRITE MT2 **
        TEST E      &TIME@60,0,NEXTMIN
        BLET        &TIME=0
        BLET        &HOUR=&HOUR+1
        TEST E      &HOUR,100,NEXTMIN
        BLET        &TIME=0
        BLET        &HOUR=0
        TRANSFER    ,NEXTMIN
```

```
*************************************************
*                TIMER TRANSACTION                *
*************************************************
        GENERATE    ,,,1
        ADVANCE     &ETIME
        TERMINATE   1
        START       1
        LET         &LEFTMI=&TOTMIN-&RESMI
*************************************************
        PUTPIC      LINES=8,&TOTMIN,&LEFTMI,&RESMI,&ETIME
=== RESCUE/EVACUATION SIMULATION RESULTS ===

TOTAL MINERS IN THE MINE: ***
TOTAL MINERS LEFT IN DISASTERS: ***
TOTAL RESCUED MINERS IN THE OPERATION: ***
ESTIMATED RESCUE TIME IN THE MINE:  **.**

"MINE SYSTEMS OPTIMIZATION & SIMULATION LABORATORY"

        PUTPIC      LINES=6,FILE=MYOUT,&TOTMIN,&LEFTMI,&RESMI,&ETIME
=== RESCUE/EVACUATION SIMULATION RESULTS ===

TOTAL MINERS IN THE MINE: ***
TOTAL MINERS LEFT IN DISASTERS: ***
TOTAL RESCUED MINERS IN THE OPERATION: ***
ESTIMATED RESCUE TIME IN THE MINE:  **.**
*TOTAL TIME REQUIRED TO RESCUE MINERS:  **.**
*************************************************
        IF          (&YES'E"Y')OR(&YES'E"y')
        PUTPIC      FILE=ATF,LINES=2,AC1
TIME *.****
END
        ENDIF
        END
*************************************************
*************************************************
```

- Second mine rescue/evacuation simulation and animation source code, including second mine refuge chambers configuration/location:

```
************************************************************
*     MINE RESCUE 2 SIMULATION AND ANIMATION MODEL         *
*     PROGRAMMED IN GPSS/H                                 *
*          BY                                              *
*     EBRAHIM K. TARSHIZI                                  *
```

```
****************************************************************
        SIMULATE
        RMULT      12345
        REALLOCATE  COM,1000000
ATF      FILEDEF    'RESCUE2.ATF'
MYOUT    FILEDEF    'RESCUE-RESULTS(2).XLS'
        INSERT     FUNCRES6.DAT
        REAL       &A,&B,&C,&D,&F,&G,&H,&I,&J,&K,&L,&M,&N,&O
        REAL       &P,&Q,&R,&S,&T,&U,&V,&W,&X,&Y,&Z,&AA,&BB
        REAL       &TT,&UU,&VV,&WW,&XX,&AB,&ZZ,&CC,&DD,&EE,&FF
        REAL       &GG,&HH,&II,&JJ,&KK,&LL,&MM,&NN,&OO,&PP,&QQ
        REAL       &RR,&SS,&AAA
        REAL       &T1,&T2,&ETIME
        INTEGER    &ML1,&ML2,&ML3Z3,&ML3Z8,&ML4,&ML5Z5,&ML5Z6
        INTEGER    &TOTMIN,&IA,&RESMI,&LEFTMI

************************************
*          INPUTS
************************************
       DO    &IA=1,80
       PUTSTRING    ('  ')
       ENDDO
       PUTSTRING    ('  ')
       PUTSTRING    ('              *** MINE SYSTEM RESCUE SIMULATIOM
(MSRS) MODEL ***')
AGAIN    PUTSTRING    ('  ')
       PUTSTRING    ('  ')
       PUTSTRING    ('  INPUT THE NUMBER OF MINERS IN LEVEL 1?')
       GETLIST     &ML1
       PUTPIC      FILE=ATF,LINES=2,AC1,&ML1
TIME *.****
WRITE ML1 **
       PUTSTRING    ('  ')
       PUTSTRING    ('  ')
       PUTSTRING    ('  INPUT THE NUMBER OF MINERS IN LEVEL 2?')
       GETLIST     &ML2
       PUTPIC      FILE=ATF,LINES=2,AC1,&ML2
TIME *.****
WRITE ML2 **
       PUTSTRING    ('  ')
       PUTSTRING    ('  ')
       PUTSTRING    ('  ---INPUT THE NUMBER OF MINERS IN LEVEL 3 (ZONE
3)?')
       GETLIST     &ML3Z3
       PUTPIC      FILE=ATF,LINES=2,AC1,&ML3Z3
```

```
TIME *.****
WRITE ML3Z3 **
       PUTSTRING   ('  ')
       PUTSTRING   ('  ---INPUT THE NUMBER OF MINERS IN LEVEL 3 (ZONE
8)?')
       GETLIST     &ML3Z8
       PUTPIC      FILE=ATF,LINES=2,AC1,&ML3Z8
TIME *.****
WRITE ML3Z8 **
       PUTSTRING   ('  ')
       PUTSTRING   ('  ')
       PUTSTRING   ('  INPUT THE NUMBER OF MINERS IN LEVEL 4?')
       GETLIST     &ML4
       PUTPIC      FILE=ATF,LINES=2,AC1,&ML4
TIME *.****
WRITE ML4 **
       PUTSTRING   ('  ')
       PUTSTRING   ('  ')
       PUTSTRING   ('  ---INPUT THE NUMBER OF MINERS IN LEVEL 5 (ZONE
5)?')
       GETLIST     &ML5Z5
       PUTPIC      FILE=ATF,LINES=2,AC1,&ML5Z5
TIME *.****
WRITE ML5Z5 **
       PUTSTRING   ('  ')
       PUTSTRING   ('  ---INPUT THE NUMBER OF MINERS IN LEVEL 5 (ZONE
6)?')
       GETLIST     &ML5Z6
       PUTPIC      FILE=ATF,LINES=2,AC1,&ML5Z6
TIME *.****
WRITE ML5Z6 **
       PUTSTRING   ('  ')
       PUTSTRING   ('  ')
       PUTSTRING   ('  ESTIMATED RESCUE TIME IN THE MINE?')
       GETLIST     &ETIME
       PUTSTRING   ('  ')
       PUTSTRING   ('  ')
       PUTSTRING   ('  DO YOU WANT ANIMATION? (Y/N)')
       CHAR*1      &YES,&YY
MYBOOL   BVARIABLE    (&YES'E"Y')OR(&YES'E"y')
       GETLIST     &YES
       PUTSTRING   ('  ')
       PUTSTRING   ('  ')
       PUTSTRING   ('  ARE YOU HAPPY WITH THESE VALUES? (Y/N)')
       GETLIST     &YY
```

```
        IF        (&YY'NE"Y')AND(&YY'NE"y')
        GOTO   AGAIN
        ENDIF
ANIM    TEST E      BV(MYBOOL),1,PH3+2
        TRANSFER    ,PH3+1
        PUTSTRING   ('  ')
        PUTSTRING   ('  ')
        PUTSTRING   ('      *** RESCUE SIMULATION RESULTS HAVE BEEN PUT
INTO EXCEL FILE ***')
        PUTSTRING   ('  ')
        PUTSTRING   ('  ')
        LET
&TOTMIN=&ML1+&ML2+&ML3Z3+&ML3Z8+&ML4+&ML5Z5+&ML5Z6
        PUTPIC      FILE=ATF,LINES=2,AC1,&TOTMIN
TIME *.****
WRITE TOTMIN ***
*************************************************
*         START MACRO DEFINITIONS              *
*************************************************
 TRAVEL   STARTMACRO
         BLET       #A=FN(#B)
         TRANSFER    SBR,ANIM,3PH
         BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1,#A
 TIME *.****
 PLACE T* ON P#C
 SET T* TRAVEL **.**
 PAT#D  ADVANCE     #A
       ENDMACRO
************************************************
*          END OF MACRO DEFINITIONS           *
************************************************
****************************************************
         GENERATE    ,,,1
         BPUTPIC     FILE=ATF,LINES=2,AC1
TIME *.****
PLAY  ALARM.WAV
         TERMINATE

******************************************
*    START WITH LEVEL-1 IN THE MINE     *
******************************************
         GENERATE    .6,,.3,&ML1,,12PH,12PL
         TRANSFER    SBR,ANIM,3PH
         BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
```

```
CREATE MINER T*
PLACE T* AT 22.94 17.06
        TRANSFER    ,PATHP33
*******************************************
*    START WITH LEVEL-2 IN THE MINE     *
*******************************************
        GENERATE    .6,,.3,&ML2,,12PH,12PL
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE MINER T*
PLACE T* AT 52.73 -29.86
        TRANSFER    ,PATHP1

*************************************************
*   START WITH LEVEL-3 (ZONE 3) IN THE MINE    *
*************************************************
        GENERATE    .6,,.3,&ML3Z3,,12PH,12PL
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE MINER T*
PLACE T* AT 93.24 -48.61
        TRANSFER    ,PATHP8

*************************************************
*   START WITH LEVEL-3 (ZONE 8) IN THE MINE    *
*************************************************
        GENERATE    .6,,.3,&ML3Z8,,12PH,12PL
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE MINER2 T*
PLACE T* AT -23.43 -41.14
        TRANSFER    ,PATHP26

*******************************************
*    START WITH LEVEL-4 IN THE MINE     *
*******************************************
        GENERATE    .6,,.3,&ML4,,12PH,12PL
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE MINER2 T*
PLACE T* AT -33.71 -75.89
```

```
          TRANSFER    ,PATHP12

**********************************************
*         START WITH LEVEL-5 IN THE MINE         *
**********************************************
**********************************************
*   START WITH LEVEL-5 (ZONE 5) IN THE MINE    *
**********************************************
          GENERATE    .6,,.3,&ML5Z5,,12PH,12PL
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE MINER2 T*
PLACE T* AT -23.40 -96.90
          TRANSFER    ,PATHP19

**********************************************
*   START WITH LEVEL-5 (ZONE 6) IN THE MINE    *
**********************************************
          GENERATE    .6,,.3,&ML5Z6,,12PH,12PL
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE MINER2 T*
PLACE T* AT 28.49 -104.08
          TRANSFER    ,PATHP24

****************************************
*          LEVEL 1
****************************************
PATHP33    ADVANCE     0
TRAVEL    MACRO      &EE,33,33,33
TRAVEL    MACRO      &FF,34,34,34
          BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET  T* CLASS MINER2
TRAVEL    MACRO      &GG,35,35,35
TRAVEL    MACRO      &HH,36,36,36
          BLET        &RESMI=&RESMI+1
          BLET        &LEFTMI=&TOTMIN-&RESMI
          BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,&LEFTMI
TIME *.****
DESTROY T*
WRITE TB  **
          TEST E      &LEFTMI,0
```

```
        BPUTPIC     FILE=ATF,LINES=2,AC1,AC1
TIME *.****
WRITE FTIME  **
        TERMINATE
*****************************************
*         LEVEL 2
*****************************************
PATHP1    ADVANCE     0
TRAVEL    MACRO       &A,1,1,1
TRAVEL    MACRO       &B,2,2,2
TRAVEL    MACRO       &C,3,3,3
TRAVEL    MACRO       &D,4,4,4
        TRANSFER    ,LCHP1        LOCATION CHAMBER P1

TRAVEL    MACRO       &F,5,5,5
TRAVEL    MACRO       &G,6,6,6
TRAVEL    MACRO       &H,7,7,7
        SEIZE       REFCH3
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
SET  CH3 CLASS FRC
DESTROY T*
        BLET        &RESMI=&RESMI+1
        BLET        &LEFTMI=&TOTMIN-&RESMI
        BPUTPIC     FILE=ATF,LINES=3,AC1,FC(REFCH3),&LEFTMI
TIME *.****
WRITE  M1 **
WRITE TB  **
        RELEASE     REFCH3
        TEST E      &LEFTMI,0
        BPUTPIC     FILE=ATF,LINES=2,AC1,AC1
TIME *.****
WRITE FTIME  **
       TERMINATE
*****************************************
*         LEVEL 3
*****************************************
PATHP8    ADVANCE     0
TRAVEL    MACRO       &I,8,8,8
TRAVEL    MACRO       &J,9,9,9
TRAVEL    MACRO       &K,10,10,10
        TRANSFER    ,PATHP40
```

```
TRAVEL    MACRO      &L,11,11,11
        SEIZE      REFCH1
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
SET  CH1 CLASS FRC
DESTROY T*
        BLET       &RESMI=&RESMI+1
        BLET       &LEFTMI=&TOTMIN-&RESMI
        BPUTPIC     FILE=ATF,LINES=3,AC1,FC(REFCH1),&LEFTMI
TIME *.****
WRITE  M2 **
WRITE TB  **
        RELEASE     REFCH1
        TEST E      &LEFTMI,0
        BPUTPIC     FILE=ATF,LINES=2,AC1,AC1
TIME *.****
WRITE FTIME  **
        TERMINATE

PATHP26   ADVANCE     0
TRAVEL    MACRO      &VV,26,26,26
TRAVEL    MACRO      &WW,27,27,27
        TRANSFER    ,PATHP44

***********************************
TRAVEL    MACRO      &XX,28,28,28
TRAVEL    MACRO      &AB,29,29,29
TRAVEL    MACRO      &ZZ,30,30,30
        SEIZE      REFCH1
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
SET  CH1 CLASS FRC
DESTROY T*
        BLET       &RESMI=&RESMI+1
        BLET       &LEFTMI=&TOTMIN-&RESMI
        BPUTPIC     FILE=ATF,LINES=3,AC1,FC(REFCH1),&LEFTMI
TIME *.****
WRITE  M2 **
WRITE TB  **
        RELEASE     REFCH1
        TEST E      &LEFTMI,0
        BPUTPIC     FILE=ATF,LINES=2,AC1,AC1
TIME *.****
```

```
WRITE FTIME  **
        TERMINATE

*****************
*     CHP1
*****************
PATHP40   ADVANCE     0
TRAVEL    MACRO       &II,40,40,40
TRAVEL    MACRO       &JJ,41,41,41
TRAVEL    MACRO       &KK,42,42,42
TRAVEL    MACRO       &LL,43,43,43
PATHP44   ADVANCE     0
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET  T* CLASS MINER2
TRAVEL    MACRO       &MM,44,44,44
LCHP1     ADVANCE     0
        SEIZE       CCHP1
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
SET  CHP1 CLASS FRC1
DESTROY T*
        BLET        &RESMI=&RESMI+1
        BLET        &LEFTMI=&TOTMIN-&RESMI
        BPUTPIC     FILE=ATF,LINES=3,AC1,FC(CCHP1),&LEFTMI
TIME *.****
WRITE  MP1 **
WRITE TB  **
        RELEASE     CCHP1
        TEST E      &LEFTMI,0
        BPUTPIC     FILE=ATF,LINES=2,AC1,AC1
TIME *.****
WRITE FTIME  **
        TERMINATE

*****************************************
*       LEVEL 4
*****************************************
PATHP12   ADVANCE     0
TRAVEL    MACRO       &M,12,12,12
TRAVEL    MACRO       &N,13,13,13
TRAVEL    MACRO       &O,14,14,14
TRAVEL    MACRO       &P,15,15,15
TRAVEL    MACRO       &Q,16,16,16
```

```
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET  T* CLASS MINER
TRAVEL    MACRO       &R,17,17,17
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET  T* CLASS MINER2
TRAVEL    MACRO       &S,18,18,18
        SEIZE       REFCH3
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
SET  CH3 CLASS FRC
DESTROY T*
        BLET        &RESMI=&RESMI+1
        BLET        &LEFTMI=&TOTMIN-&RESMI
        BPUTPIC     FILE=ATF,LINES=3,AC1,FC(REFCH3),&LEFTMI
TIME *.****
WRITE  M1 **
WRITE TB  **
        RELEASE     REFCH3
        TEST E      &LEFTMI,0
        BPUTPIC     FILE=ATF,LINES=2,AC1,AC1
TIME *.****
WRITE FTIME  **
        TERMINATE
****************************************
*           LEVEL 5
****************************************
PATHP19   ADVANCE     0
TRAVEL    MACRO       &T,19,19,19
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1
TIME *.****
SET  AGE CLASS BLOCKAGE
WRITE BLOCK Blockage
TRAVEL    MACRO       &CC,31,31,31
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET  T* CLASS MINER
        TRANSFER    ,PATHP45              NEW CHAMBER LOCATION-2

TRAVEL    MACRO       &DD,32,32,32
        SEIZE       REFCH2
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
```

```
TIME *.****
SET  CH2 CLASS FRC
DESTROY T*
         BLET       &RESMI=&RESMI+1
         BLET       &LEFTMI=&TOTMIN-&RESMI
         BPUTPIC    FILE=ATF,LINES=3,AC1,FC(REFCH2),&LEFTMI
TIME *.****
WRITE  M3  **
WRITE TB  **
         RELEASE    REFCH2
         TEST E     &LEFTMI,0
         BPUTPIC    FILE=ATF,LINES=2,AC1,AC1
TIME *.****
WRITE FTIME  **
         TERMINATE
*********************************
PATHP45   ADVANCE    0
TRAVEL    MACRO      &NN,45,45,45
TRAVEL    MACRO      &OO,46,46,46
         BPUTPIC    FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET  T* CLASS MINER2
TRAVEL    MACRO      &PP,47,47,47
TRAVEL    MACRO      &QQ,48,48,48
         SEIZE      CCHP2
         TRANSFER   SBR,ANIM,3PH
         BPUTPIC    FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
SET  CHP2 CLASS FRC1
DESTROY T*
         BLET       &RESMI=&RESMI+1
         BLET       &LEFTMI=&TOTMIN-&RESMI
         BPUTPIC    FILE=ATF,LINES=3,AC1,FC(CCHP2),&LEFTMI
TIME *.****
WRITE  MP2 **
WRITE TB  **
         RELEASE    CCHP2
         TEST E     &LEFTMI,0
         BPUTPIC    FILE=ATF,LINES=2,AC1,AC1
TIME *.****
WRITE FTIME  **
         TERMINATE

PATHP24   ADVANCE    0
TRAVEL    MACRO      &TT,24,24,24
```

```
        TRANSFER    ,PATHP55

*****************
*     CHP2
*****************
TRAVEL    MACRO       &UU,25,25,25
        SEIZE       REFCH4
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
SET  CH4 CLASS FRC
DESTROY T*
        BLET        &RESMI=&RESMI+1
        BLET        &LEFTMI=&TOTMIN-&RESMI
        BPUTPIC     FILE=ATF,LINES=3,AC1,FC(REFCH4),&LEFTMI
TIME *.****
WRITE  M4 **
WRITE TB  **
        RELEASE     REFCH4
        TEST E      &LEFTMI,0
        BPUTPIC     FILE=ATF,LINES=2,AC1,AC1
TIME *.****
WRITE FTIME  **
        TERMINATE

PATHP55   ADVANCE     0
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET  T* CLASS MINER
TRAVEL    MACRO       &RR,55,55,55
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET  T* CLASS MINER2
TRAVEL    MACRO       &SS,56,56,56
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
SET  T* CLASS MINER
TRAVEL    MACRO       &AAA,57,57,57
        SEIZE       CCHP2
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
SET  CHP2 CLASS FRC1
DESTROY T*
        BLET        &RESMI=&RESMI+1
```

```
        BLET       &LEFTMI=&TOTMIN-&RESMI
        BPUTPIC     FILE=ATF,LINES=3,AC1,FC(CCHP2),&LEFTMI
TIME *.****
WRITE  MP2 **
WRITE TB  **
        RELEASE     CCHP2
        TEST E      &LEFTMI,0
        BPUTPIC     FILE=ATF,LINES=2,AC1,AC1
TIME *.****
WRITE FTIME  **
        TERMINATE

******************************************
*        INTAKE AIR FLOW
******************************************
        GENERATE    .7,,,500
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE BLUEAF T*
PLACE T* AT -53.11 -39.99
TRAVEL    MACRO       &Y,50,50,50
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
DESTROY T*
        TERMINATE

        GENERATE    .7,,,500
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE BLUEAF T*
PLACE T* AT -23.42 15.69
TRAVEL    MACRO       &Z,52,52,52
        BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
DESTROY T*
        TERMINATE

        GENERATE    .7,,,500
        TRANSFER    SBR,ANIM,3PH
        BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE BLUEAF T*
PLACE T* AT 50.14 8.96
```

```
TRAVEL    MACRO      &AA,53,53,53
          BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
DESTROY T*
          TERMINATE

          GENERATE    .7,,,500
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=3,AC1,XID1,XID1
TIME *.****
CREATE REDAF T*
PLACE T* AT 26.52 15.61
TRAVEL    MACRO      &BB,54,54,54
          BPUTPIC     FILE=ATF,LINES=2,AC1,XID1
TIME *.****
DESTROY T*
          TERMINATE
*******************************************
*         MAIN FANS ANIMATION              *
*******************************************
          GENERATE    ,,,1      DUMMY TRANSACTION
WAIT      BPUTPIC     FILE=ATF,LINES=3,AC1
TIME *.****
ROTATE CIR 800 SPEED  700
ROTATE CIR2 -800 SPEED  700
          ADVANCE     .5
          TRANSFER    ,WAIT
*******************************************
*           CLOCK SEGMENT                  *
*******************************************
          INTEGER     &TIME,&HOUR
          GENERATE    ,,,1,150,12PL,12PH   DUMMY TRANSACTION FOR CLOCK
          TRANSFER    SBR,ANIM,3PH
          BLET        &HOUR=0
NEXTMIN   ADVANCE     1      ADVANCE THE CLOCK ONE MINUTE
          BLET        &TIME=&TIME+1
          TRANSFER    SBR,ANIM,3PH
          BPUTPIC     FILE=ATF,LINES=3,AC1,&TIME,&HOUR
TIME *.****
WRITE MT1 **
WRITE MT2 **
          TEST E      &TIME@60,0,NEXTMIN
          BLET        &TIME=0
          BLET        &HOUR=&HOUR+1
          TEST E      &HOUR,100,NEXTMIN
```

```
          BLET       &TIME=0
          BLET       &HOUR=0
          TRANSFER    ,NEXTMIN

**************************************************
*  TIMER TRANSACTION                             *
**************************************************
          GENERATE    ,,,1
          ADVANCE     &ETIME
          TERMINATE   1
          START       1
          LET         &LEFTMI=&TOTMIN-&RESMI
*************************************************
          PUTPIC      LINES=8,&TOTMIN,&LEFTMI,&RESMI,&ETIME
=== RESCUE SIMULATION RESULTS ===

TOTAL MINERS IN THE MINE: ***
TOTAL MINERS LEFT IN DISASTERS: ***
TOTAL RESCUED MINERS IN THE OPERATION: ***
ESTIMATED RESCUE TIME IN THE MINE:  **.**

"MINE SYSTEMS OPTIMIZATION & SIMULATION LABORATORY"

          PUTPIC      LINES=6,FILE=MYOUT,&TOTMIN,&LEFTMI,&RESMI,&ETIME
=== RESCUE SIMULATION RESULTS ===

TOTAL MINERS IN THE MINE: ***
TOTAL MINERS LEFT IN DISASTERS: ***
TOTAL RESCUED MINERS IN THE OPERATION: ***
ESTIMATED RESCUE TIME IN THE MINE:  **.**
*TOTAL TIME REQUIRED TO RESCUE MINERS:  **.**
*************************************************
          IF          (&YES'E"Y')OR(&YES'E"y')
          PUTPIC      FILE=ATF,LINES=2,AC1
TIME *.****
END
          ENDIF
          END
*************************************************
*************************************************
```

- Screen capture of the input and output of the developed MSRS Model:

```
              *** MINE SYSTEM RESCUE SIMULATIOM (MSRS) MODEL ***

 INPUT THE NUMBER OF MINERS IN LEVEL 1?
_ 6

 INPUT THE NUMBER OF MINERS IN LEVEL 2?
_ 4

 ---INPUT THE NUMBER OF MINERS IN LEVEL 3 (ZONE 3)?
_ 4

 ---INPUT THE NUMBER OF MINERS IN LEVEL 3 (ZONE 8)?
_ 3

 INPUT THE NUMBER OF MINERS IN LEVEL 4?
_ 6

 ---INPUT THE NUMBER OF MINERS IN LEVEL 5 (ZONE 5)?
_ 5

 ---INPUT THE NUMBER OF MINERS IN LEVEL 5 (ZONE 6)?
_ 2

 ESTIMATED RESCUE TIME IN THE MINE?
_ 30

 DO YOU WANT ANIMATION? (Y/N)
_ Y

 ARE YOU HAPPY WITH THESE VALUES? (Y/N)
_ Y

       *** RESCUE SIMULATION RESULTS HAVE BEEN PUT INTO EXCEL FILE ***

=== RESCUE SIMULATION RESULTS ===

TOTAL MINERS IN THE MINE:  30
TOTAL MINERS LEFT IN DISASTERS:   5
TOTAL RESCUED MINERS IN THE OPERATION:  25
ESTIMATED RESCUE TIME IN THE MINE:  30.00
```

- An example of the simulation program output in an Excel® spreadsheet format:

=== RESCUE SIMULATION RESULTS ===
TOTAL MINERS IN THE MINE: 30
TOTAL MINERS LEFT IN DISASTERS: 5
TOTAL RESCUED MINERS IN THE OPERATION: 25
ESTIMATED RESCUE TIME IN THE MINE: 30.00