SCHOOL OF MATERIALS AND MINERAL RESOURCES ENGINEERING
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FULL SIMULATION OF CYCLE TIME USING TALPAC SOFTWARE AT LAFARGE KANTHAN QUARRY

By

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DECLARATION

I hereby declare that I have conducted, completed the research work and written the dissertation entitled: "**Full Simulation of Cycle Time using TALPAC Software at Lafarge Kanthan Quarry**". I also declare that it has not been previously submitted for the award of any degree or diploma or other similar title of this for any other examining body or university.

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LIST OF ABBREVIATIONS

EIA	Truck and Loader Productivity and Costing
FPC	Fleet Productivity and Cost Analysis
TALPAC	Equipment Investment Analysis
OEE	Overall Equipment Efficiency
BCM	bank cubic metre
tph	tonne per hour
tpd	tonne per day
tpy	tonne per year

SIMULASI PENUH MASA KITARAN MENGGUNAKAN PERISIAN *TALPAC* DI KUARI LAFARGE KANTHAN

ABSTRAK

Masa kitaran memuat dan mengangkut bahan untuk operasi kuari mempunyai kesan yang signifikan terhadap produktiviti kuari. Pengendalian bahan yang paling tipikal adalah dengan kombinasi trak dan pemuat. Pengendalian bahan adalah salah satu unsur penting yang membantu mengurangkan atau sebaliknya pengeluaran mineral. Kajian ini memberi tumpuan kepada membangunkan simulasi penuh yang boleh digunakan semasa pengiraan produktiviti pemuat dan juga pengurusan armada pengeluaran untuk kuari. Dengan membandingkan pelbagai kaedah pemuatan yang berlainan, pengendali kuari boleh memilih kaedah terbaik untuk menghasilkan produktiviti yang tertinggi. Merujuk kepada kajian kes di *Lafarge Kanthan Cement Quarry*, simulasi ini telah terbukti menjadi wacana penting dalam menentukan metodologi pemuatan terbaik dengan mempertimbangkan kedua-dua masa kitaran dan data di lokasi termasuk komponen alam sekitar dan keadaan jalan raya bersama-sama dengan pemerhatian masa kitaran juga dikumpulkan secara berkala sepanjang tempoh kajian. Keputusan menunjukkan bahawa *full truck* untuk *bucket passes* dan *single-sidedtruck positioning*untuk metodologi pemuatan menghasilkan produktiviti tertinggi dengan masa kitaran tersingkat.Jadual kerja, kelajuan, penglihatan pemandu, keselamatan dan pengurusan trafik memberi kesan yang signifikan terhadap masa kitaran trak pembuangan. Penyumbang utama kajian ini ialah pengenalpastian dan analisis hubungan statistik pembolehubah terhadap masa kitaran.

FULL SIMULATION OF CYCLE TIME USING TALPAC SOFTWARE AT LAFARGE KANTHAN QUARRY

ABSTRACT

Cycle time of loading and hauling equipment for quarrying operations has a significant impact on quarry productivity. The most typical materials handling is by truck and loader combination. Operation of materials handling is one of the important key element that helps to reduce or vice versa the cost of mineral production. This study focused on developing a full simulation that can be used during the calculation of loader productivity as well as fleet production management for a quarry. By comparing different types of loading methodologies, quarry operators can select the best method that yield the highest productivity. In referral to the case study of Lafarge Kanthan Cement Quarry, this simulation has proved to be an important tool in determining the best loading methodology by considering both cycle time and on-site data including environmental components and haul road conditions together with cycle time observations were also collected periodically throughout the study duration. Results indicate that full truck for bucket passes and single-sided of truck positioning for loading methodology yield the highest productivity with shortest cycle time. Roster, speed, driver visibility, safety and traffic management can significantly impact the dump truck cycle time. The significant contribution of this research is the identification and analysis of statistical relationship of variables within the cycle time.

Chapter 1

INTRODUCTION

Equipment selection problem includes the phase of choosing a fleet of trucks and loaders that have the capacity to move the materials specified in targeted plan within a stipulated period is a type of problem in quarry. Purchasing a single quarrying equipment may cost several millions of moneys, however, over time, the productivity increases and the cost of operation outweighs the purchasing cost of the equipment. The equipment selection problem is usually influenced by a cascade of interdependent variables and parameters such as the cost of using a single piece of equipment which depends on its utilization, the availability and age of the equipment. The utmost goal of quarrying operation is to provide the required amount of raw material needed by the community at reduced costs. Cost of material removal can be minimized if operation succeeds while the remaining profits can be used to effectively revamp the site once all the material has been excavated. The aspect of the quarrying operation, which has the most impact on profit, is the cost of materials handling.

1.1 Background of Study

In quarrying and mining activities, work cycle comprises of repetitive operations the equipment in doing the earthwork activities. This comprise of drilling, loading, dumping, hauling and return for another load. Those work may be accomplished by a single type of equipment, or even may be done by two or more kinds of equipment working simultaneously.

Productivity should always have been maximised by project managers and this become a big challenge to be dealt with. Productivity is defined as the ratio of useful work output to the duration in time to accomplish that work. Profit is generated from effective productivity hence it is very important to plan for effective productivity (Perdomo et al., 1999).

The mining and quarrying industry is always striving in increasing its quality of processes for the sake of a sustainable operation with environmental-friendly, worker safety improvement and yielding productivity of their equipment, costs fluctuation and changes of commodity prices in the market. The latest developments in information technology have been introduced to centralize, integrate, and analyse data that leads to the generation of multiple tools to increase productivity with monitoring equipment, avoiding delay times during the production process were done to meet those needs.

. Today invention of devices with latest developments enable various activities of the equipment to be continuously monitored, recording all the vital signs and storing them in a database. The status of equipment performance can be displayed in mode of in real time or at the end of the shift. These eventually make the process of quarry planning tracking and the management of the operation can be improved.

Computer programs such as Truck and Loader Productivity and Cost (TALPAC) and Caterpillar's Fleet Production and Cost (FPC) analysis are commonly used nowadays by mining engineers in open-pit haulage truck requirements prediction. TALPAC, for instance, provides the best estimation based on manufacturers' equipment performance specifications and capabilities, such as rim pull curves. This method incorporates performance assumptions that are optimistic, as equipment is subjected to wear and tear which reduces its operational efficiency (Hardy, 2007).

1.2 Problem Statement

Loading and haulage optimization is one of the most crucial issues in quarrying activities. Many external factors may affect loading and haulage system selection: where amongst them a very chief role is played by local topography, stability conditions, size of the excavated material and capacity of the crusher. Loading and haulage are interconnected with the other steps of the production process, hence the selection of the best suited equipment is conditioned by several external factors.

Efficiency drives an earthmover's decision-making process. "Efficient job scope is a basic idea that urges to a successful mass excavation," says Tim Doucette, Marketing Manager of Liebherr Construction Equipment. "The higher the efficiency, the higher the production and profitability. Machinery standing idle such as excavators waiting for trucks, inefficient cycle times or trucks waiting to be loaded reduces production and profitability," he added.

Carl Heggen, a Product Manager of Komatsu America Corp claimed that changes in haul road conditions also able to impact the number of trucks required. Deteriorated conditions due to weather may make things even worse in certain cases. He pointed out that longer truck cycle times could add more trucks to the fleet to ensure that the excavator running at 100% efficiency and conversely, maintaining the same hourly production rate.

However, Tim Doucette, a Marketing Manager from Liebherr Construction Equipment clarify that in practice, adding more trucks to compensate for the conditions may not be practical since parked trucks consume money, and it is unlikely that any operation would simply have trucks sitting and waiting to be used if conditions deteriorate. The better idea to resolve the issue would be correct road maintenance. (Curt Bennink, 2006).

A recent study highlighted that no account is made for random events that occur over the course of a truck haul cycle. Queuing to load and unload, refuelling, operator breaks, and unloaded trucks giving way to loaded trucks on narrow sections of road or intersections are examples of events that will impact on a truck cycle time. Such events cannot be accounted for when a predicted cycle time is based on theoretical equipment capabilities. The availability of broad spectrum of equipment sizes gives various results to production. It is the matter on how efficient an equipment in yielding higher productivity and thus, a simulation model is said to be relevant for Lafarge Kanthan Quarry.

1.3 Research Objectives

Due to uncertainties regarding the future trend in size of equipment and the absence of data which is reliable to relate the impacts and benefits of equipment selection criterion, there are various drive factors come into consideration to investigate those issue. It is this need that this dissertation being aimed to address since eventually this matter impacts a quarry's return on investment. Since TALPAC serves several functions, many field works regarding quarrying activities can be done effectively. TALPAC aids to calculate truck travel time which leads to comparative analysis of haul route alternatives, fleet productivities estimation, different loading methodologies comparison to determine the optimum loading technique or loading unit bucket size, analysis of sensitivity in road design criteria to evaluate the importance of road maintenance, fuel consumption estimation, optimization of truck fleet size for analysis of under or over trucking, incremental analyses, in which simulations able to run automatically for a range of haulage segment lengths to generate productivity curves, loading analysis to optimise loader bucket size, truck capacity and number of passes.

By utilizing some of the unique features offered by TALPAC, the intent of this research was to develop a simulation to calculate travel time from a fundamental level considering equipment characteristics that affect the haul unit performance. Hence, the parameters affecting the performance is yet to be identified. This research proposed several objectives in which the main aim is to discover the efficiencies of the existing cycle time in Lafarge Kanthan Quarry. Other objectives are listed as below:

- to determine and compare influential parameters that influence efficient cycle time to be achieved

- to evaluate the compatibility between existing method of calculating cycle time to the results shown by TALPAC software
- to compare different loading methodologies and effects to the cycle time and productivity

1.4 Structure of Research Work

Many variables in science and engineering discipline are dependent upon other variables. These problems can be resolved and results can be obtained by finding out the values for other variables upon which they are dependent first. (Benjamin & Cornell, 1970). Since travel time is a variable comprises of function of other variables such as rolling resistance, grade and haul road characteristics, engine, transmission and gross weight of the vehicle itself. The analysis of variables that dependent upon other variables were previously required a complicated and difficult analysis which is tedious to be done (i.e. analytical solution of several complex differential equations).

TALPAC is one of the most widely used truck and loader simulation packages in Australian mining, but most truck manufacturers have programs that calculate results using similar algorithms, for example, FPC by Caterpillar, Inc. For mine planning purposes, the aim of computer simulation is to determine the truck-loader fleet productivity.

Defining the load and haul equipment is the first and first step in running a TALPAC simulation. Properties such as bucket/tray capacities, power ratings, and both capital and operating costs are defined for the load and haul units used by the operation. Also, the expected spotting and loading times. The user is then able to assign a statistical spread to the times that will be used in the simulation based on the expected time. This is done by observing the truck-loader operational while excavating the materials directly from the quarry to the dump point either to stockpile or crushing line.

The intended haul route then is defined as a series of sections. Each section is allocated a length, grade, rolling resistance, and speed limitation. Indication is also made as to whether the truck is loaded or empty for that section of the route. Truck spotting and loading/dumping times also are included in the haul cycle as auto entries of zero distance. The duration of these sections of the cycle are drawn from the parameters defined for the loading and dumping units.

Material properties and shift rosters are defined before the simulation is run for the extraction of the target BCM (or tonnes) of rock. Several reports are generated by the simulation relating to productivity, tyre and fuel consumption, haul cycle, and cash flow.

Chapter 2

LITERATURE REVIEW

2.1 Cycle Time

It can be described as the time spent by any equipment to complete one cycle of operation. For a truck, cycle time includes the time to spot and load, travel to the dump site; manoeuvre, spotting, and dump and drive back to the loading point, also predictable delays, unpredictable and wait times are included in the cycle.

Storage of loading times, travel time, queues and unloading times in a database are required to define the sequence of operation with the theories presented. The theories on the proper calculation of trucks per shovel with the aim of decreasing the cost of material movement. Finally, different equations are presented whose parameters should be extracted from a database. *Eq. 1* shows the components of a typical cycle time in an open pit mine.

$$\boldsymbol{CycleTime} \\ = \boldsymbol{load\ time} + \boldsymbol{dump\ time} + \boldsymbol{queuing\ time\ at\ shove} + \boldsymbol{queueing\ time\ at\ dump\ point} + \\ \boldsymbol{loaded\ haul\ time} + \boldsymbol{empty\ return\ time} \quad (1)$$

where;

load time: time taken for the excavator to load earth material into a single dump truck;

haul time: time acquired to travel from loading point to the dumpsite for single truck;

dump time: time for a single dump truck to empty the payload;

return time: time needed to return to the loading point with an empty payload.

A structure of a time model where the different time components relate among themselves has been developed. *Figure 2.1* drives to a better understanding how this time structure is correlated:

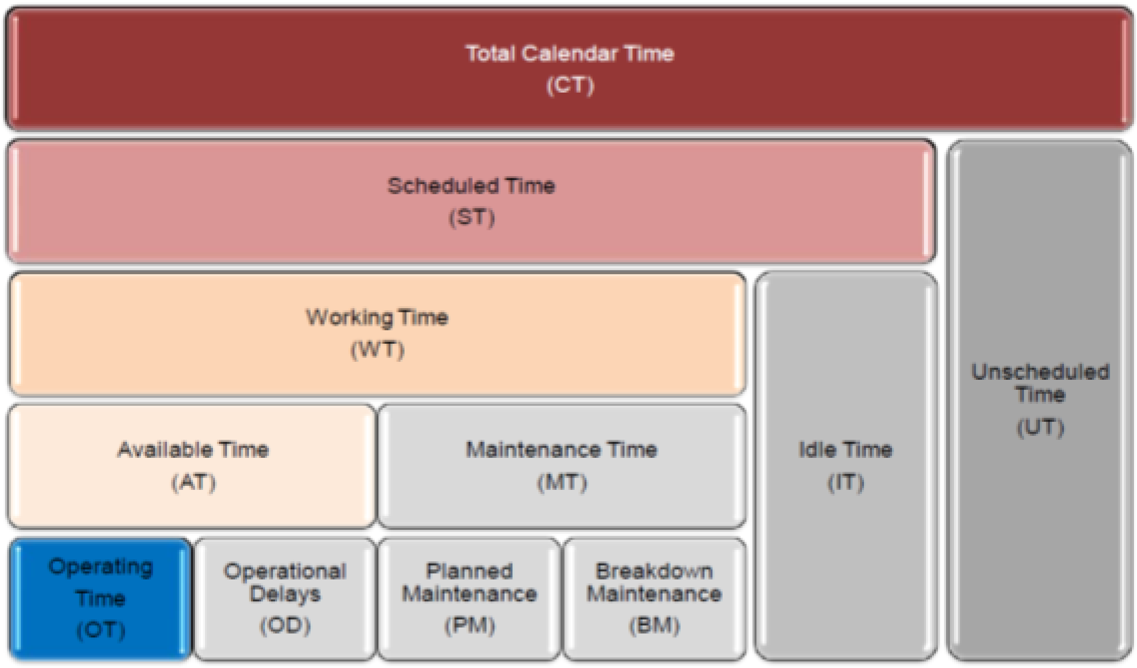

Figure 2.1 Typical Time Usage Model

Standard time definitions of this model are the following:

CT : Total available time;

ST : Time an item is scheduled to perform its required production function;

UT : Time an item is not scheduled to perform its required production function;

WT : Idle time which are timeless;

IT : Time of available equipment is available but not utilized due to internal and external factors;

AT : Working timeless maintenance time;

MT : Equipment maintenance time;

OT : Time for an item performing its required production function;

OD : Time of equipment operating but not in a productive mode;

PM : Scheduled component of maintenance time; and

BM : Unscheduled component of maintenance time.

2.1.1 Sequences

Typically, most of the quarry exist in Malaysia employ excavator-truck system in which they are applying the production cycle as shown in *Figure 2.2:*

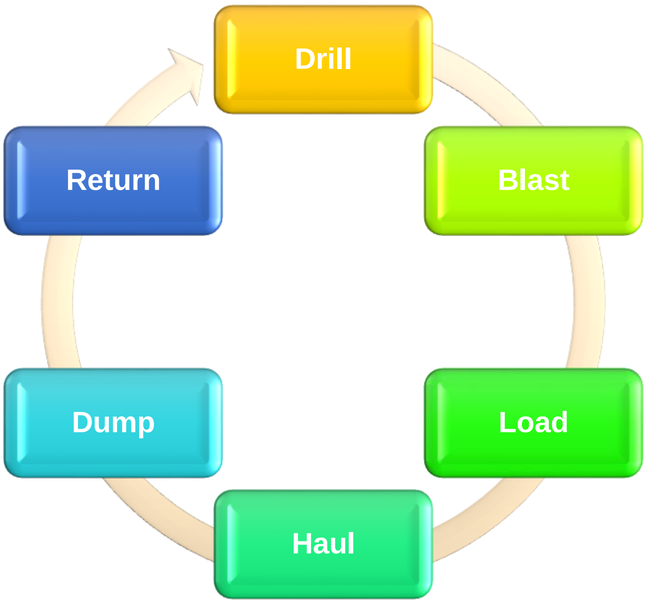

Figure 2.2 Cycle of Production

In comparison to the other system, for example belt and railway train system, this system gives range of capital cost and higher flexibility during loading and dumping. Operation can be done at minimal expenses if proper fleet of trucks and loaders are selected.

The cycle time estimation in truck-shovel system as shown in *Figure 2.3* is considering various limiting factors while developing it. It comprises of variable or travel time (haul and return time) together with the fixed time (load, dump and spot times). Cycle time is said to be the most convenient common denominator in work cycle analysis since it is true for economic evaluation of operation. This is because the manpower costs and equipment are mainly time related.

Figure 2.3 Truck-Shovel System Modelling Concept

Time of loading can be described as total time taken to fill up the hauling unit to its planned load capacity in which in this study, it is the time taken for excavator to fill the blasted rocks into the trucks. It is a function of bucket size, factor of fill, cycle time of excavator, density of loose material and truck capacity. Loading time is said to impact cycle time and job factor. There are three types of loading methods, in which they are: conventional method, staggered method (odd passes or even passes) and chain loading. Loading time is said to be controllable according to the competency of the operator of excavator in digging the materials using backhoe and trucks' operators in handling the trucks regardless the traffic conditions.

The time taken for hauling the material from loading point to dumping point is called haul time where it varies with distance of hauling, haul route conditions, power and efficiency of hauling equipment. It is together with return times and being categorised as travel time and is a function of payload, weight of vehicles, rolling and grade resistance and speed limits. When it comes to the matter of time of travel, the return distance for empty equipment may be as same as haul distance. However, there is a change in haul road profile and the speeds of empty unit may be differ than that loaded truck. Hence, return time of empty truck must also be considered as in category of travel time. In short, rolling resistance is describes as a measure of force required to overcome internal bearing friction and the effect of retarding between tires and the ground (tire penetration and tire flexing). Rolling resistance can be greatly increase or reduces by size of tires and inflation pressure. It can be expressed in terms of lb/ton of weight of vehicle or %vehicle weight. Grade resistance can be defined as force required in overcoming gravity while moving uphill and sums up both grade and rolling resistance will yield total resistance in which one of the factor to be considered while calculating cycle time.

Dumping time is another component to be foreseen while calculating cycle in which it depends on materials condition (this influences loader bucket fill factor). It is also affected by types of equipment and method of dumping. It is categorised as fixed time as loading time and typical dump time is approximately 1-1.2 minutes depending on dumping configuration. However, dumping time only contributes to a small fraction of the total cycle time.

2.2 Theory of Queue

Since quarry is categorised as open pit type, hence queuing theory can be applied to explain its operation. It signifies the basis of how haulage works in an open pit operation by developing a model where customers reach to a server for it to be served. But, if they are not served as fast as possible, they shift to another server or maybe leave the system. This scenario can be implied to the mining and quarrying case where trucks as customers and shovels are the servers. Ore or waste are expected to be served to the empty trucks that arrive to the area of loading and if they are not loaded, they will seek to consecutive shovel that can do the job. If not, they will be shifting to another place. To sustain order until the arrival of the trucks, following terms are used:

- First come, first served: FCFS;
- First in, first out: FIFO;
- Last come, first served: LCFS;
- Random selection of service: RSS;
- Priority: PR; and
- Service in random order: SIRO.

2.3 Manual Methods

By manual methods means, collection of information from the company records need to be done by the estimator. Such information to be likely collected are as such specifications of equipment and performance characteristics, manufacturer literature, and/or handbooks. Plus, predicted condition of the project need to be estimated. When the required information is available, then the estimator should calculate how does the equipment is performing under those conditions. Huge amount of data may be prompting to happen where the estimation process becomes very tedious and is exposed to error. Production records are essential, however if they are unavailable, the estimator must rely on manufacturer's literature so that the estimation of the equipment's performance can be done. This will be a help to the planning and scheduling of a project where in the other hand, this information can be used as bidding purposes. Manual methods offer a tedious and time-consuming work to be done which also require intensive labour. It is also more prone to error. Because of those reasons, manual methods can be used as a comparison to the analysis offered by the software simulation since there are high variability in the factors affecting travel time in cycle of quarry productivity.

2.4 Techniques to Select Quarrying Equipment

The utmost aim of equipment selection is to satisfy requirements of production rate which goes along in minimizing cost. It been said that the driving parameters for this purpose are deposit specifications, criteria of design and quarry economics. *Figure 2.4* depicts on how the size equipment selection process related to each other.

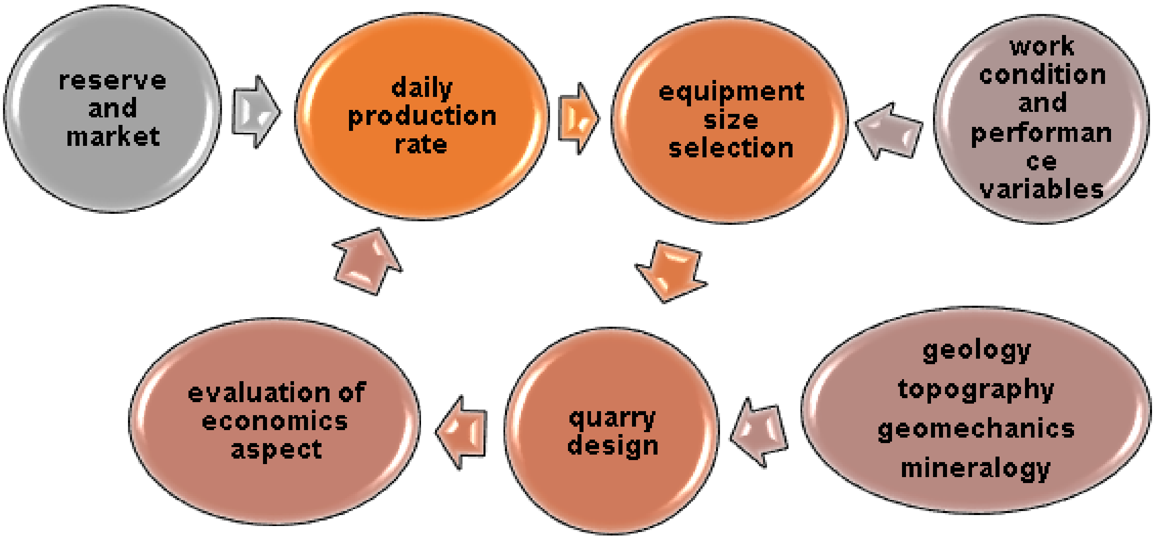

Figure 2.4 Size Equipment Selection Process

Generally, the most essential starting point and arguably highlight in quarry design is rate of production. Production rate is basically considering the reserve, the market, the production strategy and economics status of a company before it is being determined. Equipment in quarry is sized based depending on the daily production rate and potential operational conditions, for example; utilization, availabilities and layout of the quarry.

To satisfy the requirements of production, the selection process of the equipment is mainly needed. Proper matching of equipment is another essential point to the process. The process of equipment selection as shown in *Figure 2.5* which comprises of:

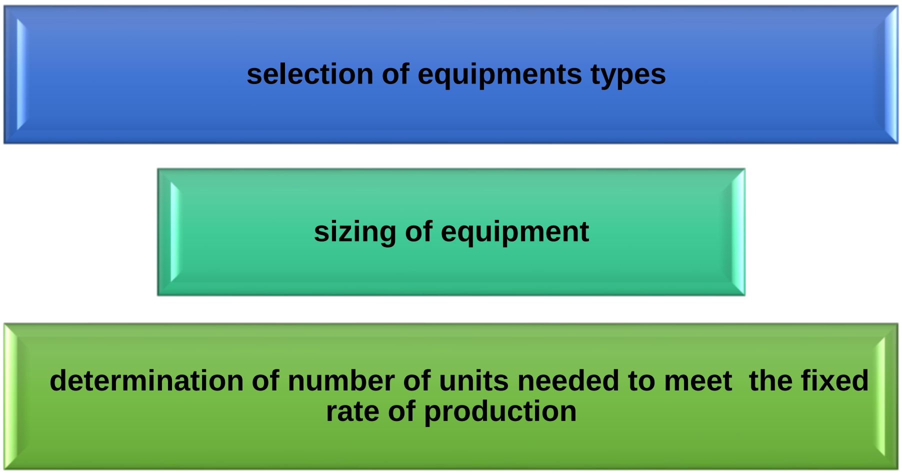

Figure 2.5 Process of Equipment Selection

The selection process in western Canada was figured out that companies let the selection of haulage equipment to manufacturers of truck and assess their proposals based on the best available deal. He recommends that the practice of selection is tied to requirements of production, quarrying plan, span of the quarry and projected usage of hauling equipment.

Despite production requirements are intent to be a driving factor in equipment selection, site and geological conditions such as groundwater condition, abrasiveness and thickness, dip and reserves distribution also are essential. Another identification which emphasizing that loading equipment must come into consideration prior to haulage equipment selection process also was done.

2.5 Computer Based Approach

The development of computer programs over recent years had assist estimators in planning specific productivity in quarry production. These programs have been ascertained to be as a precious tool since they were intended to be used to aid in equipment sales and maintenance. The development was done by equipment manufacturers and independent software developers where some of them are commercially available as stated by Perdomo et al., 1999.

In Planning and Design Systems approach for instance, specifications and performance details were included in a database of construction equipment where that information is required to perform the calculations. The conditions under which intended calculation for equipment performance and productivity can be specified. By having those information in a database format is advantageous since there is no need to search for company records seeking for information and does not depend on one's knowledge of a unit of mobile machineries. The comparison of equipment performance can be completed relatively fast since they are computed based.

It is the same when using the calculations performed in these programs to the calculations that an estimator applied when doing manual method. A simulation of different equipment configurations can be done with the information obtained about the job site even before the beginning of the project since these systems are computer based. By using computer based methods, factors that cannot be considered when using manual methods can be do so due to the reason that computers able to manage complex calculations.

However, none of the models reviewed based their calculations in comparison to fundamental data. Models back then derive their parameters from curves of rim pull where this approach may be because fundamental equipment characteristics were not disclosed by the manufacturers. It was also assumed that this is related to the reluctance to expend their time to develop a formal procedure to obtain values. Plus, rim pull curves which are available discourage previous researches from taking extra efforts to measure field parameters.

Utilisation of combination of empirical or calculated data to formulate results are currently available for truck cycle time prediction given by various products and methods. The methods are divided into three subgroups which depending on the level of manual input needed, historical data and degree of automation. Those three subdivisions of methods are: Computer Simulation, Multiple Regressions and Artificial Neural Networks. Another method is utilization of detailed method.

Chanda and Gardiner (2010) proffered a comparative study of truck cycle time methods of prediction specifically for open-pit mining. There are three methods studied which comprising computer simulation, multiple regressions and artificial neural networks with endeavour to achieve the best method for predicting truck requirements. Through this study, they figured out that computer simulation methods both under and overestimate the truck cycle times for short and long hauls distance respectively. Recommendations were made where artificial neural networks and regression models are advantageous to computer simulations in the ability of prediction (Chanda and Gardiner 2010). Detailed historical information for formulas calculation are required however, in artificial neural networks and multiple regression methods. Consequently, this made them therefore cannot be transferred between mining operations due to the nature and these systems creation complexities.

According to Chanda and Gardiner, 2010, neural networks works use the principle in which based on human brain. By this principle, hundreds of millions of neurons interact putting their benefaction (weights) to obtain the best and fastest way of outcomes. Prediction of the transport cycle time from the input variables combination can be done using this concept. They added more for multiple regressions, which the definition is a statistical approach for values find out of a dependent variable by its correlation to a set of independent variables. A factor which contributes the impact to the dependent variable are comprises of independent variables where this factor is called coefficient of variation. A formula is created based on the data where known values of variables is achieved.

2.5.1 The Fleet Production and Cost Analysis (FPC)

In assisting the determination of the most efficient equipment fleet for a project regarding earthmoving or other handling of materials, Caterpillar Dealer Channel Systems Group developed the FPC. The productivity of the fleet, cost of fleet usage and time needed for the project can be predicted as well. User able to enter one or more courses over which operation of earthmoving is probably to occur by inputting various data such as distance, rolling resistance, grade, speed and any passing obstacles. Below are factors that should be considered for FPC;

- Speed limits of site;
- Condition of haul road such as gradients/rolling resistance/distances;
- Waiting times;
- Density of material;
- Machine such as availability/fill factor of bucket/cycle times;
- Required volumes;
- Competency of operator.

Process of FPC is shown in *Figure 2.6* which explains that the simulation starts with the selection of machine characteristics according to Caterpillar equipment database seller and other input specifications from handbooks of the manufacturers or features of equipment which is been assumed. Next, further haul road criteria, materials specifications, distributions off production hour and costing equipment are required by the system. Other than that, maintenance and repair cost values also can be inputted in the tools too. Calculation of cash flow will be the main objective based on the best selection of equipment. Considering discount rates, insurance rates and other financial parameters are those input values that being programmed inside EIA which is Equipment Investment Analyses.

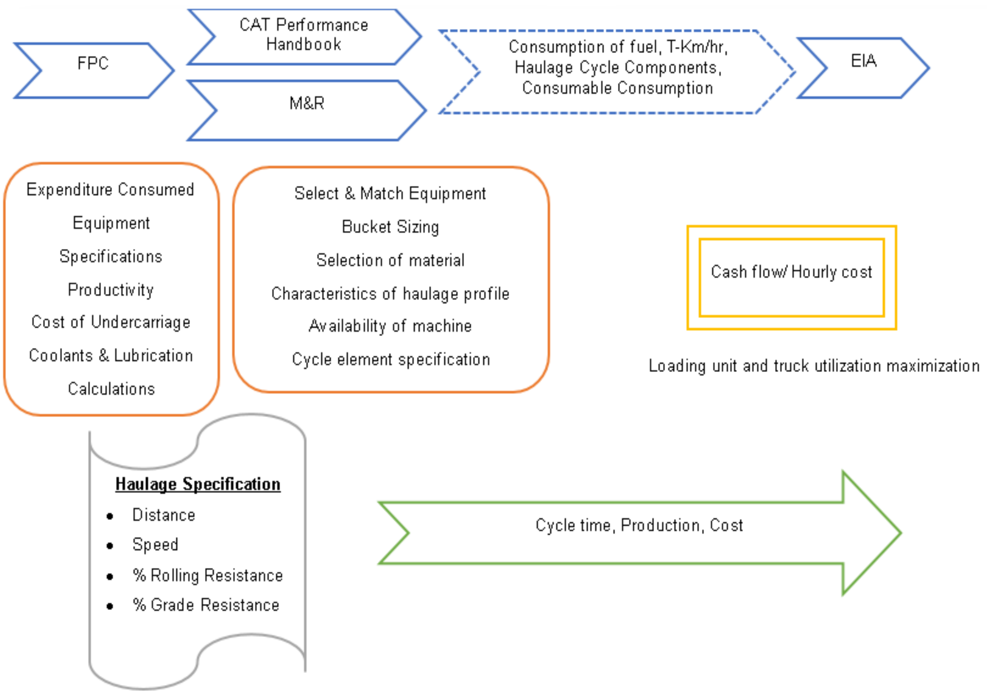

Figure 2.6 Process of Simulation FPC and EIA

The relation between trucks and shovels is involved in fleet matching and this is based on cycle time. Fleet Match calculation is shown in *Eq. 2* as follows:

$$\text{Fleet Match} = \frac{\textbf{Loader Cyce Time} \times \textbf{Number of Trucks}}{\textbf{Truck Cycle Time}} \qquad (2)$$

Cost and production is related to managers using FPC and choices regarding truck-loader matching can be simulated to maintain adequate range of production and mining operations' cost.

2.5.2 VEHSIM®

Caterpillar had developed this DOS based program called VEHSIM which was designed to predict the performance of haul unit. This was done by operation simulation with the parameters provided. Those inputs are machine to be used which was selected from a database, productive minutes per hour, initial and final velocity of haul road, return road initial and final velocity, distance, rolling resistance, material density, grade, dimension of tire in term of size, speed, fixed time and truck empty weight. Cycle time, trips per hour, average speed, production, operating minutes per hour and haul and return times will be the outputs. Since this system is a black box which is not extendable and unable to interface with other tools. The typical assumptions left to the belief of user is that this program does the exact calculations and made assumptions appropriately which are uncomfortable by many users with such systems.

2.5.3 Rockwell Software (Arena®)

By utilizing visual representations of trucks and loaders as entities, simulation process can be run. This permits the visualization of simulation process which can be used in analysis of scenario to be compared with other scenarios. Working with different types of building blocks had enable representation of trucks, shovels, crushers, location of waste dump and dynamic processes such as loading, hauling and dumping to be done. This software leads to highly faultless results to be obtained together with representations of graphic. Besides, this software functionality allows cycle time analysis since the probability distribution based on field data is shaped to scholastic variables. The advantages of Arena® are such that it aids to record and detect every activity of cycle times per truck during the simulation which triggers to the study of effect of this cycle in production and performance.

2.5.4 TALPAC: Truck and Loader Productivity and Costing

Based by a Monte Carlo-type simulation, TALPAC which was developed by RungePincockMinarco Ltd.can be claimed as a simulation and evaluation software of mining equipment in haulage. It can determine the productivities of truck-loader on bank cubic metres (BCM) per hour. To begin the haulage simulation, the utmost parameters are: the capacity of the shovel bucket and both units of load and haul, capital and operating cost and of course the power ratings.

The calculations of truck cycle times and trucks acquirements are performed by utilizing individual haulage considering the components of uphill and downhill through the usage of rim pull and retard curves, stop signs and limiting aspects of speed. Plus, the average utilisation, factors of availability and load and dump times are also needed. However, hundreds of thousands of haulages route and destination within minutes options are considered. A stochastic method of operation simulating of trucks and loading equipment over a specific haul profile is applied by the system.

2.6 Simulation

The testing for haulage efficiency and transportation processes be made possible by software simulation to reinvent different scenarios and configurations by identifying the parameters to be manipulated. Various algorithms are used in applying this simulation and an algorithm to decide the best trucks allocation was discovered. This is done with the aim to reach specific grade together to obtain a stable production. There are two models being discussed in this point of simulation and that comprises:

i. As-Is Model

The behaviour of operations can be predicted by make use of the importance of models. The operations will be understandable, problems are able to be detected and problem solving can be done. As-Is Model as stated in Business Process Improvement (BPI) as a prerequisite to understand the process execution from current system. As-Is Model guides the analysts by playing the role as a significant model for understanding and business process advancement (Lodhi et al., 2010). This model is rational to current research since it allows the understanding of open pit works by demonstrating in a simplified way mine operation, results analysis and potential bottlenecks identification.

ii. To-Be Model

After incorporating the advancement found on As-Is Model, To-Be Model is the result. It has the same structure possessed by an As-Is Model. No modification in the initial configuration allows any adjustment to be applied directly. Tan et. al. (2012) said that the usage of both models here are now an integral of simulations for management operations support in open pit mining. A real GPS tracking data from the mine are utilized and pictured three models for optimum productivity. Initially, As-Is model is created for current condition operations evaluation and then the To-Be model was developed to promote an improvement. Those improvements are based on the results and evaluation analysis shown by the As-Is model. Consequently, the calculation of extraction of the mine which is at maximum rate was carried out. When the utilization proportion of shovel increased, truck utilization is the other way around. Previous evaluation will be the basis to any improvement and if the good basis is null, the optimization process will not be conclusive. The optimal production can be maintained by identifying the optimal number of trucks and the follows by adjustment of To-Be model with the applied changes.

2.7 About TALPAC: Parameters to Consider

2.7.1 Criteria of Materials

Materials criteria is the first and foremost aspect to be considered in this software prior to ensure the best selection of haulage system for quarry operation. This parameter is crucial because each material exhibit different behaviours and this lead to a process of decision making involving the transportation mode. Different methods of handling happened when it comes to variety in materials to be handled. Hence, the selection on the best equipment that suit to the variety need to be done. Prior to equipment selection, the materials loose density and bucket fill factor should be well known. The key point is the type of material itself where if the type is known, fill in the density, then the system would give swell factor and loose density automatically. Another key point is bucket fill factor where each value is being arranged accordance to the type of loading units. Both two key points can be obtained by physical testing in the laboratory. Despite using the value obtained by laboratory work, one can use guidance as shown below in *Table 2.7*. Poor loader bucket fill factor eventually will lead to decreased in heaped bucket capacity. The values for heaped or struck bucket capacity varies to one another in the software and the difference can be visualized in *Figure 2.8*.

Table 2.7 Range of Fill Factor (Percent of Heaped Bucket Capacity)

Type of materials	Fill factor range (percent of heaped bucket capacity)
Moist loam or sandy clay	100-110
Sand and gravel	95-110
Hard, tough clay	80-90
Rock-well blasted	60-75
Rock-poorly blasted	40-50

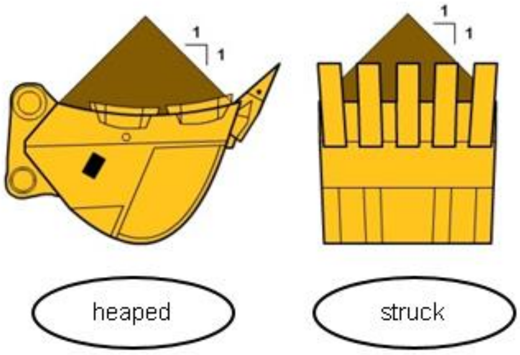

Figure 2.8 Visualization of Heaped and Struck Bucket Capacity

2.7.2 Roster

This is where the importance of workers' scheduling roster is to be checked either an organization has perfect roster or not. Perfect scheduling will aid to working timetable which is organizable, thus increasing the operators' productivity. In quarry job scope, the productivity of an operator is being described as total moved volume of earth for each operator hour and the number of work cycles completed per operator minute. High productivity of operators that an organisation has will lead to competent workers generation aligned with the high output production. Pushing the limit of operator will lead to operators' exhaustion and thus, decreasing their working efficiency.

2.7.3 Haul Cycle

For the case of haul cycle, this factor need to be decided to check the suitability of the road or haul cycle for the quarry operation. Since truck cycle time is influenced by the haul cycle which is an integral of the site condition, the measures that need to be taken with extra care are like production acquirement and schedule of operate, materials criteria, physical and climate condition, road characteristics, loading and dumping point. Haul cycle is another aspect that influence the smoothness process of cycle time since a slight change may contribute to changes in another aspect too. For example, during the day where it is a rainy day, truck drivers need to drive with care and this is where the effect of inconsistency in speed come. The weather will eventually cause the travelling speed for articulated dump truck and time travel for cycle time increases. *Figure 2.9* shows the data sheet for haul cycle which considering both physical and surrounding aspect of the hauling route: