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Application of Queuing Theory to Larfarge Cement Transportation System for Truck/Loader Optimazation

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Abstract

Surface mining is the most common mining method worldwide; open pit mining accounts for more than 60% of all surface output. This project uses queuing technique to optimize the transportation at Lafarge WAPCO (Sagamu plant) Nigeria. Queuing theory was developed to model systems that provide service for randomly arising demands and predict the behaviour of such systems. Time of arrival at excavator area (hr/min/sec), time of first load by excavator into the truck (hr/min/sec), number of loads, time of departure from the excavator (hr/min/sec) and time taken to load trucks gotten from the Lafarge (Sagamu plant) was analysed to develop a model M/M/1: FCFS/∞/∞, based on the assumption of single channel and single server with infinite number of queues. The model was used to calculate the arrival rate, service rate and number of server which at the end of it gives 7turcks/hour, 21trucks/hour and 1loader respectively. @risk software was used to fit both service and inter-arrival into exponential distribution. The result shows that as the size of the haulage truck being used increases, shovel productivity increases and truck productivity decreases. An effective number of trucks must be chosen that will effectively utilize idle time, increase productivity and reduce cost of production to the barest minimum. The idle time gotten is 66.6%; this indicates that an additional 8 to 9 trucks can be added to the company truck fleet to make use of the idle time; since time translate to cost.

Keywords: Queuing theory; Idle time; Truck fleet; Inter-arrival time; Service time

Introduction

Surface mining comprise the elementary actions of overburden removal, drilling and blasting, mineral loading, hauling and dumping and numerous secondary processes. Loading of ore and waste is administered concurrently at different locations within and the transportation of material is carried out using a system of shovels or excavators and haul trucks. After the haul trucks have been loaded, the trucks transport the material out of the mine to a dumping location where the material will either be stored or further processed. The trucks then return into the mine and the cycle repeats itself. For most surface mines, truck haulage represents as much as 60% of their total operating cost, so it is desirable to maintain an efficient haulage system [1]. As the size of the haulage fleet being used increases, shovel productivity increases and truck productivity decreases, an effective fleet size must be chosen so as to effectively utilize all pieces of equipment [2]. The shovel loading time depends on shovel capacity, digging conditions, and the capacity of the truck. At the loading point, queues are formed since different sizes of trucks may be used for individual loading. Thus, the allocation of trucks to haul specific material from a specific pit makes it a complicated problem. Certainly, efficient mining operations strongly depend on proper allocation of truck-shovel and proper selection of hauling equipment.

One method of truck selection involves the application of queuing theory to the haul cycle. Queuing theory was developed to model systems that provide service for randomly arising demands and predict the behaviour of such systems. A queuing system is one in which customers arrive for service, wait for service if it is not immediately available, and move on to the next server once they have been serviced [3]. For modelling truck-shovel systems in a mine, haul trucks are the customers in the queuing system, and they might have to wait for service to be loaded and also wait at the dumping locations.

One of the major issues in the analysis of any queuing system is the analysis of delay. Delay is a more subtle concept. It may be defined as the difference between the actual travel time on a given segment and some ideal travel time of that segment. This raises the question as to what is the ideal travel time. In practice, the ideal travel time chosen will depend on the situation; in general, however, there are two particular travel times that seem best suited as benchmarks for comparison with the actual performance of the system. These are the travel time under free flow conditions and travel time at capacity. Most recent research has found that for highway systems, there is comparatively little difference between these two speeds. That being the case, the analysis of delay normally focuses on delay that results when demand exceeds its capacity; such delay is known as queuing delay, and may be studied by means of queuing theory. This theory involves the analysis of what is known as a queuing system, which is composed of a server; a stream of customers, who demand service; and a queue, or line of customers waiting to be served.

In general we do not like to wait. But reduction of the waiting time usually requires extra investments to decide whether or not to invest, it is important to know the effect of the investment on the waiting time. So we need models and techniques to analyse such situations. Attention is paid to methods for the analysis of these models, and also to applications of queuing models. Important application areas of queuing models; are production systems, transportation and stocking systems, communication systems and information processing systems. Queuing models are particularly useful for the design of this system in terms of layout, capacities and control.

Queuing theory

Queuing theory was developed to provide models capable of predicting the behaviour of systems that provide service for randomly arising demands. Queuing theory deals with the study of queues (waiting lines).The earliest use of queuing theory was in the design of a telephone system; randomly arising calls would arrive and need to be handled by the switchboard, which had a finite maximum capacity. Applications of queuing theory are found in fields such as; traffic control, hospital management, and time-shared computer system design [4-7]. Typical example of a queue model is shown in Figure 1 [8]. The following terms are commonly used in queuing theory;

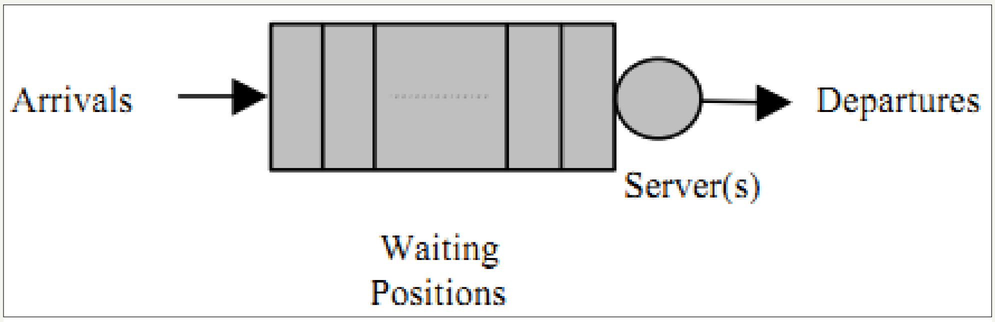

Figure 1: Model of a queue [8].

Customers: The persons or objects that require certain service are called customers.

Server: The person or a machine that provides certain definite service is known as server.

Service: The activity between server and customer is called service, this consumes some time.

Queue or Waiting line: A systematic arrangement of a group of persons or objects that wait for service.

Arrival: The process of customers coming towards service facility or server to receive a certain service.

Queuing system

There are six basic characteristics that are used to describe a queuing system; input (arrival pattern), service mechanism (service pattern), queue discipline, customer's behaviour, system capacity, number of service channels [3].

The input (arrival pattern)

The input describes the way in which the customers arrive and join the system. Generally customers arrive neither in a more or less random fashion which is not worth making the prediction. Thus the arrival pattern can be described in terms of probabilities and consequently the probability distribution for inter arrival times (the time between two successive arrivals) must be defined. In other words the input is the rate at which customers arrive at a service facility. It is expressed in flow (customers/hr vehicles/hour in transportation scenario) or time headway (seconds/customer or seconds/vehicle in transportation scenario). If inter arrival time that is time headway (h) is known, the arrival rate can be found in Equation 2.1.

$$\lambda = 3600 / h \qquad (2.1)$$

The service mechanism (service pattern)

This means the arrangement facility to server customers. If there is infinite number of servers then all the customers are served instantly on arrival and there will be no queue. If the number of servers is finite then the customers are served according to a specific order with service time as a constant or a random variable. Distribution of service time which is important in practice is the negative exponential distribution. The mean service rate is denoted by μ. the service rate can be calculated from equation 2.2.

$$\mu = 3600 / h \qquad (2.2)$$

The queue discipline

Queue discipline is a parameter that explains how the customers arrive at a service facility.

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The various types of queue disciplines are;

a. First in first out (FIFO)

b. First in last out (FILO)

c. Served in random order (SIRO)

d. Priority scheduling

e. Processor (or Time) Sharing

First in first out (FIFO)

If the customers are served in the order of their arrival, then this is known as the first-come, first-served (FCFS) service discipline. Prepaid taxi queue at airports where a taxi is engaged on a first-come, first-served basis is an example of this discipline.

First in last out (FILO)

Sometimes, the customers are serviced in the reverse order of their entry so that the ones who join the last are served first. For example, assume that letters to be typed, or order forms to be processed accumulate in a pile, each new addition being put on the top of them. The typist or the clerk might process these letters or orders by taking each new task from the top of the pile. Thus, a just arriving task would be the next to be serviced provided that no fresh task arrives before it is picked up. Similarly, the people who join an elevator first are the last ones to leave it.

Served in random order (SIRO)

Under this rule, customers are selected for service randomly irrespective of their arrival in the service system. In this every customer in the queue is equally likely to be selected. The time of arrival of the customers is, therefore, of no relevance in such a case.

Priority service

Under this rule customers are grouped in priority classes on the basis of some attributes such as service time or urgency or according to some identifiable characteristic, and FIFO rule is used within each class to provide service. Treatment of VIPs in preference to other patients in a hospital is an example of priority service.

Processor (or time) sharing: the server is switched between all the queues for a predefined

Slice of time (quantum time) in a round-robin manner. Each queue head is served for that specific time. It doesn't matter if the service is complete for a customer or not. If not then it'll be served in its next turn. This is used to avoid the server time killed by customer for the external activities (e.g. preparing for payment or filling half-filled form).

Customer's behavior

The customers generally behave in the following four ways:

Balking: The customer who leaves the queue because the queue is too long and he has no time to wait or has no sufficient waiting space.

Reneging: this occurs when a waiting customer leaves the queue due to impatience.

Priorities: In certain application some customers are served before the others regardless of their arrival. These customers have priority over others.

Jockeying: Customers may jockey from one waiting line to another.

System capacity

If a queue has a physical limitation to the number of customers that can be waiting in the system at one time, the maximum number of customers who can be receiving service and waiting is referred to as the system capacity. These are called finite queues since there is a finite limit to the maximum system size. If capacity is reached, no additional customers are allowed to enter the system.

Number of service channel

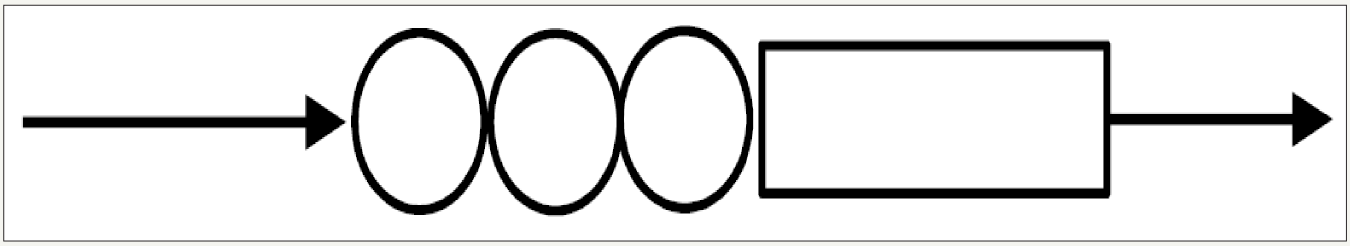

Figure 2: Single channel queuing system [9].

The number of service stations in a queuing system refers to the number of servers operating in parallel that can service customers simultaneously. In a single channel service station, there is only one path that customers can take through the system. Figure 2 [9] shows the path customers, represented by circles; take through a single service channel queuing network. The customers arrive at the server, represented by the rectangle, and form a queue to wait for service if it is not immediately available, and then proceed through the system once service has been completed.

When there are multiple servers available operating in parallel, incoming customers can either wait for service by forming multiple queues at each server, as shown in (a) of Figure 3, or they can form a single queue where the first customer goes in line goes to the next available server, as shown in (b). Both of these types of queues are commonly found in day-to-day life. A single queue waiting for multiple servers is generally the preferred method, as it is more efficient at providing service to the incoming customers.

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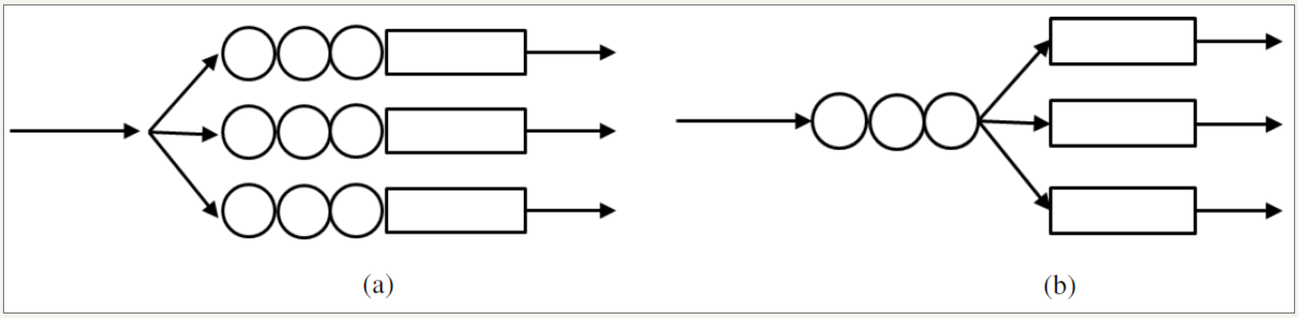

Figure 3: Multichannel queuing systems [9].

Notations

Queuing processes are frequently referred to by using a set of shorthand notation in the form of (a/b/c/): (d/e/f) where the symbols a through f stand for the characteristics shown in Table 1. The symbols a through f will take different abbreviations depending on what type of queuing symbols. A and b both represent types of distributions and may contain codes representing any of the common distributions listed in Table 2.

Table 1: Queuing notation abbreviations.

Symbol	Characteristics
a	Arrival distribution
b	Service distribution
c	Number of parallel servers
d	Service discipline
e	Maximum number of units that can be in the system at one time
f	Source population size

Table 2: Distribution abbreviations.

Symbol	Explanation
M	Markovian: exponentially distributed inter-arrival or service times
D	Deterministic: constant distribution
El	Erlang distribution with parameter 1
G	General distribution

Materials and Methods

This section introduces the study area, talks briefly about Lafarge Cement WAPCO Plc. the data sources, instrument for data collection, and discusses the methods of data analysis and ways in which the data can be presented. In this research, the arrival and departure time were capture using stopwatch. The data captured were subjected to queue.

Method of data analysis

In this research, the model adapted is the M/M/1: FCFS/∞/∞ queuing system. The model refers to negative exponential arrivals and service times with a single server and infinite queue length with an infinite population. This is the most widely used queuing systems in analysis and pretty much everything is known about it. M/M/1: FCFS/∞/∞ is a good approximation for a large number of queuing systems. Suitability of M/M/1: FCFS/∞/∞ queuing is easy to identify from the server standpoint. For instance a single transmit queue feeding a single link qualifies as a single server with an unlimited queue length and can be modeled as an M/M/1: FCFS/∞/∞ queuing system.

The model assumes a Poisson arrival process and exponentially distributed service process. This assumption is a very good approximation for arrival process in real systems that meet the following rules:

a) The number of customers in the system is very large.

b) The impact of a single customer for the performance of the system is very small, that is, a single customer consumes a very small percentage of the system resources.

c) All customers are independent, i.e. their decisions to use the system, does not depend on other users.

Model description

a) Arrivals are random, and come from the Poisson probability distribution (Markov input).

b) Each service time is also assumed to be a random variable following the exponential distribution (Markov service).

c) Service times are assumed to be independent of each other and independent of the arrival process.

d) There is one single server in the queue.

e) The queue discipline is First Come First Serve (FCFS) also known as first in first out, and there is no limit on the size of the line.

f) The average arrival and service rates do not change over time. The process has been operating long enough to remove effects of the initial conditions

Basic numeric characteristics of m/m/1: fcfs/∞/∞ queue

System must be operating long enough so that the probabilities resulting from the physical characteristics of the problem may satisfy the requirements of the mass selection of a statistical observation - that is, the system must be in equilibrium (steady state) .The characteristic of this queuing model can be classified as inputs and outputs.

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Inputs

To use this model, the values for the number of loaders operating, the arrival rate of new trucks, and the service rate per loader must be known to be used as inputs to the model. The necessary inputs are outlined in the table below, The arrival rate, λ, is the average rate at which new trucks arrive at the loader. The service rate, μ, is the service rate of an individual loader. In cases with more than one loader in operation, all loaders are assumed to be equivalent, so μ would be the average service rate of the loaders. The arrival rate, λ, and service rate, μ, should both be input in the form of trucks per hour. Both the arrival rate and the service rate are independent of queue length.

Outputs

When given the appropriate inputs, the model calculates and outputs values for various aspects of pit activity. These include loader utilization; the average time a truck spends in the system, the average time a truck spends waiting to be loaded, the average number of trucks waiting in line, the average number of trucks in the system, and the system output in trucks per hour. Table 3 below lists the outputs created by the model and the appropriate units for each variable.

Table 3: Queuing model inputs.

Variables	Description
Λ	Average arrival rate of new trucks
M	Average service rate per loader
C	Number of loaders operating in parallel

Based on this queuing system and input variables, the variables r and ρ are defined as,

$$r = \lambda / \mu \quad (3.1)$$

$$\rho = r / c = \lambda / c\mu$$

$$\text{Since } c = 1 \quad \rho = \lambda / \mu \quad (3.2)$$

Where r is the expected number of trucks in service, or the offered workload rate, and ρ is defined as the traffic intensity or the service rate factor or loader utilization factor (Giffin, 1978). This is a measure of traffic congestion. When ρ > 1, or alternately λ >cμ where c is the number of loaders, the average number of truck arrivals into the system exceeds the maximum average service rate of the system and traffic will continue back up.

For situations when ρ > 1, the probability that there are zero trucks in the queuing system (P_o) is defined as;

$$Po = 1 - \rho \quad \text{Where } \rho \text{ is utilization factor} \quad (3.3)$$

$$P1 = \lambda / \mu \times Po = \rho\ P0 \quad (3.4)$$

$$P2 = (\lambda / \mu) 2P0 = \rho 2\ P0 \quad (3.5)$$

$$Pn = (\lambda / \mu) n\ P0 = \rho n P0 \quad (3.6)$$

Where P_0 = probability that there are zero trucks in the queuing system.

P_1 = Probability that there is one truck in the queuing system.

P_2 = Probability that there are two trucks in the queuing system.

P_n = Probability that there are n trucks in the queuing system.

Where n is the number of trucks available in the haulage system. Even in situations with high loading rates, it is extremely likely that trucks will be delayed by waiting in line to be loaded. The queue length will have no definitive pattern when arrival and service rates are not deterministic, so the probability distribution of queue length is based on both the arrival rate and the loading rate [3]. The expected number of trucks in the system LS, can be calculated using the following equation.

$$LS = \rho / 1 - \rho \quad (3.7)$$

The expected number of trucks waiting to be loaded Lq, can be calculated using the formula below;

$$LS = Lq + expected\ server$$

$$LS = Lq + (\lambda / \mu) \quad (3.8)$$

$$Lq = LS - (\lambda / \mu)$$

The average number of trucks in the queuing system, LS and the average time a truck spends waiting in line Wq can be found by applying Little's formula which states that; the long term average number of customers in a stable system, LS, is equal to the long term average effective arrival rate, λ, multiplied by the average time a customer spends in the system, WS [3]. Little's equation captures the relationship between the length of any system and time associated with the system. Mathematically, this is expressed as;

$$LS = \lambda WS \quad (3.9)$$

And can also be applied in the form

$$Lq = \lambda Wq \quad (3.10)$$

Using equations 3.10 & 3.11, the average time a truck spends waiting to be loadedWq can be calculated as follows.

$$Wq = Lq / \lambda \quad (3.11)$$

The average time a truck spends in the system, Ws, is defined as;

$$Ws = Ls / \lambda$$

Results and Discussion

Presentation of inter-arrival time and service time

Table 4: Queuing model outputs.

Variable	Units	Description
P	%	Loader utilization
Ws	Hours	Time spent in system
Wq	Hours	Time spent in queue
Ls	Number of trucks	Expected Number of trucks in system
Lq	Number of trucks	Expected number of trucks in queue

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From the (Table 4), the arrival times for five days at 2-4 hours per day were combined to form a list of all the trucks arrival for that shift. These arrival times were used to calculate the inter-arrival times of the trucks to be loaded. The inter-arrival time (time between each arrival) was calculated by taking the difference between each successive time of arriving trucks. Also, the time taken for the shovel to load trucks was also combined to form a list of the service time of all trucks for that shift.

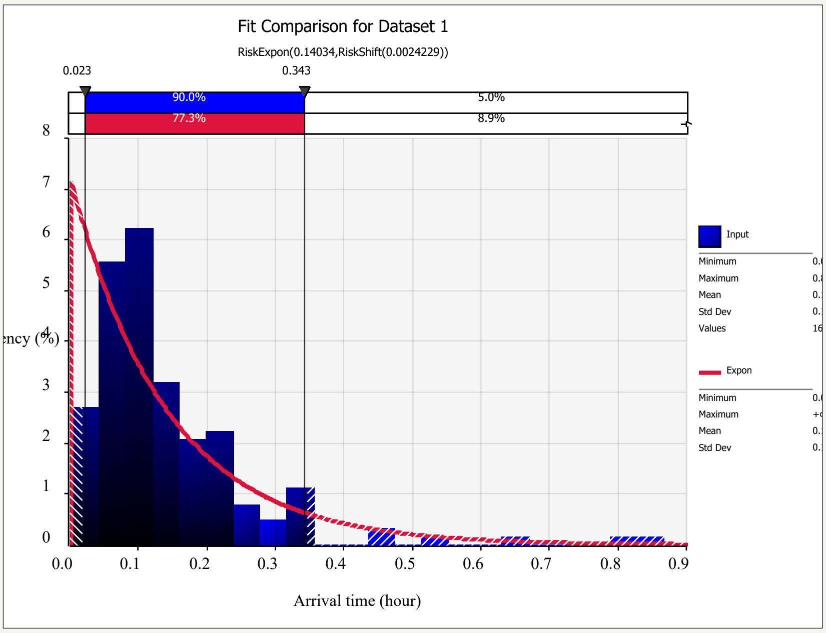

Figure 4: Graph of frequency versusinter-arrival time.

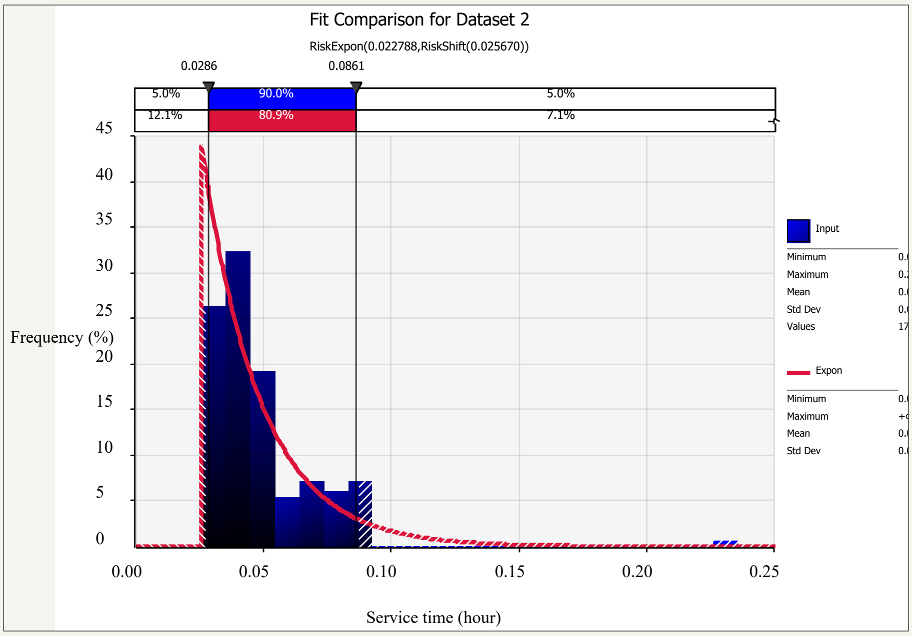

Figure 5: Graph of frequency versus service time.

The inter-arrival times were fitted into the @risk software to create a graph of frequency versus time between new arrivals as shown in (Figure 4). Frequency is represented as a percentage of the total number of arrivals that occurs during the shift and arrival times in hours. The graph shows that the system follows an exponential manner which is an adequate fit for the inter-arrival times of trucks in the system. Also @risk software was able to compute the mean arrival time, standard deviation, minimum and maximum for both normal and exponential distribution as shown in the (Figure 5).

From (Figure 4) the minimum is 0.00330hr,the maximum is 0.8666hr,the mean arrival times is 0.1436hr and standard deviation is 0.1283 for a normal distribution while minimum is 0.00242hr,maximum is +∞,mean arrival time is 0.1428hr and standard deviation is 0.1403 for an exponential distribution.

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The list of service times were fitted into the @risk software to create a graph of frequency versus service time with frequency represented in percentage of the total number of service rendered and service time represented in hour. (Figure 5) indicates that the service time follows an exponential distribution. The mean service time and standard deviation was automatically computed by @ risk software and it can be shown in the (Figure 5). The software computes minimum to be 0.0258.maximum to be 0.2358 mean service time to be 0.0486 and standard deviation to be 0.0225 for a normal distribution while minimum to be 0.0257,maximum to be +∞,mean service time to be 0.0485 and standard deviation to be 0.0228 for an exponential distribution.

Calculations of input and output characteristics of m/m/1: fcfs/∞/∞ model

From the graph, the mean arrival times is 0.1428hr and mean service time is 0.0485hr

$$Arrival\ time = 1/\lambda 4.1$$

$$\lambda = arrival\ rate = 1/(arrival\ time)$$

$$\lambda = 1/0.1428 = 7.0\ trucks/hour$$

$$Service\ time = 1/\mu \quad (4.2)$$

$$\mu = service\ rate = 1/(service\ time)$$

$$\mu = 1/0.0485 = 20.6 \simeq 21\ trucks/hour$$

From equation 3.2, utilization factor $\rho = r/c = \lambda / c\mu$

$$\lambda = 7 trucks/hour$$

$$\mu = 21\ trucks/hour$$

$$c = 1$$

$$\rho = 7/(1 \times 21) = (1)/3 = 33.3\%$$

Utilization factor = 33.3%

From Equation 3.3, the probability that there are no trucks in the system, Po = 1-ρ

$$Po = 1 - 1/3 = 2/3 = 0.66 = 66.6\%$$

Probability that the serve is not free, that is there is a minimum of one truck in the system;

$$(P \geq 1) = 1 - Po$$

$$(P \geq 1) = 1 - 2/3 = 0.33 = 33.3\%$$

This means that 66.6% of the time, the server would be free and 33.3% of the time there would be at least one truck in the system.

Probability that there are no trucks queuing = Po + P1

From Equation 3.4, P1 = ρP_o

$$P\ (no\ queue) = Po + \rho Po$$

$$P\ (no\ queue) = 2/3 + [1/3 \times 2/3] = 2/3 + 2/9 = 8/9 = 0.88 = 88.8\%$$

About 88.8% of the time, there will be no queue.

From Equation 3.7, the expected number of trucks in the system, $Ls = \rho/(1-\rho)$

$$Ls = (1/3)/(1-1/3) = 1/3 \div 2/3 = 1/2 = 0.5$$

From Equation 3.8, the expected number of trucks in the system, $Lq = Ls - \lambda/\mu$

$$Lq = 1/2 - 7/21 = 1/6 = 0.16$$

From Equation 3.12, the average waiting time in the system $Ws = Ls/\lambda$

$$Ws = 1/2 \div 7 = 1/14 = 0.0714hr\ (04:17\ in\ min/sec)$$

From Equation 3.11, the average waiting time in the queue $Wq = Lq/\lambda$

$$Wq = 1/6 \div 7 = 1/42 = 0.0238hr\ (01:27\ in\ min/sec)\ 3$$

Result of the input and output variables

The result from the calculation of the input and output are shown in the (Table 4).The queue will not have an impatient truck since it would be unrealistic for haul trucks not to join the line to be loaded regardless of how many trucks are already waiting. There would also be no jockeying for position since trucks form single line waiting to be served. The queuing model M/M/1: FCFS/∞/∞ is appropriate for this research because truck data from 12th to 16th October was examined and used to verify the queuing model created. This queuing model is useful for analysing the efficiency of mining haulage and loading operations for the configurations in which they are currently operating. The amount of time trucks spend waiting to be loaded, Wq, and the server utilization, ρ, are both indicators of how efficiently the system is operating. The larger the values of Wq, the longer trucks are spending idling waiting at the loaders, burning fuel without contributing to the haulage process. The server utilization indicates what proportion of operational time loaders are actually in use. Both of these values can be combined with costing data for the equipment in use to find out how much money is being spent on idling equipment.

Result shows that the arrival rate of the entire shift is 7 trucks per hour and service rate is 21 trucks per hour, this means that on an average, 7 trucks enters the system that is, every 8.59minsa truck arrives in the queue. And on average, 21 trucks are being served per hour meaning that every 2.86min, a truck leaves the system. Analysis also shows that the service rate is more than the arrival rate and this implies that there is going to be an increase in the idle probability. At every 66.6% of the time, the system is idle, in order to utilize the idle time, about 8 to 9 trucks can be added to the number of trucks entering every hour and by so doing the system has been duly optimized by maximizing the number of trucks entering per hour.

From (Table 5), the time trucks spent waiting to be loaded Wq is 1:27min/sec, with Wq having a smaller value, the waiting time is at a reduced level therefore, there is no problem of unnecessary burning of fuel while waiting. Also, the arrival and service rate were confirmed to fit exponential distributions. Optimization has been carried out by increasing the number of trucks entering per hour by 8 to 9trucks, and this will lead to an increase in productivity of the mine, efficient operation of the system and unnecessary cost in production process (Table 6).

Table 5: Result for inter-arrival time and service time between 12th to 16th of October, 2015.

S/N	Interarrival Time (min/sec)	Interarrival Time (hr)	Service Time (min/sec)	Service Time (hr)
1	02:35	0.0431	03:27	0.0575
2	06:52	0.1144	03:47	0.063
3	11:18	0.1883	04:43	0.0786
4	11:39	0.1942	04:50	0.0805
5	05:49	0.0969	03:58	0.0661
6	05:45	0.0958	05:26	0.0905
7	12:24	0.2066	04:09	0.2358
8	07:59	0.133	04:26	0.0738
9	27:33:00	0.4591	05:04	0.0844
10	00:16	0.0044	04:59	0.083
11	09:00	0.15	04:47	0.0797
12	12:46	0.2127	05:09	0.0858
13	13:40	0.2277	05:15	0.0875
14	15:07	0.2519	04:20	0.0722
15	19:20	0.3222	04:05	0.068
16	13:20	0.2222	05:22	0.0894
17	04:18	0.0716	04:04	0.0677
18	11:56	0.1988	04:22	0.0727
19	21:20	0.3555	04:55	0.0819
20	15:28	0.2577	04:50	0.0805
21	06:25	0.1069	05:10	0.0861
22	10:14	0.1705	4;25	0.0736
23	20:17	0.338	04:08	0.0688
24	12:08	0.2022	05:29	0.0913
25	03:11	0.053	05:20	0.0888
26	13:02	0.2172	01:45	0.0292
27	02;25	0.0431	02:16	0.0377
28	02:27	0.0408	01:45	0.0292
29	08:27	0.1408	01:36	0.0267
30	03:45	0.0625	02:24	0.04
31	10:03	0.1675	01:57	0.0325
32	01:51	0.0308	02:44	0.0455
33	02:32	0.0422	02:09	0.0358
34	06:32	0.1089	02:17	0.038
35	04:43	0.0786	02:19	0.0386
36	02:55	0.0486	02:04	0.0344
37	04:59	0.083	01:51	0.0308
38	01:24	0.0233	02:10	0.0361
39	01:59	0.033	01:50	0.0305
40	02:30	0.0416	01:53	0.0313

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41	07:28	0.1244	02:47	0.0464
42	07:15	0.1208	01:46	0.0294
43	00:15	0.0041	02:38	0.0438
44	08:54	0.1483	02:16	0.0377
45	01:00	0.0166	03:01	0.0503
46	03:37	0.0602	03:06	0.0517
47	02:40	0.0444	03:54	0.065
48	06:11	0.103	01:43	0.0286
49	02:56	0.0488	02:11	0.0363
50	06:01	0.1002	02:46	0.0461
51	01:55	0.0319	02:35	0.043
52	04:23	0.073	01:56	0.0322
53	04:57	0.0825	03:08	0.0522
54	12:01	0.2002	03:00	0.05
55	02:15	0.8666	05:11	0.0863
56	20:16	0.0375	03:08	0.0522
57	10:47	0.1797	03:46	0.0628
58	02:44	0.3377	03:02	0.0505
59	00:12	0.0033	02:28	0.0411
60	09:00	0.15	04:58	0.0827
61	07:55	0.1311	02:34	0.0427
62	01:50	0.0305	02:31	0.0419
63	01:59	0.033	01:59	0.033
64	01:00	0.0166	02:44	0.0455
65	11:01	0.1836	05:07	0.0852
66	05:31	0.0919	03:21	0.0558
67	07:36	0.1266	02:29	0.0413
68	01:03	0.0175	02:20	0.0388
69	12:10	0.2027	03:10	0.0527
70	06:24	0.1066	04:00	0.0667
71	12:13	0.2036	02:52	0.0477
72	04:14	0.0705	02:34	0.0427
73	18:21	0.3058	02:25	0.0402
74	01:10	0.0194	04:39	0.0775
75	38:53:00	0.648	03:26	0.0572
76	49:23:00	0.823	01:59	0.033
77	15:25	0.2569	03:19	0.0552
78	07:46	0.155	02:59	0.0497
79	07:05	0.118	15:45	0.2625
80	11:30	0.1916	01:47	0.0297
81	06:22	0.1061	02:20	0.0388
82	04:15	0.0708	02:42	0.045
83	20:40	0.3444	04:49	0.0747
84	11:36	0.1933	03:40	0.0611
85	08:52	0.1477	05:08	0.0855

86	04:39	0.0775	02:57	0.0491
87	10:27	0.1741	03:25	0.0569
88	06:52	0.1144	03:55	0.0652
89	14:01	0.2336	04:10	0.0694
90	08:10	0.1361	03:28	0.0577
91	08:00	0.1333	03:15	0.0541
92	12:27	0.2075	05:17	0.088
93	10:37	0.1769	02:58	0.0494
94	08:09	0.1358	04:50	0.0805
95	05:34	0.0927	04:55	0.0819
96	17:11	0.2863	05:26	0.0905
97	10:08	0.1688	03:27	0.0575
98	14:25	0.2402	04:47	0.0797
99	03:59	0.0663	05:09	0.0858
100	08:02	0.1338	04:04	0.0677
101	13:42	0.2283	04:22	0.0727
102	05:47	0.0963	04:09	0.0691
103	20:34	0.3427	05:10	0.0861
104	05:05	0.0849	05:25	0.0902
105	31:36:00	0.5266	05:43	0.0952
106	16:55	0.2819	04:05	0.068
107	07:21	0.1225	01:35	0.0263
108	09:19	0.1552	02:39	0.0441
109	26:58:00	0.4494	02:34	0.0427
110	08:58	0.1494	02:05	0.0347
111	06:25	0.1069	02:13	0.0369
112	07:05	0.118	01:59	0.033
113	05:23	0.0897	02:41	0.0447
114	06:29	0.108	02:45	0.0458
115	05:20	0.0888	03:09	0.0525
116	05:30	0.0916	03:29	0.058
117	03:10	0.0527	02:29	0.0413
118	05:50	0.0972	02:23	0.0397
119	06:16	0.1044	02:24	0.04
120	03:44	0.0622	03:14	0.0538
121	03:30	0.0583	02:22	0.0394
122	05:18	0.0883	02:09	0.0358
123	07:33	0.1258	02:52	0.0477
124	05:43	0.0952	01:39	0.0275
125	03:00	0.05	01:42	0.0283
126	12:06	0.2017	02:00	0.0333
127	03:39	0.0608	01:57	0.0325
128	07:01	0.1169	02:28	0.0411
129	04:20	0.0722	01:50	0.0305
130	05:49	0.0969	01:49	0.0302

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131	13:41	0.228	02:10	0.0361
132	04:29	0.0747	02:35	0.043
133	04:53	0.0813	01:57	0.0325
134	05:09	0.0858	02:38	0.0438
135	04:41	0.078	02:37	0.0436
136	04:27	0.0741	02:08	0.0355
137	03:42	0.0616	02:59	0.0497
138	09:55	0.1652	02:55	0.0486
139	04:55	0.0819	02:16	0.0377
140	04:47	0.0797	01:51	0.0308
141	03:15	0.0542	01:49	0.0302
142	01:54	0.0316	02:18	0.0383
143	05:56	0.0988	02:14	0.0372
144	03:37	0.0602	03:21	0.0558
145	04:21	0.0725	01:35	0.0263
146	06:27	0.1075	03:00	0.05
147	04:49	0.0802	01:48	0.03
148	19:24	0.3233	02:18	0.0383
149	14:49	0.2469	02:08	0.0355
150	05:58	0.0994	02:44	0.0455
151	06:49	0.1136	03:51	0.0641
152	07:22	0.1227	02:43	0.0452
153	04:03	0.0675	01:45	0.0291
154	03:56	0.0655	01:59	0.033
155	06:10	0.1027	01:33	0.0258
156	04:09	0.0691	02:02	0.0338
157	07:32	0.1255	02:08	0.0355
158	04:01	0.0669	02:12	0.0366
159	06:42	0.1116	01:45	0.0291
160	05:11	0.0863	01:55	0.0319
161			02:04	0.0344
162			02:15	0.0375
163			02:50	0.0472
164			03:25	0.0569
165			02:35	0.043

Table 6: Result of the input and output variables.

Basic characteristics	Result	Remark
λ	7 trucks/hour	Input
µ	21 trucks/hour	Input
C	1	Input
ρ	33.30%	Output
Ls	0.5	Output
Lq	0.16	Output
Ws	0.0714hr (4:17 in min/sec)	Output
Wq	0.0238hr (1:27 in min/sec)	Output

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Conclusion

Time of arrival at excavator area (hr/min/sec), time of first load by excavator into the truck (hr/min/sec), number of loads, time of departure from the excavator (hr/min/sec) and time taken to load trucks gotten from the Lafarge (sagamu plant) was analysed to develop a model M/M/1: FCFS/∞/∞, based on the assumption of single channel and single server with infinite number of queues. The model was used to calculate the arrival rate, service rate and number of server which at the end of it gives 7turcks/hour, 21trucks/hour and 1loader respectively. @risk software was used to fit both service and inter-arrival into exponential distribution. The result shows that as the size of the haulage truck being used increases, shovel productivity increases and truck productivity decreases. An effective number of trucks must be chosen that will effectively utilize idle time, increase productivity and reduce cost of production to the barest minimum. The result shows 66.6% idle time; this indicates that an additional 8 to 9 trucks can be added to the company truck fleet to make use of the idle time; since time translate to cost.

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