Simulation Model for Outbound Logistics in Quarry Business

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Abstract—**This study of outbound logistics is part of quarrying process where final products are being served to customers. An increasing of customer demands within limited serving space causes a higher total flow time customer spent in the system which also leads to longer queues. The study aims to simulate a current outbound logistics for a quarry business using ARENA simulation model and analyze truck queueing and loader scheduling policy that help reduce total flow time of truck and loader's travel time. An outbound logistics includes all activites begins from when a truck entering weight station to when the truck leaves the system after a final weighing. After testing different methods in two policies, the results show that the *Combined Policy* of *Shortest Processing Time (SPT) policy* and *Shortest Travelling Time (STT) policy* is recommended for the outbound logistics management. By implementing the *Combined policy* into the current system, not only it can help decrease total flow time a customer spent in the system, it can also benefit the company on a better operational efficiency since it allows the system to be able to serves a higher number of incoming customers using the same available resources.**

Index Terms—**simulation, outbound logistics, quarry, queuing policy, scheduling policy.**

I. Introduction

QUARRY business is similar to mining business and has a strong bond to construction industry. University of Leicester, geology department, defined quarry as place where materials were extracted from the surface of earth [1]. These materials then went through crushing and screening process until they became a final product called aggregate – a material that can be used in construction such as crushed rock, sand, fine dust etc. The main activity of quarry in this paper involves aggregate production and serving them into customer's trucks.

Since aggregate is considered as one of the main materials for construction work, the more construction and infrastructure projects, the more demand for aggregates from quarry business. ASEAN trend has immensely affected the growing in public construction investments in Thailand. This case study is in Chiang Rai, Thailand which is one of the members of ASEAN Economic Community (AEC). Chiang Rai got a great impact from the open of AEC as it becomes a northern gate connects Thailand to its neighboring countries; hence, a lot of construction and infrastructure projects are blooming within the province.

The Bureau of the Budget [2] announced that the budget of 2018 fiscal year assigned to Chiang Rai province was a total of 13.603 billion THB, in which 4.722 billion THB belonged to government construction projects within Chiang Rai. A study done by Krungsri bank [3] also forecasted that for the next two years, Thailand public construction business would grow on average of 8%-12% per year. The future projects supported by the government ensure a strong demand in aggregate market using in construction within area.

With an increasing in customer demands within limited serving space, a queue issue raises a concern of customer's total flow time spent in the system. The model is be built base on the current state of the system using data collected in the month of May and June, 2018. There are three types of customer arriving based on hourly schedule, in which the amount of customer differs throughout the day on a weekly pattern and each customer is with a probability of choosing one out of seven aggregate products. The production rate, although remains at constant rate throughout the production process, cannot be adjusted individually base on each product. This implies that it is impossible to increase a production of a certain product while reducing the production of the rest. This combination of customer arrivals base on schedule and how a quarry production line operates require a need of using simulation model to analyze the current outbound logistics system and the problem of the truck queuing and loader's scheduling. Hence, this paper is focused on truck's flow time and loader's time traveling reduction.

This paper aims to determine policies for truck queueing and for loader scheduling policy. An optimized alternative for truck queuing and loader scheduling policy can help improve the outbound logistics operation of quarry business. A large number of customer truck leads to a complication and complexity in managing the logistics process and affects limited serving space and safety. This study and a new policy use monthly production plan as a simulation timeframe.

The following definitions are used in this paper. *Outbound logistic* defines as logistics activities related to customers end in which includes all the activities from when an empty truck enters the system until a full truck leaves the system. Fig. 1 shows a flow chart of the outbound logistics activities. *Total flow time* means the time a truck spent in the system; from the time a truck first enters the system at

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weight station to the time it leaves the system after weight station. *Work day* means a 9-hr operation in which there are six total work days per week. *Production hours* refers to the current quarrying production hours with a daily average runs time of 5.5 hours. *Truck* represents customers in the system. There are types of trucks: 6-wheeler (6T), 10-wheeler (10T), and double-axis-trailer truck (DT). This study uses *Truck* and *Customer* interchangeably. *Products* refers to final aggregate products that are ready to sell; currently there are seven types of products. *Production rate* refers to rate of production of each product which is modeled in discrete manner in this study and that the breakdown of each product cannot be adjusted accordingly. *Loading time* differs base on type of trucks and refers to the process that a loader serves aggregate to truck. Please noted that products cannot be mixed, and this system assumes a full truck load when a truck is served. *Weight carry* differs base on type of truck and type of products. *Traveling time (of loader)* refers to time loader takes to travel from one aggregate stockpile to another stockpile and is measured in second.

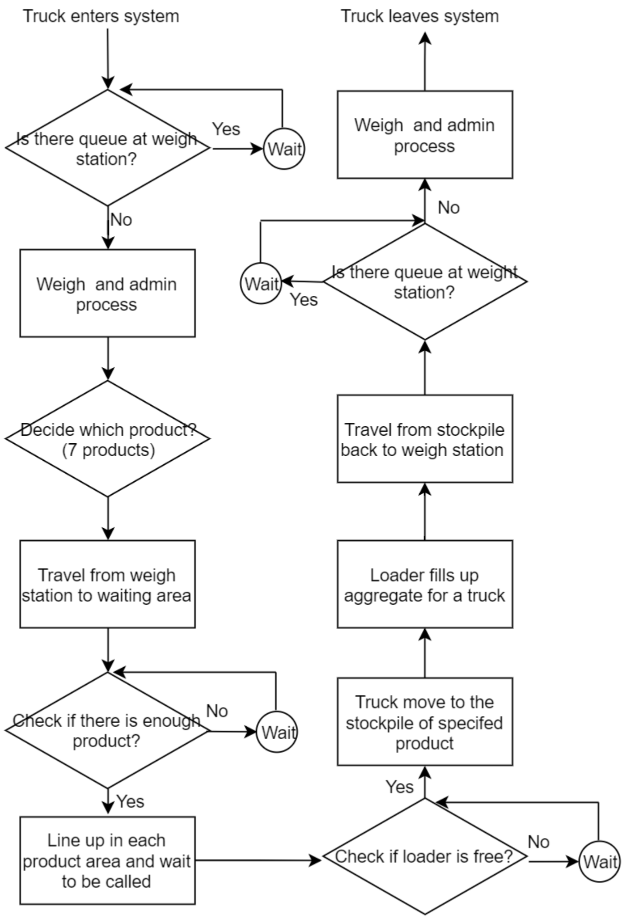

Fig 1: Flowchart of Outbound Logistics

In this paper, Shortest Processing Time (SPT), Shortest Traveling Time (STT), and Maximum Number in Queue (MaxQ) policy are presented to solve either truck queuing or loader scheduling policy. The paper is organized into the following sections: Section 2 describes the literature review on how simulation model can be used in quarry business especially using Arena simulation software, and a few theories on queuing and scheduling policy. Section 3 describes solution methodology. Section 4 describes result of the experiment. Finally, section 5 describes conclusion and suggestion on future work.

II. Literature Review

The method of simulation provides a risk-free environment and saves money and time as compare to experimenting on a real asset; hence, many industries choose a simulation method as a mean to study any operational issue in order to improve the current system. Arena is one of a well-known software that is widely selected to simulate a real-world problem into a simulation model to help test, analyze, and improve the system.

Arena is a discrete event simulation software bases on SIMAN language that involves the use of flowchart and data modules. Flowchart modules define the processes to be simulated while data modules describe the characteristics of various process elements i.e. variables, resources, and queues. In the process of simulation, entities are created and as they move through the model, they are acted on by the module. Arena also contains function such input and output analyzer that fit the model and historical data to statistical distributions [4]. In additional to this, ARENA can help analyze bottleneck for long duration process in order to reduce waiting time and reduce flow time [5].

In the mining and quarry industry, the use of simulation model has been widely used and Arena is selected as a tool to simulate a real problem. However, most study focuses on mining production planning and efficiency improvement of open-pit extraction logistics (inbound logistics) whereas this study focus on the improvement of outbound logistics. Ataeepour and Baafi [6] showed that Arena could help prove that dispatching policy was more productive than non-dispatching policy since it could minimize the queue time of trucks in open-pit area when waiting to be served by shovels. Kang et.al [7] utilized Transporter flowchart model in Arena to study productivity of truck movement transporting rock. Their study also simulated truck's speed reduction at the intersection as well as integrated a map representing the topography of the jobsite. Planning schedule, mining plan, and forecasting production to reduce variance of the actual production could also be addressed using Arena simulation [8]. In addition to this, although a quarry production is close to continuous behavior, it can be modeled using discrete tools with a very precise presentation of the continuous behavior by modeling the material flow as big portions that are treated as discrete entities on the modelling code [9].

This research focuses on testing and analyzing different policies for truck queuing policy and loader scheduling policy. Since policy requires time to implement and training, they cannot be changed regularly. Hence the policy needs to be tested and analyzed using simulation model in order to reduce time and investment.

Queue begins when trucks who need the service come into a system. The queue process is a process starting from truck arrives into a service facility, waits in the queue line in order to be served, to truck finally leaves the facility after the

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completion of the service [10]. Queuing theory is the study of queue or waiting lines. It includes but not limited to topics such as expected waiting time in the queue, average time in the system, expected queue length, and expected number of customers served at one time [11]. The queuing theory can be applied with statistical knowledge on flow time, in order to improve duration time [12]. Shortest Processing Time is a well-known rule used in the field of job-shop scheduling and is known to be optimal if the objective is to minimize the average flowtime [13]. Hence, this paper leverages the idea of shortest processing time into a testing policy for truck queuing policy.

Moreover, the paper also aims to minimize the traveling time of loader transporting between different aggregate stockpiles by using two policies: shortest path problem and maximum queuing of truck. Shortest path problem is a study of network flow in order to optimize the route and widely used in many transportation problems [14]. The method relies on the logic of finding the shortest path or route from a starting point to a final destination [15]. The maximum queuing method, on the other hand, is based on the idea of identifying the longest product queue lines. Hence, this paper leverages the two ideas into two testing policies for loader scheduling policy.

III. Methodology

To simulate a current system using ARENA software, the following steps were carried out: (A) Survey and collect data on the current state on quarry production and outbound logistics process, (B) Develop the simulation model, (C) Verify and validate the simulation model, (D) Calculate number of replica, and (E) Analyze and test queuing methods.

A. *Survey and collect data on the current state*

At current state, there are seven aggregate products being served to three types of customers. Each product is assumed to be produced at a constant rate in unit of ton per minute. Loading time, moving time and weight-admin processing time were collected. Table I represents production rate of each product, demand of each type of product for each customer group, and weight carry distribution whereas Table II represents other distribution used in the model. In addition to this, customers arrival assumes to follow a weekly schedule pattern in hourly basis as can be seen in Fig. 2.

Table I
DATA USED IN THE BASE MODEL PART I

Product	Production Rate (ton/min)	Probablity of choosing a product			Data Distribution: Weight Carry (ton)		
		6T	10T	DT	6T	10T	DT
1	0.71	11	3.17	22.36	1+GAMM(0.59, 12.5)	11+20*BETA(0.37, 1.47)	8+WEIB(20.70, 7.17)
2	2.5	33.09	56.09	25.13	2+WEIB(6, 3.69)	NORM(14.10, 1.53)	10+ERLA(4.56, 4)
3	0.64	18.13	7.84	5.52	NORM(8.06, 2.10)	UNIF(11.06, 14.22)	5+26*BETA(1.21, 0.37)
4	1.27	27.12	28.21	28.88	WEIB(8.39, 4.64)	NORM(13.20, 1.67)	3+WEIB(26.60, 8.57)
5	0.13	0.45	0	2.69	TRIA(3.18, 6.09, 9)	0	WEIB(30.23,35.40)
6	0.51	3.16	3.83	7.63	3+LOGN(4.71, 2.60)	NORM(29.4, 2.86)	8+WEIB(21.60, 12.80)
7	0.64	7.05	0.86	7.79	3+LOGN(10.4, 13.70)	NORM(29.4, 2.86)	NORM(30.40, 2.86)

Table II
DATA USED IN THE MODEL PART II

	Loading time (min)	Moving time to/from Weigh Station (min)	Weigh & Admin Processing Time (sec)
6T	1.23+WEIB(0.756,2.39)	UNIF(0.25,0.70)	UNIF(34.01,83.42)
10T	2+2*BETA(1.81,2.15)	UNIF(1.70,2.50)	UNIF(34.01,83.42)
DT	TRIA(3.52,4.19,5.88)	UNIF(2.40,3)	UNIF(34.01,83.42)

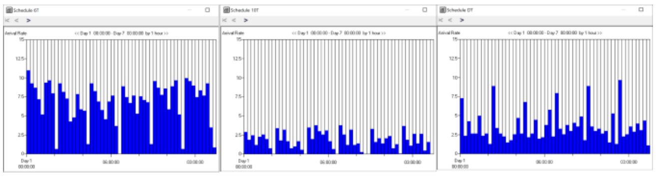

Fig. 2: Arrival Schedule of 6T, 10T and DT Truck

B. *Develop the simulation model*

There are four major parts that comprise the model using ARENA: (1) customer arrival, (2) production process, (3) weighing operation, and (4) loading operation, as can be seen in Fig. 3. In this study, when a new testing policy is implemented, there will be an adjustment or add-on modules in these major parts.

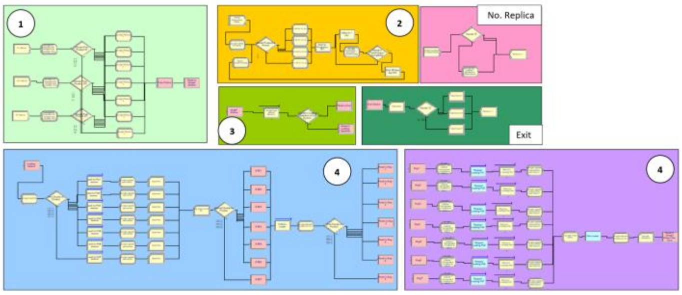

Fig 3. Simulation Configuration

(1) *Customer arrival*: Three types of trucks were created based on a weekly schedule pattern on hourly basis as can be seen in Fig. 3. Each truck knows which type of aggregate products it wants and how much it can carry. The probability of choosing a product and weight of each product that each truck can carried can be seen in Table I. Please noted that the weight carry depends on both type of truck and type of products based on the real collected data.

(2) *Production process*: Since the operation time is 9 hours but the current production line runs on average of 5.5 hours per day, the study assumes four production patterns in the current simulation model. The four production patterns are the following: (1) 8:00-13:30, (2) 9:00-14:30, (3) 10:00-15:30 and (4) 11:00-16:30. Each pattern is assumed with a 0.25 probability of occurring. The 5.5 hours of production is considered a normal operation during low season production since there are always a pause on production such as an uncertainty of rain. In addition to this, Table I also illustrates the production rate in ton/min for each product.

(3) *Weighing operation*: The process of weighing also includes the administration work; the time it takes to complete both weigh and administration process can be seen in Table II. There are two times when a truck enters a weigh operation. First is when an empty load truck arrives at the weigh station and later is when the truck is fully loaded and is about to leave the system. In addition to this, Table II also displays the time it takes for a truck to move from weigh station to the waiting area and the time the truck travels back from a stockpile area to the weigh station.

(4) *Loading operation*: The loading operation is when a loader fills up an aggregate for a truck. The time it takes to fill can be seen in Table II, which depends on the type of truck. In the current model, FIFO queue is used when loader calls for a customer truck to be served. In addition to this, this study also considered a traveling time the loader travels from one stockpile to another stockpile. Traveling time (in second) can be seen in Table III.

TABLE III
LOADER'S TRAVELING TIME BETWEEN STOCKPILE (SEC)

		Product Position						
	sec	1	2	3	4	5	6	7
Product Position	1	0	19	32	39	45	47	50
	2	19	0	12	19	26	27	30
	3	32	12	0	7	13	15	18
	4	39	19	7	0	6	8	11
	5	45	26	13	6	0	2	4
	6	47	27	15	8	2	0	3
	7	50	30	18	11	4	3	0

C. Verify and validate the simulation model

For the simplicity of verification purpose, the model was run under *simpler* characteristics i.e. fixed number of truck arrivals instead of using schedule, fixed production rate, fixed weight carries for each type of truck. Hence the study was able to verify production process, selling amount, as well as number of completed trucks.

Since the study is interested in a particular time period and because productions always exceed demands, the system never reach a steady state. Hence, the system is a terminating system. When running the system, both initial state i.e. initial volume of each product and run length are specified.

The study uses two-sample t-test with a significant level of 0.05 to validate the model against a real data. Using the following parameter: number of each type of trucks out in each week, total time spent for each type of truck, and amount sold in each week of each product, the study proved that all the selected parameter passes the statistical test since the p-value is greater than 0.05 for all parameters. Therefore, it can be concluded that with 95% confidence there is no significant difference occurred between the model and the real data sampling. Table IV and Table V show the p-value for the selected parameter.

TABLE IV
PARAMETERS USED FOR VALIDATION

Number of trucks (1 week)					Total time spent for each truck				
Truck	Source	Avg.	Std.	P-value	Truck	Source	Avg.	Std.	P-value
6T	Real	344.9	73.8	0.486	6T	Real	30.3	24.0	0.073
	Model	365.6	10.2			Model	35.4	27.2	
10T	Real	81.3	26.0	0.164	10T	Real	35.7	34.8	0.631
	Model	96.9	5.1			Model	37.3	25.7	
DT	Real	192.1	18.8	0.998	DT	Real	45.0	39.2	0.533
	Model	192.2	6.5			Model	47.4	33.8	

TABLE V
PARAMETERS USED FOR VALIDATION (CONT'D)

Amount sold in each week of each product				
Product	Source	Avg.	Std.	P-value
1	Real	1533.3	699.7	0.954
	Model	1549.1	69.4	
2	Real	2862.9	504.6	0.391
	Model	3039.8	124.5	
3	Real	811.7	278.5	0.467
	Model	893.5	57.2	
4	Real	2700.5	1023.8	0.901
	Model	2650.5	53.8	
5	Real	182.8	209.3	0.853
	Model	167.5	34.0	
6	Real	588.3	314.9	0.744
	Model	629.1	63.3	
7	Real	495.5	480.9	0.114
	Model	832.2	81.1	

D. Calculate number of replicas

This study uses Sequential Sampling method to attain a desired 95% confidence interval of chosen parameters. This method helps with variance reduction and allows the simulation to run until it reaches the specified confidence interval halfwidth before stops the run at "N" replication [16]. After running a simulation, the study found that a 101 replication results in 95% confidence interval.

E. Analyze and test policies

There are two main parts that a testing policy could be implemented into. First is the truck queueing part and second is loader scheduling part. In this study, four policies were implemented into the model. The first one focuses on improving truck queueing part; the next two focus on improving loader scheduling part; and the last one focuses on improving both truck queueing and loader scheduling part.

The following contains logic that is used to build each testing policy:

(1) *Truck Queuing Policy:*

- *Shortest Processing Time (of Customer) Policy (SPT)*

This policy gives priority to truck with lower processing time. Since the average processing time for 6T, 10T and DT is 2:04 min, 2:54 min and 4:41 min, respectively, the priority for 6T, 10T, DT is in descending order. This implies that when all the

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trucks waiting in queue, truck with higher priority will pass truck with lower priority. For the SPT policy to work, the priority attribute is created in addition to the base model. Noted that this policy does not affect loader scheduling; hence, loading still serves trucks based on FIFO.

(2) *Loader Scheduling Policy:*
-Shortest Traveling Time (of Loader) Policy (STT)
This policy applies the idea of shortest traveling time of loader. Since there is only one loader serving in the system choosing among seven products, STT policy will ask the loader to move to the product stockpile which locates next (closest) to the current one. In this policy, it is also assumed that the loader cannot return to the previous stockpile that it had served before the current stockpile. This can be concluded that the pattern that loader will move will be 1,2,3,4,5,6,7 then 7,6,5,4,3,2,1. In addition to this, since the goal is to minimize loader traveling time, a batch of "n" trucks is allowed. This means that if there happens to have multiple trucks who request the same product as to where loader is currently serving, loader will also serve those few more trucks depending on a designated batch size before move to the next stockpile. Noted that although batching trucks of the same product could help enhance loader scheduling policy since it would reduce traveling distance of loader, it is not necessary means that the higher batch would result in a better process performance [17].

(3) *Loader Scheduling Policy:*
-Maximum Number in Queue Policy (MaxQ)
This policy utilizes the idea of identifying the bottleneck in a process and gives priority of work on that bottleneck area first. The physical area constraint of the quarry limits the number of trucks that could be in the system at the same time. This implies that the higher queue in a particular product line results in the bottleneck of the system since it creates traffic and takes a lot of space. In MaxQ policy, loader will first serve the longest queue length of a product. To simply put, the system will analyze which product line has the longest queue at a current time and gives signal to loader to work on that product line. In addition to this, a batch of "n" truck is also be applied if within the current serving product line has multiple trucks waiting at the point in time. Once loader finishes serving a truck and checking if there is a need for batch serving, the system will re-evaluate the next longest product line.

(4) *Combined Policy (SPT & SPP)*
The combined policy help improving both truck queueing and loader scheduling part. This policy selected the best policy from truck queueing policy (SPT) and loader scheduling policy (STT) and combined them together.

IV. RESULTS

Using simulation model to analyze current system, the study found that in the current state, the system has an average total flow time of 39.22 min for all type of trucks. This high total flow time of truck was partially resulted from a long average waiting time for production of product 1 and product 4: 27.39 min waiting time for product 1 production and 63.41 min waiting time for product 4 production. This indicates that there is a bottleneck issue in the production part. However, since production rate of the current system cannot be adjusted accordingly, the study intends to use the simulation model to test truck queueing and loader scheduling policies in order to improve both the average flow time of a truck in the system and traveling time of loader. Hence, the selected performance measurement are both total flow time of truck and traveling time of loader.

For *Truck Queueing Policy*, only *SPT Policy* is tested against the current model. From Table VI, it can be seen that by applying *SPT Policy* to the current simulation model, it can decrease 5.5 minutes of the average total flow time spent of a truck from 39.22 minutes to 33.72 minutes and decrease 627 seconds of monthly travel time of loader.

On the other hand, for *Loader Scheduling Policy*, two testing methods, *STT Policy and MaxQ Policy* are tested against the current model**.** Since the batch serving trucks are allowed for loader scheduling policy, only the selected best batch setting is presented in the testing result in Table VI. After running a range of batch "n" from n = 1 to n =8 in each policy setting, the study found that batch n = 2 yields the best pair of total flow time and monthly traveling time for both *STT Policy and MaxQ Policy*. From Table VI, it can be concluded that for *Loader Scheduling Policy*, *STT Policy* with batch n = 2 surpass *MaxQ Policy* with batch n = 2. *STT Policy* help reduces the total flow time by 4.07 minutes and reduces loader's traveling time of one month by 3,108 seconds whereas *MaxQ Policy* help reduces by 2.0 minutes and 1,524 seconds per month, respectively.

After identifying the best method setting for both *Truck Queueing Policy* and *Loader Scheduling Policy*, a combination of both is further tested and compare against the current system. The selected combination which makes *Combined Policy* is *SPT* and *STT*. Table VI shows that by using *Combined Policy* at the same time, total flow time and loader's monthly traveling time can be reduced by 10.61 min and 3,168 seconds, respectively. This represents a 27.05% reduction in total flow time and 7.56% reduction in loader's monthly traveling time.

TABLE VI
SIMULATION RESULTS FOR DIFFERENT METHODS IN EACH POLICY

Policy	Batch Setting	Avg Total Time of Truck (min)	Montly Travel Time of Loader (second)
Current model	-	39.22	41,889
Truck queuing policy			
SPT	-	33.72	41,262
Loader scheduling policy			
STT	2	35.15	38,782
MaxQ	2	37.22	40,365
Combined policy			
SPT & STT	2	28.61	38,721

V. CONCLUSION

The simulation model in this study focuses on outbound logistics in a quarry business. The system starts from the time that a truck enters at the weigh station until it leaves after a final weigh at the weigh station.

This paper has investigated methods that can help minimize average total flow time of a truck and loader's monthly traveling time in order to improve outbound logistics system in a quarry business. In *Truck Queueing Policy*, the study recommends *Shortest Processing Time (of Customer) Policy* whereas in *Loader Scheduling Policy*, the study recommends *Shortest Traveling Time (of Loader) Policy*.

By combining the best policy from both *Truck Queuing and Loader Scheduling Policy*, the study also found that the *Combined Policy* help reduce 27.05% of the total flow time from 39.22 min to 28.61 min and 7.56% of the loader's monthly traveling time from 41,889 seconds to 38,721 seconds.

The proposed simulation model in queuing and scheduling policy can help improve the current system without a major equipment investment and an expansion in space area. Future work can be applied in other seasonal settings such as different trend of incoming customers, truck scheduling, and rate of production. In addition to this, the simulation model can be further investigated for a potential of appointment system if a quarry company owns its own fleet management.

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