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Simulation of Trucks Haulage Operation at Ashaka Cement Company in Gombe State, North-Eastern Nigeria

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Abstract
This study examined the simulation of truck haulage operation at Ashaka Cement Company in Ashaka, Gombe State, North-eastern Nigeria. Data collected included cycle time, tonnage of limestone produced and truck capacity. Field data plotted on Microsoft Excel software was used in generating prediction equations through polynomial model expressions. The model was then validated using historical data of truck haulage, and subsequently simulated. Results of the study showed that the optimum cycle time of North-North pit was 39 minutes long, producing 7587 tonnes per day, the cycle time for the North-West pit was 26 minutes, peaking 8100 tonnes per day; and the South-West pit cycle time, lasted 19 minutes and reaching up to 8640 tonnes per day respectively. The findings imply that truck haulage operation in the company has attained optimum production. To sustain this feat, it was recommended that hindrances to production such as boulders hook (over size), buildup of wet material and cleaning-associated delays (rollers, affront feeder) should be minimised to the bearest minimum.

Keywords: *Initial void ratio, natural moisture content, settlement, compression ratio, one-dimensional consolidation.*

1.0 Introduction

Successful mining operations require the transportation of loaded run-of-mine ore to the processing plant and extraction of waste boulders, and overburden from the mine site. Therefore, a choice must be made for an adequate fleet selection which considers precise haulage equipment category and dimensions in order to enhance production efficiency and reduce capital and operating expenses (Balogun, 2024; Namin *et al*., 2023; Owolabi, 2019; Senses and Kumral, 2025). However, choosing equipment for efficient operation often poses substantial obstacles to mine operators (Owolabi, 2019). Therefore, given the high costs of production processes, haulage systems design for surface mining becomes imperative, regardless of differences in extraction outlays, depending on mine planning and mining methods adopted (Askari-Nasab *et al*., 2007; Awuah-Offei, 2016; Balogun, 2024; Firoozi *et al*., 2024; Kokkinis *et al*., 2024: Laurence, 2011). Thus, mines are prone to irregular machine abnormalities and equipment breakdowns due to their dynamic nature (Akbar *et al*., 2023; Gunasegaram *et al*., 2024; Greggi *et al*., 2024; Sun *et al*., 2025; Zhen *et al*., 2025). Suitable simulation systems, therefore, need to be created and developed to drive a powerful haulage system logic due to complex mining environment (Baek and Choi, 2019; Eskandari *et al*., 2013; Nobahar *et al*., 2024; Ondov *et al*., 2025).

Olaleye and Adagbonyin (2011) contend that before putting such policies and decision-making guidelines to the test on an actual system, they need to be subjected to a model trial. As a result, both surface and underground mine haulage systems use a variety of simulation methodologies (Park *et al.,* 2014). Simulation can be used, for example, to forecast metrics related to mine productivity, such as production and equipment utilization, system operating conditions, task time, equipment quantity, dispatch interval, and time spent on each task (Park *et al*., 2016; Park *et al*., 2023; Samatemba *et al*., 2020; Sung *et al*., 2025; Wang *et al*., 2023). Consequently, it is possible to identify the best equipment combinations for potential design and development (Nobahar *et al*., 2022; Salama, 2012; Dindarloo *et al*., 2015), implement equipment dispatch plans (Upadhyah *et al*., 2018), and determine the best haulage routes (Temeng *et al*., 1998; Choi *et al.,* 2009).

A simulation process creates model of an actual system whereby experiments are run on it to either analyze different operating strategies for the system or comprehend its behavior (Olaleye and Adagbonyin, 2011). Fioroni *et al*. (2008) also produced short-term planning schedules by using optimization and simulation models. The monthly schedules for an open-pit mine were created using Lingo optimization software and Arena simulation software, with the goal of minimizing shovel movements, while meeting grade and production requirements. The randomness present in the truck-and-shovel mechanism is captured by the model. In their method, Yuriy and Vayenas (2008) combined a simulation model with a mathematical programming paradigm. The model's reliability goal in this case is to determine time lapse between failures for each fleet by employing a genetic algorithm. Thus, the model's output serves as the simulation model's input. In order to assess how failures affect production rate

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and to estimate fleet availability and utilization, the simulation model replicates mine operations. A model for scheduling a set fleet of trucks for a specific operation was also created by Topal and Ramazan (2010). The model's goal is to reduce truck maintenance costs while taking production targets and other constraints into consideration. The scheduling is done annually over a period of several years. A linear programming model was created by Gurgur *et al.* (2011) to maximize truck allocation in open-pit mining. Constraints such as truck and shovel availability, shovel placement, and road profile are taken care of by the model. Many mines encounter difficulties with material hauling as a result of such system's short-term planning (Al Habib *et al.*, 2023; Blom *et al.*, 2019; Li *et al.*, 2021; Ozdemil and Kumral, 2018; Nikbin *et al.*, 2025; Silva-Junior *et al.*, 2023). As a result, mining operations seldom achieve the expected profit margins because proper planning and consideration of the design of an effective haulage system are lacking (Joko and Mulyono, 2023; Mishra and Mohanty, 2020). Therefore, in order to have an ideal and lucrative outcome from mining activity, there is a requirement for thorough insight into production planning with an efficient truck haulage system (Cervantes and Askari-Nasab, 2017; Gutiérrez-Diez *et al.*, 2024). This study is, therefore, aimed at encouraging truck haulage operations in Ashaka Cement Company's limestone quarry by building a model of truck haulage, and enhancing the simulated model for better efficiency.

2.0 Methodology

2.1 Location and Accessibility of the Study Area

Ashaka Cement Company is located in Ashaka village which is 80 kilometres from Gombe town. The company lies in the Northern part of Gombe between longitude 100 45'N and 110 00'N and latitude 110 15'E and 110 30'E (Gurama *et al.,* 2020). It is located in the North –Eastern in Funakaye Local Government area of Gombe State. It is surrounded by the following villages Bage, Gongila, Badabdi, Bungum, Feshimgo, Maza, Ashaka Gari and the nearest site, Jalingo. Ashaka covers an area of about 5800 km and share boundary with Nafada, Dukku and Kwami Local Government Areas of Gombe State respectively. It also shares boundary with Yobe State.

2.2 Geological Description of the Study Area

Gombe State is part of the Central Nigerian highlands (Abashiya and Sule, 2024; Mayomi *et al.*, 2016). Although Gombe State is mostly flat, there are a few isolated hills in its northern and southern regions. The hill is between 700 and 800 meters above sea level, whilst the plain is roughly 600 meters above sea level. The primary drainage system is the Gongola River, which flows about north-south toward the Benue River Basin. The majority of the river's tributaries pour into the river from the west to the east (Mbaya, 2020).

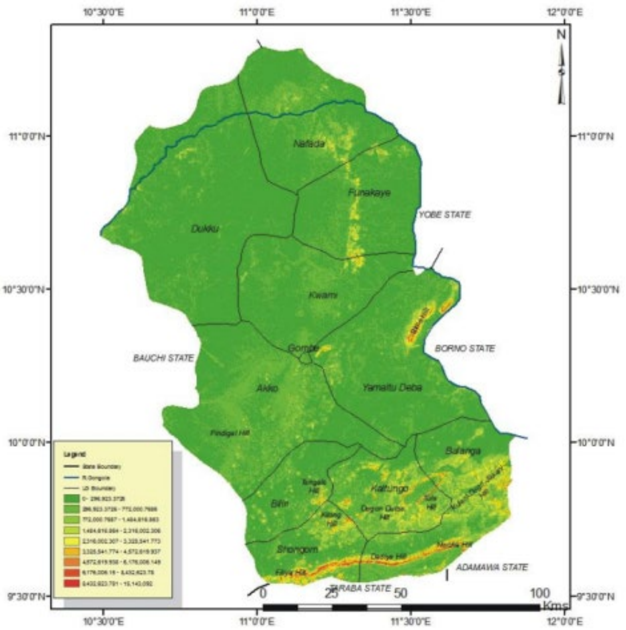

Fig. 1: Geological Map of Gombe (Source: Mayomi *et al.*, 2016)

With over 6000 m of Cretaceous-Tertiary sedimentary rocks, Gombe State is a large sedimentary basin that is a component of the upper Benue Trough (Usman *et al.,* 2017). These rocks are exposed all aound the state, although geologically, the eastern portion of the state is older than the western portion. Traditional layers of the Cenomanian Yolde and Jessu formations replaced the exposed non-marine Bima Sandstone westward in the south-eastern part of the state (Shettima *et al.*, 2020). The Marnae lie on top of these. The Gombe Sandstone which dates from the

Late Cretaceous comes behind the Cenomanian to Caniacian shales and limestone of the Pindiga Formation (Jauro *et al.*, 2007). The early Tertiary Kerikeri formation which is composed of sandstones, siltstone, and ironstone and originated in estuaries, lies beneath half of Gombe State (Isah *et al.*, 2022; Odedede and Adaikpoh, 2011). The northern section of the state is covered by the Chad formation, a series of continental silts and clay with lake origins that dates to the Late Tertiary. Figure 1 shows the geological map of Gombe State.

2.3 Field Studies and Data Collection

Truck haulage operation data were collected from the field, including the variables which were tabulated according to truck capacity. Cycle times were collected and then calculated for North -North pit, North - South pit and South - West pit respectively, while the tonnages of limestone produced were recorded for further computations.

2.4 Data Analysis and Modeling

Data collected from the three pits namely North-North pit, North-West pit and South-West pit and their respective calculated cycle times calculated including pit productions, average cycle time and pit productions, as well as their respective prediction expressions were subjected to further analysis for subsequent modeling. Their corresponding historical, exponential, linear logarithmic and polynomial model predictions were also generated for further interpretation. From the analysis, it is shown that the cycle time calculated for the North-North pit was 39 minutes, implying low production due to long distance of the pit. Six trucks were used in hauling materials from the pit to the crusher in order to avoid longer waiting time. It is also established that the calculated cycle time for North-West pit was 26 minutes with five trucks being used for materials haulage. It has an average distance compared to the North-North pit with higher production apparently due to an average distance. The calculated cycle time for South-West pit was 19 minutes has higher rate of productions due to short distance of the pit to the crusher. Four trucks were used for hauling of materials. Average Truck cycle time with production of N-N, N-W and S-W respectively were determined to plot the model and see the behavior of the model.

The data collected was tabulated and further analyzed. The cycle time in minutes was obtained and used for calculating the average production/day. The production/day serves as dependent variable that dependents on the cycle time. The calculated average Truck cycle time and corresponding production values of N-N, N-W and S-W pits were calculated and tabulated respectively. The tabulated result was then plotted using Microsoft excel for model prediction, while the curve relationship was used for several mathematical models. The model that best suits the curve was chosen. The models related to plot originated from equation of a line but then can be transformed due to the complexity of the equation.

Thus, $y = c \pm mx$ ………………… 1

where y = unknown dependent variable

x = independent variable.

c = constant value

m = gradient of the curve or line

2.5 Simulation and Model Prediction

This involves the implementation of the model developed thereby inputting desired variables for further prediction. The simulation was carried out by fitting the independent variable to get the corresponding dependent variable by inserting the values in the model,

$y = 2.2454x^2 - 176.73x + 4741.9$ …. equ. 2

The value, y, is the production in tonnes (dependent variable), while x represents the cycle time in minutes (independent variable). The value of the independent variable used is selected from 15 to 40. Microsoft Excel was used for simulation. The model prediction was done by plotting the trucks daily production against the cycle time.

2.6 Model Development and Validation

The prediction equations were generated by linearization and the relationship that best describe the behavior of the curve in a polynomial relationship of second-degree order with higher R^2 value. Prediction expressions of Ashaka Cement truck haulage depict the type of model prediction, equation and R^2 value respectively.

3.0 Results and Discussion

Results from data analysis, modeling and simulation as well as model prediction, development and validation are as shown in Tables 1 to 9, and represented in Figures 1 to 7. From the results, it has been shown that cycle time (loading time, haul time, waiting time, turn, spot and dump time, return time, and spot load time) for the North-North, North-West and South-West pits in the study company varies from one quarry location to another. It was observed that in the North-North Pit, for instance, low production is caused by long distance which may be attributed to a number of factors. It was also established that longer waiting period of haulage trucks can be

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eliminated by the deployment of more loading trucks. Hence, higher production is a factor of shortened haulage distance and provision of more haulage trucks. As postulated by Nobahar *et al.* (2022) and corroborated by Amin *et al.* (2017), production targets and decreased operational costs can thus be achieved for the best accuracy in predictions with a minimal lost opportunity in fleet management, provided all the important variables are considered, regardless of their size. Therefore, prediction expressions of Ashaka Cement truck haulage shown in Table 8 determine the type of model prediction equation and R^2 value obtained. The model prediction shown in Figure 2 from the results of exponential model prediction also indicates that the curve relationship does not fit the model. In the same vein, as shown in Figure 3, the curve relationship of the model prediction is linear, while the prediction does not also fit the model. Therefore, the logarithmic model prediction of Ashaka Cement truck haulage and the curve relationship do not seem to fit the model. This finding appears to align with the views of many studies (Elijah *et al.*, 2021; Fan *et al.*, 2022; Grossoni *et al.*, 2021; Jung *et al.*, 2021; Nibkin *et al.*, 2025; Nitsche *et al.*, 2011; Kolodziej *et al.*, 2025; Mkokweza *et al.*, 2024; Cheng *et al.*, 2025). However, as shown in Figure 4, the second order polynomial model prediction of Ashaka Cement truck haulage and the curve relationship indicate that the model was perfectly fitted, while the value of the predicted model was used for simulation in that regard. This postulation has seeming concurrence with the studies of Ostertagova (2012) and Alnaqbi *et al.* (2024). The established dispatches of '6 to 1', '5 to 1', and '4 to 1', for the three pits indicate that six trucks are allocated to 1 shovel respectively. This implies that the quarry only operates with one shovel in all the pits. Consequently, the simulation for this was carried out by fitting the independent variable to get the corresponding dependent variable by inserting the values in the model:

$$y = 2.2454x^2 - 176.73x + 4741.9 \quad \ldots\ldots\ldots\ldots.. \quad 2$$

where y value implies production in tonnes (dependent variable) x representing cycle time in minutes (independent variable). As shown in Table 9, the value of independent variable used is selected from 15 to 40. From the results, all the trucks used in the Ashaka Cement quarry met up with the production targets, sometimes surpassing the projected production. However, boulders hook (over size), build - up of wet materials, cleaning-associated delays (rollers, affront feeder) and occasional stoppage of conveyor belt have been identified as the major production constraints.

Table 1: North-North Cycle Time

Truck ID	Loading time (min)	Haul travel time (min)	Waiting time (min)	Turn spot & dump time (min)	Return time (min)	Spot load time (min)	Cycle time (min)
Vol.A35D 10	3.55	15.35	3.45	0.55	11.35	1.55	35.8
SMT Vol.A35f_2	3.60	15.25	4.55	0.45	12.55	2.00	38.4
SMT Vol.A40f_6	4.00	16.00	2.60	1.20	12.50	2.20	39.15
Cat 770_1	4.50	16.40	2.00	1.00	13.00	1.60	39.50
Cat 770_2	4.45	16.55	3.00	0.60	13.00	2.00	39.60
Cat 773_2	5.00	17.00	3.00	1.40	14.00	2.55	42.95
Total time	**25.1**	**96.55**	**18.6**	**5.2**	**76.4**	**11.9**	**235.4**
Average time	**4.2**	**16.09**	**3.1**	**0.87**	**12.73**	**1.98**	**39.23**

Table 2: North- West Cycle Time

Truck ID	Loading time (min)	Haul travel time (min)	Waiting time (min)	Turn sport & dump time (min)	Return time (min)	Spot load time (min)	Cycle time (min)
Vol.A35D 10	3.5	9.7	3.4	0.95	6.1	1.5	25.15
SMT Vol.A35f_2	3.6	9	3.9	1	6.2	1.4	25.1
SMT Vol.A40f_6	3.9	10.1	3.2	1.55	6.3	1.7	26.7
Cat 770_1	4	10.2	3.2	1.6	6.4	1.75	27.15

Truck ID	Loading time (min)	Haul travel time (min)	Waiting time (min)	Turn sport & dump time (min)	Return time (min)	Spot load time (min)	Cycle time (min)
Cat 773_2	3.2	10.3	3.9	1.7	7.5	2.5	28.8
Total time	**18.2**	**49.3**	**17.6**	**6.8**	**32.5**	**8.85**	**132.9**
Average time	**3.64**	**9.86**	**3.52**	**1.36**	**6.5**	**1.77**	**26.77**

Table 3: South-West Cycle Time

Truck ID	Loading time (min)	Haul travel time (min)	Waiting time (min)	Turn sport &dump time (min)	Return time (min)	Spot load time (min)	Cycle time (min)
Vol.A35D 10	3.2	5.2	2.9	0.95	4.3	1.9	18.45
SMT Vol.A35f_2	3.4	5.1	3.2	1	4.2	1.9	18.9
SMT Vol.A40f_6	3.9	5.6	3.4	0.98	4.1	2.1	20.08
Cat 770_1	3	5.5	2.95	1.2	3.95	1.8	18.4
Total time	**13.5**	**21.4**	**12.45**	**4.13**	**16.55**	**7.7**	**75.83**
Average time	**5.4**	**8.56**	**4.98**	**1.652**	**6.62**	**3.08**	**19.3825**

Table 4: North-North Pit Productions

Truck ID	Cycle time (min)	No. of trucks (hour)	Trucks capacity (tonnes)	Daily Production (tonnes)	Monthly Production (tonnes)	Annual Production (tonnes)
Vol.A35D 10	35.8	1.7	35	1071	32,130	385,560
SMT Vol.A35f_2	38.4	1.6	35	1008	30,240	362,880
SMT Vol.A40f_6	40.15	1.5	40	1080	32,400	388,800
Cat 770_1	38.5	1.6	50	1440	43,200	518,400
Cat 770_2	39.6	1.5	50	1350	40,500	486,000
Cat 773_2	42.95	1.4	65	1638	49,140	589,680
Total	**235.4**	**9.3**	**275**	**7587**	**227,610**	**2,731,320**
Average	**39.2**	**1.55**	**45**	**1264.5**		

Table 5: North-West Pit Productions

Truck ID	Cycle time (min)	No. of trucks (hour)	Trucks capacity (tonnes)	Daily Production (tonnes)	Monthly Production (tonnes)	Annual Production (tonnes)
Vol.A35D 10	27	2	35	1260	37,800	453,600
SMT Vol.A35f_2	25.9	2	35	1260	37,800	453,600
SMT Vol.A40f_6	27.15	2	40	1440	43,200	518,400
Cat 770_1	27.15	2	50	1800	54,000	648,000
Cat 773_2	26.65	2	65	2340	70,200	842,400
Total time	133.85	10	225	8100	243000	2916000
Average time	26.77	2	45	1620		

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Table 6: South-West Pit Productions

Truck ID	**Cycle time (min)**	**No. of truck (hour)**	**Trucks Capacity (tonnes)**	**Daily Production (tonnes)**	**Monthly Production (tonnes)**	**Annual Production (tonnes)**
Vol.A35D 10	19.45	3	35	1890	56700	680,400
SMT Vol.A35f_2	19.6	3	35	1890	56700	680,400
SMT Vol.A40f_6	20.08	3	40	2160	64800	777,600
Cat 770_1	18.4	3	50	2700	81000	972,000
Total time	**77.53**	**12**	**160**	**8640**	**259200**	**3110400**
Average time	**19.3825**	**3**	**45**	**2160**		

Table 7: Truck Cycle Time with Production

Average Cycle time (min)	**Average Production (tonnes)**	**Average Production (tonnes)**
39.23333	1264.5	1264.5
26.77	1620	1620
19.3825	2160	2160

Table 8: Prediction Expressions

Type	**Equations**	**R^2 Value**
Exponential	$y= 3463.5e^{-0.026x}$	$R^2 = 0.9645$
Linear	$y= -43.374x+2916$	$R^2 = 0.9314$
Logarithmic	$y=- 1260\ln(x)+5847.1$	$R^2 = 0.9724$
Polynomial-2	$y= 2.2454x^2-176.73x+4741.9$	$R^2 = 1$
Polynomial-3	$y= 2.2454x^2-176.73x+4741.9$	$R^2 = 1$
Polynomial-4	$y= 2.2454x^2-176.73x+4741.9$	$R^2 = 1$
Polynomial-5	$y= 2.2454x^2-176.73x+4741.9$	$R^2 = 1$

Table 9: Simulation of Truck Haulage

S/no	X (min)	Y (tonnes)
1	15	2596.165
2	20	2105.46
3	25	1727.025
4	30	1460.86
5	35	1306.965
6	40	1265.34

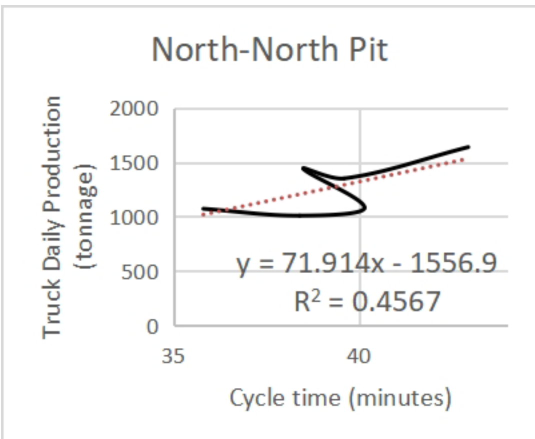

Fig. 1: Historical Truck Haulage Model Prediction of North-North Pit

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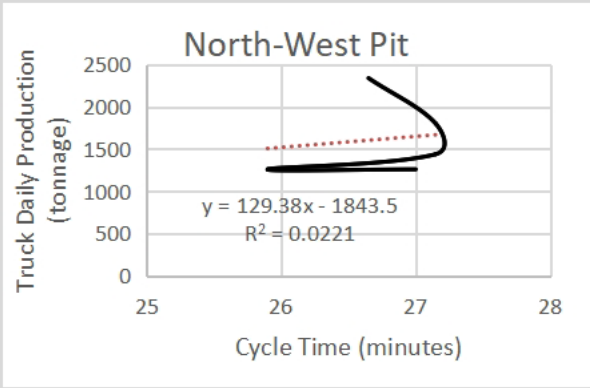

Fig. 2: Historical Truck Haulage Model Prediction of North-West Pit

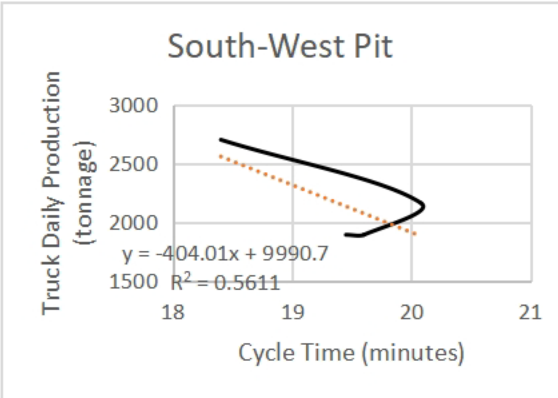

Fig. 3: Historical Truck Haulage Model Prediction of South-West Pit

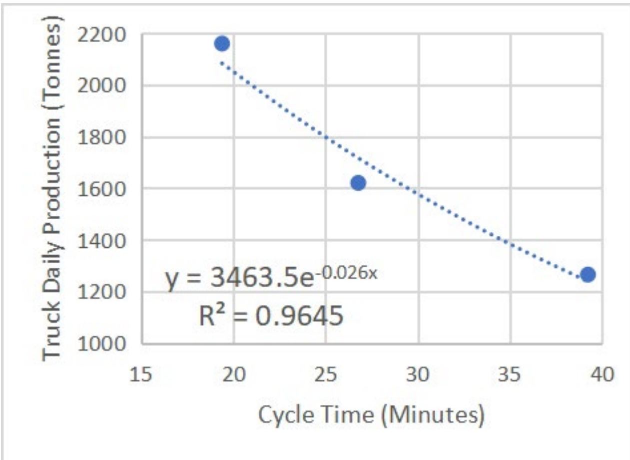

Fig. 4: Exponential Model Prediction of Ashaka Cement Truck Haulage

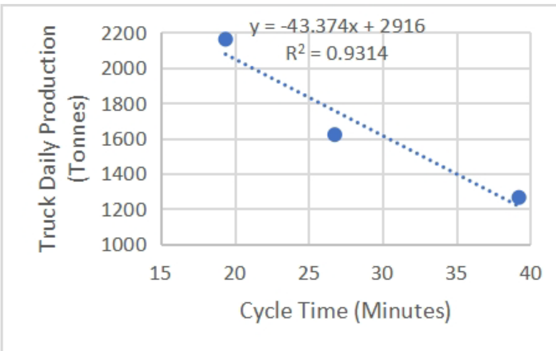

Fig. 5: Linear Model Prediction of Ashaka Cement Truck Haulage

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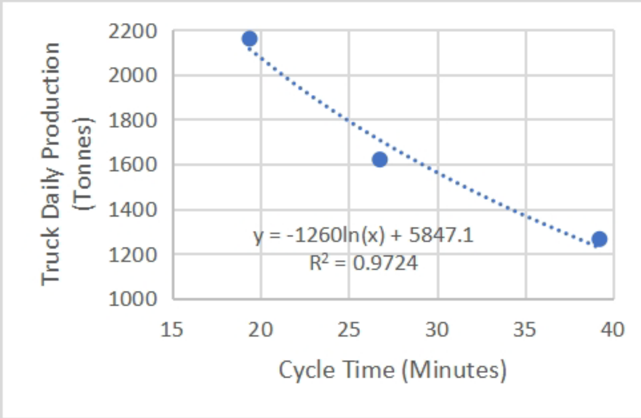

Fig. 6: Logarithmic Model Prediction of Ashaka Cement Truck Haulage

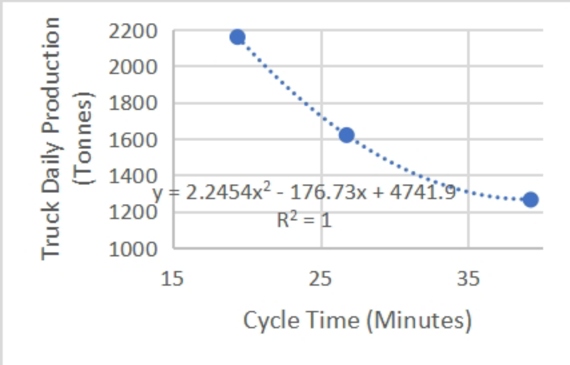

Fig. 7: Second Order Polynomial Model Prediction of Ashaka Cement Truck Haulage

4.0 Conclusion

Findings from the simulation of truck haulage operation at Ashaka Cement Company in Gombe State, North-eastern Nigeria, have shown that the operation is effective since about 100% of the production rate is achieved. Hence, to sustain continuous increased production, hindering factors such as boulders hook (over size), buildup of wet material and cleaning-associated delays (rollers, affront feeder) must be tackled. The one dependent to one independent variable relationship should, therefore, be further alternated with other operations research methods for prediction of haulage operation simulation to sustain increased productivity in the company's quarry.

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