



**BUSITEMA
UNIVERSITY**
Pursuing Excellence



Faculty of Engineering

Department of Mining and Water Resources Engineering

**ANALYSIS OF SHOVEL-TRUCK SYSTEM FOR
OPTIMAL SELECTION AT TORORO CEMENT
QUARRY**

By

Lokwe Emmanuel

Reg no: BU/UG/2012/1803

EMAIL: - lokweemma@gmail.com

Supervisor: Mr. Nasasira Hillary

Final year Research Report submitted to Busitema University in partial fulfillment
for the award of a Bachelor of Science in Mining Engineering.

May

ABSTRACT

This project report entails the analysis of shovel-truck system for optimal selection at Tororo Cement Limited Quarry, in Tororo-Uganda, with the basic aim of optimizing cycle time, material size, loading distance through and cost of shovel-truck system.

This is justified by the fact that, Material handling account for 60% of the total operating cost of the mines, so it is desirable to maintain an efficient material handling system. This is due to the facts that as the size of fleet being used increases, shovel productivity increases but truck productivity decreases, so an effective fleet size must be chosen that utilize all equipment.(May et al. 2012)

This was done by thoroughly reviewing literatures of shovel-truck productivity, cost of handling material, effects of field parameters and application of models that optimize the time parameter and general impact on a company's productivity at the quarry.

Shovel-truck system operational data from the quarry was analyzed and applied to a multi-channel queuing model representative of the loading process of the haul cycle. The outputs of the model was compared with actual data to evaluate the validity of the queuing model used.(May et al. 2012)

The end aim of project is to optimize the time to ensure that the practices is conducted in the fastest means possible with maximum utilization of the availed equipment for output and profit maximization.



DECLARATION

I LOKWE EMMANUEL, BU/UG/2012/1803, Pursuing a Bachelor of Science in Mining Engineering do hereby declare that, this project report has been compiled by me and has not been presented to any University or other institution of higher learning for any academic award.

Signature.....

Date.....30th/05/2014

BUSITEMA UNIVERSITY LIBRARY
CLASS No.:.....
ACCESS NO.: FF 0358

APPROVAL

This piece of work has been endorsed by:-

Signature: _____

Date: _____

MR. NASASIRA HILLARY

MAIN SUPERVISOR

TABLE OF CONTENTS

ABSTRACT.....	i
DECLARATION	ii
APPROVAL.....	iii
TABLE OF CONTENTS.....	iv
LIST OF FIGURES.....	vii
LIST OF TABLES.....	viii
ABBREVIATIONS AND ACRONYMS	ix
CHAPTER ONE	1
1.0. INTRODUCTION.....	1
1.1. BACKGROUND OF TCL.....	1
1.1.1. Location and address	1
1.1.2. Geology of Tororo rock suite	1
1.1.3. Limestone/dolomite/travertine of Uganda	2
1.1.4. Brief history of TCL formation.....	4
1.1.5. Mine material handling costs in global perspective	5
1.1.6. Brief history of mining in Uganda	5
1.1.7. Trend of Uganda nonmetallic minerals industry	6
1.1.8. TCL mining and quarry operations.....	7
1.1.9. Introduction queuing theory.....	8
1.2. PROBLEM STATEMENT.....	9
1.3. OBJECTIVES	9
1.3.1. Main objective	9
1.3.2. Specific objectives.....	9
1.4. PURPOSE OF STUDY	9
1.5. JUSTIFICATION	9
1.6. SCOPE AND LIMITATIONS	10
CHAPTER TWO - LITERATURE REVIEW	11
2.1. INTRODUCTION.....	11
2.2. METHODS OF SELECTING FLEET NUMBER.....	11
2.2.1. Expert system fleet number selection methods.....	11

2.2.2. Mathematical modeling fleet selection methods.....	12
2.2.3. Genetic algorithm fleet selection method.....	13
2.2.4. Multiple attribute decision making techniques method.....	13
2.2.5. Queuing theory selection method.....	14
2.3. METHODS OF SHOVEL-TRUCK PRODUCTIVITY CALCULATION.....	14
2.3.1. Mathematical methods.....	14
2.4. SELECTING SIZE OF EQUIPMENT.....	17
2.5. QUEUING THEORY APPLICATION TO MINING.....	18
2.5.1 Preamble.....	18
2.5.2 Queuing model.....	18
2.5.3 Conclusion.....	27
CHAPTER THREE - METHODOLOGY.....	28
3.0. PREAMBLE.....	28
3.1. EQUIPMENT, MEASUREMENTS AND DATA COLLECTION.....	28
3.1.1. Equipment used for analysis.....	28
3.1.2. Parameters measurements.....	28
3.1.3. Data collection methods.....	29
3.2. ACTUAL AND MANUFACTURER SHOVEL PRODUCTIVITY ANALYSIS.....	29
3.2.1. Geological field data computation.....	30
3.2.2. Shovel field productivity analysis.....	30
3.2.3. Shovel manufacturer productivity analysis.....	32
3.3. ACTUAL AND MANUFACTURE TRUCK PRODUCTIVITY ANALYSIS.....	32
3.3.1 Truck field productivity analysis.....	32
3.3.2. Manufacturer truck production analysis.....	34
3.4. ANALYSIS OF EFFECTS OF SHOVEL AND TRUCK PARAMETERS.....	35
3.4.1 Equipment used.....	35
3.4.2 Excavator bucket and truck capacity.....	35
3.4.3 Number of trucks.....	36
3.4.4 Hourly production output.....	36
3.5. SELECTION OF SHOVEL-TRUCK SYSTEM.....	37
3.7.1. Queuing model (m1/m2/c)-Kendell notation.....	37

3.7.2. Inputs data to the model	37
3.7.3 Equations for the model	38
3.7.4 Outputs	39
CHAPTER FOUR - RESULTS AND DISCUSSION	41
4.0. PREAMBLE	41
4.1A. SHOVEL FIELD DATA RESULTS AND DISCUSSION	41
4.1a.1. Field geological data computations	41
4.1a 2. Field management and operational results	41
4.1A.3. SHOVEL FIELD PRODUCTION RESULT DECISIONS	47
4.1a.4. Shovel manufacturer production result	50
4.1a.5. Shovel manufacturer production result analysis	52
4.1a.6. Shovel field and manufacturer production results	52
4.1a.7. Shovel field and manufacturer production results discussions	53
4.1B. TRUCK FIELD AND MANUFACTURER DATA ANALYSIS	53
4.1b.1. Truck field production result	53
4.1b.2. Truck field results discussions	55
4.1B.3. TRUCK MANUFACTURER PRODUCTION RESULTS	56
4.1b.4. Truck field and manufacture result analysis	58
4.2. ANALYSIS OF EFFECTS OF SHOVEL AND TRUCK PARAMETERS	58
4.2.1. Results discussion	59
4.3. SHOVEL-TRUCK SYSTEM COTS ANALYSIS AND DISCUSSION	61
4.3.2. Field and manufacture cost analysis	61
4.4. OPTIMAL SHOVEL-TRUCK SYSTEM SELECTION USING QUEUING THEORY	62
4.4.1. Queuing model (m1/m2/c)-Kendell notation	62
4.4.2 Outputs	64
CHAPTER FIVE- CONCLUSIONS AND RECOMMENDATIONS	66
5.1. CONCLUSIONS	66
5.2. RECOMMENDATIONS	66
REFERENCES	67
APPENDICES	69

LIST OF FIGURES

Figure 1.1 Distribution of Tororo Suite granitoids (code A3T-within black dashed line on map)¹	2
Figure 1.2 Production of non-metallic minerals for Uganda²	7
Figure 4.1. Graph of shovel cycle time against loading time on loading a truck³	47
Figure 4.2. Number of buckets variation with material size⁴	47
Figure 4.3.Loading time against material size⁵	48
Figure 4.6 Graph of Bucket capacities against bucket fill factors for material sizes⁶	49
Figure 4.7 Graph of Bucket capacities against bucket fill factors for material sizes⁷	50
Figure 4.8 showing cycle time at two loading points @ 0.4 & 0.7 kms ⁸	55
Figure 4.9 showing truck productivity variations for two loading points⁹	56

LIST OF TABLES

Table 1.1 Cost Distribution of Unit Operations (Copper Mines) (Bonates, E.j.l., 1992) ¹	5
Table 3.1 Queuing Model Inputs ⁻¹	37
Table 3.2 Queuing Model Outputs ⁻²	40
Table 3.3 Screenshot of Model³	40
Table 4.1. Showing computed geological field data⁰⁻¹	41
Table 4.3b. Cycle times per trip for CAT 336D L (optimal blast)⁻²	42
Table 4.3c. Cycle times per trip for CAT 336D L (over size blast)⁻³	42
Table 4.4 showing shovel parameter variation with limestone fragments size⁸	46
Table 4.5. Showing effects of fill factors on bucket capacity for classes of limestone ⁰⁻⁵	48
Table 4.6 showing bucket fill factor against number of bucket loaded¹⁰	49
Table 4.7 showing data for CAT 336D L shovel and operation condition ¹¹	50
Table 4.8 showing data for CAT 336D L shovel and operation condition ¹²	52
Table 4.9 Shovel Field and manufacturer Result for CAT 336D L ¹³	52
Table 4.10a. Showing cycle time for dump truck operation at point 0.7kms ¹⁴	53
Table 4.10b. Showing cycle time for dump truck operation at point 0.4kms¹⁵	53
Table 4.10c Truck production results comparisons @ 0.4kms & @ 0.7kms ¹⁶	55
Table 4.11b Truck production results comparisons @ 0.4kms & @ 0.7kms ¹⁷	58
Table 4.12a Operating cycle at TCL Quarry¹⁸	58
Table 4.12b Haulage cycle as a function of speed¹⁹	59
Table 4.12c. The effect of increased speed on the haulage cycle ²⁰	59
Table 4.13a Shovel Field and manufacturer Result for CAT 336D L ¹³	61
Table 4.13b Truck production results comparisons @ 0.4kms & @ 0.7kms ¹⁷	62
Table 4.14a Queuing Model Inputs ⁰⁻¹	62
Table 4.14b Queuing Model Inputs ⁰⁻¹	63
Table 4.14c Queuing Model Inputs ⁰⁻¹	63
Table 4.14d Queuing Model Inputs ⁰⁻¹	64
Table 4.14d Queuing Model Inputs ⁻¹	64
Table 4.14e Queuing Model Outputs ²	64
Table 3.14f Screenshot of Model³	65

ABBREVIATIONS AND ACRONYMS

TCL- Tororo cement limited

M/M/c- Kendall notation

GDP- Growth Domestic Product

LSM -Large-Scale Mining

Kms – kilometers

UCI - Uganda cement industry

UDC- Uganda Development Corporation

BCY - Bank cubic yard

UDC Uganda Development Corporation

CHAPTER ONE

1.0. INTRODUCTION

This chapter contains, TCL background information, Problem statement describing the context for the study and the purpose statement to provide a specific and accurate synopsis of the overall purpose of the study, and the significance indicating how this project will refine, revise, and extend the existing knowledge on Shovel-truck systems to Tororo cement limited (TCL) Quarry. It further incorporates the scope, justification and limitations of the proposed research project.

1.1. BACKGROUND OF TCL

1.1.1. Location and address

TCL is located in the Eastern part of Uganda about 230Kms from the Capital city Kampala. It is 10Kms before the Uganda/Kenya border town of Malaba. Access from Kampala is by an all-weather tarmac road. The coordinates of the main factory are 00 39 36N, 34 09 18E (Longitude: 0.6600; latitude: 34.1550).

Email: tcl@tororocement.com **Website:** www.tororocement.com

Tel: 0352-512500 **Fax:** 0352-512517

P.O. Box 74 Tororo -Uganda

1.1.2. Geology of Tororo rock suite

Rocks of the Tororo Suite occupy the eastern segment of the WTT, underlying a surface of ca. 3,000 km². Tororo Suite granitoids are typically biotite bearing and composed of several sub-facies including gneissic granite and granodiorite, hornblende-bearing granodiorite, granite and diorite, porphyritic granite, biotite granite, medium-grained granite with pegmatite and the dated Kisoko granite (~2.664 Ga). A special facies of Tororo Suite rocks is formed by Na-K metasomatic halos surrounding the Neogene carbonatite plugs of the alkaline Elgon Complex. Regionally, the contours of the Tororo Suite can be distinguished from the surrounding rock units by their high

REFERENCES

- Bazzaz, A.A., Osanloo, and M., Karimi, B. (2008). Mine Planning and Equipment selection. In *Optimal Open Pit Mining Equipment Selection Using Fuzzy Multiple Attribute Decision Making Approach* (pp. p.253-268.). China .
- Alkass, S., El-Moslmani, K., & AlHussein, M. (2003). *A Computer Model for Selecting Equipment for Earthmoving Operations Using Queuing Theory*. Montreal, Canada:: Concordia University.
- Amirkhanian, S.A., Baker, N.J. (1992). Expert System for Equipment Selection for Earthmoving Operations. *Journal of Construction Engineering and Management*, Vol. 118, No. 2, p.318 - 331.
- Bandopadhyay, S., Venkatasubramanian, P. (1987). Expert systems as decision aid in surface mine equipment selection . *Journal of Mining, Reclamation and Environment*, p.159-165.
- Bascetin A. (2003). A Decision Support System for Optimal Equipment Selection in Open Pit Mining. *Analytical Hierarchy Process, Istanbul Tech University journal of Geoscience*, , vol.16, p.1-11.
- Bascetin A., Oztas, O., and Kanli, A.I. (2006). EQS: Computer Software Using FUZZY Logic for Equipment Selection in Mining Engineering. *The Journal of The South African Institute of Mining and Metallurgy*, Vol.106, p.63-70.
- Bonates, E.j.l. (1992). *The development of assignment for semi-automated truck- shovel system Evolutionary Water Cooled Reactors* . Monteral: University of McGill.
- Bozorgebrahimi, E., Hall, R. A., and Blackwell, G. H. (2003). Sizing equipment for open pitmining –a review ofcritical parameters Mining Technology. In E. H. Bozorgebrahimi, *Sizing equipment for open pitmining –a review ofcritical parameters Mining Technology*, (pp. Vol. 112, p.A171-A179).
- Caterpillar. (2012). improving efficiency underground. *A challege work trucking*, VIEWPOINT,7,2.
- Çelebi, N. (1998). An equipment selection and cost analysis system for openpit coal mines. *International Journal of Mining, Reclamation and Environment*,12:4, p.181-187.
- Clement, G. K. (Director). (1980). *Capital and operating Cost Estimating System Manual for mining and beneficiation of metallic and non-metallic minerals except fossil fuels in the United States and Canada* [Motion Picture].
- Denby, B. and Schofield, D. (1990). Applications of expert systems in equipment selection for surface mine design. *International Journal of Mining, Reclamation and Environment*, p.165-171.
- E. P. Pflaide. (1973). Surface haulage and storage. In E. P. Pflaide, *SME mining engineering handbook, volume 2*, .

- Ercelebi, S. G., & Bascetin, A. (2009). Optimization of shovel-Truck system for Surface Mining. *The Journal of The Southern African Institute of Mining and Metallurgy*, 433-439.
- Erdem, B., Çelebi, N., and Pasamehmetoglu, A.G. (1998). Optimum dragline selection for strip coal mines. *Min. Industry*, pp. p.A13-A24.
- Fytas, K., Collins, J.L., Flament, F., Galibois, A., and Singhal, R. (1988). Potential applications of knowledge-based systems in mining. *CIM Bulletin*, pp. p.38- 43.
- Ganguli, R. B. (2002). Expert System for Equipment Selection. *International Journal of Mining, Reclamation and Environment*, 16:3, p.163-170.
- Gentry D. W and O'Neil T. J. (1984). Mine investment analysis. In G. D. J, *SME*.
- Gross, D., & Harris, C. M. (1998). *Fundamentals of Queueing Theory*. New York: John Wiley & Sons, Inc.
- Haidar, A., Naoum, S., Howes, R., and Tah, J. (1999). Genetic Algorithm Application and Testing quipment Selection. *journal of Construction Engineering and Management*, Vol. 125, No. 1 January/ February,, p.32-38.
- Hartman, H. L., & Mutmansky, J. M. (2002). *Introductory Mining Engineering*. Hoboken, NJ:: John Wiley & Sons, Inc.
- May, Meredith Augusta. (2012, december 19). *Applications of Queuing Theory for Open-Pit Truck/Shovel Haulage Systems*. Blacksburg, VA: Faculty of the Virginia Polytechnic Institute and State University. Retrieved september 6, 2015
- Najor, J., & Hagan, P. (2004). *Mine Production Scheduling within Capacity Constraints*. Sydney, Australia: The University of New South Wales.
- Pfleider, E. P. (1973). Surface haulage and storage, . In E. P. Pfleider, *SME mining engineering handbook*, , (p. volume 2).
- Samanta, B., Sarkar, B., and Mukherjee, S. K. (2002). Metall. Sect. A: Min. Technology. *Selection of opencast mining equipment by a multi-criteria decision-making process*, *Trans. Instn Min*, p.A136-A142.
- Tayeb, S., Ahcene, B., Jerome, P., Omar, S., and Mouloud, B.K. (2007). Equipment Selection by Numerical Resolution of the Hessian Matrix and TOPSIS Algorithm. *Asian Journal of Information Technology*, Vol.6(1), p.81-88.