

**PRODUCTIVITY IMPROVEMENTS OF QUARRY
PROCESS BY IDENTIFYING LEAN WASTES**

MASTER OF SCIENCE

IN

CONSTRUCTION PROJECT MANAGEMENT

U.L.W.K.Gunasinghe

Department of Civil Engineering

University of Moratuwa

December 2015

PRODUCTIVITY IMPROVEMENTS OF QUARRY PROCESS BY IDENTIFYING LEAN WASTES

By

U.L.W.K.Gunasinghe

Supervised by

Dr. Lesley Ekanayake

This dissertation was submitted to the Department of Civil Engineering of the University of Moratuwa in partial fulfillment of the requirements for the Master of Science in Construction Project Management.

Department of Civil Engineering

University of Moratuwa

December 2015

DECLARATION

I certify that this thesis does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any university to the best of my knowledge and believe it does not contain any material previously published, written or orally communicated by another person or myself except where due reference is made in the text. I also hereby give consent for my dissertation, if accepted, to be made available for photocopying and for inter library loans, and for the title and summary to be available to outside organizations.

.....

Signature of Candidate

.....

Date

The above particulars are correct, to the best of my knowledge.

.....

Signature of Supervisor

.....

Date

ABSTRACT

The Sri Lankan Central Bank Annual Report 2013 revealed that, the construction industry contribution to GDP has reached 8.7% in year 2012 with continual growth from 2003. It further says that, more public investments in the highway sector contributed to sustaining the growth momentum in the construction industry. Hence construction has automatically become one of the major energy consuming industries in the country. In that regard, the Asphalt concrete production process is at the top level of energy consumption due to the higher amount of energy used to raise the temperature of raw materials to a high mixing temperature of around 150 C.

Key findings of a research done on the Asphalt Coating Plant in Scotland, reveals that it is economical to have daily production throughout of at least 100 tones and 1% moisture increment of aggregate, increases the fuel consumption by 0.7 liter/tonne (Gillespie, 2012). The above research doesn't cover the stone quarrying process which provides the aggregates for asphalt production. The research done by Rylander (2013) on the quarrying process has contributed to find lean wastes happening in the raw material supplying process from quarry to crusher.

Controlling aggregate production costs are a significant problem in the quarrying process due to high competition in the industry. The production cost of aggregates is severely affected by the selected crushing circuit. In this thesis, the study was carried out based on two different crushing circuits to find a more productive crushing circuit in the quarrying process. The lean principles were applied to identify the lean wastes over production, waiting, transportation, non-value-added processing, excess inventory, defects, excess motion and underutilized people in two crushing processes. The identified wastes of each circuit were analyzed compared to the other circuit. This study was limited to horizontal flow crushing.

The analyzed results show that cellular manufacturing with intermediate stockpile increases the availability of the system by minimizing the waiting. At two-stage crushing circuit uses less manpower, machinery and electricity power than a three-stage crushing circuit since two-stage crushing minimizes the waste over conveyance, over motion and over utilization of people. Finally, the study recommends that by selecting the circuit, two-stage crushing with cellular manufacturing can increase the productivity of the system.

ACKNOWLEDGEMENT

I would like to thank the many people who made this project possible and gave their supportive hands all along the research study and made the journey very stimulating and enjoyable. Firstly, I am very grateful to the Department of Civil Engineering of the University of Moratuwa, for giving me the opportunity to carry out this research study. I would like to express my sincere gratitude to my supervisor Dr. L.L. Ekanayake for his valuable guidance and immense support.

I deeply appreciate the valuable suggestions and comments given by Prof. Asoka Perera, Prof. Neranjan Gunawardane, Prof. Chintha Jayasinghe and Dr. R.U. Halwatura during the progress presentations. Further my appreciation goes to the Executive Director, Senior Management and all other staff members of NEM Construction (Pvt) Ltd, for encouraging me throughout the exercise and being a great support.

Finally, my thanks and appreciation are due to my family for their understanding, motivation and patience during exercise as well as my colleagues and friends who helped me in the preparation of this dissertation.

Wasantha Gunasinghe

December 2015

Table of Contents

DECLARATION	iii
ABSTRACT	iv
ACKNOWLEDGEMENT	v
List of Figures	ix
List of Tables	x
ABBREVIATIONS	xi
CHAPTER 1	1
1.0 Introduction	1
1.1 Background	1
1.2 Problem Definition	2
1.3 Research Objectives	3
1.4 Significance of the study	3
1.5 Methodology	4
1.6 Limitations of the research	4
1.7 Main Findings	5
1.8 Component of the Report	5
CHAPTER 2	6
2.0 The Literature Review	6
2.1 General	6
2.2 History and Background of Lean Manufacturing.....	6
2.3 Importance of the Lean Manufacturing Process	7
2.4 General Principles of Lean Manufacturing	9
2.5 Lean Transformation Process	11
2.5.1 Planning the change	11
2.5.2 Success factors	11
2.5.3 Lean Tools and Techniques	13
2.5.4 Implementation	14
2.5.5 Measuring Progress.....	16
2.6 Lean Construction	18
2.7 Lean Application to Quarry Process	19
2.8 Summary	20
CHAPTER 3	21

3.0	Research Methodology.....	21
3.1	General	21
3.2	Quarry Operation.....	21
3.3	Crusher Operation	22
3.3.1	Crushing Theory	22
3.3.2	Crushing Equipment	22
3.3.3	Crushing Circuits and Stages	27
3.4	Cellular Manufacturing	28
3.4.1	Workcell.....	28
3.4.2	Cellular Layout	28
3.4.3	Machining Workcell	29
3.5	Framework of the research	29
3.5.1	Research Approach	29
3.5.2	Selected plant complexes	30
3.6	Method of Data collection.....	32
3.6.1	Initial preparation for data collection.....	32
3.6.2	The information system of the plant production.....	32
3.7	Processing of Data.....	35
3.7.1	Plant production data	35
3.7.2	Plant Production Cost	37
3.7.3	Energy consumption	39
3.8	Method of Data analysis.....	40
3.9	Summary	40
CHAPTER 4		41
4.0	Analysis & Discussion	41
4.1	General	41
4.2	Availability of Crushing Circuits	41
4.2.1	Analysis of Availability for Two Crushing Circuits.....	41
4.3	Discussion of Crushing Circuit Availability	44
4.4	Analysis of Machinery and Manpower Involvement.....	44
4.5	Discussion of Machinery and Manpower Involvement	47
4.6	Analysis of Energy Consumption in Two Circuits	48
4.7	Discussion of Energy Consumption in the Two Circuits.....	49

4.8	Summary	49
CHAPTER 5		50
5.0	Conclusions and Recommendations.....	50
5.1	Summary of Findings	50
5.2	Conclusion.....	50
5.3	Recommendation.....	51
5.4	Implementation.....	51
5.5	Recommendations for Future Study.....	54
References.....		55
APPENDIX A.....		58
APPENDIX B		62
APPENDIX C		67
APPENDIX D.....		74

List of Figures

Figure 1: Framework for lean manufacturing implementation (Duque and Cadavid,2007).....	15
Figure 2: The model for successful lean implementation (Vieazindiene and Ciarniene, 2013)	18
Figure 3 : Cross Section of a Jaw Crusher	23
Figure 4: Cross Section of a Cone Crusher.....	24
Figure 5: Impact Crusher	25
Figure 6: Feeder	25
Figure 7: Vibratory Screen.....	26
Figure 8: Conveyor	26
Figure 9: U Shape Layout	28
Figure 10: Straight Layout	29
Figure 11: Layout of Plant No.01 (Two-stage in Single Cell).....	30
Figure 12: Layout of Plant No. 2 (Three-stage in Multi Cells).....	31
Figure 13: Availability of Plant No.01	42
Figure 14: Availability of Plant No.02	43
Figure 15: Availability of Single Cell & Multi Cell	44
Figure 16: Machinery Cost of Plant No.01 & Plant No.02 (Production Average 5000 Cube/Month).....	45
Figure 17: Manpower Cost of Plant No.01 & Plant No.02 (Production Average 5000 Cube/Month).....	46
Figure 18: Machinery and Manpower Cost of Two-stage & Three-stage	47
Figure 19 : Power Consumption of Plant No.01 and Plant No.02 (Kw/Cube)	48
Figure 20: Energy Consumption of Two-stage and Three-stage	49
Figure 21: Proposed Plant Layout.....	51
Figure 22: Drawing Developed by a Vendor Based on Proposed Layout.....	52
Figure 23: First Stage Crushing in Proposed Crusher Plant	53
Figure 24: Second Stage Crushing in Proposed Crusher Plant.....	53

List of Tables

Table 1: Indicators for lean implementation measurement.....	16
Table 2: Plant No.01 (Two-stage in Single Cell).....	35
Table 3: Plant No 02 (Three-stage in Three Cells)	36
Table 4: The Percentage of Production Hour Loss with Reference to Plant Production Percentage	37
Table 5: Monthly Plant Production Cost of Plant No. 01	38
Table 6: Monthly Plant Production Cost of Plant No.02	38
Table 7: Power Consumption of Plant No.01	39
Table 8: Power Consumption of Plant No.02	39
Table 9: Availability of Plant No.01	42
Table 10: Availability of plant No.02	43
Table 11: Machinery Cost of Plant No.01 & Plant No.02 (Production Average 5000 Cube/Month).....	45
Table 12: Manpower Cost of Plant No.01 & Plant No.02 (Production Average 5000 Cube/Month).....	46
Table 13: Power Consumption of Plant No.01 and Plant No.02 (Kw/Cube)	48

ABBREVIATIONS

JIT - Just In Time

JIC - Just In Case

VSM - Value Stream Mapping

WIP - Work in Process

CSS - Closed Side Setting

PO - Purchase Order

MRF - Material Requisition Form

GRN - Goods Received Note