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# Lean Manufacturing and Productivity Improvement in Coal Mining Industry

Er. Manoj Ade[1], Dr. V.S.Deshpande[2]
[1]*Western Coalfields limited*
[2]*Principal RKNEC, Nagpur India*

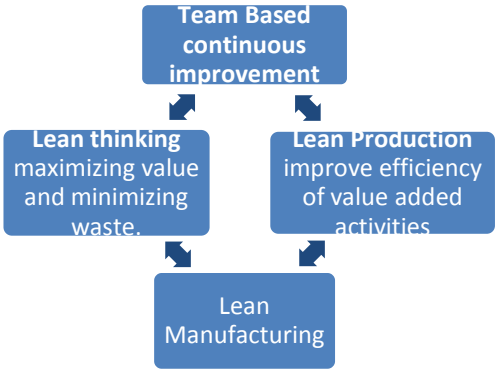
***Abstract—The economic reforms- Liberalization, Privatization, Globalization, (LPG) started in 1991 in India. The main objective of the government was to achieve high economic growth and industrialize the nation for the well-being of Indian citizens. Thus Indian market became Global and open market. Coal industry was not an exception to these phenomena of globalization. The improvement in productivity has become need of coal industry to take the competitive advantage of global marketing. Productivity improvement through Lean manufacturing means optimization and co-ordination of the input resources to minimize the wastes to reduce total production cost. This can be achieved by Lean thinking (to identify and eliminate wastes) and Lean Manufacturing (to improve efficiency and effectiveness of equipment). In this paper researcher has applied lean manufacturing concept in order to increase productivity of coal mining. By application of lean tools the Overall Human Effectiveness is analyzed which is converted into productive output to increase the productivity and develop an overview of the conceptual framework of lean manufacturing practices to minimize the production cost of mining.***

***Keywords—Lean thinking, Lean Manufacturing, Lean production, wastes, Overall Human Effectiveness.***

## I. INTRODUCTION

Henry Ford is known as "Father of the Management", continued his focus on waste minimization while developing his mass assembly manufacturing system and work standardization. While standardizing the work, each activity is analyzed on the basis of desirable activity or undesirable activity. All the desirable activities are known as value added activity and undesirable activities are known as wastes. Thus work standardization has become the basis of **Lean thinking.**

**Lean thinking** is an approach to achieving manufacturing excellence based upon the continued value addition and **elimination of waste**. Lean thinking is a set of methodologies for maximizing value of an item or feature for which a customer is willing to pay. All other items aspects are deemed waste. *Figure-1*




**Lean production and Lean maintenance**- utilizes techniques and principles that **improve efficiencies** of value, product development, operations, suppliers and customers relations that requires less human effort, less space, less relations that requires less human effort, less space, less capital and less time to make products with fewer defects compared with the previous system of mass production. **Lean maintenance**- Maintenance works that is to be carried out by application of TPM, 5S, Kanban and Andon with less waste, less human effort, less maintenance space, less investment in tools, less inventory, and in less time.

TPM is a lean tool to optimize the effectiveness of equipment and tooling. It is total Employee Involvement, to create a culture where operators develop ownership of their equipment, and become full partners with Maintenance, Engineering and Management to assure equipment operates properly everyday.

**Lean Manufacturing** – Lean Manufacturing is a way to eliminate waste and improve efficiency in a manufacturing environment. Lean manufacturing was successfully implemented by Toyota in his factory hence named as Toyota production. [1] Taiichi Ohno identified wastes as - Elimination of waste is the goal of Lean. Toyota defined three types of waste-

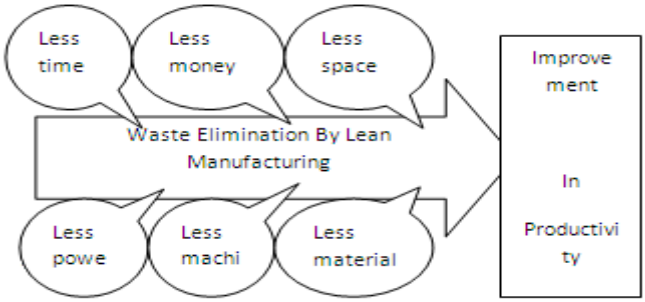
1) Muri – Muri focuses on the preparation and planning of the process or what can be avoided proactively by design.
2) Mura- Mura focuses on implementation and the elimination of fluctuation at the scheduling or operations level such as quality and volume.
3) Muda- Muda is after the process is in place and is dealt with reactively. Taiichi Ohno identified **seven types of wastes** in operational working. These are-
    1) Overproduction – Production ahead of demand.
    **2) Transportation- Moving products that are not actually required to perform the processing**
    3) Waiting- Waiting for the next production step.
    4) Inventory- All components, work-in-progress and finished product not being processed.
    **5) Motion People or equipment moving or walking more than is required to perform the processing.**
    **6) Over processing – Due to poor tool or product design creating activity.**
    7) Defects- The effort involved in inspecting for and fixing defects.

Lean manufacturing is the production of coal using less of everything compared to traditional mass production: less waste, human effort, manufacturing space, investment in tools, inventory, and engineering time to develop a new product.

The term "Lean" as [4] Womack and his colleagues define it denotes a system that **utilizes less, in term of all inputs, to create the same outputs as those created end customer.** The Lean Manufacturing discipline is to work in every facet of the value stream by eliminating waste in order to reduce cost, generate capital, bring in more sales and remain competitive in a growing global market. This business philosophy goes by different names. Agile manufacturing, just-in-time manufacturing, synchronous manufacturing, world-class manufacturing and continuous flow are all terms that are used in parallel with Lean Manufacturing. So the resounding principle of Lean Manufacturing is to reduce cost through continuous improvement that will eventually reduce the cost of services and products thus growing more profits.

**Lean manufacturing as a technique of productivity improvement** – Lean Manufacturing in mining is the production of coal using less of everything compared to traditional mass production: less waste, human effort, manufacturing space, investment in tools, inventory, and engineering time to develop a new product.

Productivity improvement through Lean manufacturing means optimization and co-ordination of the input resources to minimize the wastes. Improvement in productivity has become need of any industry to take competitive advantage in the Global market to satisfy the customer at minimum cost. *Figure-2*




## II. PROBLEM IDENTIFICATION

In search of a critical problem, the identified problems have been categorized according to the capability of group members , the involvement of the management and other external agencies, in three categories, i.e.,

- 'A' category problem – Minimum involvement of other departments in solving them.
- 'B' category problem – Involvement of the other department is a necessity.
- 'C' category problem – Management sanction may be needed in implementing the solution.

### 1.1 IDENTIFICATION OF WASTES:- Table-1

| WASTES/PROBLEMS | CATEGORY OF THE PROBLEM |
|---|---|
| a) Coal seam height thin and thick which is very difficult to excavate, and the need of coal does not permit to leave it un-mined. | **C** |
| b) **Coal spillage and re-handling of the spilled coal.** | **A** |
| c) Overall Equipment Effectiveness (OEE) | **B** |
| d) Pumping system in under ground mine. | **B** |
| e) **Bottleneck (under ground bunker) of the coal transportation system.** | **C** |

| | | |
|---|---|---|
| f) | **Proper tool bit profile during re-sharpening process.** | A |
| g) | **Human energy loss due to heavy working conditions** | **C** |

1) **Lean Production Beliefs-** People are an organizations' most important asset. The way in which we value those people, are our competitive advantage. Keeping them safe and providing excellent working conditions help to show this value. While going through the balance sheet of CIL the expenditure on remuneration is nearly 44% of the major six expenditures. It is the most vital and critical area to optimize for better output. Manpower is to be effectively used for increase of production. *Figure-3 Bar Chart*

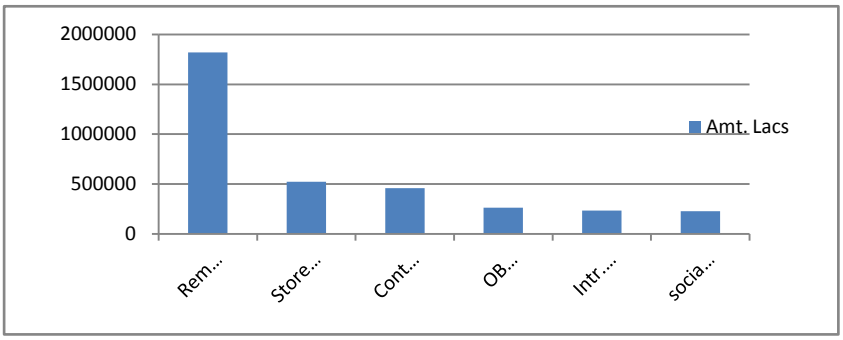
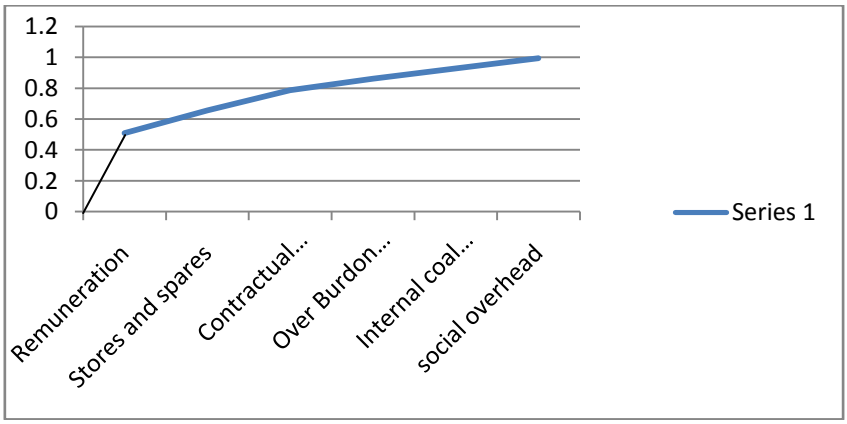



*Table-2*

| Description in CIL Balance Sheet (AR page no.117) | Rs.x (00000) |
|---|---|
| Remuneration | 1821104 |
| Stores and spares | 523145 |
| Contractual expenses | 458003 |
| Over Burdon Removal | 261847 |
| Internal coal consumption | 234129 |
| social overhead | 227012 |

***Figure – 4 Parato Chart***




## III. METHODOLOGY

**Standardization of Work**

Defined as the sequence of job tasks that must be performed by an operator to efficiently and effectively perform a given job function The persons engaged for coal preparation and coal production are considered as a cell. The working of

the cell is dependent on one another and operations are performed sequentially. These operations are to be optimized for better output.

Each workman has to carry additional weight of gum boot, helmet, belt and cap lamp, along with his tools and tackles (that is not standardized hence weight not taken into consideration) to perform their duty in underground mine. A person has spent his energy in carrying the material and becomes less efficient.

As per the ergonomics principle-

1) As per book "Motion and Time Study Design and Measurement of Work" by [3]**Ralph M. Barnes**, in chapter **'Factors affecting degree of Fatigue'**- A person can work with an energy expenditure up to 5 calories per minutes over an 8 hour day without going into "oxygen debt". On a task that does not tax a person beyond this level, no rest period would be needed. If the work is more demanding physically than the 5 Calories/min then rest periods should be introduced.
2) **Calculation of rest period** -Then total rest required can then be computed from the formula:-
**R = T(K-S) / (K-1.5)**

R= Rest required in minutes
T=Total working time
K=Average Kcal/min of type of work (heavy/low)
For heavy physical work K ranging from 7.5-10 Kcal/min, avg.= **8.75 Kcal/min**
For light physical work K ranging from 2.5-5 Kcal/min, avg.= 3.75 Kcal/min
S= Standard Kcal/min = 5 Kcal/min
Working in mine and walking on upstairs and downstairs comes under heavy category.
Therefore we will take value of K= 8.75 Kcal/min.
If worker does not take rest it will result into **fatigue** which causes low work output, deteriorated performance, **accidents or absenteeism** from the duties.

**The mine chosen for study-** Saoner Mine no. 1 in Nagpur Area. It is 45 Kms from Nagpur, having working of Bord and Pillar method of mining.
In a mine of incline gradient of 1:4.5 and coal seam is 130M below the ground level and the nearest working face is nearly 2KM from the incline at low inline gradient of 1:20-1:30.

**Cellular manufacturing**- it is one of the cornerstones when one wants to become Lean. A cell consists of persons, equipment and workstations that are arranged in order to improve the productivity. Arranging people and equipment into cells has great advantage in terms of achieving Lean goals. One of the advantages of cells is the one-piece flow concept.
In mines there are three districts of working, in each districts there are two cellular groups are deployed for coal preparation. Each cellular group of 10 persons is consists of- comprising of Mining Sardar, Driller 3, Dresser 2, Carrier 2, Pump operator 1 and Machine operator 1.
Time analysis of one cellular group is noted.
**Total time** = Unavoidable time + Available time
Unavoidable time=(Preparation time+In/out travelling time+normalization time)
Available time = (working time+ idle time+ tiffin time)
Corresponding time is represented in bar diagram. The total availability of workers in % is calculated.

**Activities Analysis of A Cellular Group During Working** ***Figure-5***

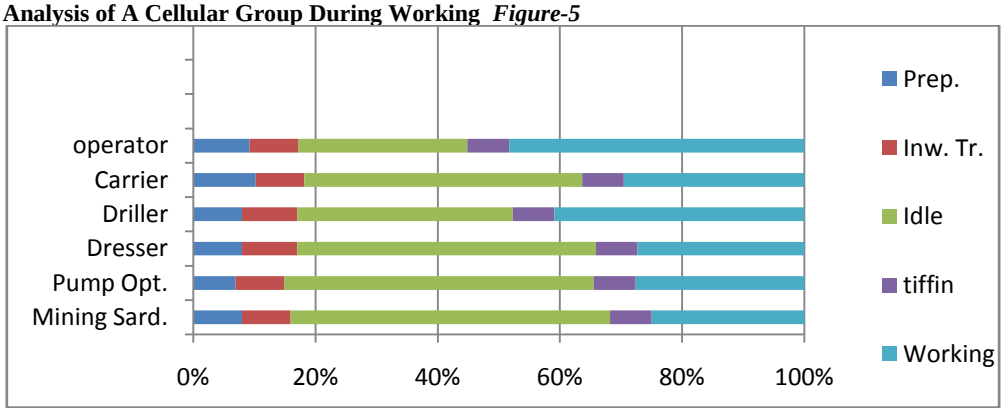



***Table – 3*** **Time Study Prior to Installation of Man Rider**

| Person/ Activity | Mining Sardar | Pump optr | Dri-1 | Dri-2 | Dri-3 | Dre-1 | Dre-2 | Carrier | S.Firer | M. Optr. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Prepration | 32 | 30 | 34 | 34 | 32 | 31 | 34 | 40 | 38 | 37 | 342 |
| Inmove | 40 | 38 | 40 | 37 | 41 | 39 | 38 | 40 | 42 | 40 | 395 |
| Outmove | 43 | 41 | 42 | 41 | 40 | 42 | 40 | 40 | 44 | 42 | 415 |
| Normalize | 43 | 41 | 42 | 40 | 42 | 42 | 40 | 42 | 44 | 42 | 420 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Unavoid.** | **158** | **150** | **158** | **152** | **155** | **154** | **152** | **162** | **168** | **161** | **1570** |
| Lunch | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 300 |
| Idle | 111 | 136 | 65 | 68 | 73 | 135 | 136 | 140 | 130 | 81 | 1075 |
| tot.idle | 141 | 166 | 95 | 98 | 103 | 165 | 166 | 170 | 160 | 111 | 1375 |
| **Working** | **181** | **164** | **227** | **230** | **222** | **161** | **162** | **148** | **152** | **208** | **1855** |

**Summary of Time Study**

| Total time | Unavoidable time | Available Working time |
|---|---|---|
| 480 mins*10=4800 mins | 1570 mins | 3230 mins |
| | 32.71% | 67.29% |

**Human energy calculation**

On the basis of ergonomics principles to obtain optimum condition two criteria have to be satisfied:

i) Energy expenditure should not average more than 5 Kcal/min
ii) Work should continue at a rate exceeding 5 Kcal/min for an optimum length of time after which rest should be taken.

***Data Table No. 4:*** AVERAGE WEIGHT CARRIED BY A WORKMAN (Director General of Mines Safety Approved)

| DISCRIPTION WEIGHT | I KG/PAIR | II KG/PAIR | III KG/PAIR | IV KG/PAIR | V KG/PAIR | AVERAGE |
|---|---|---|---|---|---|---|
| GUM BOOT NO.5 | 2.020 | 2.010 | 2.040 | 2.030 | 2.025 | 2.025 |
| GUM BOOT NO.6 | 2.090 | 2.100 | 2.110 | 2.100 | 2.100 | 2.100 |
| GUM BOOT NO.7 | 2.170 | 2.190 | 2.180 | 2.200 | 2.180 | 2.180 |
| GUM BOOT NO.8 | 2.220 | 2.230 | 2.230 | 2.240 | 2.230 | 2.230 |
| GUM BOOT NO.9 | 2.250 | 2.250 | 2.260 | 2.260 | 2.255 | 2.255 |
| AVERAGE WEIGHT OF BOOT | | | | | | 2.158 |
| HALMET | 0.280 | 0.275 | 0.280 | 0.280 | 0.285 | 0.280 |
| CAP LAMP TEE TYPE | 2.390 | 2.400 | 2.380 | 2.390 | 2.390 | 2.390 |
| CAP LAMP OLDHAM | 2.330 | 2.340 | 2.350 | 2.340 | 2.340 | 2.340 |
| BELT | 0.250 | 0.260 | 0.260 | 0.255 | 0.245 | 0.250 |
| TOTAL AVERAGE WEIGHT CARRIED | | | | | | 5.078 KG |

**Work that is expected from a normal worker is @ 5Kcal/min.**

Working for 8x60 = 480 min./day = 480 Min/day x 5 cal/min = 2400 cal/day.

*Data Table No. 5*:- ENERGY CALCULATION

Energy spent in just reaching to and fro from the pit is calculated by website(by calories calculator on website www.pro health.com, //www.runners web.com / ).

| Person Name | Age | Weight. | Height. | Down Move | To & fro | Up move | Carry Access. | Total energy spent | **Balance energy** |
|---|---|---|---|---|---|---|---|---|---|
| Laxman | 39 | 166 | 69 | 107 | 105 | 284 | 373 | 869 | **1531** |
| Sharad | 44 | 154 | 68 | 99 | 97 | 264 | 246 | 706 | **1694** |
| Rahim | 43 | 156 | 66 | 100 | 99 | 267 | 351 | 817 | **1583** |
| Nathoo | 53 | 178 | 72 | 114 | 113 | 305 | 400 | 932 | **1468** |
| Bandoo | 57 | 148 | 66 | 95 | 94 | 254 | 332 | 775 | **1625** |
| Jitendra | 44 | 152 | 68 | 98 | 96 | 260 | 341 | 795 | **1605** |
| Mohan | 34 | 144 | 64 | 92 | 91 | 247 | 323 | 753 | **1647** |
| Yadav | 37 | 168 | 65 | 108 | 106 | 288 | 77 | 579 | **1821** |
| Babloo | 55 | 180 | 66 | 116 | 114 | 308 | 404 | 942 | **1458** |
| Mukesh | 48 | 188 | 69 | 121 | 119 | 322 | 422 | 984 | **1416** |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Total | | | | | | | | | **15848** |

| Total work Calories | Unavoidable calories | Available Working Calories |
|---|---|---|
| 2400 cal/day*10 person = 24000 cal/cell | 8152 cal | 15848 Calories/cell |
| | 33.96% | 66.04% |

Nearly 34% of the energy is being spent to just reach up to the working face by a normal man at 120BPM @ 5 kal/ min. Need of this **wasted** 800 Kcal/person is to be converted into productive output.

## IV. DATA ANALYSIS AND RESULTS

**Overall human Effectiveness** (OHE) is a measure of the overall capacity utilization of workmen of that cellular group. OHE can be broken down into:

**1. Availability**

How much time has to be given to the worker to normalize after travelling inwards and outwards of the mine with accessories (average weight 5.078Kg) and tools and tackles in heavy working conditions.

From table- the total time taken by ten persons is (inwards movement = 395mins and outwards movement = 415 mins) 810 mins.

Average time taken by a person to move inward and outwards = 810/10

=81 mins.

Calculating Rest period for a person for 81 minutes travelling inwards and outwards in mine (which is considered as heavy working condition)

**R = T(K-S) / (K-1.5)**

R= Rest required in minutes

T=Total working time

K=Average Kcal/min of type of work (heavy/low)

For heavy physical work K ranging from 7.5-10 Kcal/min, avg.= **8.75 Kcal/min**

For light physical work K ranging from 2.5-5 Kcal/min, avg.= 3.75 Kcal/min

S= Standard Kcal/min = 5 Kcal/min

= 81(8.75 – 5.00) / (8.75 – 1.50)

= 41.89 minutes needed by a worker to normalize (recover from Oxygen debt) himself. Nearly 42 minutes time is waste from the total time available and it is treated as non value added activity, due care must be taken to minimize this time and increase the worker in productive outputs.

**2. Performance efficiency**

The machine's actual throughput when it is operating compared to its designed maximum capacity or the maximum it could produce based on continuous processing.

In our case availability is 67.29% and performance efficiency is 66%, then the OHE would be:

**Availability x Performance Efficiency = OHE**

**67.29 % x 66% = 44.41%**

The Overall Human Effectiveness is 44.41% in manual mining system. While going through the balance sheet of CIL the expenditure on remuneration is nearly 44% of the major six expenditures. It is the most vital and critical area to optimize for better output. Need of effective and efficient use of manpower is to increase the production and narrow the gap of demand supply for nation's development. Data collected for manual working with OHE 44.41%, the drilling time / face comes to 57.67 min obtained from 31 days record for four faces/day & production of that shift and trying to find relationship among them. V-2 is dependent variable on V-1 drilling time, V-3 availability and V-4 balance human energy. Pearson Correlation prior to man rider system is as below:- *Table-6*

**Correlations**

| | | V1 | V2 | V3 | V4 |
|---|---|---|---|---|---|
| V1 | Pearson Correlation | 1 | -.672** | -.254 | -.545** |
| | Sig. (2-tailed) | | .000 | .168 | .002 |
| | N | 31 | 31 | 31 | 31 |
| V2 | Pearson Correlation | -.672** | 1 | .575** | .688** |
| | Sig. (2-tailed) | .000 | | .001 | .000 |
| | N | 31 | 31 | 31 | 31 |
| V3 | Pearson Correlation | -.254 | .575** | 1 | .259 |
| | Sig. (2-tailed) | .168 | .001 | | .159 |

| | | | | | |
|---|---|---|---|---|---|
| | N | 31 | 31 | 31 | 31 |
| V4 | Pearson Correlation | -.545** | .688** | .259 | 1 |
| | Sig. (2-tailed) | .002 | .000 | .159 | |
| | N | 31 | 31 | 31 | 31 |

**. Correlation is significant at the 0.01 level (2-tailed).

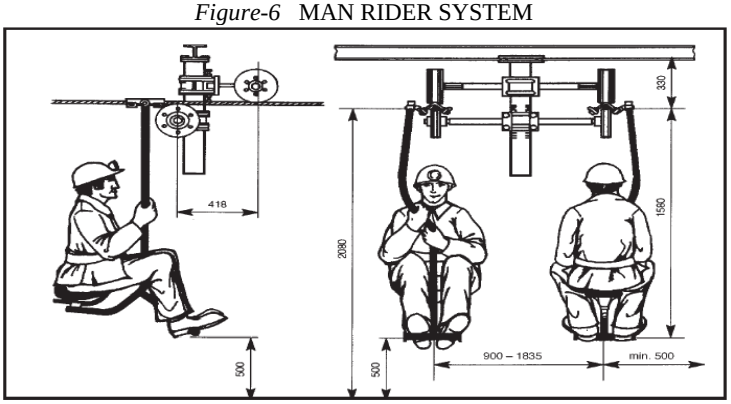
MANUAL OPERATIONS- *Table-7*

**Model Summary**

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | .856[a] | .733 | .703 | 2.519 |

a. Predictors: (Constant), V-4, V-3, V-1

*Figure-6* MAN RIDER SYSTEM




**3. Providing of man riding system for Manpower transportation**

When manpower is transported by mechanized mode at **faster speed** and nearer to the working face it offers less travelling time, **more energetic manpower availability**, increases the effective working time for production and more availability to operate the equipments. Consequently there will be increase in production and increase in productivity. It will increase the attendance/ presence of workers and reduction in medical bills. Pay back of investment can be easily justified, therefore it is to be installed in each and every mine

**4. Over all Human Effectiveness after mechanized transportation**

In a mine of incline gradient of 1:4.5 and coal seam is 130M below the ground level and the nearest working face is nearly 2KM from the incline at low inline gradient of 1:20-1:30.

**5. Increased Availability**

The man rider can transport the manpower irrespective of the inclination and gradient. For the same parameters @1.5-1.7 m/sec speed man can move to and fro in 45min. and there will be net saving of 35 minutes.

The energetic manpower available in mine for production and the 42 minutes time required to normalize the body will also be saved which a person avails during his working.

There will be net time saving = Travelling time saved + normalizing time = 35min +42min =77 min. saved/ person/day

| Person/Activity | Mining. Sardar | Pump optr | Dri-1 | Dri-2 | Dri-3 | Dre-1 | Dre-2 | Carrier | S.Firer | M. Optr. | Total Time |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Prepration | 30 | 36 | 32 | 33 | 34 | 32 | 32 | 38 | 42 | 36 | 345 |
| (In+walk)move | 24 | 24 | 25 | 26 | 24 | 25 | 26 | 26 | 24 | 24 | 248 |
| (Out+walk)move | 25 | 26 | 24 | 25 | 26 | 24 | 25 | 26 | 25 | 26 | 252 |
| Normalize | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 80 |
| **Unavoid.** | **87** | **94** | **89** | **92** | **92** | **89** | **91** | **98** | **99** | **94** | **925** |
| Lunch | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 300 |
| Idle | 115 | 142 | 68 | 64 | 75 | 132 | 128 | 135 | 130 | 82 | 1071 |
| **tot.idle** | **145** | **172** | **98** | **94** | **105** | **162** | **158** | **165** | **160** | **112** | **1371** |
| **Working** | **248** | **214** | **293** | **294** | **283** | **229** | **231** | **217** | **221** | **274** | **2504** |

*Table-8*

***6.*** **Summary of Time Study** ***Table-9***

| Total time | Unavoidable time | Available Working time |
|---|---|---|
| 480 mins*10=4800 mins | 925 mins | 3875 mins |
| | 80.72% | 80.72% |

***7.*** **Performance efficiency** ***Table-10***

The total energy consumed in carrying the accessories by ten persons is given below:-

1. The total expected work @ 5 Kcal/min is 2400 Kcal in eight hour working.
2. ([4] www.healthyforum.com,www.prohealth.com/ //www.runners web.com / ).

| NAME | AGE | WT (lbs ) | Height in Inches | To & Fro walk energy | Carry Access. Energy | Total Energy spent | ENERGY BALANCE |
|---|---|---|---|---|---|---|---|
| Manohar | 38 | 136 | 65 | 86 | 75 | 161 | **2239** |
| Kunal | 44 | 147 | 66 | 93 | 81 | 174 | **2226** |
| Tirath | 42 | 123 | 69 | 78 | 68 | 146 | **2254** |
| Mustaque | 53 | 165 | 68 | 104 | 91 | 195 | **2205** |
| Prabhakar | 59 | 141 | 66 | 89 | 78 | 167 | **2233** |
| Deepak | 57 | 151 | 65 | 95 | 83 | 195 | **2205** |
| Lallan | 34 | 165 | 68 | 104 | 91 | 195 | **2205** |
| Sudhir | 54 | 180 | 70 | 114 | 99 | 213 | **2187** |
| Ayodhya | 52 | 191 | 72 | 121 | 105 | 226 | **2174** |
| Chandu | 58 | 171 | 73 | 108 | 94 | 202 | **2198** |
| | | | | | | | **22126** |

| Total work Calories | Unavoidable calories | Available Working Calories |
|---|---|---|
| 2400 cal/day*10 person = 24000 cal/cell | 1874 cal/cell | 22126 Calories/cell |
| | 7.80% | 92.20% |

After installation of man rider system there is increase of 13.43% in human availability from 67.29% to 80.72% and increase of 26.2% in human efficiency. Overall Human Effectiveness after man rider system is

**Availability x Performance Efficiency = OHE**
**80.72 % x 92.20% = 74.42%**

From above comparison it is clear that by providing mechanized transportation there is **increase of 30.01% in Overall Human Effectiveness**. Data collected for manual working with OHE 74.42%, the drilling time / face comes to 48.85 min obtained from 31 days record for four faces/day & production of that shift and trying to find relationship among them. V-6 is dependent variable on V-5 drilling time, V-7 availability and V-8 balance human energy. Pearson Correlation prior to man rider system is as below:- *Table-11*

**Correlations**

| | | V5 | V6 | V7 | V8 |
|---|---|---|---|---|---|
| V5 | Pearson Correlation | 1 | -.801** | -.603** | -.600** |
| | Sig. (2-tailed) | | .000 | .000 | .000 |
| | N | 31 | 31 | 31 | 31 |
| V6 | Pearson Correlation | -.801** | 1 | .705** | .794** |
| | Sig. (2-tailed) | .000 | | .000 | .000 |
| | N | 31 | 31 | 31 | 31 |
| V7 | Pearson Correlation | -.603** | .705** | 1 | .566** |
| | Sig. (2-tailed) | .000 | .000 | | .001 |

| | | | | | |
|---|---|---|---|---|---|
| | N | 31 | 31 | 31 | 31 |
| V8 | Pearson Correlation | -.600** | .794** | .566** | 1 |
| | Sig. (2-tailed) | .000 | .000 | .001 | |
| | N | 31 | 31 | 31 | 31 |

****. Correlation is significant at the 0.01 level (2-tailed).Increase in correlation coefficient of availability balance energy and (-)drilling time there is increases in production of 16.77%.**

Model Summary *Table12*

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | .906[a] | .821 | .802 | 1.938 |

a. Predictors: (Constant), V8, V7, V5

**8. Analysis**

In above table- after man riding system associated variables V-5 to V-8 analyzed. V-6 is the dependent variable that is production and V-7 availability in mine, V-8 balance human energy & V-5 is drill time of the faces has been analyzed for their correlation. It is observed that drilling time is showing negative coefficient which indicates inverse relationship. Drilling time Pearson correlation is stronger than the availability and human energy. Lesser the face drilling time the more will be the production. Among balance human energy and availability in mine, balance human energy is the more contributing factor in perspective of production.

We have compared the data of production with independent variables availability of manpower, balance human energy and face drilling time, which shows significant relationship with production output. After man riding system there is increase in production with linear correlation. Man rider system is to be provided to achieve better productivity for better utilization of reducing manpower to cater the energy needs of the country.

**9. Tangible benefits**

- Improved morale of the employees and better quality of life.
- Absenteeism rate has decreased and better mine management.
- Medically challenged persons also goes to mine.
- Indirect cost involved reduced fatigue, accidents and medical expenses.
- As the working is cellular and each activity is dependent on one another the waiting time is minimized and can move together.

## V. CONCLUSION

In manual operation human energy coefficient was more correlated with the production. After man rider installation Availability (13.43%) and human efficiency (26.2%) increase contributes in increase in (16.77%) production.

Lean philosophy is the only way for reduction of waste and improve effectiveness of the resources to compete the world. Identification of wastes is a continuous and never ending process, with the application and implementation of lean production the coal can be produced with highest quality at cheaper rate.

It is clear that global competition demands the effective implementation of lean tools in coal industry and more research is needed on application of lean tools in the process industry.

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