Enhancing the Performance Utilization of Locos and Minimizing the Demurrage of Rakes in A Steel Plant

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***Abstract* - This paper deals with enhancing the performance utilization of locos (Railway Engines) by uncovering the non-value adding activities in raw material unloading yard (RMUY) of an integrated steel plant. The capacity expansion of steel industry involves expansion of the production capacity at different stages of steel making like Raw material handling system, Treatment plants, Iron making, Steel making, Casting, & Rolling mills. At present Cold Rolling Mill-2 and Steel Making Shop-3 are going to be commissioned shortly. Hence with the expansion of the steel plant, the demand for raw materials will increase which will increase the number of inbound rakes arriving at RMUY. The increase in number of rakes arriving at RMUY causes congestion at the tracks causing bottlenecks for the unloading facilities and limits the rake movements within RMUY. The external railway agency providing the rail service, charges for demurrage (delay in return of rakes beyond 8hr of free unloading time). Thus such bottlenecks not only adversely affect the unloading capabilities of the yard, but also increase the demurrage costs.**

Using Work Measurement Technique, 24hr Time study has been conducted in raw material unloading yard to estimate the existing utilization of nine locos simultaneously three shifts per day. Process chart is drawn to identify the separate steps or events that occur during a series of actions carried out by loco in RMUY and activity chart is drawn to identify operation time, travel time & idle time of locos in continuous three shifts. Daily Loco requirement plan is developed for different production levels and rake arrival plan to enhance the performance utilization of Locos.By using Value Stream Mapping Technique the non-value adding activities in RMUY are reduced which will reduce the lead time of unloading the rake and delay in return of rakes, hence demurrage cost is minimized. Based on utilization and various scenarios of different production levels, it is found out that the existing number of locos can handle the increased arrival of raw materials due to plant expansion.

By reducing the lead time of rake unloading process, congestion in tracks is reduced & by modifying the unloading facilities, the operational costs in the form of demurrage charges will be saved, which will lead to a savings of Rs 100 million over a period of 14 months. The proposed system is currently under implementation by steel plant.

Key Words: RMUY, Locos, Work Measurement Technique, Time study, Process chart, Activity chart, Utilization, Bottleneck, Optimization, Value Stream Mapping, Lead Time, Demurrage cost.

I. INTRODUCTION

A major Indian steel manufacturer is planning for plant capacity expansion. The capacity expansion involves expansion of the production capacity at different stages of steel making which is shown in Figure 1[1].

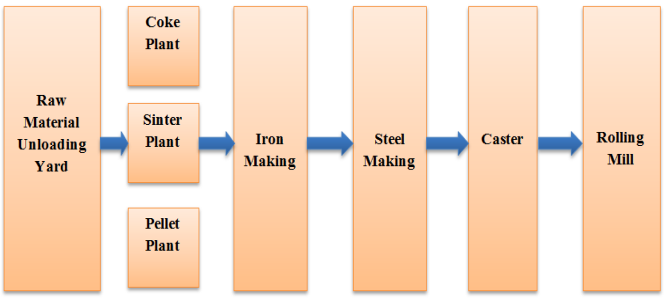


Figure 1: The typical steel making process of a Steel Plant

At the RMUY, major raw materials such as iron ore, Non Coking coal, Coking coal, coke, Limestone, Dolomite, Quartzite and Manganese Ore are received from various sources through goods trains called rakes, provided by an external railway agency. The rakes are sent to mechanized unloading stations (wagon tipplers & track hoppers), where material is unloaded. In this plant, the in-plant movement of rakes is through captive locomotives that run on diesel. The external railway locomotives, deliver the rakes to the yard and leave. Some rakes are divided into smaller wagon sets before being sent to unloading stations. After unloading, the wagon sets are joined together. This process of splitting and joining of rakes is called rake handling. All the rakes after unloading and handling, if needed, are then handed over back to the railway agency. The external railway agency providing the rail service, charges for demurrage (delays in return of rakes beyond a certain time limit). Hence delay in return of rakes must be avoided to reduce the demurrage cost.

Logistics is the management of the flow of resources between the point of origin and the point of destination in order to meet some requirements of customers or corporations.

Operating responsibility of Logistics is repositioning of raw materials, work in process & finished goods where required at lowest cost possible & quality service. It is difficult to accomplish any Receipt/Dispatch processes, repositioning of products & manufacturing without a Professional Logistics Support.

This plant is producing 10 Million Tonne of Steel per annum, aiming to achieve 16 MTPA in the coming years. To cater the raw material requirement and also to dispatch the finished products, it is having rail infrastructure at plant premises. To produce this capacity of steel, it has to bring in nearly 40 MTPA of various types of raw materials and also move nearly 10 MTPA of finished products. Both inbound and outbound traffic is handled by having own Locomotives and Railway Yards. Logistic department internally has an infrastructure of 40 Locomotives, 160 km of Track

The steel plant owned Locomotives are used for internal shunting operation at plant premises. Raw materials booked from various ports / sidings are received in railway wagons and are handed over to thesteel plant.

South Yard being the main receipt yard with 26 lines handles the rakes offered. The logistics section at south yard instructs the shunting operation of rakes to offer for unloading at Wagon Tipplers, Track Hopper or Manual unloading. The feeding lines to tipplers are limited, the rakes parked at different lines are to be shunted and placed in the minimum possible time.

At present 40 Locos are existing in the plant for various requirements like

1. Input Raw material handling at South Yard, (9+1=10)
2. Hot metal handling at 4MT and 7,10MT Iron making to SMS-1&2, (19+1=20)
3. Finished goods handling at North Yard and HSM-1, HSM-2, BRM and WRM. (9+1=10)

A process flow diagram for the raw material unloading process is provided in Figure 2.

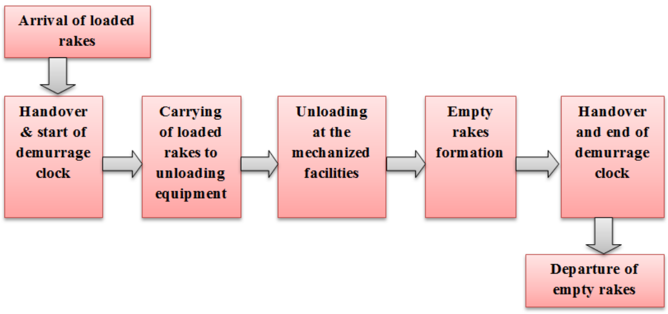


Figure 2: Raw Material Unloading Process

The adequacy of the current facilities for handling the increased arrival of raw materials needed to be investigated and in case of inadequacy, appropriate changes needed to be proposed, so that the system is capable of unloading the annual requirement of raw materials with minimum network congestion.

II. OBJECTIVES

- To investigate the adequacy of the current facilities for handling the increased arrival of raw materials.
- To estimate the existing utilization of nine locos deployed for raw material handling at south yard.
- To enhance the utilization of locos, which lead to optimization of required number of locos.
- To develop loco requirement plan.
- To reduce the lead time of rake unloading process which in turn reduce the delay in return of rakes to minimize the demurrage cost.

III. TOOLS AND TECHNIQUES USED

- Work Measurement.
    - Time and motion study.
- Process Chart.
- Activity Chart.
- Value Stream Mapping (VSM).

IV. LITERATURE REVIEW

A case study research was conducted by N. Yusoff at a local car seat polyurethane (p/u) injection manufacturing company by extensively exploiting the work study methods and techniques during the on-site studies. Two fundamental approaches in work study namely method study and work measurement offer a systematic and organized steps in the research studies. The work measurement has been widely used as a method for measuring actual working time via its several techniques i.e time study. This paper discusses on the application of the work measurement technique in establishing a benchmark time for producing the car seat p/u injection line of the case study subject[2].

A research was carried out by K. Al-Saleh at the Motor Vehicle Periodic Inspection (MVPI) station to improve and enhance the bottleneck inspection point by using different applications to reduce the inspection time. The main problem of this research was an inspection point (No. 1) which consumed more time in comparison with the other inspection points. Accordingly, this inspection point increases the flow time in the inspection lanes. This research investigated and searched for possible solutions and alternatives aimed at achieving the objective using some tools from motion and time study and ARENA software to simulate and predict the changes expected to occur in the inspection lanes[3].

“Lean’’ approach has been applied more than frequent in many manufacturing management floors over these few decades. Started in the automotive industry, sequential improvement initiatives were implemented to enhance the manufacturing practice changes. The team described a case where Lean Production (LP) principles were adapted for the process sector of an automotive part manufacturing plant. Value Stream Mapping (VSM) is one of the key lean tools used to identify the opportunities for various lean techniques. The contrast of the before and after the LP initiatives in determine managers potential benefits such as reduced production lead-time and lower work-in-process inventory. As VSM involves in all of the process steps, both value added and non-value added, are analysed and using VSM as a visual tool to help see the hidden waste and sources of waste. A Current State Map is drawn to document how things actually operated on the production floor. Then, a Future State Map is developed to design a lean process flow through the elimination of the root causes of waste and through process improvements.

The use of the VSM improved the approach in LP initiatives as it reveals obvious and hidden waste that affected the productivity of D45T production. There is a significant amount of the time products spent on the production system usually was waiting and non-value added. Quantitative evidence showed that many of the Lean tools have an expected impact related to the reduction of this waiting time [4].

V. METHODOLOGY

To meet the main aim and the specific objectives of the study a quantitative research methodology study along with a comprehensive literature review were employed.

1. Using Work Measurement Technique, 24hr Time study has been conducted in raw material unloading yard to estimate the existing utilization of nine locos simultaneously three shifts per day.

2. Process chart is drawn to identify the separate steps or events that occur during a series of actions carried out by loco in RMUY and activity chart is drawn to identify operation time, travel time & idle time of locos in continuous three shifts. In addition to the calculation of exiting utilization of locos, various scenarios of different production levels like present day average, medium, and maximum capacity material receipt are considered to maximize the utilization of existing locos and unloading equipments, resulting in optimization of required number of locos. Daily Loco requirement plan is developed for different production levels and rake arrival plan to enhance the performance utilization of Locos.

3. By using Value Stream Mapping Technique the non-value adding activities in RMUY are reduced which will reduce the lead time of unloading the rake and delay in return of rakes, hence demurrage cost is minimized.

VI. DATA COLLECTION

Process flow of steel plant

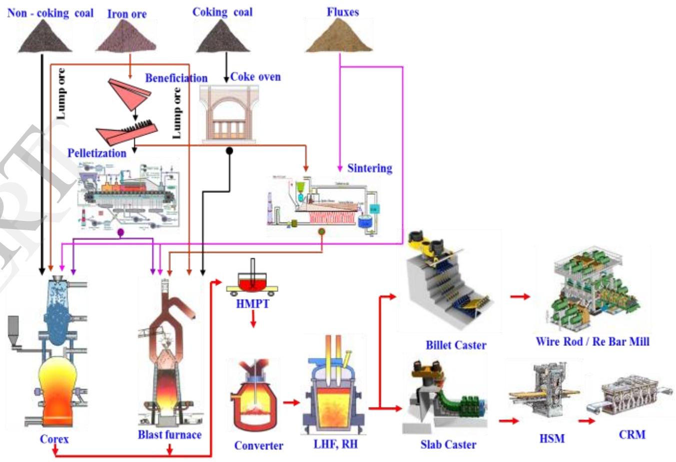


Figure 3: Process flow of steel plant

South yard loco time and motion study Data

Table 1: Time study data of loco 4 .

South Yard Loco Time Study				
Date: 15 & 16-2-2014	Loco No: 4	Shift: C,A,B		
Activity	Loco Movements	Time in min		
		From	To	Elapsed
Shift relieving	Shift relieving	22:00	22:40	00:40
5 rear , 9 rear Empty rake formation	LL from R8 to 5 rear	22:40	22:50	00:10
	Placing 5 rear empty for cleaning	22:50	23:40	00:50
	5 rear , 9 rear empty rake shunting & backing to R19	23:40	00:00	00:20
	LL from R19 to R14	00:00	00:10	00:10
Idle	WFT in R14	00:10	02:45	02:35
Placement of load to T1	LL from R14 to R7	02:45	03:00	00:15
	Attached to load rake WF brake release	03:00	03:30	00:30
	Placing load rake to T1	03:30	03:40	00:10
Placement of load to CY	LL from R7 to R8	03:40	03:45	00:05
	Banker attachment to CY load	03:45	03:50	00:05
	Weighment of CY load	03:50	04:05	00:15
	Pushing load rake from R8 to CY	04:05	05:45	01:40
	Reached SY 4rear LL from 4rear to R1	05:45	06:00	00:15
Shift relieving	Shift relieving	06:00	06:35	00:35
Idle	WFT in R1	06:35	06:52	00:17
Bulge wagon removing	LL from R1 to 10 rear	06:52	07:00	00:08
	Attached to 2 bulge wagons and pulling towards DL	07:00	07:10	00:10
	Shunting bulge wagons to empty rake in R20	07:10	07:25	00:15
	LL from R20 to R14	07:25	07:35	00:10
Idle	WFT in R14	07:35	08:35	01:00
10 rear & 13 rear Empty rake formation	LL from R14 to 10 rear	08:35	08:45	00:10
	Shunting 10 rear & 13 rear empty rake & pulling to DL	08:45	09:10	00:25
	LL from DL to 11 rear	09:10	09:15	00:05
Idle	WFT in 11 rear	09:15	09:30	00:15
5 rear Empty rake formation	Pulling 5 rear empty from DL to R19	09:30	09:50	00:20
	LL from R19 to R2	09:50	09:55	00:05
	WF signal at top pt	09:55	10:15	00:20
	LL from top pt to R2	10:15	10:25	00:10
Idle	WFT in R2	10:25	11:10	00:45
Miscellaneous	LL from R2 to top pt & again to R2	11:10	11:20	00:10
Idle	WFT in R2	11:20	14:00	02:40
Shift relieving	Shift relieving	14:00	14:30	00:30
Miscellaneous	LL from R1 to DL	14:30	14:40	00:10
	LL from DL to R2	14:40	14:50	00:10
	Shifting brake wagon from R2 to R3	14:50	15:10	00:20
Idle	WFT in R3	15:10	17:30	02:20
10 rear Empty rake formation	LL from R3 to 10 rear	17:30	17:40	00:10
	Placing 10 rear empty rake for cleaning	17:40	18:30	00:50
	Pulling 10 rear empty to DL	18:30	18:40	00:10
12 rear Empty rake formation	LL from DL to 12 rear	18:40	18:50	00:10
	LL from 12 rear to DL	18:50	19:00	00:10
	Pulling 12 rear empty rake from DL to R18	19:00	19:20	00:20
4 rear Empty rake formation	LL from R18 to DL via R20	19:20	19:50	00:30
	Pulling 4 rear empty from DL to R20	19:50	20:10	00:20
	LL from R20 to R13	20:10	20:20	00:10
Idle	WFT in R13	20:20	20:30	00:10
Bulge wagon removing	Shifting 17 bulge wagons from DL to R7	20:30	21:00	00:30
	Placing bulge wagons to T1	21:00	21:10	00:10
5 rear Empty rake formation	LL from R7 to R9	21:10	21:20	00:10
	LL from R9 to DL	21:20	21:25	00:05
	Pulling 5 rear empty from DL to R9	21:25	21:40	00:15
	LL from R9 to R8	21:40	21:45	00:05
Idle	WFT in R8	21:45	22:00	00:15

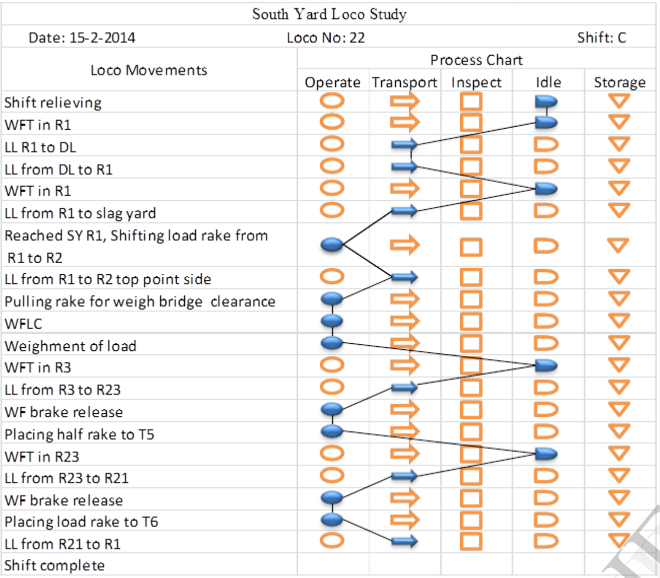
Table 2:Time study data of loco 17 .

South Yard Loco Time Study				
Date: 15 & 16-2-2014	Loco No: 17	Shift: C,A,B		
Activity	Loco Movements	Time in min		
		From	To	Elapsed
Shift relieving	Shift relieving	22:00	22:40	00:40
13 rear Empty rake formation	LL from R14 to 13 rear	22:40	22:50	00:10
	Pulling 13 rear empty to DL	22:50	23:05	00:15
12 rear Empty rake formation	LL from DL to 12 rear	23:05	23:10	00:05
	WFLC in 12 rear	23:10	23:15	00:05
	Pulling 12 rear empty to DL	23:15	23:30	00:15
5 rear , 9 rear Empty rake formation	LL from DL to 9 rear	23:30	23:40	00:10
	5 rear ,9 rear empty rake shunting & backing to R19	23:40	00:00	00:20
	LL from R19 to R14	00:00	00:10	00:10
Idle	WFT in R14	00:10	03:40	03:30
Miscellaneous	LL from R14 to R23	03:40	03:50	00:10
	Pulling 29 load wagons from R23 to DL	03:50	04:20	00:30
9 rear Empty rake formation	LL from DL to 9 rear	04:20	04:30	00:10
	Attached to 9 rear empty WFLC	04:30	05:10	00:40
	Pulling 9 rear empty to DL	05:10	05:15	00:05
12 rear Empty rake formation	LL from DL to 12 rear	05:15	05:25	00:10
	Pulling 12 rear empty to DL	05:25	05:40	00:15
	Pushing 12 rear empty from DL to R26	05:40	06:00	00:20
Shift relieving	Shift relieving	06:00	06:35	00:35
Idle	WFT in R26	06:35	07:15	00:40
Bulge wagon removing	LL from R26 to R23	07:15	07:25	00:10
	T5 bulge wagon shunting	07:25	07:35	00:10
13 rear Empty rake formation	LL from R23 to 13 rear	07:35	07:45	00:10
	Pulling 13 rear empty rake up to poling	07:45	08:00	00:15
	LL from 13 rear to R1	08:00	08:10	00:10
Idle	WFT in R1	08:10	09:20	01:10
Maintenance	LL from SY to NY for Diesel	09:20	12:15	02:55
Idle	LL reached SY, WFT in R1	12:15	13:40	01:25
Placement of load to T2	LL from R1 to R4	13:40	13:45	00:05
	Placing load rake to T2	13:45	13:50	00:05
	LL from R4 to R1	13:50	14:00	00:10
Shift relieving	Shift relieving	14:00	14:30	00:30
Placement of load to T5	LL from R1 to R24	14:30	14:45	00:15
	Placing load rake to T5	14:45	14:55	00:10
Placement of load to T4	LL from R24 to R12	14:55	15:15	00:20
	Placing load rake to T4	15:15	15:30	00:15
Placement of load to T1	LL from R12 to R7	15:30	15:45	00:15
	Placing load rake to T1	15:45	15:55	00:10
	LL from R7 to R8	15:55	16:05	00:10
Idle	WFT in R8	16:05	16:30	00:25
EY Empty rake formation	LL from R8 to R10	16:30	16:40	00:10
	Removing 2 empty box from R10 rake	16:40	16:50	00:10
	Shifting 2 empty box from R10 to R8	16:50	17:15	00:25
	WF another 2 box attachment	17:15	17:30	00:15
	Pulling 4 empty box to DL	17:30	17:45	00:15
	Another one box attachment in DL	17:45	18:00	00:15
	Pulling 5 empty wagons from DL to EY	18:00	21:20	03:20
Idle	Reached SY, WFT in 11 rear	21:20	21:30	00:10
9 rear Empty rake formation	Pulling 9 rear empty from DL to R14	21:30	21:50	00:20
	LL from R14 to R3	21:50	22:00	00:10

VII. FINDINGS AND DISCUSSION

Process Chart

The process chart is a device for recording a process in a compact manner, as a means of understanding it better and improving it. The chart represents graphically the separate steps or events that occur during a series of actions [5]. Process chart is drawn to identify the separate steps or events that occur during a series of actions carried out by loco in the raw material unloading yard. Process chart is drawn to the data collected through time and motion study.



Activity Chart

Although the process chart give the picture of the different steps in the process, it is often desirable to have a breakdown of the process or of a series of operations plotted against a time scale. Such a picture is called an activity chart [3]. Activity chart is drawn to identify operation time, travel time & idle time of locos in continuous three shifts.

South Yard Loco Study			
Date: 15-2-2014		Loco No: 22	Shift: C
Time in min			Activity
From	To	Elapsed	
22:00	22:40	00:40	Shift relieving
22:40	23:00	00:20	WFT in R1
23:00	23:10	00:10	LL R1 to DL
23:10	23:20	00:10	LL from DL to R1
23:20	00:05	00:45	WFT in R1
00:05	01:20	01:15	LL from R1 to slag yard
01:20	01:35	00:15	Reached SY R1, Shifting load rake from R1 to R2
01:35	01:40	00:05	LL from R1 to R2 top point side
01:40	01:45	00:05	Pulling rake for weigh bridge clearance
01:45	02:00	00:15	WFLC
02:00	02:30	00:30	Weighment of load
02:30	03:30	01:00	WFT in R3
03:30	03:40	00:10	LL from R3 to R23
03:40	04:10	00:30	WF brake release
04:10	04:20	00:10	Placing half rake to T5
04:20	04:50	00:30	WFT in R23
04:50	05:00	00:10	LL from R23 to R21
05:00	05:30	00:30	WF brake release
05:30	05:40	00:10	Placing load rake to T6
05:40	06:00	00:20	LL from R21 to R1
06:00			Shift complete

Table 3: 1st Day Analysis.

Sum of Elapsed Time	Loco Numbers									
Description	4	17	18	22	24	26	30	38	41	Grand Total
Planned shift relieving	0:45:00	0:45:00	0:45:00	0:45:00	0:45:00	0:45:00	0:45:00	0:45:00	0:45:00	6:45:00
Shift relieving loss = SR - PSR	1:00:00	1:00:00	1:00:00	1:00:00	1:00:00	1:00:00	1:00:00	1:00:00	1:00:00	9:00:00
Idle Time = Idle + Shift relieving loss + Loco Shutdown	11:17:00	8:20:00	10:47:00	5:30:00	10:55:00	10:17:00	12:55:00	3:28:00	11:17:00	84:46:00
Working Time = AT - IT	12:43:00	15:40:00	13:13:00	18:30:00	13:05:00	13:43:00	11:05:00	20:32:00	12:43:00	131:14:00
Available Time	24:00:00	24:00:00	24:00:00	24:00:00	24:00:00	24:00:00	24:00:00	24:00:00	24:00:00	216:00:00
Utilization = WT/AT	53%	65%	55%	77%	55%	57%	46%	86%	53%	61%

- In south yard of this steel plant, 9 Locos are deployed for raw material handling.
- 216 Loco hours has been considered for study.
- Utilization of 9 Locos is 61%. Out of 39% loss time, 89% is due to idle (waiting for task) & remaining 11% is due to shift relieving loss.

Table 4: 2nd Day Analysis.

Sum of Elapsed Time	Loco Numbers									
Description	4	17	18	22	24	26	30	38	41	Grand Total
Planned shift relieving	00:45	00:45	00:45	00:45	00:45	00:45	00:45	00:45	00:45	06:45
Shift relieving loss = SR - PSR	00:25	00:25	00:25	00:25	00:25	00:25	00:25	00:25	00:25	03:45
Idle Time = Idle + Shift relieving loss + Loco Shutdown	9:40:00	5:40:00	8:40:00	10:20:00	8:00:00	6:40:00	4:15:00	5:20:00	4:53:00	56:23:00
Working Time = AT - IT	14:20:00	18:20:00	15:20:00	13:40:00	16:00:00	17:20:00	19:45:00	18:40:00	19:07:00	159:37:00
Available Time	24:00:00	24:00:00	24:00:00	24:00:00	24:00:00	24:00:00	24:00:00	24:00:00	24:00:00	216:00:00
Utilization = WT/AT	60%	76%	64%	57%	67%	72%	82%	78%	80%	74%

- Utilization of 9 Locos is 74%. Out of 26% loss time, 80% is due to idle (waiting for task), 13% is due to loco shutdown & remaining 7% is due to shift relieving loss.

Table 5: 3rd Day Analysis.

Sum of Elapsed Time	Loco Numbers									
Description	4	17	18	22	24	26	30	38	41	Grand Total
Planned shift relieving	00:45:00	00:45:00	00:45:00	00:45:00	00:45:00	00:45:00	00:45:00	00:45:00	00:45:00	6:45:00
Shift relieving loss = SR - PSR	00:25:00	00:25:00	00:25:00	00:25:00	00:25:00	00:25:00	00:25:00	00:25:00	00:25:00	3:45:00
Idle Time = Idle + Shift relieving loss + Loco Shutdown	9:30:00	10:20:00	9:30:00	10:10:00	7:25:00	11:15:00	8:15:00	7:30:00	5:15:00	79:10:00
Working Time = AT - IT	14:30:00	13:40:00	14:30:00	13:50:00	16:35:00	12:45:00	15:45:00	16:30:00	18:45:00	136:50:00
Available Time	24:00:00	24:00:00	24:00:00	24:00:00	24:00:00	24:00:00	24:00:00	24:00:00	24:00:00	216:00:00
Utilization = WT/AT	60%	57%	60%	58%	69%	53%	66%	69%	78%	63%

- Utilization of 9 Locos is 63%. Out of 37% loss time, 95% is due to idle (waiting for task), & remaining 5% is due to shift relieving loss.

After estimating the existing utilization of nine locos it is found that the utilization of locos is low. Hence to enhance the utilization and optimize the required number of locos different hot metal production levels in terms of tons per day (TPD), tons per annum (TPA), and metric tons per annum (MTPA) are considered. For hot metal production calculation norms for one ton of hot metal is considered. Optimum number of locos required for different production levels and rake arrivals is proposed. Table 6 shows the proposed system for handling increased arrival of raw material.

Table 6: Proposed system for various production levels.

	Present System				Proposed System						
	1st day	2nd day	3rd day	Average							
Available No. of Locos	9	9	9	9	9	9	9	9	9	9	
Loco Utilization	61%	74%	63%	66%	71.98%	75.41%	78.83%	82.26%	85.69%	88.27%	
Number of rakes handled	19	24	22	22	24	25	26	27	28	29	**Norms for one tonne of Hot Metal**
Materials				**Quantity**							
Coal	34463.66	21955.56	33014.13	29811.12	29250.59	30643.48	32036.36	33429.25	34822.14	35870.98	1.39289
IOF	15066.00	11174.49	21950.55	16063.68	29723.89	31139.31	32554.73	33970.15	35385.58	36451.39	1.41542
C-ore	0.00	15514.69	7751.50	7755.40	7204.77	7547.86	7890.94	8234.03	8577.11	8835.46	0.34308
ROM	7469.95	15664.43	7885.21	10339.86	6299.99	6599.99	6899.99	7199.99	7499.99	7725.89	0.30000
L/S	2750.58	10101.87	10903.58	7918.68	9089.83	9522.68	9955.53	10388.38	10821.23	11147.16	0.43285
Dolomite	3663.10	7296.99	0.00	3653.36	4256.85	4459.55	4662.26	4864.97	5067.67	5220.31	0.20271
Quartz	4052.25	7817.10	0.00	3956.45	875.04	916.71	958.37	1000.04	1041.71	1073.09	0.04167
Total	**67465.54**	**89525.13**	**81504.97**	**79498.55**	**86700.96**	**90829.58**	**94958.19**	**99086.81**	**103215.43**	**106324.28**	
Iron Material	**22535.95**	**42353.61**	**37587.26**	**34158.94**	**43228.65**	**45287.16**	**47345.66**	**49404.17**	**51462.68**	**53012.73**	
Hot metal/TPD	**10945.09**	**20569.99**	**18255.10**	**16590.06**	**21000.00**	**22000.00**	**23000.00**	**24000.00**	**25000.00**	**25753.00**	
Hot metal/TPA	3994959.57	7508046.45	6663113.11	6055373.05	7665000.00	8030000.00	8395000.00	8760000.00	9125000.00	9399845.00	
Hot metal/MTPA	**3.99**	**7.51**	**6.66**	**6.06**	**7.67**	**8.03**	**8.40**	**8.76**	**9.13**	**9.40**	
Required No. of Locos @existing locos utilization	5	7	6	6	6	7	7	7	8	8	

- Average utilization of 9 Locos 1st day, 2nd day, and 3rd day of study is 61%, 74%, 63% respectively.
- Average existing utilization of 9 Locos at south yard is 66%.
- Average number of rakes handled per day is 22 & average quantity of raw material received per day is 79498.55 tons.
- For various production levels, utilization of Locos is estimated.
- To achieve the target of 9.4 MTPA, 29 rakes has to be received per day.
- At maximum production level the utilization of Locos is 88.27%.

Table 7: Loco requirement plan

Loco Requirement Plan		
Daily production plan in terms of hot metal tons per day	**Range of rakes per day**	**Number of Locos required**
10945.09	15 to 18	5
21000	19 to 22	6
23000	23 to 27	7
25753	28 to 31	8
>25753	31 to 34	9

- Daily Loco requirement plan is developed for different production levels and rake arrival plan to enhance the performance utilization of Locos.
- Based on number of rakes arrival plan on particular day, number of Locos deployment can be planned.
- Remaining Locos can be sent to other yard or these locos can be shut down so that unnecessary diesel consumption will be saved.

Value stream mapping

Current state value stream map

From the available data current state value stream map is drawn using Microsoft Visio software to find out lead time of rake unloading process. Figure 4 shows the current state value stream map.

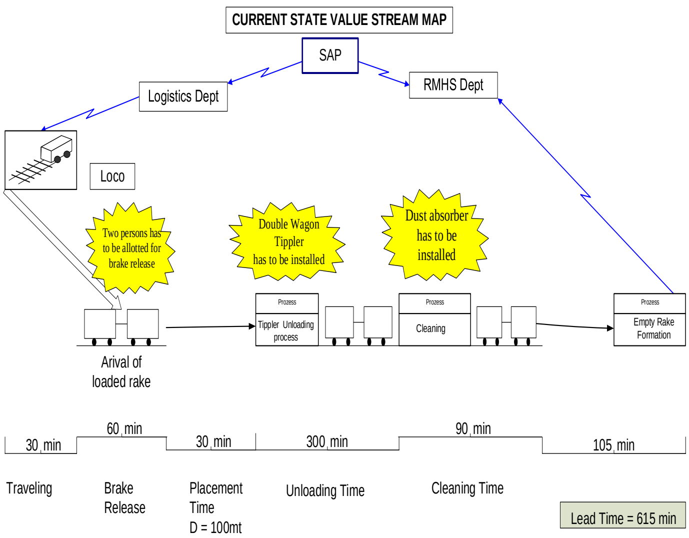


Figure 4: Current state value stream map.

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- **Inferences**
- From figure 4: Current state value stream map.
    - The total lead time for unloading one rake is 615 min.
    - 615 min includes, traveling time of 30min, brake release time 60min, placement time 30min, unloading time 300min, cleaning 90min, and empty rake formation time of 105min.
    - From current state value stream map three improvement activities are identified.

Future state value stream map

After study and analysis of current state value stream map future state valuestream map is designed. Figure 5 shows future state value stream map.

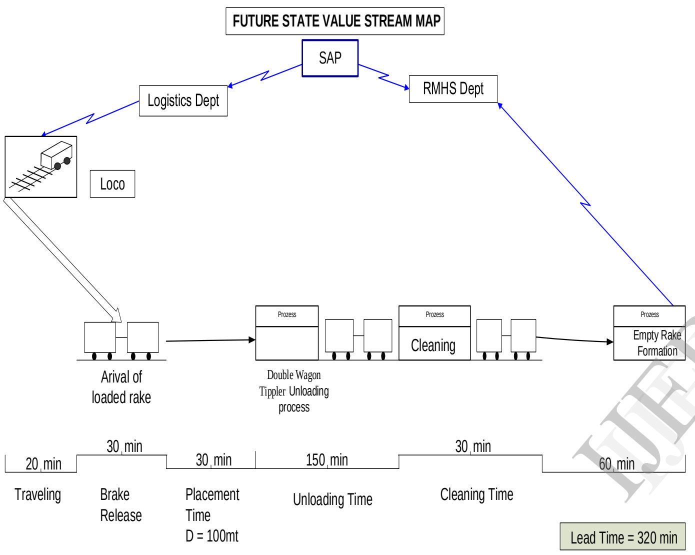

Figure 5: Future state value stream map.

- **Inferences**
- From figure 5: Future state value stream map.
    - The total lead time for unloading one rake can be reduced from 615min to 320 min.
    - 320 min includes, traveling time of 20min, brake release time 30min, placement time 30min, unloading time 150min, cleaning 30min, and empty rake formation time of 60min.

Cost Benefit Analysis

For demurrage cost (DC) analysis total number of rakes handled during study period, Unloading facility, demurrage charged rakes, demurrage hours, number of wagons per rake, demurrage amount in rupee are considered. Table 8 gives Rake wise DC analysis.

Table 8: Rake wise DC analysis

Observation Day	Total Rakes Studied	Name of the Unloading Facility	DC Rake	DC Hrs	Amount in Rs	No.of Wagon/ Rake
1st Day	19	C/Y	1	3	26100	58
		TH 01	1	1	7800	52
		T3&T1&T6	1	4	35400	59
		Total	**3**	**8**	**69300**	
2nd Day	24	T5	1	3	26550	59
		T4	1	3	26550	59
		T5	1	5	44250	59
		T3&T6	1	2	17100	57
		T4	1	1	8850	59
		T3	1	3	26550	59
		T6	1	1	8850	59
		T2	1	4	35400	59
		T1&T4	1	1	8850	59
		T2	1	2	17700	59
		T1&T4	1	2	17700	59
		C/Y	1	3	26550	59
		C/Y	1	9	79650	59
		T2	1	1	8850	59
		T5	1	1	8850	59
		T2	1	2	17700	59
		Total	**16**	**43**	**379950**	
3rd Day	22	T5	1	1	8700	58
		TH-01	1	1	7800	52
		T5&T3	1	3	26550	59
		T5	1	1	8850	59
		C/Y	1	1	8850	59
		TH-01	1	2	17700	59
		T6	1	5	44250	59
		T3	1	2	17100	57
		Total	8	16	139800	
Total	**65**		**27**	**67**	**589050**	

- Demurrage cost charged by Indian Railway is Rs 150/wagon/Hr.
- Total number of rakes handled during 3day study is 65. Out of which for 27 rakes demurrage cost is incurred.
- Total demurrage cost incurred during study period is Rs 5,89,050/-
- Average demurrage cost incurred per rake is Rs 26,030.35/-

- Average demurrage hours per rake is 2.96hr.That means 2.96hr extra time is taking for unloading, than the scheduled free unloading time of 8hr.

Track Hopper

Table 9: Track hopper DC hours analysis

Type of Unloading Facility	**Name of the Unloading Facility**	**DC Hrs**
TH	TH-01	2
TH	TH 01	1
TH	TH-01	1
	Average DC Hrs	**1.33**

- Demurrage cost incurred per rake due to 1:20 DC hr is Rs 11800/-
- In case of 1rake per day cost of 3 man power for one shift is Rs 1200/-
- We can save Rs 10600/- per day. Rs 38.69 lakhs per annum.
- If we increase the number of BOBSN rakes received per day from 1 to 6
- We can save Rs 8200/- per day & Rs 179.58 lakhs per annum.

Single Wagon Tipplers

In south yard out of 6 WT 1,2,3&4 are single wagon tipplers, 5 & 6 are double wagon tipplers.

Table 10: Wagon tippler DC hours analysis

Type of Unloading Facility	Unloading Facility No	DC Hrs
SWT	T3	2
SWT	T2	2
SWT	T2	1
SWT	T2	2
SWT	T4	3
SWT	T2	4
SWT	T3	3
SWT	T4	1
	Average DC Hrs	2.25

- Demurrage cost incurred per rake due to 2:15 DC hr is Rs 19,912.5/-
- Tippler modifying cost from SWT to DWT is considered as 200 lakhs per tippler. For 4 tipplers total of 800 lakhs has to be invested.
- By modifying the system we can unload the rake within the free unloading time & we can save Rs 19,912.5/-per rake.
- Considering average of 10 rakes per day we can save Rs 1,99,125/-, for a month Rs 59,73,750/- , Rs 7,16,85,000/- per annum and for 14 months 836 lakhs.
- Hence back payment of invested amount can be achieved within 14 months at the rate of Rs 59,73,750/- per month.

VIII. RECOMMENDATIONS

- Daily Loco requirement plan is developed for different production levels and rake arrival plan to enhance the performance utilization of Locos.
- Based on number of rakes arrival plan on particular day, number of Locos deployment can be planned.
- Remaining Locos can be sent to other yard or these locos can be shut down so that unnecessary diesel consumption will be saved.
- Based on utilization and various scenarios of different production levels it is found out that the existing number of locos can handle the increased arrival of raw materials due to plant expansion.
- Shift relieving losses must be minimized by providing scheduled transportation facility for loco drivers and points men.

- Track hopper
  - Loco attachment time can be avoided by using Indian Railway Engine only for placement of rake and return.
  - Unloading time can be reduced by deploying additional 4 man power.
  - Material receiving through BOBSN rake must be increased from 1 to 6 rakes per day.

- Single wagon tippler
- From figure 5: Future state value stream map.
  - The total lead time for unloading one rake can be reduced from 615min to 320 min.
  - 320 min includes, traveling time of 20min, brake release time 30min, placement time 30min, unloading time 150min, cleaning 30min, and empty rake formation time of 60min.
  - Traveling time of loco can be reduced from 30min to 20 min by keeping it near top point.
  - Brake release time can be reduced from 60min to 30min by deploying two persons.
  - Unloading time can be reduced from 300min to 150min by installing double wagon tippler.
  - Cleaning time can be reduced from 90min to 30min by installing dust absorber at wagon tipplers.
  - Empty rake formation time can be reduced from 105min to 60min by keeping the loco rear side of the tippler.

Instead of procuring new Loco, we have to go for expansion of unloading facility i.e. from single wagon tippler to double wagon tippler at wagon tippler 1,2,3,4, which reduces unloading time, which in turn reduces delay in return of rakes, hence we can save demurrage cost.

IX. CONCLUSIONS

This paper deals with enhancing the performance utilization of locos by uncovering the non-value adding activities in raw material unloading yard (RMUY) of an integrated steel plant. The capacity expansion of steel industry involves expansion of the production capacity at different stages of steel making like Raw material handling system, Treatment plants, Iron making, Steel making, Casting, & Rolling mills.

Using Work Measurement Technique, 24hr Time study has been conducted in raw material unloading yard to estimate the existing utilization of nine locos simultaneously three shifts per day. Process chart is drawn to identify the separate steps or events that occur during a series of actions carried out by loco in RMUY and activity chart is drawn to identify operation time, travel time & idle time of locos in continuous three shifts. In addition to the calculation of exiting utilization of locos, various scenarios of different production levels like present day average, medium, and maximum capacity material receipt are considered to maximize the utilization of existing locos and unloading equipments, resulting in optimization of required number of locos. Daily Loco requirement plan is developed for different production levels and rake arrival plan to enhance the performance utilization of Locos. And is successfully implemented in south yard of steel plant.

By using Value Stream Mapping Technique the non-value adding activities in RMUY are reduced which will reduce the lead time of unloading the rake and delay in return of rakes, hence demurrage cost is minimized. Based on utilization and various scenarios of different production levels, it is found out that the existing number of locos can handle the increased arrival of raw materials due to plant expansion.

By reducing the lead time of rake unloading process, congestion in tracks is reduced & by modifying the unloading facilities, the operational costs in the form of demurrage charges will be saved, which will leads to a savings of Rs 100 million over a period of 14 months. The proposed system of modifying the unloading facility is currently under implementation by steel plant.

X. SCOPE FOR FURTHER STUDY

- Proper scheduling of incoming rakes.
- Pre scheduling and assignment of locos to particular activities based on rake arrival schedule.
- Study and implementation of signaling and transport system at rear side of the tipplers in raw material unloading yard.

ANNEXURE

Abbreviations

Loco	Railway Engine
SY	South Yard
NY	North Yard
CY	Cement Yard
Y	Yard
SMS	Steel Making Shop
HSM	Hot Strip Mill
BRM	Bar Rod Mill
R1toR26	Railway tracks
WFT	Waiting For Task
WFLC	Waiting For Line Clearance
LL	Light Loco
TH	Track Hopper
WT	Wagon Tippler
SWT	Single Wagon Tippler
DWT	Double Wagon Tippler
T	Tippler
MTPA	Metric Tons Per Annum
IOF	Iron Ore Fines
ROM	Raw Ore Magnetite
DRI	Directly Reduced Iron ore
L/S	Lime Stone
RMMD	Raw Material Managing Dept.
RMHS	Raw Material Handling System
RMUY	Raw Material Unloading Yard
VSM	Value Stream Mapping
DC	Demurrage Cost
BOBSN	Bogie hopper wagon side discharge
BOBRN	Bogie open rapid discharge hopper wagon (It is a type of wagon in which material is unloaded with the help of gravity.)

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