INTERNAL LOGISTICS OPTIMISATION OF FERRO ALLOY MANUFACTURING PLANT

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ABSTRACT

In any manufacturing organization internal logistics plays a vital role in improving and maintaining the productivity. In Ferro Alloys manufacturing organization where there is huge input of rawmaterial in terms of ore, reductants and variety of fluxes amounting to about four times of the mass of alloy produced need to be handled from yard to furnaces , internal logistics requires utmost attention. Any deviation or mismatch between stock and requirement will affect furnace operation. Though the activities are being outsourced by most of the organization, these require close monitoring. This communication presents an optimization model which can work as a ready reference for the manager to decide upon the material quantity and the furnace to be fed with an objective of minimizing the cost of handling and zero production loss.

1. INTRODUCTION

According to Lambert and Stock [1], logistics, a widely accepted term by today's professionals, had in the past a variety of names including physical distribution, business logistics etc. The Council of Logistics Management defines logistics as "The process of planning, implementing and controlling the efficient, cost-effective flow and storage of raw materials, in process inventory, finished goods and related information from the point of origin to the point of consumption for the purpose of conforming to customer requirements". According to the above definition, logistics consist of four flows. Material Flow, Merchandise Flow, Money Flow and Information Flow .Since interruptions in any of the four flows will affect an organization's raw material supply (Purchasing & Inventory), manufacturing (Operations) and Marketing (distribution) function according to Fawcett and Fawcett [2], there exists a need to integrate these flows through effective management of infrastructure, materials, technology and people.

2. MATERIAL FLOW LOGISTICS PROBLEMS IN FERRO ALLOYS PLANT

Any Ferro Alloys Plant is a material and energy intensive manufacturing unit that converts raw materials (ore, reductant, fluxes and pastes) in to finished goods as different alloys. To manufacture one metric ton of Ferro alloys about 4.5 tonnes of raw materials are used. Figure 1 represents the materials flow of a typical ferro alloy plant. For internal movement of materials, a ferro alloys plant uses dumpers, pay loaders, conveyers, overhead cranes, ladles, etc.

The internal material flow logistics significantly influences many strategic decisions of any ferro alloys plant. The need and importance of internal logistic support for manufacturing agility is stressed by Gyula *et al*, [3]

3. INTERNAL LOGISTICS

The out come of a questionnaire survey among the ferro alloys manufacturers shows that internal logistics is one of the important factors in the supply chain of the ferro alloy manufacturing. The major function of the internal logistics of the organization is of feeding of rawmaterial to all furnaces. Case study of a ferro alloys plant has been considered .Daily feeding of rawmaterial to different furnaces is about 1000 metric tonne. In five furnaces there are 50 day bin bunkers for storing different material for a day consumption. The movement of materials inside the plant is shown in Fig- 2. Though the company has out sourced the total activity on per metric tonne handling basis, there are many problems associated with these activities.

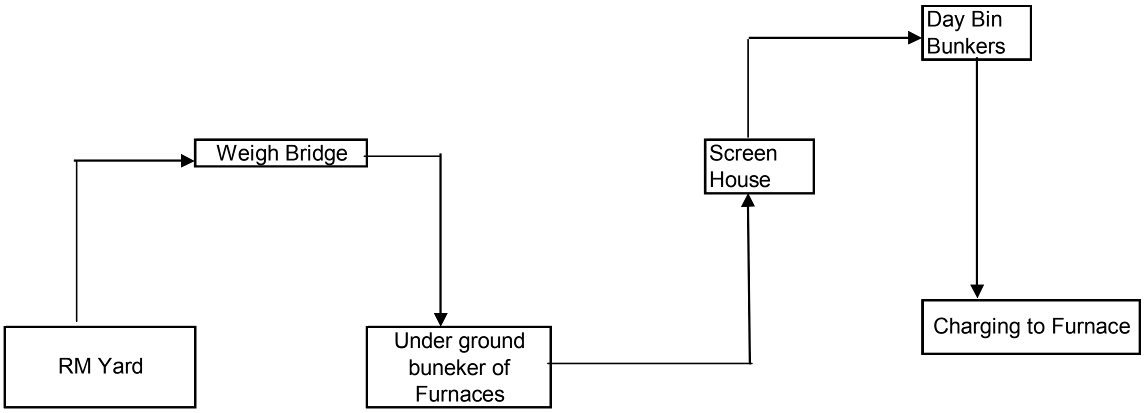

Figure 1: Material flow of a Ferro Alloys Plant

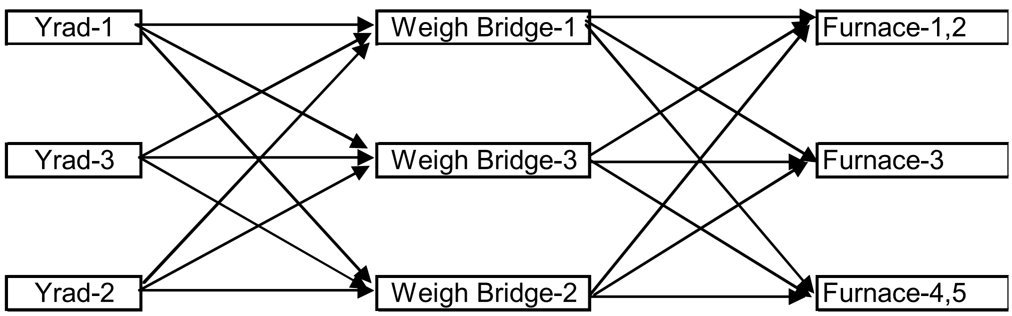

Figure 2: Raw material movement inside the plant

4. PRESENT PRACTICE AND PROBLEMS BEING FACED

The present practice of handling the raw material is as follows. The company operates in three shifts. A-shift runs from 6 AM to 2 PM; B shift from 2 PM to 10 PM; C shift from 10 PM to 6AM. At about 6.30 AM, the shift in-charges get feed back about the status of raw material stocks in different bunker and in different yards and accordingly provides verbal instruction to the contractor for feeding material to different bunkers and priorities for feeding. The company follows a policy of not feeding the material in "C" shift unless some emergency arises. However, the following problems are being faced by the company in internal handling of material.

- Loss of production due to non-availability of material in the day bunker even if the material is available in the storage yard. Some bunkers are totally filled whereas some bunkers are empty.
- Additional deployment of material handling equipment in over time duty leading to increase in raw material handling cost.
- Frequent feeding of material in 'C 'shift
- Dissatisfaction of the contractor for not getting time for maintenance of the material handling equipments.

This happens mainly due to non-availability of any specific documented guidelines for deciding upon the quantity to be handled, i.e., how much quantity of material, from which yard to which furnace so that the furnace operation will not be affected.Figure-3 represents the internal materials flow of the ferro alloys plant under study. An attempt was made to develop an optimization module to handle this problem of the organization.

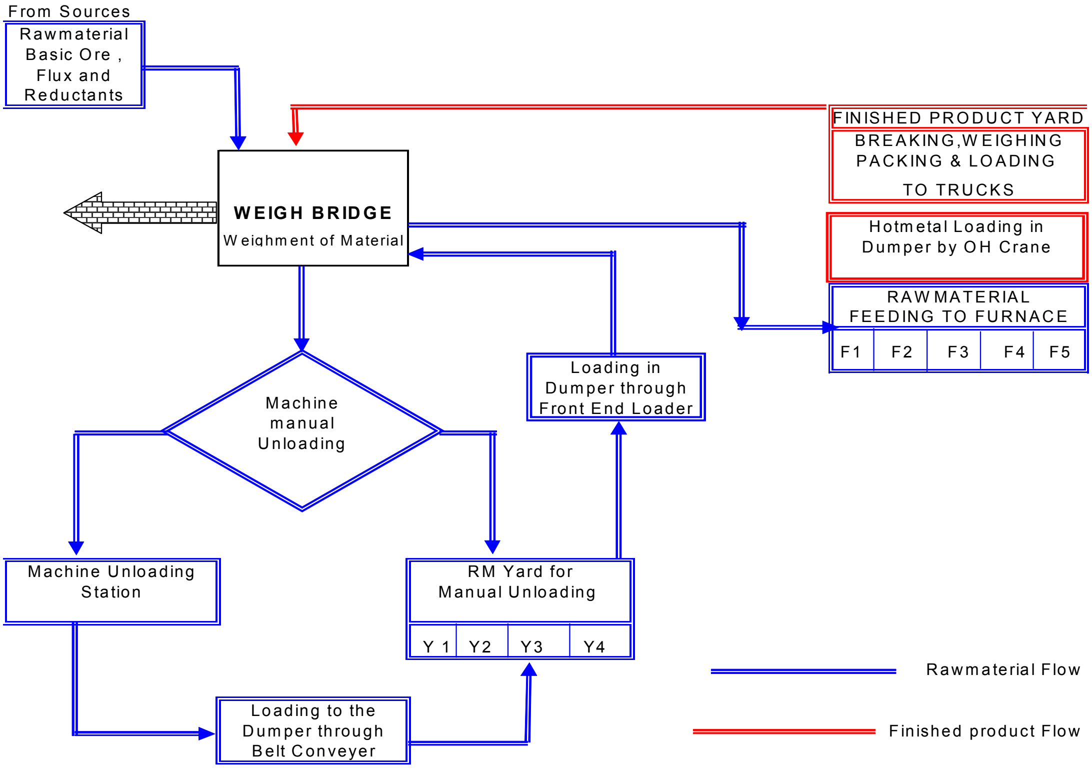

Figure 3: Internal Materials Flow of the Ferro Alloy Plant

5. MODEL FORMULATION

A non linear optimization model has been developed with different objectives of raw material handling without affecting the production requirements. The Objectives of the Model are:

1. Minimization of handling Cost
2. Optimization of quantity handled

6. OBJECTIVE- MINIMIZATION OF HANDLING COST

$$MinimiseZ = \sum_{i-1}^{n} \sum_{j=1}^{3} \sum_{k=1}^{5} Xijk \times Cjk \tag{1}$$

$Xijk$ = rawmaterial *'i'* from yard *'j'* to furnace *'k'*

Cjk= Cost of transportation from yard *'j'* to furnace *'k'*

$$Xijk \geq MRi \leq BCik \tag{2}$$

Where MRi = Minimum rawmaterial requirement to run the furnace for next 36 hours

BCi = Bunker Capacity of (i)th Bunker of (k) th Furnace

$$\sum_{i-1}^{n}\sum_{j=1}^{3}\sum_{k=1}^{5} Xijk \leq Si \tag{3}$$

Si is the inventory of the material *i*

$$\left(\sum_{i-1}^{n}\sum_{j=1}^{3}\sum_{k=1}^{5} Xijk \div Qi\right)\times Tjk \leq 14 hours \tag{4}$$

Qi= Quantity of (*i*) material handled per trip

Tjk= Cycle time for transporting the material from yard *j* to furnace *k*

7. OBJECTIVE – OPTIMIZE HANDLING QUANTITY

The model was also formulated with an objective of optimizing the feeding quantity within the specified time frame.

$$MaximiseZ = \sum_{i-1}^{n}\sum_{j=1}^{3}\sum_{k=1}^{5} Xijk \tag{5}$$

Xijk = rawmaterial *'i'* from yard *'j'* to furnace'k'

Cjk= Cost of transportation from yard *'j'* to furnace'k'

$$Xijk \geq MRi \leq BCik \tag{6}$$

Where *MRi* = Minimum rawmaterial requirement to run the furnace for next 36 hours

BCi=Bunker Capacity of (i)th Bunker of (k) th Furnace

$$\sum_{i-1}^{n}\sum_{j=1}^{3}\sum_{k=1}^{5} Xijk \leq Si \tag{7}$$

Si is the inventory of the material

$$\left(\sum_{i-1}^{n}\sum_{j=1}^{3}\sum_{k=1}^{5} Xijk \div Qi\right)\times Tjk \leq 14 hours \tag{8}$$

Qi= Quantity of (*i*) material handled per trip

Tjk= Cycle time for transporting the material from yard '*j'* to furnace '*k'*

Both models were executed and run for a period of seven days without any limitation in inventory of material. The rawmaterial feeding requirement is shown in the table-1. The maximum and minimum quantities of feeding have been derived considering the capacity of the bunker and minimum material requirement for the day's production respectively. From the three rawmaterial storage yards rawmaterial are being feed to different furnace as per the requirements. The feeding systems of furnace-1 and 2, furnace 4 and 5 have common feeding system whereas furnace 3 has a separate feeding system. The costs of handling material from different yards to different feeding points are different as shown in the table-1.The feeding quantity should be in between the maximum and minimum levels subject to other constraints.

Table 1: Raw material feeding requirement

	From Yard No	Material	Transportation Cost (Rs/MT)	Quantity to be fed(MT)	
				Max	Min
FUR-1,2	1	R1	4	80	24
	1	R2	4	80	24
	1	R3	4	80	24
	1	R4	4	80	24
	2	O1	4.5	80	40
	2	O2	4.5	80	40
	2	O3	4.5	80	40
	2	O4	4.5	80	40
	2	C1	4.5	80	40
	2	C2	4.5	80	40
	2	F1	4.5	80	40
	2	F2	4.5	80	40
	2	F3	4.5	80	40
	3	B1	5	80	30
	3	B2	5	80	30
	3	B3	5	80	30
	3	B4	5	80	30

The above requirement is for one furnace and similar requirements for other furnaces have been developed. The cycle time of the dumper for lifting the raw material from yard to unload the material in the under-ground bunker and again reporting at yard for loading varies from yard to yard and furnace to furnace. The table 2 present the cycle time of handling the material.

Table 2: Cycle time in minutes

	Furnace-1,2	Furnace-3	Furnace-4,5
Yard-1	10	12	15
Yard-2	15	14	17
Yard-3	20	18	22

Since the bulk density of different materials are different the weight of the material transported per trip are different. The weight of different material handled per trip of dumper is presented in table-3

Table 3: weight of different material handled per trip of dumper

Material	Quantity (MT/Trip)	Material	Quantity (MT/Trip)	Material	Quantity (MT/Trip)	Material	Quantity (MT/Trip)
R1	8	O1	10	B1	10	F1	10
R2	8	O2	10	B2	10	F2	10
R3	8	O3	10	B3	10	F3	10
R4	8	O4	10	B4	10		
		C1	10				
		C2	10				

The output of both the model has been compared w.r.t the quantity handled, cost of handling and the utilization of material handling equipment. The out put of the model having objective function of minimizing the cost of handling cost has been represented in table-4

Table 4: Quantity to be feed from different yard to different furnaces

Yard	Material	Day-1 MT	Day-2 MT	Day-3 MT	Day-4 MT	Day-5 MT	Day-6 MT	Day-7 MT
1	R1	59	59	59	59	59	59	59
1	R2	59	59	59	59	59	59	59
1	R3	59	59	59	59	59	59	59
1	R4	59	59	59	59	59	59	59
2	O1	90	90	90	90	90	90	90
2	O2	90	90	90	90	90	90	90
2	O3	90	90	90	90	90	90	90
2	O4	90	90	90	90	90	90	90
2	C1	90	90	90	90	90	90	90
2	C2	90	90	90	90	90	90	90
2	F1	90	90	90	90	90	90	90
2	F2	90	90	90	90	90	90	90
2	F3	90	90	90	90	90	90	90
3	B1	80	80	80	80	80	80	80
3	B2	80	80	80	80	80	80	80
3	B3	80	80	80	80	80	80	80
3	B4	80	80	80	80	80	80	80
Total (MY)		1366	1366	1366	1366	1366	1366	1366
Feeding Time (Hrs)		13	13	13	13	13	13	13
andling Cost (Rs Lacs)		0.07	0.07	0.07	0.07	0.07	0.07	0.07

The output of the model having objective functions of maximizing the quantity of rawmaterial handling has been represented in table -5. The output of both the models have been compared in terms of the total quantity handled, cost of handling and the vehicle utilization. The comparisons have been shown in table-6

Table 5: Quantity to be feed from different yard to different furnaces

Yard	Material	Day-1 MT	Day-2 MT	Day-3 MT	Day-4 MT	Day-5 MT	Day-6 MT	Day-7 MT
1	R1	59	74	74	74	74	74	69
1	R2	59	74	74	74	74	74	69
1	R3	59	74	74	74	74	74	69
1	R4	59	74	74	74	74	74	69
2	O1	90	105	105	105	105	105	105
2	O2	90	105	105	105	105	105	105
2	O3	90	105	105	105	105	105	105
2	O4	90	105	105	105	105	105	105
2	C1	90	105	105	105	105	105	105
2	C2	90	105	105	105	105	105	105
2	F1	90	105	105	105	105	105	105
2	F2	90	105	105	105	105	105	105
2	F3	90	105	105	105	105	105	105
3	B1	109	95	95	91	90	90	90
3	B2	97	95	95	95	95	93	90
3	B3	95	95	95	95	95	95	90
3	B4	116	94	90	90	90	90	90
Total (MY)		1462	1620	1616	1612	1611	1609	1581
Feeding Time (Hrs)		14	13	13	13	13	13	13
Handling Cost (Rs Lacs)		0.08	0.09	0.09	0.09	0.09	0.09	0.09

Table 6: Comparison of different models

	Model Maximisation of quantity	Model Minimisation of handling cost	Variance
Total (MT)	11112	9562	1550
Feeding Time (Hrs)	92	89	
Handling Cost (Rs Lacs)	0.61	0.52	0.09
Handling Cost (Rs/MT)	5.47	5.45	-0.01

8. OBSERVATION AND CONCLUSION

It has been observed that there is not much difference in the quantity of feeding in both the models .There is about 15% more feeding incases of quantity maximization where as handling cost (Rs/MT) remains at the same level (increase by 0.2%). There is an increase in the capacity utilization of the material handling equipment by 3% which is value addition to the supplier.

In the case of the maximum feeding quantity model, there is a reduction in the maximum feeding quantity as there is a stock accumulation in the bunker. This will facilitate the furnace in charge to take decision on monthly maintenance of the material handling equipment.

In the case of cost minimization the quantity of feeding is restricted to the minimum requirement for the day operation where as in the case of maximizing model, the quantity is more than the minimum requirement quantities which add to the flexibility of furnace in charges for modification or change in the charge mix without further feeding of rawmaterial.

In case of cost-minimization model , any emergency requirement for additional material , the material handling equipments may be utilized on over time for additional feeding whereas incase of quantity maximization such a situation will not arise as there is always surplus material stock in the bunker for emergency use.

Considering the above points, it is suggested that the quantity maximization model should be followed for internal handling of the material.

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