Optimal Loading of Hot Rolled Coils at Tata Steel , India

(Operational Research - Information Technology Interface)

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Introduction: Operational Research & Management Science has found its successful application time and again in different industries. It is becoming increasingly popular as a problem-solving tool to the managers of newer generations. It is based on sound theoretical equations & models and still focused on day-to-day applications of real life. This paper briefly tells about an implemented application of OR&MS for problem solving.

Every since the globalisation of business, cost competitiveness have emerged as a key words to the new dimension to any business, the companies have been trying to identify new areas of reducing cost, enhance product quality and become more customer oriented.

Transfer of materials from factory to warehouses and to customer is an important part of any business. This is also a major post manufacturing cost head. Goods are either transferred through railways or through roads.

Railway despatches are generally preferred for long distant and bulk transfers. Roadways are used for small tonnages, for terrain's inaccessible by railways and for destinations where the rail fare is very high. Transportation by rail involves idle freight. Idle freight is defined as the freight paid by the company to the railways for underloading a wagon (i.e. loading a wagon below the chargeable load).

In other words, if X be the chargeable weight on the which the railways would decide the tariff for a given type of product to the company for transferring finished goods and Y be the weight in tons loaded in the wagon. If (X-Y) is greater than zero, an idle freight is incurred.

This project was so successful in correctly addressing the customer's requirement, that after the implementation of the project, the delighted customer Mr. Mahapatra (General Manager, Flat Products) wrote in a letter to Executive Director (Operations) that, " (this project)..... has proved to be very efficient in cutting down the idle freight......is worthy of approbation for an excellent job done in the area of system improvement and knowledge management".

Problem in the existing system: TATA STEEL, India's premier steel maker was paying a huge idle freight to the tune of nearly $3 miilion per year. Out of the various products that the company transferred to its warehouses, Hot Rolled Coils (HRC) contributed the maximum part of it.

This gave rise to the two problems stated below:

1. Under utilisation / under loading the wagon capacity.
2. Transfer prices were higher, as $/ton transferred increased.

As a whole the post manufacturing expenses of the company were increasing.

Hot rolled coils (HR coils) are dispatched from HSM both by wagons (rail) and by road. In case of wagons, freight is charged based on the carrying capacity of the wagons. But in many cases the carrying capacity of a wagon is not fully utilized. That happens mainly due to lot of constraints on wagon loading, and also due to unplanned loading to some extent. This unutilized part of the total freight is known as idle freight, which is an unnecessary cost element. To reduce this idle freight an OR model was developed in 1997, but that got discontinued from January '98. As a result *idle freight was shooting up.*

A study was carried out rake-wise for each destination where HRC were transferred, to obtain the following inferences:

1. Wide ranges of HRC, having different weight are despatched.
2. There were four types of wagons used for despatch, each with a different carrying capacity and chargeable load.
3. Loading of coils on the wagon was carried out without the help of any model, which could suggest the best way to load.
4. The coils varied in weights, widths and thickness.
5. A few destinations had a demand for a particular specification and weight of coil.

Root causes identified: It was found out that the earlier model had two major problems. Firstly it did not take into consideration certain constraints of loading. Secondly it had certain technical limitations.

The constraints that were not considered by the earlier model were as follows:

a) Prime and defective coils cannot be loaded into same wagon.
b) Coils of 2 different customers cannot be loaded into same wagon.

c) Restrictions on axle loading.

The technical limitations were:

a) A small number of combinations (of coils) were considered, as a result many coils used to be left out.
b) Coil identification numbers were not shown.
c) The model used to run on the old Lotus platform.

Approach: The solution to such a number of issues, demands for an effective, user-friendly and compatible decision support system. This could handle all the possible constraints, and at the same time maximise loading of HRC on the wagons.

A linear programming model was developed in Microsoft Excel using the optimisation package *What's* Best. The model included macro programming (in Visual Basic) to assist the user to handle the model with great ease and at the click of a button.

The model is bounded by constraints, imposed by railways.

Methodology:

1. Estimating the average carrying capacity of wagons:

Indian railways supplied 5 types of wagons namely BRN/BRH, NBOX, BOX, SADDLE and BFR. These wagons differed w.r.t their carrying capacities, minimum number of wagons required to form a rake and number of Hot rolled coils that can be loaded.

For instance a saddle wagon can handle only three coils. Thus to overcome this problem, a large sample of wagon were studied and a average carrying capacity was estimated at 58 tons for BRN/BRH, NBOX,BOX, SADDLE wagon. While BFR was at 44 tons.

In addition to this 2 tons of allowance was allowed by railways. This enhanced the carrying capacity from 58 tons to 60 tons in case of BRH/BRN.

2. **Segregating the variety of coils into groups/types:**

On the basis of the weights of the coils, all the coils were categorised into ten types (A, B, C, D, E, F, G, H1, H2, and J). These categories have a range of weights where individual coil weights are linked. This is clearly shown in the table below.

The average weights were derived at, after obtaining the average of the distribution they varied in their respective group. To derive at such averages, large numbers of coils were considered.

COIL TYPE	AVG. WT.(T)	COIL WT RANGE (T) MIN	MAX
H1	8.80	6.00	10.00
H2	12.00	10.00	13.40
A	14.40	13.40	15.00
B	16.00	15.00	16.40
C	17.00	16.40	17.80
D	18.60	17.80	19.50
E	20.30	19.50	21.00
F	22.00	21.10	22.50
G	23.70	22.50	24.80
J	25.30	24.80	27.00

3. **Obtaining efficient combinations:**

Using the average weights of coil categories, various combinations are obtained to maximise loading and minimise the idle freight. The combinations are so built that the sum of the average weights is greater than or equal to the chargeable weight.

In addition, a few combinations were made to allow a few tons of idle freight. This will help in maximising loading, but the loading without idle freight will be preferred. Ultimately, at the end the company should despatch its finished goods with very little or ideally no idle freight.

A table below shows a table consists of some combinations used in the model.

WAGON	COIL COMBINATIONS	TOTAL

TYPE	AXLE 1	AXLE 2	CENTER	WT(T)
BRN / BRH	F	F	B	60.00
BRN / BRH	G	G	H2	59.40
BRN / BRH	J	J	H1	59.40
BRN / BRH	E	F	C	59.30
BRN / BRH	C	C	J	59.30
BRN / BRH	A,A	A,B	-	59.20
BRN / BRH	E	E	D	59.20

4. Downloading the data:

The information related to the individual coil weights, destination code, identification number etc are stored in the mainframe/SAP system. These data are essential to run the model. The weight data for the basis for further categorising these coils into desired types. This downloading was carried out by the use of SQL programs and accessing the DB2 database. The identification numbers were used make the model user friendly. The destination codes were used to down load data for a given destination for which the rake is to be formed.

Modeling:

A linear optimisation was build in MS Excel and using What's Best optimisation package. The model was customised using buttons containing detailed macro programmes in Visual Basic. The available number of wagons and the total number of coils for each type are constraints to the model.

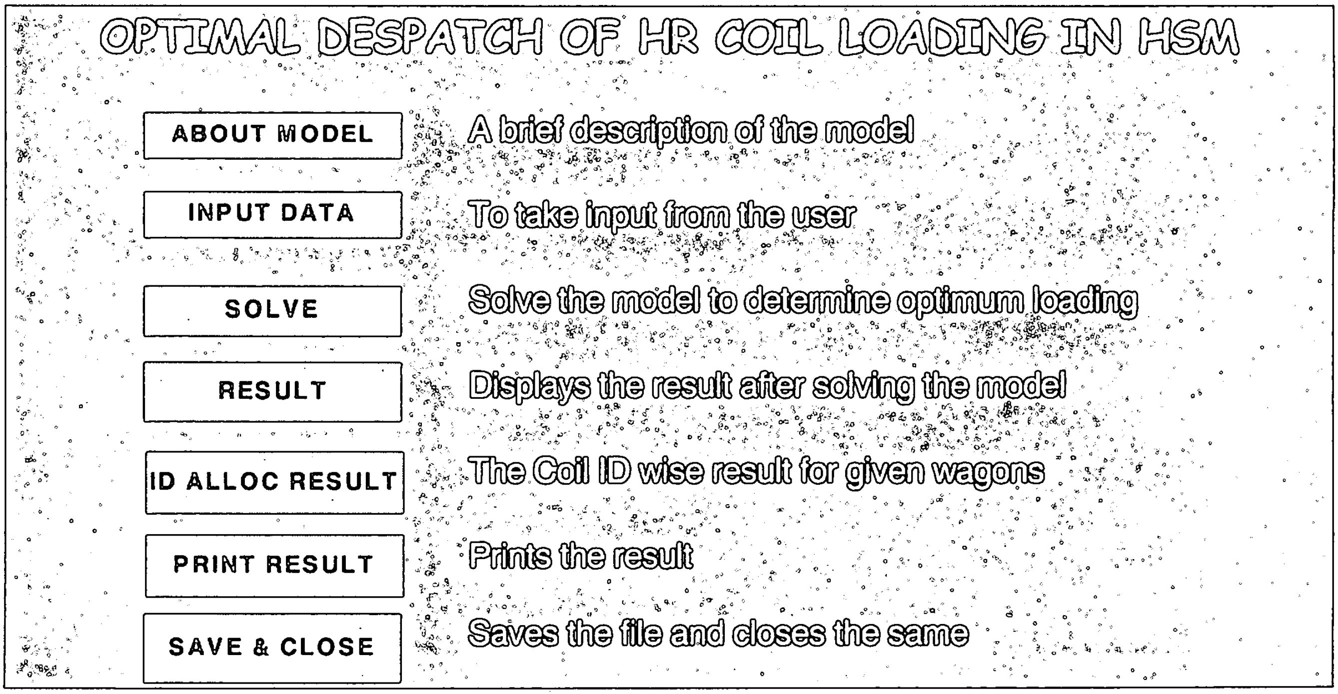
Numbers of coil types are A, B, C, D, E, F, G, J, H1, and H2.
There are five types of wagons available: BRN, SADDLE, BOX, NBOX, and BFR.

The various combinations of these coil types are used to obtain the desired combination where the idle freight varies from 0 to 10 tonnes per wagon. The sum product of the all the possible combinations gives the total tonnage loaded for the given destination.

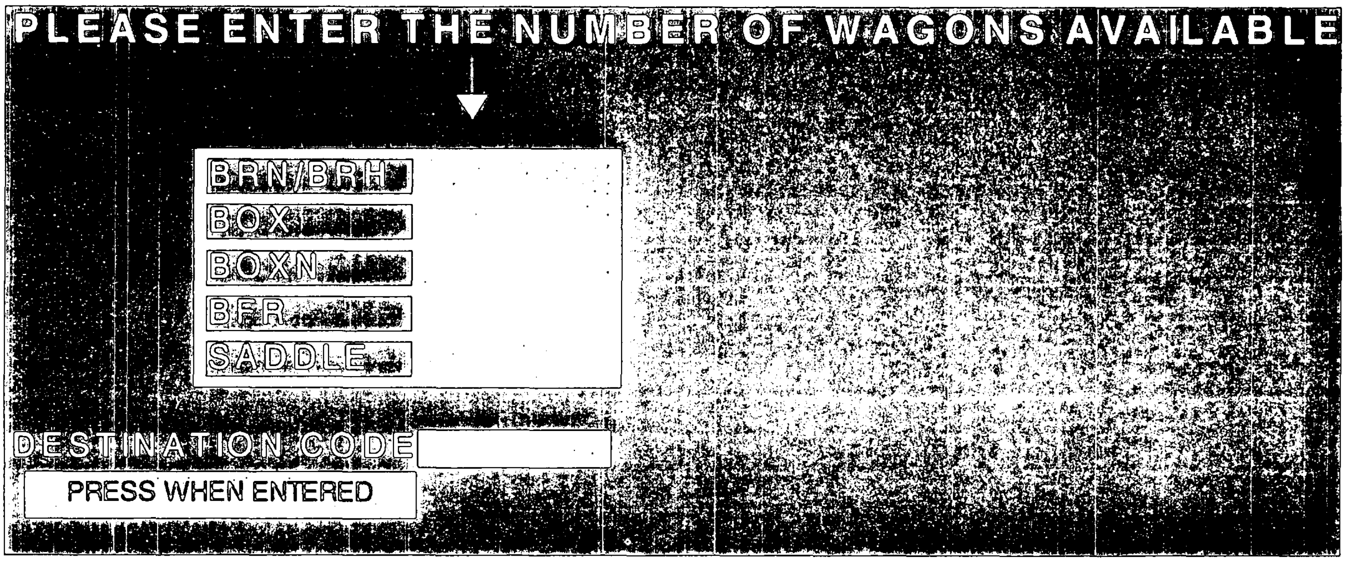
The average idle freight for each wagon, the total tonnes of idle freight and the idle freight as a percentage of total weight is established.

Further to this individual wagons are loaded with coils specified with individual coil ids and the coil weights. This gives a detailed customisation report and acts as a ready loading plan for the available wagons for the given destination.

The main focus of the model was to bring in user friendliness. So the main menu was given a very easy-to-understand look. It consists of several buttons as shown below through which the user can input some information, solve the problem of optimal loading, get the allocation of coil ID's in different wagons and print the results if he wants.



To start with, the user needs to feed in the number of wagons available for each kind through the button 'INPUT DATA'. The data entry form used for this purpose is shown here:



After putting in the number of wagons available and the destination code, the user only presses the 'SOLVE' button and the model determines the optimal pattern of coil loading so as to minimise the idle freight. Then the user can browse the summary results and advanced results (coil ID wise) and decide which coil to be loaded into which wagon for best performance in terms of idle freight.

A sample summary result is shown below:

	WAGON TYPE					
	BRN / BRH	BOX	BOXN	BFR	SADDLE	TOTAL
CARRYING CAPACITY (T)	54	54	54	44	54	
NO. OF WAGONS AVAILABLE	15	20	16	24	0	75
NO. OF WAGONS LOADED	12	16	2	24	0	54
NO. OF COILS AVAILABLE						116
NO. OF COILS LOADED	28	34	6	48	0	
ACTUAL LOAD (T)	604.4	723.2	105.2	1005.5	0	2438.3
IDLE WEIGHT (T)	57.7	140.8	6.3	50.5	0	255.3
IDLE WEIGHT T/WAG.	4.80833333	8.8	3.15	2.1041667	-	4.727778
IDLE WT. AS % OF CH. WT.	8.90%	16.30%	5.83%	4.78%	-	9.54%

COIL TYPE	AVG. WT.(T)	COIL WT RANGE (T) MIN	MAX	COILS AVAILABLE	COILS LOADED	COILS LEFT
H1	8.80	6.00	10.00	3	3	0
H2	12.00	10.00	13.40	2	2	0
A	14.40	13.40	15.00	0	0	0
B	16.00	15.00	16.40	20	20	0
C	17.00	16.40	17.80	28	28	0
D	18.60	17.80	19.50	6	6	0
E	20.30	19.50	21.00	12	12	0
F	22.00	21.10	22.50	26	26	0
G	23.70	22.50	24.80	17	17	0
J	25.30	24.80	27.00	2	2	0
			TOTAL	116	116	0

While this output is sufficient for the management, the operators need to know in more details about the loading pattern. Keeping that in mind, the model generates a guideline for allocating different coils on different type of wagons as follows (a sample):

Sr.No	WAGON	AXLE1	AXLE2	Center	ID_Axle	Wt_Axle	ID_Axle	Wt_Axle	ID_Cente	Wt_Cent
1	BRN /	E	E	C	5562031	19.86	5534010	20.4	5546047	16.74
2	BRN /	D	D	D	4516011	18.83	5530013	19.06	5208055	19.35
3	BRN /	D	D	D	4932008	18.92	5399015	19.3	4904006	19.38
4	BRN /	C	C	E	5548025	16.43	5543036	16.69	5054010	20.99
5	BRN /	G	E	H1	5554050	22.66	5232021	20.5	5057020	8.12
6	BRN /	E	E	H2	5562033	19.96	5562030	20.72	5405017	10.08
7	BRN /	E	E	H2	5562032	20.02	5562034	20.78	5398028	11.44

The above output shows the operator which coil is to be loaded into what type of wagon. This has drastically reduced the complications of the earlier system and also simplified the operator's job to a large extent.

Mathematical formulation:

Loading a wagon may lead to the following three cases:

CASE 1: w < CW, Idle freight is incurred; IW = CW – w.

CASE 2: CW <= w <= (CW+A),No Idle freight incurred;IW = 0.

CASE 3: w> (CW + A), This is not permitted.

Where,

w – *Total weight of the loaded coil in a wagon.*

CW – *Chargeable weight of wagon.*

IW – *Idle Weight.*

A – *Allowance for wagon.*

Wagon loading:

Let,

i = Coils available in stock (i = 1,2,3,.........., n).

j = Wagons to be loaded (j = 1,2,3, ...,m).

k = No of coils in a wagon (k = 1, 2, 3).

W_i = Weight of the i^{th} coils.

C_j = Chargeable Weight of j^{th} wagon.

X_{ijk} = 1, if coil i is loaded in wagon j on the position k. 0, Otherwise.

Objective function: Minimize

$$Z = \sum_{j=1}^{m} (C_j - \sum_{k=1}^{3} \sum_{i=1}^{n} w_i * x_{ijk})$$

Implementation:

The DSS was successfully implemented in the Shipment Execution and Co-ordination group of the company responsible for clearing the order load for a given destination and instructing the shippers to load the material for final transfer.

The model was used to plan, load and take decision regarding the final transfer of finished goods. The scientific approach helped them to take unbiased, effective and error free decision.

Conclusion:

The implementation of this model helped the company not only in taking better decision in loading and despatching the HRC, but drastically reduced the idle freight in $/tons. The model has helped to earn audited savings of $1 million.