"An Arrangement of Goods According to Holding Capacity of Freight Trains"

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ABSTRACT

Rail transportation is more affordable than road transportation for long distances due to capacity these freights can handle. Despite being one of the most cost effective and sustainable mode of transport, freight railways have been globally losing market values. In India the availability of rakes also poses a great challenge. In this work a model is proposed for management in freight train's holding capacity and their better utilization for different commodities. An integer programming problem model is formulated for an arrangement of goods according to holding capacity of freight trains.

INTRODUCTION

The ideal modes of transport which has a large load carrying capacity is freight railway transportation. Accepting changes and adapting to dynamic market conditions is the key to the freight segments sustainable expansion. It is less affected by external factors, however planning freight rail transportation needs most advanced structured planning. Railway freight transportation is preferred method of transport, especially when large volumes and long-distance cargoes are to be transported. Rail can also accommodate shipment of many shapes and sizes, from grains to wind turbine blades. Indian railway has modernized in technology to improve the efficiency of its operations. It has implemented several initiatives to improve the freight business. Railway freight transportation system must offer quick, reliable, and optimized flexible services.

LITRATURE REVIEW

A new problem of redirecting freight trains to revised destinations as a last-minute risk mitigation strategy is given [3]. The problem is approached from a consignee's perspective as the demand for a change of destination is made by the consignee. An Integer Non-Linear Programming (INLP) model is formulated to minimize the cost of redirecting trains subject to various constraints. A two-stage freight demand analysis method considering customers' choice intention and actual supply capacity was designed [1]**.** In this paper [2], the objective is to find the optimal sequence of jobs and the optimal resource allocation separately. This paper [4]aims to optimize the service mode and routing for hazardous freight transportation in a rail-truck network with bi-objectives optimization approach. In the paper[5], a research work on freight delays in the Indian railway setting by analyzing how section controllers make freight train stop and hold decisions while dispatching freight trains is given. The NITI Aayog report - The report focuses on the product mix of Indian Railways, which has been skewed towards the movement of bulk commodities such as coal, cement, iron ore, steel, petroleum, foodgrains , and fertilizers. In, 2018-19 , coal holds 50 percent of the total freight movement of 1,221 million tonnes , followed by Iron Ore (11%), Cement (10%), Mineral Oil (4%), Fertilizers (4%), Iron & Steel (4%), Foodgrains (3%), Limestone and Dolomite (2%), Stones (including gypsum) other than marble (2%) and other commodities (9%). The challenges faced in movement of containers via rail, and low share in domestic container movement have been discussed.

Mathematical Formulation:

An integer programming model is formulated for an arrangement of goods according to holding capacity of freight train, and hence to minimize operational cost of freight train subject to various constraints.

At first we set some notifications, script and subscripts to the problem;

A = commodity type

Fw = weight of commodity

W = wegons

R = rate charge

Parameters and Variables :

A_{ij} (i,j = 1,2,3,……n) = i^{th} freight train carry different types of commodities (material)

F_{wei} = avg least weight of any commodity (fixed)

W_i = total no. of wagon/operational holding capacity of i^{th} train

Q_{ij} = maximum quantity per commodity in i^{th} train

R_{ij} = rate charge for any material per ton per km

w_i = expandation of wagons if needed

Now Multiple Objectives are:

G_{i1} – avoid any underutilisation of holding capacity of i^{th} train

G_{i2} – limit the expandation of wagons to w_i

G_{i3} – achieve the total holding capacity of material Q_{ij}

G_{i4} – minimize the overloading of wagons as much as possible

Let x_{ik} = no. of wagons used for holding material Aij (k depends on no. of commodity)

Since the holding capacity of i^{th} train is Wi wagon and expandation is allowded

Now constraints are:

(d_{i1}^-) = underutilization of holding capacity W_i

(d_{i1}^+) = overutilization of holding capacity W_i

This implies holding constraint is

$\Sigma x_{ik} + d_{i1}^- - d_{i1}^+ = Wi$

Since the maximum no. of materials A_{ij} are restricted to Q_{ij} resp. thus it is assumed that overachievement beyond maximum limits are impossible, so taking

F_{wi} d_{i2}- = underachievement of Q_{i1}

F_{wi} d_{i3-} = underachievement of Q_{i2}

And so on,

The holding constraint are:

$F_{wi}\ x_{i1} + d_{i2}- = Q_{i1}$

$F_w i\ x_{i1} + d_{i2}- = Q_{i2}$

And so on,

- i.e. $x_{i1} + d_{i2}- = Q_{i1}$

  $x_{i2} + d_{i3}- = Q_{i2}$

  …………

  $x_{in} + d_{i(n+1)} = Q_{in}$

Overloading operational capacity constraints :

Since overloading operational capacity should be limited to w_i wagons or less, however to meet higher order of Gi2 it can be greater than w_i wagons, so

$(d_{i1}^{+}) + (d_{i12}^{-}) - (d_{i13}^{+}) = w_i$

Thus objective functions are:

Priority P_{i1} – to minimize d_{i1}-

Priority P_{i2} – to minimize d_{i12}+

Priority P_{i3} – to minimize d_{i2}- , d_{i3}- ,….$d_{i(n+1}$-)

Priority P_{i4} – to minimize d_{i1}+

*since the rate per wagon for materials are different, hence weight should be attached to priority 3

Thus the objective function of the problem is:

- Minimize $Z_i = P_{i1}\, d_{i1}^{-} + P_{i2}\, d_{i12}^{+} + P_{i3}\ \Sigma\,(R_{in}\ d_{i(n+1}^{-})) + P_{i4}\, d_{i1}^{+}$

  Subject to the constraints;

  $$\Sigma x_{ik} + d_{i1}^{-} - d_{i1}^{+} = W_i$$

  $$x_{i1} + d_{i2}^{-} = Q_{i1}$$

  $$x_{i2} + d_{i3}^{-} = Q_{i2}$$

  …………

  $$x_{in} + d_{i(n+1}^{-} = Q_{in}$$

  $$d_{i1}^{+} + d_{i12}^{-} - d_{i13}^{+} = w_i$$

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And $x_{i1}, x_{i2}, \ldots\ldots x_{in}, d_{i1}^-, d_{i2}^-, \ldots\ldots d_{in}^-, d_{i(n+1)}^- \; d_{i1}^+, d_{i12}^-, d_{i13}^+ \geq 0$

Hence the problem is formed in integer linear programming problem.

RESULT ANALYSIS

One specific result with the problem is detailed here. Data obtained for Dhanbad Division, in which there are three loading areas - Jharia area, Barkakana area, Chopan area.

Freight loading (in million tones) = 193.90

Freight loading (in tones) Avg / day = 7441

Revenue earnings (in cr) = 26,688.63

INDIAN RAILWAYS FREIGHT SERVICES

EXPECTED FREIGHT CHARGES

Date:28-05-2025

Station From: DHANBAD JN.- DHN (EC)
Station To: RANCHI JN.- RNC (SE)
Wagon Type: BOST- BOGIE OPEN AIR-BRAK
Commodity: IRON OR STEEL SLAB
Wagon Load Freight Rate(for Class-165W): 382.50 Rs/Tonne, Train Load Freight Rate(for Class-165): 347.70 Rs/Tonne
Distance: 164 Kms, Carrying Capacity Information: CC+8 Tonnes
Permissible Carrying Capacity: 65.10 Tonnes/Wagon, Expected Travel Time: 14 Hrs, No. of Wagons: 10
Expected saving in GHG emissions (Tonnes CO2): 3 Rail Green Points

Charge Name	Wagon Load
Charged Rate Class	165W
Basic Freight Rate (Rs./T)	382.50
Surcharge (Rs./T)	57.38
Normal Tariff Rate (Rs./T)	439.88
**Other Charge (Rs./T)	61.99
***Rebate (Rs./T)	0.00
Freight Rate (Rs./T)	501.87
Total Chargeable Weight (Rs./T)	651.00
Total Freight (Rs.)	3,26,717.37
Other Lumpsum Charges (Rs.)	0.00
Other Lumpsum Rebate (Rs.)	0.00
Indicative Freight (Rs.)	3,26,717.37
+GST @5% (if app.) (Rs.)	16,336.00
Indicative Freight (incl.GST) (Rs.)	3,43,054.00

Indicative Freight (incl. GST) for Wagon Load (in words): Three Lakh Forty-Three Thousand Fifty-Four Rupees Only
+GST if applicable, will be leivied as per extant rules.
*Surcharge includes DYNAMIC PRICING FOR COMMODITIES OTHER THAN COAL AND COKE,
**Other Charge includes DEVELOPMENT CHARGE,ORIGINATING TERMINAL CHARGES,DESTINATION TERMINAL CHARGES,

INDIAN RAILWAYS FREIGHT SERVICES

EXPECTED FREIGHT CHARGES

Date:28-05-2025

Station From: DHANBAD JN.- DHN (EC)
Station To: RANCHI JN.- RNC (SE)
Wagon Type: BCN- BOGIE COV. AIRBK
Commodity: CEMENT TILES
Wagon Load Freight Rate(for Class-140B): 298.50 Rs/Tonne, Train Load Freight Rate(for Class-140A): 271.30 Rs/Tonne
Distance: 164 Kms, Carrying Capacity Information: CC+8 Tonnes
Permissible Carrying Capacity: 63.40 Tonnes/Wagon, Expected Travel Time: 14 Hrs, No. of Wagons: 10
Expected saving in GHG emissions (Tonnes CO2): 3 Rail Green Points

Charge Name	Wagon Load
Charged Rate Class	140B
Basic Freight Rate (Rs./T)	298.50
Surcharge (Rs./T)	44.78
Normal Tariff Rate (Rs./T)	343.28
**Other Charge (Rs./T)	57.16
***Rebate (Rs./T)	51.49
Freight Rate (Rs./T)	348.95
Total Chargeable Weight (Rs./T)	634.00
Total Freight (Rs.)	2,21,234.30
Other Lumpsum Charges (Rs.)	0.00
Other Lumpsum Rebate (Rs.)	0.00
Indicative Freight (Rs.)	2,21,234.30
+GST @5% (if app.) (Rs.)	11,062.00
Indicative Freight (incl.GST) (Rs.)	2,32,297.00

Indicative Freight (incl. GST) for Wagon Load (in words): Two Lakh Thirty-Two Thousand Two Hundred Ninety-Seven Rupees Only
+GST if applicable, will be leivied as per extant rules.
*Surcharge includes DYNAMIC PRICING FOR COMMODITIES OTHER THAN COAL AND COKE.
**Other Charge includes DEVELOPMENT CHARGE,ORIGINATING TERMINAL CHARGES,DESTINATION TERMINAL CHARGES,
***Rebate includes TRADITIONAL EMPTY FLOW DIRECTION REBATE,
Wagon Load Remarks: 15.00% REBATE UNDER TRADITIONAL EMPTY FLOW DIRECTION.THIS REBATE SHALL ONLY BE APPLICABLE UPTO END OF CURRENT MONTH.

From Freight operation information system (FOIS), we have

Now, from our proposed model, we formulate the problem in ILPP problem and solving by GP programming and simplex method,

For train 1 data contains:

W – Holding capacity of freight train = 20 wagons

A_1 – Cement tiles

A_2 – Iron or Steel slab

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Fwe_1 (permissible carrying capacity of commodity A_1) = 65 tones /wagon

Fwe_2 (permissible carrying capacity of commodity A_2) = 63 tones /wagon

Q_1 (holding capacity of commodity A_1) =651 tones

Q_2 (holding capacity of commodity A_2) = 634 tones

R_1 (train load freight rate profit from A_1) = 34 Rs

R_2 (train load freight rate profit from A_2) = 27 Rs

w (expandable no. of rakes/wagons) = 5

Now by introducing slack variables and priority factors ;

ie. (d_1^-) = underutilization of holding capacity

(d_1^+) = overutilization of holding capacity

(d_2^-) = underachievement of holding capacity of commodity A_1

(d_3^-) = underachievement of holding capacity of commodity A_2

The objective function is;

Minimize $Z = P_1 (d_1^-) + P_2 (d_{12}^+) + P_3 (34 d_2^- + 27 d_3^-) + P_4 (d_1^+)$

Subject to constraints:

$$X_1 + x_2 + (d_1^-) - (d_1^+) = 20$$

$$65 x_1 + d_2^- = 651$$

$$63 x_2 + d_3^- = 634$$

$$(d_1^+) + (d_{12}^-) - (d_{13}^+) = 5$$

And $x_1, x_2, d_1^-, d_1^+, d_2^-, d_3^-, d_{12}^-, d_{13}^+ \geq 0$

Solving this step by step through simplex method

Taking $x1 = 0 = x2 = d_1^+ = d_{13}^+$

We get $d_1^- = 20$

$d_2^- = 651$

$d_3^- = 634$

$d_{12}^- = 5$

And by formulation of the initial table we proceed to solve this.

At the last table we see that all goals are achieved except priority goal P_3.

Also $X_1 = 10$, $x_2 = 10$

We get $d_1^- = 0$, $d_{12}^- = 0$, $d_1^+ = 0$

$d_{13}^- = 0$, $d_{12}^- = 5$

The Z values are;

$P_1 = 0$, $P_2 = 0$, $P_4 = 0$,

$P_3 = 34\, d_2^- + 27\, d_3^- = 108$

ie. $d_3^- = 4$

Hence, there is an underachievement of holding capacity of material A2.

So, the freight rate for commodity A_1 (cement tiles) = 2,17,462 Rs

For commodity A_2 (iron or steel slab) = 3,26,151 Rs which are less than the indicative freight rates.

Also, the freight train i^{th} can carry another (634-630) = 4 tonnes extra by its holding capacity of cement tiles, which increases the revenue of freight train transportation system.

CONCLUSION

The model suggests a low-cost plan for rearrangement of goods in freight trains, which is beneficial for both the customers and the freight train management system. Future studies can focus on developing an integrated model for both bulk and non-bulk commodities. Also, the model can be tested further with diverse problem instances and bigger problem sizes. This includes coordinating with freight train management and customers to synchronize orders and bundles shipment.

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