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Industries and Indian Railways: Bridging the Procurement Gap

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Abstract— **Pressing on the profitability factor and comparing two different modes for procurement in Indian context; railways and roadways, railway being more economical for freight transport yet the freight share of roadways dominates the railway freight. Delay stands as one of the major issues of Indian Railways that hinders industries to prefer them for procurement of goods; the issue could be addressed by maintaining calculated safety stock which compensates the delays. The present paper compares the two modes of transport by introducing a safety stock while procuring goods through railways and calculates annual handling cost for the both. Scrutinizing on the basis of economy-speed tradeoff further feasibility analysis is made. The key objective is to find out if railway procurement could be made profitable by introducing the safety stock and bearing the inventory carrying cost for the same. The study proves the railways as a feasible and profitable mode for procuring the consignment with a significant margin.**

Index Terms— **Inventory theory, Indian Railways, Economic Order Quantity (EOQ), Safety stock, Economy-speed tradeoff.**

I. INTRODUCTION

Given the last ten decades, Indian industrial sector has seen quiet a remarkable growth, and in parallel to the developing industrial sector freight traffic is also increased. Several reports have proven that in Indian context, road transport is dominating the rail traffic for years. Also that, the rail freight traffic share has decreased from 86.2% in 1951 to 29.55% in 2016. [1] This decrement is due to several inherent limitations and problems concerned to rail transport.

One such issue is delay, as rail transport is a slower medium it takes comparatively more time when compared to road transport. Furthermore, there are delay issues when rail transport is concerned, this is partly due to the priority given to the passenger trains than freight ones, and they both currently shares major track routes the transport trains are put on hold while the passenger train is crossing.

From an industrial point of view, due to delays, procurement lead time is increased. Increased lead time results in varying inventory levels and for industries working on low inventory levels; machine downtime due to unavailability of material.

Albeit the delay issues in rail transport, when compared the freight rates are significantly lower when compared to road transport. This economical edge of rail transport could be used to increase the profits, however, the delay issues needs to be addressed.

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The delay issue could be managed by scientific inventory keeping and managing a safety stock, a safety stock could be introduced to compromise the delays in transportation. If the monetary savings outweighs the inventory carrying cost when two different freight modes (rail and road) are compared and if the difference is significant, this could make rail transport feasible and profitable.

II. LITERATURE REVIEW

National Council of Applied Economic in their report titled ***'Factors Impacting Railway Freight Traffic in India'*** published in 2016 divulges the conditions of Indian Railways and its freight traffic. It also provides the record share of road and rail freight over the years. The take from this report was the short falls and the status of Indian Railways. Section 8 of the report discusses the outlooks and recommendations. Albeit the profound statistics and analysis, how industries could aid into the process is missing. This motivated us to search for alternatives, tools that could be used at the end of industries to increase the railway freight. [1]

E. L. Porteus's Foundations of Stochastic Inventory Theory (2009) explains the role of inventory and how inventory could be used to compensate the fluctuations of demand and supply. [2] ***Max Müller*** in ***Essentials of Inventory Management (2011)*** shares the same view and presents the expression for Economic Order Quantity. Understanding order quantity is important to predict inventory and its costs. The book extends the theory and delves the inherent limitations of the model exploring and suggesting other valid propositions to the same. However, both of the literature does not addresses the transportation costs and mode of transport. [3]

W.J. Baumol and H.D. Vinod in their paper ***'An Inventory Theoretic Model of Freight Transport Demand'*** address the transportation costs, speed, economy and other factors. The economy-speed tradeoff is introduced which is a significant tool for the assessment of the data and visual representation of complex constraints. The paper also provides a rather simplistic safety stock model and explains how safety stock could be calculated. Yet the paper does not address different probabilistic features other than Poisson's distribution for the calculation of safety stock. [3]

III. OBJECTIVE

- Computing annual handling cost for two transport modes (rail and road) for a specific order quantity.
- Calculating the difference of annual handling cost i.e. the net amount saved by opting more economical mode
- Finding economy-speed tradeoff and analyzing the result for feasibility in using the given freight mode.

IV. METHODOLOGY

A. Inventory Theory and Economic Order Quantity

Inventory is stock of tangible goods stored in order to compensate the fluctuations in demand, supply and other factors. Inventory could be in terms of raw material, finished goods or WIP (work in progress). Managing a defined level of inventory assures uninterrupted production.

There are various advantages of managing a defined level of inventory however, there are costs associated with inventory keeping. These costs are introduced due to inventory management, personnel's required, capital costs and deterioration costs. These could be understood as the bearing cost for assurance of uninterrupted flow of material.

As the inventory level is increased the costs associated with it increases and as the inventory level is decreased the probabilistic feature of uninterrupted flow decreases. Therefore, inventory models and scientific inventory keeping is introduced.

Introduced by F.W. Harris in 1915, the Economic Order Quantity (EOQ) formula determines the inventory level to be managed for minimum bearing costs. [3] It is given by:

EOQ = $\sqrt{\frac{2TC_o}{C_u i}}$ *eq.1*

Where T = Total annual demand

C_o = Replenishment cost or Ordering cost

Cu = Cost per unit

i = Inventory carrying cost in %

The EOQ formula helps to determine optimal order quantity, total cost, average inventory level and maximum inventory level. However, due to its facile assumptions it falls short at times. As inventory carrying cost and ordering cost at times is indeed dependent on the quantity ordered but demand rate does fluctuate and on a probabilistic scale there could be stock out situations. Therefore, industries use this EOQ approach to roughly estimate the inventory level and afterwards compounds it with other factors.

B. Annual Handling Cost (C)

Annual handling cost is the summation of all the costs associated in transit and inventory carrying from the planned order release to actually receiving the procurement, [4] for the calculation of annual handling cost we would employ the following notations: let,

C = Expected total annual variable cost of handling (₹)

T = Total amount transported per year (quantity demanded annually) (tons)

r = shipping cost per unit of commodity (including freight rate, insurance, etc.) (₹)

t = average time required to complete a shipment (in years)

s = average time between shipments in years (1/12 for a monthly made shipment)

u = carrying cost in transit per unit per year (interest plus deterioration plus pilferage rate) (₹)

w = warehouse carrying cost per unit per year (₹)

a = cost of ordering and processing per shipment (₹)

i = average inventory level (tons)

Annual handling cost comprises of following:

1. Direct shipping cost = (unit shipping cost) x (amount shipped) = rT *eq.2*
2. Total in-transit carrying cost = (cost per unit of time) x (transit time) x (amount shipped) = utT *eq.3*
   s = time interval between shipment
   ⇨ 1/s = shipment made in a year
3. Ordering cost = (cost per shipment) x (number of shipment) = a/s *eq.4*
4. Inventory carrying cost: inventory at a time = sT; average inventory = $sT/2$ *eq.5*
5. Inventory carrying cost = w_i = $wsT/2$

Summing up all the respects costs, we get:

$$C = rT + utT + \left(\frac{a}{s}\right) + \left(\frac{wsT}{2}\right) \quad eq.6$$

C. Safety Stock

As EOQ approach does not incorporate the risk of stock-out situations which may arise due to uncertainties in supply, hence additional compensations are made by maintain a safety stock. Maintain safety stock incorporates the uncertainties in supply and demand and conclusively delay. [4] There are several ways to calculate the safety stock, one such expression is:

Safety stock = $k((s+t)T)^{1/2}$ *eq.7*

Where s = average time between shipments in years accounting to possible delay as order misses its shipment

t= delay in transit which is depended on the mode of freight for the contingency situation, this could correlate with the average time required to complete a shipment if the mode of transport is still same as before

k(Constant)= 2.326[4]

Maintaining a safety stock required additional cost of the goods stored therefore,

Cost of safety stock = $wk((s+t)T)^{1/2}$ *eq.8*

Safety stock is also given by [5]:

Safety stock= $\left(Z * \sqrt{\frac{PC}{T_1}} * \sigma D\right) + \left(Z * \sigma_{LT} * D_{avg}\right)$eq.9

However, in the absence of delay reports we cannot calculate the stock by eq. 9 therefore for the current scenario where railway transport is not implemented eq. 7 could be used. After incorporating the transport mode further reports could be generated and better stock conditions could be predicted by eq.9

D. Loading and Unloading Cost

Additionally; Road transport features a door to door service which rail transport does not, therefore additional loading and unloading costs ($C_{l/u}$) are incorporated.

The total annual handling cost is therefore:

$$C = rT + utT + \left(\frac{a}{s}\right) + \left(\frac{wsT}{2}\right) + wk((s+t)T)^{\frac{1}{2}} + C_{l/u}$$

eq.10

V. VALIDATION OF MODEL

Step 1: Acquiring required data and formulating a table

XYZ Synthetics procures goods by both roadways and railways. For the purpose of this study, a specific consignment regime was taken. The following data was acquired:

Table 1: Variables for different transport mode

S.No.	Data (Variables)	Rail transport	Road Transport
1	r (Shipping cost/ unit)	₹ 1.59/kg (₹1590/Ton)	₹ 2.2/kg (₹2200/Ton)
2	T (ton per year)	150 X 52 = 7800	150 X 52 = 7800
3	Ws (Unit cost)	₹ 54000 /Ton	₹ 54000 /Ton
4	u (In transit carrying cost)	1% (₹ 540)	1% (₹ 540)
5	a (cost of ordering)	0.1% (₹ 54)	0.1% (₹ 54)
6	s (average time between shipment in years)	1/52	1/52
7	t (average time required for shipment in years)	6.85×10^{-3}	3.246×10^{-3}

Source: Data computed by survey of respective industry

Step 2: Calculating annual handling cost by road transport

Annual handling cost by road transport = C_{road}, putting in the values for the variables in eq.8 we get:

$$C_{road} = (2200 * 7800) + (540 * 0.003246 * 7800) + (54 * 52) + \left(\frac{54000 * \left(\frac{1}{52}\right) * 7800}{2}\right)$$

$$C_{road} = 17160{,}000 + 13672.152 + 2808 + 4050{,}000$$
$$C_{road} = ₹\ 2{,}12{,}26{,}480.152$$

Step 3: Calculating annual handling cost by rail transport

Annual handling cost by rail transport = C_{rail}, feeding the variable we calculate the respective costs. Additionally, loading and unloading costs, cost of safety stock is added to the same:

$$C_{rail} = (1590 * 7800) + (540 * 0.00685 * 7800) + (54 * 52) + \left(\frac{54000 * \left(\frac{1}{52}\right) * 7800}{2}\right) + C_{safety} + C_{l/u}$$

As we introduce a safety stock for railway transport, we calculate cost of safety stock:

Cost of safety stock = C_{safety}

$$C_{safety} = \left[(54000 * 2.326)\left(\left(\left(\frac{1}{52}\right) + 0.00685\right) * 7800\right)^{\frac{1}{2}}\right]$$

$$C_{safety} = 1791475.89$$

$$C_{rail} = 12402000 + 28852.2 + 2808 + 4050000 + 1791475.89 + C_{l/u}$$

$$C_{rail} = ₹18275136.09 + C_{l/t}$$

Now, calculating loading unloading cost;

Table 2. Loading / Unloading cost

S. No.	Capacity (Metric Tons)	Loading/ Unloading cost (₹)
1	<12	2,420
2	12 – 24	2,820
3	24 – 30	3,470
4	>30	5,470

Source: Compiled from local transport carriers

T= 7800 Tons

1/s = 52 yearly consignments;

Quantity per consignment = $7800/52$ = 150 Tons

$C_{l/t}$ = number of consignments X loading/unloading cost

$C_{l/t} = 2 * 52 * 2420 = ₹\ 2{,}51{,}680$

Therefore; $C_{rail} = 18275136.09 + 251680 = ₹\ 1{,}85{,}26{,}816.09$

Step 4: Calculating the difference in annual handling cost

Difference (Δ) = $C_{road} - C_{rail} = 21226480.152 - 18526816.09 = ₹\ 26{,}99{,}664.062$

As the difference in amount turns out to be positive, that implies that rail transport for the specific procurement is comparatively profitable.

Step 5: Calculating economy index and speed index

Economy index and speed index are comparative quantities which are helpful in numerical representation of data. Economic index and speed index are inversely related to the shipping cost(r) and average time required to complete a consignment (t) respectively. In the following calculation we would make necessary adjustments to bring the quantity to one's digit:

Economic index for road (e_{road}) = $1/r_{road} = \frac{10}{2.2} = 4.55$

Economic index for rail (e_{rail}) = $1/r_{rail} = \frac{10}{1.59} = 6.29$

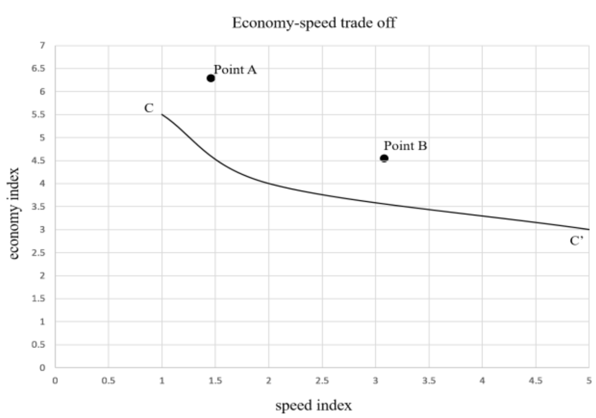
Speed index for road (v_{road}) = $1/t_{road} = \frac{10}{3.246} = 3.08$

Speed index for rail (v_{rail}) = $1/t_{rail} = \frac{10}{6.85} = 1.46$

Step 6: Plotting economy-speed trade off

By plotting the graph between economy and speed we can pictorially represent the data and make an assessment for the same.

Figure 1: Economy-speed tradeoff



In figure 1, point A represents rail transport and point B represents road transport. It could be interpreted that point A (i.e. rail transport) has a higher economy index and a lower speed index when compared to point B. The curve CC' is the indifferent curve which was drawn by the computing the points of past orders made and the mode of transport used, the points were further joined to form a smooth curve. All the points below the curve would be considered not economical then other options, therefore not feasible; and all the points above the curve are economical and are thus feasible to opt. amongst the point A and point B, both lies above the curve and are therefore feasible. Furthermore, point A is preferable as it is more economical, given that it is indeed feasible.

VI. RESULTS

Since safety stock is introduced for the rail transport which assures the uninterrupted flow and compensates the delay issues, after the implementation of same the net amount saved annually is approximately ₹26,99,664. However, this amount is subject to change (decreases) when further packaging and insurance costs are added to the same.

As both the freight modes (point A and B) are mapped above the indifferent curve which implies that both of the transportation modes are feasible to implement, which proves that railway transport could be incorporated for the procurement.

Opting for railway transport, as the in-transit time is longer, the procurement lead time is increased. For the industries like XYZ where procurements are made at relatively regular intervals, the length of transit period does not affect significantly, given that the planned order receipt is affirmatively made, terminus weekly and the deterioration is relatively less.

VII. LIMITATIONS OF THE STUDY

The data used in the study is subject to change and therefore any change in the data may not assure the results of the study. The data is combined from primary and secondary sources which are highly dependent on the accuracy of such data.

All the factors involved in scrutiny of subject are not considered, only the basic factors are used to formulate the results. For a better and precise model other factors are required to be incorporated like insurance costs, incentives, tax relaxations etc.

The defined inventory model and annual handling costs are highly subjective and are defined for the procurement of a specific commodity; therefore, if different commodity is to be procured the model is to be applied for each product individually and thus requires separate analysis.

VIII. FUTURE SCOPE

At present, the paper theoretically calculates the annual handling costs based on a rigid order quantity. This order quantity could be further derived based on minimum handling costs. Also that, the only costs incorporated besides the loading/unloading cost are inventory and transport-medium dependent; while exploiting railway network further packaging costs, insurance costs would also be incorporated.

For calculating the safety stock, the probability that a consignment is missed is assumed, however, by acquiring delay reports and relevant data a unique probability distribution could be made which can further assist in better and more accurate calculation of safety stock which in turn would further reduce the probability of stock out conditions.

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