OPEN ACCESS

International Journal Of Modern Engineering Research (IJMER)

Impact and Dynamics of Centralization in Transportation Cost of Cement Bag's Vendor and Retailer

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ABSTRACT: *The goal of many research efforts cognate to supply chain management is to propose mechanisms to reduce operational costs. Inventory holding and conveyance costs are regarded as the most paramount operational costs in inventory management. Many researches in supply chain management only consider the inventory cost as a criterion to decide replenishment policy. In the replenishment process, in juxtaposition of the inventory cost, the conveyance cost is a major cost factor which affects the shipment size. Thus in this research work the conveyance cost is additionally considered to minimize the inventory cost.*

Two models are studied: when the retailers make decisions independently i.e. Decentralized decision model and when the retailers are branches of the same firm i.e. Centralized decision model to determine the best solution to minimize costs.

Keywords: *Supply Chain Management, Operation Research, Economic Order Quantity, Replenishment Cost, Carrying Cost, Transportation Cost, Total Cost, Total Cost of Retailer, Total Cost of Warehouse, Decentralized Model, Centralized Model*

I. Introduction

Incrementing evidence suggests the prosperity of most world-class companies is due in grand part to an adroit management of "inventories, capacity utilization, and arbitrariness in the engenderment environment. Not surprisingly, these three areas have become the target of major perpetual amelioration efforts in a sizably voluminous number of western business organizations. However, the fact is that operations research studies dealing with the interaction of these three factors seem to be more the exception than the rule. The inventory control has a long time been a very classical OR quandary. Since 1913 with Harris, a great number of OR researchers have studied this subject. From the available literature, it seems that inventory quandaries have received less attention in the recent past. However, general difficulties practiced by Finns and budget restrictions seem to have aroused incipient interest in this field of research".

The incrementing popularity of management concepts predicated on the cooperation of business along the supply chain inspirits businesses use current methods for their operational orchestrating. The main feature expected from contemporary approaches is "to enable the simultaneous analysis of the flow of goods along the chain at multiple links of the chain. Nowadays, a congruous structure of a distribution system and cull of distribution and inventory policies affects not only the cost of product supply execution, but additionally inventory cost and customer accommodation quality. In their efforts to amend the culled characteristics of the entire or a particular part of the supply chain, the businesses have to solve quandaries which prove much more involute than in the case of traditional approaches, where a single subject is analyzed only."

In the case of distribution warehouses, this proportion is even more paramount because the main activity (the only integrated value) is to receive pallets of items from vendors, stock them and distribute customer orders containing different items. In integration, with the amelioration in information technology, it becomes possible to develop implements which can avail managers to handle warehouse and inventory issues more efficiently".

At all classical levels of decision (strategic, tactical and operational), warehouse managers have to tackle quandaries which can be divided into two broad classes:

"Warehouse management and inventory management problems".

"Regarding warehouse management issues, managers have to decide where to assign the products inside the warehouse. Concerning inventory management, managers must decide which product, and how much of each product need to be stored in the warehouse. All those decisions are interrelated but are dealt independently. Up to now, warehouse and inventory issues are handled in a pyramidal top-down approach where the flexibility of decisions decreases from top to bottom. Strategic decisions are first taken and then engender limits to decisions taken at the tactical and operational levels. For example, once the size and the design of the warehouse are fine-tuned, these decisions will have to be venerated when replenishment policies have to be designed as well as when the size of the different warehouse areas has to be optimized. On top of this, decisions taken at each level of the pyramid are additionally handled independently and sequentially."

II. List Of Abbreviations

SCM - Supply Chain Management, OR -Operation Research, EOQ - Economic Order Quantity, CR/CR - Replenishment Cost, CC/CC - Carrying Cost, CT/CT - Transportation Cost, TC - Total Cost, TCr - Total Cost of Retailer, TCw - Total Cost of Warehouse.

III. Mathematical Model

Each Retailers and warehouse contain a set of control parameters which affect the total inventory cost. The main object in both centralized and decentralized inventory model is:

Minimize TC= $\sum_{r=1}^{12} TC_r + TC_w$
Where,

TCr = Total Cost of Retailers TCw = Total Cost of Warehouse
So total cost of all retailers and a single warehouse is minimized jointly

Notations Used
"In our models the following notations are used":

Table 1: Notations used in Models

Sr. No.	Notations	Meaning
1	N	Total number of retailers
2	R	retailers index (r = 1, 2. . .6)
3	ρ	density of retailers (retailers/square km)
4	Q_r	replenishment ordered quantity in bags of retailer r (bags)
5	Q_R	sum of all replenishment order quantities from retailer 1 to 12
6	F_r, F_w	fixed cost of order at the retailers and warehouse (Rs.)
7	V_r, V_w	variable purchase cost of item at retailer and warehouse (Rs.)
8	D_r	demand quantity of retailer r (bags)
9	d_{wr}' d_{sw}	traveling distance from warehouse to retailer r and from supplier to warehouse (km)
10	h_r, h_w	carrying charge in % at retailer r and at the warehouse
11	L_{wr}' L_{sw}	lead-time from warehouse to retailer r and supplier to warehouse (month)
12	S	truck capacity (bags)
13	I_w	interval between two orders in the warehouse (month)
14	T_w, T_s	fixed cost of transportation from warehouse to retailer r and supplier to warehouse (Rs.)
15	t_w, t_s	variable cost of transportation from warehouse to retailer r and supplier to warehouse (Rs.)

(A) Decentralized Ordering Optimization

In this section "the warehouse and retailers are considered to be distinct entities making individual decisions." The total cost of the warehouse and the each retailer is computed as following:

(a)Retailer model

Here we consider "the case that each retailer determines its own Economic Order Quantity and optimal cost." We assume that "the retailer's costs include transportation costs, the cost of replenishment, and carrying cost." The total cost to each retailer is defined as follows:

TCr = CRr + CCr + CTr

The "first term indicates the replenishment cost and can be determined as": CRr = Fr × D r / Qr

The "second term indicates the carrying cost and can be determined as":

CCr = (Qr/2 + σrLwr) Vrhr [here, σrLwr = √(Lwr × σr2)]

Finally, "the third term indicates the cost of transportation":

CTr = [Tw + tw(Qr/S)dwr] × (D r / Qr)

DATA COLLECTION

RETAILERS	1	2	3	4	5	6	7	8	9	10	11	12
DEMAND	1000	800	750	1050	700	900	800	850	900	950	800	750

Mean (Dr) $=\frac{1000+800+750+1050+700+900+800+850+900+950+800+750}{12} = 854.166$

Var(σr2)$=\frac{(1000-854)^2+(800-854)^2+(750-854)^2+(1050-854)^2+ \ldots\ldots + (950-854)^2+(800-854)^2+(750-854)^2}{12} = 10607.67$

Table 2: Common data for all Retailers

Sr. No.	Notation	Value
1	Fixed Cost per order (Fr)	220 Rs.
2	Variable Cost per order (Vr)	150 Rs.
3	Carrying Charge (hr)	1%
4	Fixed Cost of transportation per order (Tw)	1000 Rs.
5	Variable Cost of transportation per order (tw)	180 Rs/ton.
6	Truck Capacity (S)	320 Bags

(1) Retailer 1:

Table 3: Individual data of Retailer 1

Sr. No.	Notation	Value
1	Lead Time (L_{wr})	1 Day i.e.0.03 Month
2	Replenishment order Quantity per order (Q_r)	100 Bags
3	Distance between warehouse and retailer (d_{wr})	163 km
4	Demand Quantity (D_r)	1000 Bags

(a) Replenishment Cost (CR) $= \frac{FrDr}{Qr} = \frac{220\times1000}{100} = 2200\ Rs$

(b) Carrying Cost (CC) $=\left(\frac{Qr}{2} + \sigma_r L_{wr}\right) V_r h_r$

Where $\sigma_r L_{wr} = \sqrt{L_{wr} + \sigma_r{}^2} = \sqrt{0.03 + 10607.67} = 102.9937$

$$C_c = \left(\frac{100}{2} + 102.9937\right) 150 \times 1 = 22949.055\ Rs$$

(c) Transportation cost (CT) $= \left[T_w + t_w\left(\frac{Q_r}{S}\right) d_{wr}\right] \frac{D_r}{Q_r}$

$$= \left[1000 + 180 \left(\frac{100}{320} \right) 163 \right] \frac{1000}{100} = 101687.5\, Rs$$

(d) Total Cost of Retailer 1 = 2200 + 22949.055 + 101687.5 = **126836.555 Rs**

Similarly we can find the Total Cost of all Retailer i.e for Retailer 2,3,4,5,6,7,8,9,10,11,12

(2) Retailer 2:

Table 4: Individual data of Retailer 2

Sr. No.	Notation	Value
1	Lead Time (L_{wr})	1 Day i.e.0.03 Month
2	Replenishment order Quantity per order (Q_r)	105 Bags
3	Distance between warehouse and retailer (d_{wr})	160 km
4	Demand Quantity (D_r)	800 Bags

Total Cost of Retailer 2 = C_R+C_C+C_T

= 1676.19 + 23324.055 + 79619.05 = **104619.295 Rs**.

Similarly we can find the total cost of Retailers and all the data is listed in the table.

Table 5: Model Evaluation of Decentralized Retailers (in Rs.)

R	F_r	V_r	L_{wr}	S	T_w	t_w	D_r	Q_r	d_{wr}	C_{Rr}	C_{Cr}	C_{Tr}	TC_r
1	220	150	.03	320	1000	180	1000	100	163	2200.00	22949.06	101687.50	126836.56
2	220	150	.03	320	1000	180	800	105	160	1676.19	23324.06	79619.05	104619.29
3	220	150	.03	320	1000	180	750	110	127	1500.00	23699.06	60396.31	85595.37
4	220	150	.03	320	1000	180	1050	100	125	2310.00	22949.06	84328.13	109587.18
5	220	150	.03	320	1000	180	700	95	177	1621.05	22574.06	77062.17	101257.28
6	220	150	.03	320	1000	180	900	110	152	1800.00	23699.06	85131.82	110630.88
7	220	150	.03	320	1000	180	800	90	160	1955.56	22199.06	80888.89	105043.51
8	220	150	.03	320	1000	180	850	100	161	1870.00	22949.06	85478.13	110297.18
9	220	150	.03	320	1000	180	900	90	162	2200.00	22199.06	92012.50	116411.56
10	220	150	.03	320	1000	180	950	110	163	1900.00	23699.06	95739.49	121338.55
11	220	150	.03	320	1000	180	800	105	161	1676.19	23324.06	80069.05	105069.30
12	220	150	.03	320	1000	180	750	95	145	1736.84	22574.06	69066.61	93377.51
-	Total						10250	1210	-	22445.83	276138.72	991479.65	1265665.08

Total Decentralized Retailer Cost = 126836.555 + 104619.295 + 85595.365 + 109587.18 + 101257.275 + 110630.875 + 105043.505 + 110297.18 + 92012.5 + 121338.545 + 105069.295 + 93377.505 = **1265665.075 Rs.**

(b) Warehouse Model:

"We search for the optimal strategy of the warehouse that will minimize the costs of total inventory cost. Here the total cost is comprised of replenishment cost, carrying cost, shortage cost, and transportation cost." Hence, the total cost of warehouse can be defined as follows:

TCw = CRw + CCw + CTw

here, CRw , CCw and CTw can be determined as follows:

CRw = Fw × No. of orders

CCw = [μ w (Iw+ Lsw)/2 + σw(Iw+ Lsw)] × V w.hw

[here, σw(Iw+ Lsw)= √(Iw+ Lsw) × √(σr2)]

CTw = Ts + ts(μ w.Iw/S)dsw× (∑Nr=1 Dr/ QR)

Data Collection:

Table 6: Individual data of Warehouse

Sr. No.	Notation	Value
1	Fixed Cost per Order (Fw)	200 Rs.
2	Variable Cost per order (Vw)	110 Rs
3	Interval between orders i.e. Review Period (Iw)	20 Days = 0.67 Month
4	Lead Time(Lsw)	1 Day = 0.03 Month
5	Distance from supplier to warehouse (dsw)	25 km
6	Carrying Charge (rw)	1%
7	Truck Capacity (S)	560 Boxes
8	Fixed Cost of transportation per order (Ts)	1500 Rs.
9	Variable Cost of transportation per order (ts)	160 Rs.

Total forecasted demand

$$(\mu_w) = \sum_{r=1}^{12} D_r = 1000 + 800 + 1050 + 750 + 700 + 750 + 900 + 800 + 850 + 900 + 950 + 800 = 10250\, bags$$

Total replenishment quantity

$$(Q_R) = 100 + 105 + 110 + 100 + 95 + 110 + 90 + 100 + 90 + 110 + 105 + 95 = 1210\, bags$$

Replenishment Cost (CR) = FW × No. of Orders = 200 × 9 = 1800 Rs.

Carrying Cost (CC) = $\left[\frac{\mu_w (I_w + L_{sw})}{2} + \sigma_w (I_w + L_{sw})\right] V_w h_w$

Where

$$\sigma_w (I_w + L_{sw}) = \sqrt{(I_w + L_{sw})} \times \sqrt{\sigma_r^2} = \sqrt{(0.67 + 0.03) \times 10607.67} = 86.1705$$

$$C_C = \left[\frac{10250(0.67 + 0.03)}{2} + 86.1705\right] 110 \times 1 = 404103.76$$

Transportation Cost (CT) = $\left[T_s + t_s \left(\frac{\mu_w I_w}{S}\right) d_{sw}\right] \sum_{r=1}^{12} \frac{D_r}{Q_R}$

$$= \left[1500 + 160 \left(\frac{10250 \times 0.67}{560}\right) 25\right] 8.4 = 424650\, Rs.$$

Total Decentralized warehouse Cost = 1800 + 404103.76 + 424650 = **830553.76 Rs**

Total Decentralized Cost = Total Decentralized Retailer Cost + Total Decentralized warehouse Cost
= 1265665.075 + 830553.76 = 2096218.835 Rs.

(B) Centralized Ordering (Collective) Optimization:

A number of different posits have made in the centralized injuctively authorizing model. In the decentralized injuctively authorizing, it is postulated that "each retailer finds its optimal order quantity, sends it to the warehouse, and receives it afterward. The main motivation of the centralized authoritatively mandating policy is to explore whether such a policy leads to a lower total system-wide cost by amending the inventory and conveyance decisions."

We propose "a collective form of authoritatively mandating by retailers and plan to minimize the inventory cost of the retailers and the warehouse jointly. The warehouse observes a sequence of ordinant dictations from a group of retailers situated in a given region. Ideally, these ordinant dictations should be shipped immediately. Retailers observe their customers' demand and then collaborate to explore the optimal joint order amount and send it to the warehouse. Therefore, the warehouse and the retailers must optimize their decision variables in a way to reduce the total cost of the system. This denotes that we first find the total cost of the system (which is the summation of the warehouse and retailers costs) and then endeavor to determine the optimal value for the joint order size. Each retailer's costs include conveyance cost, cost of replenishment and carrying cost."

(a) Retailer Model:

The total cost to each retailer is defined as follows:

TCr = CRr + CCr + CTr

hereCRr , CCr and CTr can be determined as follows:

$$C_{Rr} = \frac{F_r}{Q_R} \sum_{r=1}^{12} D_r$$

$$C_{Cr} = \left(\frac{Q_r}{2} + \sigma_r L_{wr}\right) V_r h_r \qquad [\text{here, } \sigma_r L_{wr} = \sqrt{L_{wr} \times \sigma_r^2}\ ]$$

$$C_{Tr} = \left[T_w + t_w \left(\frac{Q_R}{S}\right) d_{wr} + \frac{N\sqrt{(1/\rho)}}{(Q_R/S)}\right] \times \left(\sum_{r=1}^{N} \frac{D_r}{Q_R}\right)$$

Data Collection:

Table 7: Collective data of all Retailers

Sr. No.	Notation	Value
1	Fixed Cost per Order (F_r)	220+220+....+220 = 2640 Rs
2	Variable Cost per Order (V_r)	150 Rs
3	Replenishment Order Quantity (Q_R)	100+105.......+95 = 1210 bags
4	Lead Time (L_{wr})	2 Days i.e. 0.06 Month
5	Carrying charge (h_r)	2.5 %
6	Retailers density (ρ)	5
7	Truck Capacity (S)	600 bags
8	Fixed Cost of transportation per order (T_w)	2500 Rs
9	Variable Cost of transportation per order (t_w)	280 ton

(a) Replenishment Cost $(C_R) = \frac{F_r}{Q_R} \sum_{r=1}^{12} D_r = \frac{2640 \times 10250}{1210} = 22363.64\ Rs.$

(b) Carrying Cost $(C_C) = \left(\frac{Q_r}{2} + \sigma_r L_{wr}\right) V_r h_r$

Where $\sigma_r L_{wr} = \sqrt{L_{wr} \times \sigma_r^2} = \sqrt{0.06 \times 10607.67} = 25.2282$

$C_C = \left(\frac{1210}{2} + 25.2282\right) 150 \times 2.5 = 236335.58$ Rs.

(c) Transportation Cost $(C_T) = C_{Tr} = \left[T_w + t_w \left(\frac{Q_R}{S}\right) d_{wr} + \frac{N\sqrt{(1/\rho)}}{(Q_R/S)}\right] \times \left(\sum_{r=1}^{N} \frac{D_r}{Q_R}\right)$

$$(C_T) = C_{Tr} = \left[2500 + 280\left(\frac{1210}{600}\right) 79 + \frac{12\sqrt{(1/5)}}{(1210/600)}\right] \times \left(\frac{10250}{1210}\right) = 399083.6\ Rs.$$

(d) **Total Centralized Retailer Cost** = 22363.64 + 236335.58 + 399083.6 = **657782.82 Rs**

(b) Warehouse model:

The total cost to each warehouse is defined as follows:

TCw = CRw + CCw + CTw

hereCRw , CCw and CTw can be determined as follows:

CRw = (Fw / QR) × ∑Nr=1 Dr

CCw = (QR/2 + σwLsw) Vwhw [here, σwLsw = √(Lsw × σr2)]

CTw = [Ts + ts(QR/S)dsw] × (∑Nr=1 Dr/ QR)

The goal of centralized ordering model is "to jointly minimize the combined inventorycost of retailers and the warehouse."

Data Collection:

Table 8: Collective data of Warehouse

Sr. No.	Notation	Value
1	Fixed Cost per Order (Fw)	600 Rs
2	Variable Cost per Order (Vw)	500 Rs.
3	Distance from supplier to warehouse (dsw)	25 km
4	Lead Time (Lsw)	2 Days i.e. 0.06 Month
5	Truck Capacity (S)	700 Bags
6	Fixed Cost of transportation per order (α s)	3000 Rs
7	Variable Cost of transportation per order (ts)	350 Rs

(a) Replenishment Cost $(C_R) = \frac{F_w}{Q_R}\sum_{r=1}^{12} D_r = \frac{600 \times 10250}{1210} = 5082.65\ Rs.$

(b) Carrying Cost $(C_C) = \left(\frac{Q_R}{2} + \sigma_w L_{sw}\right) V_w h_w$

Where $\sigma_w L_{sw} = \sqrt{L_{sw} \times \sigma_r^2} = \sqrt{0.06 \times 10607.67} = 25.2282$

$C_C = \left(\frac{1210}{2} + 25.2282\right) 500 \times 1$ = 315114.1 Rs.

(c) Transportation Cost $(C_T) = \left[T_s + t_s\left(\frac{Q_R}{S}\right) d_{sw}\right] \times \left(\frac{\sum_{r=1}^{12} D_r}{Q_R}\right)$

$$(C_T) = \left[3000 + 350\left(\frac{1210}{700}\right) 25\right]\left(\frac{10250}{1210}\right) = 153538.22\ Rs.$$

(d) **Total Centralized Warehouse Cost** = 5082.65+315114.1+153538.22 = **473734.97 Rs**

Total Centralized Cost = Total centralized Retailer Cost + Total Centralized Warehouse Cost
= 657782.82 + 473734.97 = 1131517.79 Rs.
Difference between Total Decentralized Cost and Total Centralized Cost = 2096218.835 – 1131517.79 = 964701.045 Rs

IV. Conclusion

We have formulated "a multi-level inventory model that includes transportation costs for planning the replenishment of a single commodity. The conclusion of the research is minimization the total inventory cost while considering a discrete transportation cost. Finally, development of a collective form of ordering by retailers and plan to minimize the inventory cost of the retailers and the warehouse jointly."

Two models are developed considering "the scenarios of centralized ordering and decentralized ordering. A numerical example was solved for both models. Results indicate that having collaboration among the retailers and the warehouse or applying a collective ordering strategy results in reduced costs when compared to the decentralized ordering strategy. Furthermore, it was shown that the transportation cost contains a considerable percentage of the total cost, while this cost has been usually overlooked."

The difference between the total cost of decentralized and centralized model is **964701.05 Rs**. So, the total cost is minimized by minimizing the transportation cost.

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