Journal of Material Science and Mechanical Engineering (JMSME)
p-ISSN: 2393-9095; e-ISSN: 2393-9109; Volume 6, Issue 2; April-June, 2019 pp. 121-127

http://www.krishisanskriti.org/Publication.html

An Optimization Model for Container Space Utilization for a Single Warehouse and Multiple-Retailer System

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Abstract—*In this paper, we have considered optimization of the container capacity for its maximum utilization for a single-warehouse multiple-dealers (SWMD) system. The system consists of a single warehouse, where finished goods are received from different production units, and demand of the customer is fulfilled through multiple retailers. Also, we have assumed that warehouse is utilizing vender managed inventory (VMI) approach to cater the demand of the customer. This problem is optimized using mixed integer linear programming (MILP) algorithm by assuming accurate demand forecast.*

Keywords*: Warehouse, Mixed integer linear programming (MILP), Vender managed inventory (VMI).*

1. INTRODUCTION

Supply chain management (SCM) consists of planning and managing activities including sourcing, logistics, operations and marketing for the efficient utilization of resources. It helps to improve the competitive position of an organization in today's unstable market environment. The modern supply chains rely heavily on warehouses for fulfillment of the customers' demands (Yang et al., 2012). Warehousing consists of receiving product, quality control, storage, picking, sorting, packing and shipping. The efficiencies of these activities largely depend on the interpersonal relationship between suppliers, manufacturers, retailers and consumers. The goal of the single warehouse multiple-dealers (SWMD) problem is to minimize the total transportation and inventory replenishment costs in the system (Shen et al., 2017). The dealers are interested in minimizing their inventory costs. Vendor managed inventory (VMI) is an integral part of supply chain management in which the supplier (vendor) takes the full responsibility of maintaining an agreed level of inventory at buyer's location. The vendor constantly monitors, and updates the inventory targets as per mutually agreed framework (Elvander et al., 2007). **Figure 1** shows the movement of goods produced by a company from warehouse to the consumer.

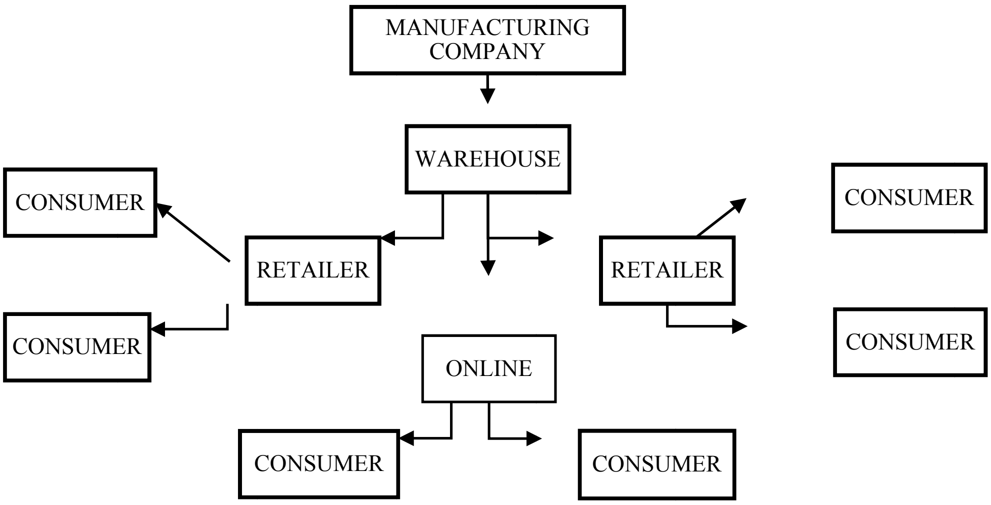

Figure 1: Movement of Goods from Manufacturer to Consumer.

2. LITERATURE REVIEW

Many authors have addressed the single warehouse multiple dealer concept and have observed various factors influencing the performance of this policy. Levi et al., (2007) have used a constant approximation algorithm (CAA) for solving one-warehouse multi-retailer (OWMR) problem involving real-life situations. It uses a linear programming-based algorithm used to make approximate solution for inventory problems faced in OWMR. It concludes that by taking the best warehouse order, we can get the most expected cost. The one-warehouse multiple-retailer system is subjected to random disruptions in a deterministic demand and having identical retailers, and stocks up the produces where holding cost is low. The authors conclude that by ignoring the disruption, there will not be a good relationship with the consumer and this will drastically affect the cost. Atan and Snyder (2012) effectively used time partitioning heuristics for one warehouse multi-item multi-retailer system that can deal with the dynamic lot-sizing problems. Federgruen and Tzur (1999) found that how different elements can be chosen to ensure asymptotic optimality and ϵ optimality. Kogan and Perlman (2009) predicted the replenishment time using game theory and found solution close to the Nash solution. And using Stackelberg leadership increasing transportation cost can be cut off. Cunha (2005) conducted a theoretical study to compare the linear relaxation bounds obtained by dynamic programming-based formulation (DDP) and shortest path formulation (SP). It is difficult to point out that DDP is dominating the SP on an OWMR system, but these two methods are superior to other methods for transportation problems. There is no limit on order quantity for each period, but there are cargo constraints, which require additional container trucks to dispatch the items, when single container capacity exceeds. There is a fixed cost per container dispatched from warehouse to the retailers, and linear holding costs at the warehouse and retailers. When vendor managed inventory (VMI) is combined with one warehouse multiple-dealer system to improve the flow of items, it requires an appropriate policy to be selected by the supply chain members.

3. MATHEMATICAL MODEL

Consider a single-warehouse multi-dealer system with a demand forecast to analyse the maximum utilisation of space in a container truck. Let the dealer wants to replenish n number of items produced by the company. The company is maintaining a single central warehouse to fulfil the requirement of the m number of dealer. Let R be the transportation cost of the container from warehouse to the dealers and all trucks are identical with capacity of W units except online order vehicle of capacity W_1. Here we have tried to study the effect of demand over the replenishment of the supplies, so that we can provide the maximum number of products in a single transportation. The objective of this model is to reduce the cost of transportation, provide space for the new stock in the warehouse and effectively use the space provided by the container truck. Here, warehouse is using vendor-managed inventory (VMI) to supply the products.

Let w, v, b, l, h and p are the weight, volume, width, length, height and price of the product X_n respectively where $n \leq \infty$, and n denotes the number of products variety produced like television, refrigerator, etc. Similarly, W, V, B, L, H and P are the weight, volume, width, length, height and price of the container as well as the dealer store. Size of the container varies with the quantity of the order placed, like if it's an online shopping then the warehouse uses W_1 to denote the capacity of small container.

3.1. Assumptions Applied for The Model

- The production of items is continuous as per the demand of customer.
- The rate of consumption of items is constant with rate of production.
- All demands must be satisfied without backorders.
- The warehouse is connected with the production line.
- The warehouse has enough products to replenish the entire dealer.

Minimizing

$$\sum_{i=1}^{\infty} - DX_{mn}$$

Subject to

$$W = \sum_{i=1}^{\infty} (w_{mn} . X_{mn})$$

$$V = \sum_{i=1}^{\infty} (v_{mn} . X_{mn})$$

$$B = \sum_{i=1}^{\infty} (b_{mn} \cdot X_{mn})$$

$$L = \sum_{i=1}^{\infty} (l_{mn} \cdot X_{mn})$$

$$H = \sum_{i=1}^{\infty} (h_{mn} \cdot X_{mn})$$

$$P = \sum_{i=1}^{\infty} (p_{mn} \cdot X_{mn})$$

$$\forall i, m > 1, n > 1$$

And, Transportation cost = Cost/km + Cost/kg

i.e. $R = R_1 + R_2$

As we can see that there are two factors defining the cost of the transportation, one is cost per unit kilometre and the other one is cost per unit kilogram. Since we are most concern about the maximum utilization of space, we try to minimize the number of container to be utilized for the replenishment of the dealer.We model the problem as a mixed-integer linear program (MILP), where X_{nm} is the number of *n* products sent by the warehouse to *m* dealers as per the demand. Algorithm was implemented using MATLAB code and run under MATLAB17.

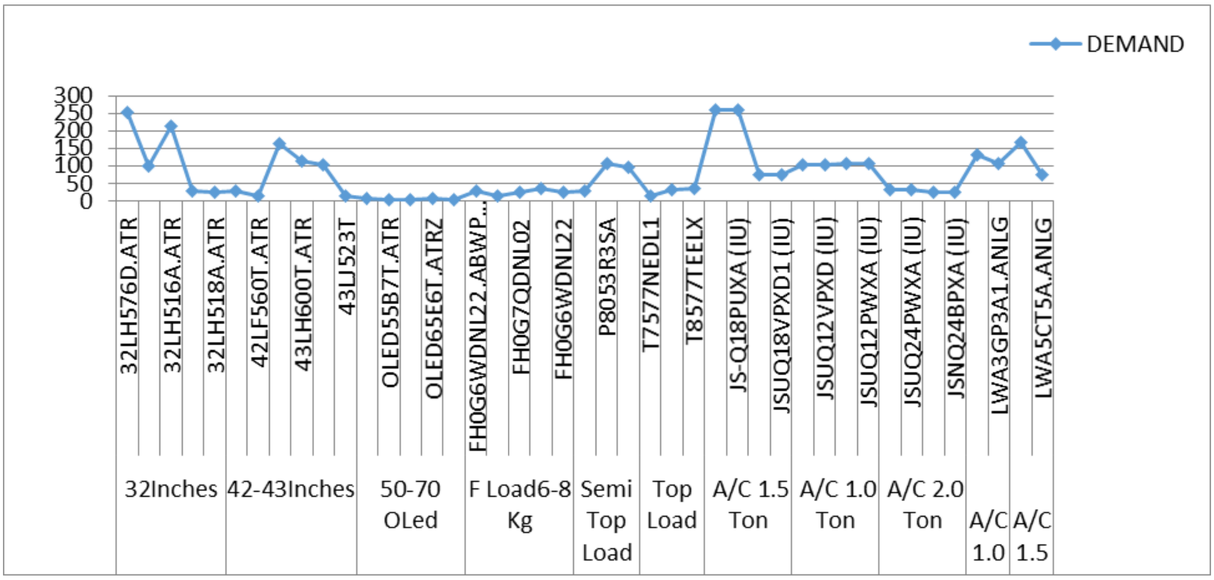

Figure 2 shows the demand of domestic appliances of a manufacturing company during summer period of a particular year.

Table 1 shows the product data that is used to get the results of the algorithm.

S.No	Inches	Models	WIDTH (mm)	HEIGHT (mm)	LENGTH (mm)	VOLUME(mm3)	PACKAGE VOL. (mm)	WEIGHT (Kg)	PACKING WG.(Kg)
1	32Inches	32LH576D.ATR	870	500	150	65250000	71775000	7.7	7.8925
2		32LH602D.ATR	800	520	140	58240000	64064000	6.5	6.6625
3		32LH516A.ATR	800	520	140	58240000	64064000	6.43	6.59075
4		32LH512A.ATR	786	500	132	51876000	57063600	6.12	6.273
5		32LH518A.ATR	790	510	130	52377000	57614700	6.45	6.61125
6	42-43Inches	42LF553A	959	560	57	30611280	33672408	11.3	11.5825
7		42LF560T.ATR	961	560	560	301369600	331506560	9.2	9.43
8		43LH576T.ATR	1060	656	216	150197760	165217536	11.1	11.3775
9		43LH600T.ATR	1040	630	150	98280000	108108000	11.5	11.7875
10		43LF6300.ATR	1040	640	150	99840000	109824000	13	13.325
11		43LJ523T	976	621	209	126674064	139341470.4	8.4	8.61
12	50-70 OLed	OLED55C7T.ATR	1230	217	75	20018250	22020075	25	25.625
13		OLED55B7T.ATR	2108	1263	285	758785140	834663654	14	14.35
14		OLED65C7T.ATRZ	1453	873	217	275257773	302783550.3	24.7	25.3175
15		OLED65E6T.ATRZ	1461	893	200	260934600	287028060	25.5	26.1375
16		OLED65B7T.ATR	1453	873	217	275257773	302783550.3	24.7	25.3175
17	F Load6-8 Kg	FH0G6WDNL22.ABWPEPL	920	640	620	365056000	401561600	60	61.5
18		FH2G6HDNL42.ALSPEPL	920	660	530	321816000	353997600	60	61.5
19		FH0G7QDNL02	940	650	650	397150000	436865000	70	71.75
20		FH4G6TDNL42	930	650	650	392925000	432217500	80	82
21		FH0G6WDNL22	920	640	620	365056000	401561600	65	66.625
22	Semi Top Load	P7550R3FA	820	515	103	43496900	47846590	65	66.625
23		P8053R3SA	820	510	102	42656400	46922040	70	71.75
24		P8541R3SA	830	510	102	43176600	47494260	75	76.875
25	Top Load	T7577NEDL1	620	620	103	39593200	43552520	65	66.625
26		T8067NEDLR	620	620	102	39208800	43129680	70	71.75
27		T8577TEELX	620	600	104	38688000	42556800	75	76.875
28	A/C 1.5 Ton	JS-Q18PUXA (II)	890	280	216	53827200	59209920	9.5	9.7375
28		JS-Q18PUXA (IU)	810	568	270	124221600	136643760	32	32.8
29		JSUQ18VPXD1 (II)	890	280	216	53827200	59209920	10	10.25
29		JSUQ18VPXD1 (IU)	810	568	270	124221600	136643760	30	30.75
30	A/C 1.0 Ton	JSUQ12VPXD (II)	890	280	216	53827200	59209920	9.5	9.7375
30		JSUQ12VPXD (IU)	715	495	230	81402750	89543025	25	25.625
31		JSUQ12PWXA (II)	890	280	216	53827200	59209920	9.5	9.7375
31		JSUQ12PWXA (IU)	715	495	230	81402750	89543025	25	25.625
32	A/C 2.0 Ton	JSUQ24PWXA (II)	1090	300	218	71286000	78414600	12	12.3
32		JSUQ24PWXA (IU)	870	655	322	183491700	201840870	39	39.975
33		JSNQ24BPXA (II)	1090	300	218	71286000	78414600	12	12.3
33		JSNQ24BPXA (IU)	870	655	322	183491700	201840870	39	39.975
34	A/C 1.0 Ton	LWA3GP2A.ANLG	600	380	560	127680000	140448000	43	44.075
35		LWA3GP3A1.ANLG	600	380	560	127680000	140448000	43	44.075
36	A/C 1.5 Ton	LWA5CP3A.ANLG	660	428	770	217509600	239260560	55	56.375
37		LWA5CT5A.ANLG	660	428	770	217509600	239260560	55	56.375

Figure 2: Demand Forecast of The Products Which Are to Be Supplied to The Dealer. Table 1: dimensions, weights and prices of the produc

Computation Results

Table 2: Allocation Of Products To Be Supplied

ITEM	CONTAINER1	CONTAINER2	CONTAINER3	CONTAINER4	CONTAINER5
32LH576D.ATR	5	5	5	5	5
32LH602D.ATR	5	5	5	0	0
32LH516A.ATR	5	5	5	5	5
32LH512A.ATR	5	5	5	0	0
32LH518A.ATR	5	5	5	0	0
42LF553A	5	5	5	0	0
42LF560T.ATR	4	4	0	0	0
43LH576T.ATR	5	5	5	0	0
43LH600T.ATR	5	5	5	0	0
43LF6300.ATR	5	5	5	0	0
43LJ523T	5	5	3	0	0
OLED55C7T.ATR	0	0	3	0	0
OLED55B7T.ATR	0	0	0	0	0
OLED65C7T.ATRZ	0	0	0	0	0
OLED65E6T.ATRZ	0	0	0	0	0
OLED65B7T.ATR	0	0	0	0	0
FH0G6WDNL22.ABWPEPL	5	5	0	0	0
FH2G6HDNL42.ALSPEPL	5	5	0	0	0
FH0G7QDNL02	5	5	0	0	0
FH4G6TDNL42	5	5	5	0	0
FH0G6WDNL22	5	5	0	0	0
P7550R3FA	5	5	5	0	1
P8053R3SA	5	5	5	5	5
P8541R3SA	5	5	5	5	5
T7577NEDL1	5	5	5	0	0
T8067NEDLR	5	5	5	0	0
T8577TEELX	5	5	5	0	0
JS-Q18PUXA	5	5	5	5	5
JSUQ18VPXD1	5	5	5	0	0
JSUQ12VPXD	5	5	5	0	0
JSUQ12PWXA	5	5	5	5	5
JSUQ24PWXA	5	5	5	0	0
JSNQ24BPXA	1	1	0	0	0
LWA3GP2A.ANLG	5	5	5	5	5
LWA3GP3A1.ANLG	5	5	5	4	4
LWA5CP3A.ANLG	5	5	5	5	5
LWA5CT5A.ANLG	5	5	5	0	0
SPACE (mm3)	33100000000	67500000000	15500000000	33100000000	67500000000
QUANTITY (kg)	28200	28200	12500	28200	28200
ITEMS COST (Rs)	5000000	5000000	5000000	1000000	1000000

The table shows the number of every item which is added to the container (five containers are considered) for optimal supply without compensating with the demand rate of the dealer. The values used for the container size, the weight to carry and the money invested are different for different types of dealers. Every container has same

This solution is further divided keeping in mind the container size, by using same algorithm, to get the number of containers that are to be used for the transportation of items.

Condition 1- Maximum Amount of Goods Transported in a Container

We have compared volumes and weights of items, and capital invested with each other to study and get the maximum demanded items, which are to be delivered to the dealer. We have considered five cases, and compared the items on the basis of their volume, weight and capital invested to get the result of all the outcomes. Also, we have assumed that maximum five items are allotted to the dealer, as in this algorithm, we can use $i = \infty$ number of items to get the result. That is why it is the upper limit that is bounded to certain limit to study the cases.

Case 1- Moderate volume, High investment and Heavyweight

Here we can see that only highly demanded products are allotted to the container, which is the required objective to achieve.

Case 2- High volume, High investment and Heavyweight

As the results shows, there is no improvement compared to case 1. So we can use container 1 instead of container 2 to reduce the transportation cost.

Case 3- Low volume, High investment and Lightweight

This shows almost same result as in case 1. Even though its investment is same, the carrying capacity is comparatively low.

Case 4- Moderate volume, Low investment and Heavy weight

There is a drastic decline in the number of products. Only the most required products are allotted.

Case 5- High volume, Low investment and High weight

Only one more product is added compared to case 4. As already concluded only when the carrying weight is increased, then only this container is to be used.

From the above discussion of five cases, we can conclude that every parameter is interdependent, and increase or decrease of one parameter will affect the other. By setting the proper upper bound, we can get the proper amount of highly demanded items, which are to be sent to the dealer.

Condition 2- Sending the Product to the Online Customer Directly

Suppose the customer specifically asks for the specified product through an online market. The warehouse is required to take the decision about how to dispatch the product from warehouse to the specified location. The product is dispatched to a specific location as per the website owner. Most of the time the product is dispatch with the dealer’s container, which is near to the costumer’s location and then it is transport to the costumer from the dealer with the help of a small delivery vehicle. In this type of case, we simply add the required product with the usual replenishment.

4. CONCLUSION

Using the algorithm discussed in the present paper, we can use the maximum space of the container, which will subsequently reduce the cost of transportation in terms of number of vehicles used. We have tested our algorithm using randomly generated problems and clarified the effectiveness of the algorithm.

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