ELSEVIER

Int. J. Production Economics 59 (1999) 179–187

international journal of
production
economics

A proposed model of JIT purchasing in an integrated steel plant

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Abstract

Just-in-time (JIT) till recently has been more confined to manufacturing sectors. But the recent literature is full of articles on JIT in purchasing and service sectors [Ansari and Modarress, Potential benefits of JIT purchasing for US manufacturers, Production and Inventory Management Journal 28 (2) (1987) 30–35; Ansari and Modarress, JIT purchasing as a quality and productivity centre, International Journal of Production Research 26 (1) (1988) 19–26; Schonberger and Ansari, Just in time purchasing can improve quality, Journal of Purchasing and Materials Management 20 (1) (1984) 2–7 [1–3]] in Japanese and western countries. Somehow, this idea has not percolated down to the developing world where many manufacturers are still suffering from "not invented here" kind of syndrome. They have their mind set about the old system of purchasing and manufacturing and any thing new finds a lot of resistance in getting absorbed in their rigid concept. In this article an effort has been made to work out a conceptual model for the JIT application in the purchase section of an integrated steel plant in India. The following issues have been considered: (a) Identification and classification of materials and vendors which can be brought under JIT network. (b) Suggesting a freight consolidation model (FCM) to collect the items from the vendors.

Keywords: Logistics; JIT; Purchase; Quality; Sourcing

1. Introduction

JIT in purchasing broadly means frequent ordering and frequent deliveries of materials in smaller lots from preferably local, and quality certified suppliers to the point of their consumption at the time of usage in right quantity and quality.

Purchase section has been selected to lead the JIT implementation because it is the first line of defence of a plant as far as quality and timely supply of items are concerned. JIT purchase is not about reducing inventories. In fact, inventory reduction is perhaps the most visible result that JIT brings about. JIT in reality is a philosophy of supply chain excellence.

1.1. Description of the problem

The study has been carried out in an integrated steel plant in India. It has a capacity to produce 3 million ton of steel per year. It also produces long and flat products like: hot rolled coils, wire

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0925-5273/99/$ - see front matter
PII: S0925-5273(98)00099-1

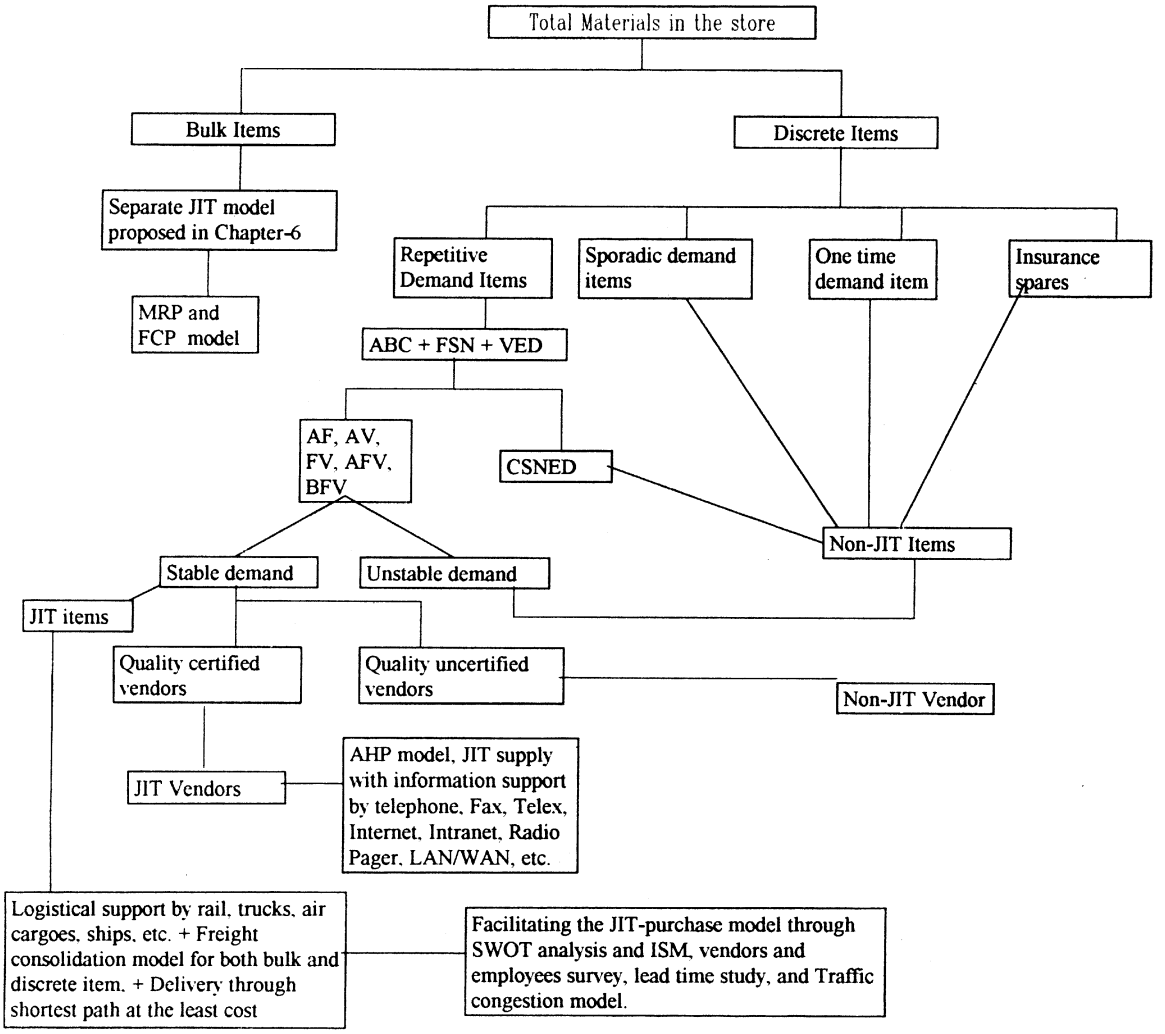

Fig. 1. Materials classification for JIT-purchasing in steel plant.

products, plates, sheets, etc. In addition to the major *bulk* raw materials used (viz., iron ore, coke, and fluxes, etc.), there are about 80 000 different types of *discrete* items in the inventory which are maintained by a system of central and sub-stores. At present all these items are supplied by both the local and remote suppliers in various lots to the stores. The term "local supplier" means the one located within the radius of 30 kms from the plant. The aim of the plant, however, has been to develop the sources of supply in its close vicinity. The total number of vendors at present is about 3500 which includes about 100 local vendors.

The demand of the items is both regular and irregular. The items have either single or multiple-sourcing. Some of the vendors are quality certified but most of them are not certified (see Fig. 1). Materials worth Rs. 12 000 millions (US $300 million) are purchased every year which excludes the bulk items.

The items supplied by the vendors are centrally received, inspected, documented and stored in

several wards of the central stores and sub-stores. After that the document called goods receipt note (GRN) is prepared to enable the payment. The time taken for GRN has been reduced from 30–16 days. However, there is a great scope for further improvement. If the materials are found unsuitable, they are returned to the vendors at their cost. This process takes a week or more.

Awareness level about JIT is confined to the top and the middle management and is practically nil with the operators at the shop floor level. No awareness programme about JIT benefits exists for the suppliers and purchase staff.

The plant has made reasonable progress in computerisation of its stores. However, manual records have not been fully dispensed with. Documents related to each transaction like issue, receipt, return store, inter-store transfer, purchase requisition and purchase order etc., are fed into the computer. Periodic stock status reports, purchase requisitions, enquiries and purchase orders are generated by the computer.

1.1.1. Materials classification (existing)

From the selective control point of view all the items in the store are classified in groups like: ABC, FSN, VED.

(i) *ABC grouping* is based on annual consumption value (ACV). A-class consists of items with high values (in terms of rupees or dollars), B-class consists of items with moderate values, whereas the C-class has the items with low values. A-class items are given maximum attention to control the cost. ABC classification of materials in brief is represented in Table 1.

Table 1
ABC classification

Division	Class	Percent	Criteria	No. of items[a]
09	A	10%	ACV > \$2446	1600
	B	20%	\$412 < ACV < \$2446	3200
	C	70%	ACV < \$412	76 000

[a]1 US\$ = Rs. 36.00.

(ii) *FSN grouping* is based on the movement of materials or their rates of consumption. FSN stands for *Fast*, *Slow*, *and the Non-moving* items. An item is said to have made one move if it is issued to the user department at least once or more than once in a month. According to this rule if the material has made 12 moves in the last 24 months then it is a fast moving item or else it is slow moving. If the material has not moved at all in five years then it is treated as a non-moving item. Maximum attention is paid to the fast moving items and the least to the non-moving items. If the movement of material per month is denoted by V, then for

F-type: $V > 12$,

S-type: $V < 12$,

N-type: $V = 0$ in last 5 years.

(iii) *VED grouping* is based on the criticality of the item. VED stands for *vital*, *essential and desirable*. Maximum control is exercised on the vital few than on the trivial many.

(iv) *Special items*: These items are treated differently for the purpose of replenishments and control because of their peculiar nature. They are further subdivided as: insurance spares, bulk and canalised items, and imported spares.

(a) *Insurance spares*: These are very slow moving items which may not be required at all during the entire life cycle of an equipment but their stock-out may lead to huge loss of revenue. About 1300 such items are identified and maintained [4]. Approximately, 30% of equipment spares which were purchased along with the main equipment have never been drawn from the stores.
(b) *Bulk and canalised items*: These items are consumed in bulk and their supply is regulated through Government agencies. Some of them are: high speed diesel, lubricants, wire ropes, cables etc.
(c) *Imported spares*: A large number of spares have to be imported, mainly from the USA, Germany, the UK, and Japan. The procurement policies of such items are designed to take care of the long and uncertain lead time in their procurement.

2. Essential requirements of JIT purchase

- Demand of items should be repetitive and their delivery schedule should be stable.
- Advance information about the material requirement schedule is provided to the suppliers.
- Suppliers should be quality certified so that the items supplied by them need not be checked at the buyer's place.
- Long term contract and mutually beneficial relationship between the suppliers and the buyer is essential.
- Single sourcing per item is preferred.

2.1. JIT requirements and the hurdles in JIT purchase

Looking at the JIT requirements and the situation in the plant under study, we find the following deviations due to internal and external factors:

The demands of bulk raw materials used in steel production are stable, repetitive and predictable. However, the demand patterns for most of the discrete items are stochastic. They are not repetitive in most of the cases. Only a small percentage of such items have quality certified suppliers. Hence, these items are not easily amenable to JIT mode of supply.

The delivery of items can be delayed by external factors like: a traffic jam on the road and the river bridges which connect the suppliers to the buyer. This can be a potential bottleneck in the supply chain specially during the day time but the problem of traffic jam is less during the night. Delay can also be caused by the problems at the supplier's plant, breakdown of vehicles in-transit, strikes processions of a different nature (religious and political), rainy season, poor roads, and slow traffic.

2.2. The way out

The author feels that some amount of safety stock, violating the true spirit of JIT, can absorb the unforeseen delays in supply. Religious processions can be predicted from the calendar of festivals and strikes are generally restored to by political parties only after prior notification to the people and the local administration, hence these are deterministic and, therefore, the shipments can be rescheduled as per the situation. Only lightning or wild cat strikes can cause delivery problems.

3. Proposed conceptual model of the JIT in purchase

Since the consumption patterns for most of the discrete items of the plant are not stable, we cannot implement JIT mode of supply in all the discrete items. From JIT point of view all the discrete items and the vendors supplying them can be defined as discussed below.

3.1. JIT material classification

JIT-items consist of items: with stable and repetitive demands, which have very high-consumption and high-criticality value. For the plant under study, the A-class, Fast moving, and Vital items belong to JIT type of materials.

3.2. Non-JIT items are those which do not fulfil the above JIT definition

With these criteria in mind we classify the entire items of the plant into JIT (F, A, AF, AV, and AVF types) and non-JIT categories (see Table 2). It is seen from the Table that about 7% of the total items fall into the JIT category of materials. They constitute about 4.5% in terms of annual consumptions value.

3.3. JIT vendor classification

As per our definition "A JIT vendor is one who is quality certified, has a proven record of reliability and punctuality in supply of items, is willing to participate and co-operate in the JIT mode of supply, and has proper training and understanding of the JIT philosophy". Vendors who do not satisfy this definition are called non-JIT vendors.

Table 2
Material classification for JIT

JIT items	Type	Quantity	% of total items	ACV in million (Rs.)	% of ACV
	F	2766	3.46	153.67	1.28
	A	1671	2.08	254.96	2.12
	AF	873	1.09	120.90	1.01
	AV	62	0.08	7.53	0.06
	AVF	02	0.00	0.39	0.00
	Subtotal JIT	5364	6.70	537.44	4.48
Non-JIT items	Non-JIT items	74 636	93.30	11462.55	95.52
Total items	JIT + Non-JIT	80 000	100.00	12000.00	100.00

With these criteria in mind, it is difficult to find JIT vendors in India. Most of the vendors are neither quality certified nor trained in JIT philosophy. However, some vendors have a longterm relationship with the buyer in the form of an annual rate contract (ARC). The vendor base and the number of sources per item for the plant under study is shown in Tables 3 and 4, respectively. From the table of vendors supplying 80 items on ARC basis it is found that 56.25% of items have a single supplier. Similartly, 17.5% of the items have two suppliers per item, 16.25% of the items have three suppliers, 2.5% of the items have four suppliers, and so on (see Tables 4 and 5).

Table 3
Number of vendors per item

No. of vendors per item	1	2	3	4	5	6	7	8
% of items	56.25	17.50	16.25	2.5	2.5	2.5	1.25	1.25

Table 4
Trends of vendor base

Vendor base during past 4 yr		
Year	Total number of vendors	% reduction in vendor base
1993	18 000	0
1994	12 000	33.33
1995	5000	72.22
1996	3500	80.50

Table 5
Annual demand of JIT items

Item	1	2	3	4	5	6	7	8	9	10
Demand of items per year ('00)	120	200	80	18	90	160	8	1	9	10

3.4. *How to collect and transport the JIT items to the buyer economically?*

Once we have identified the JIT items and JIT vendors, the next logical step is to work out the logistics to collect and transport these items from the vendors to the buyer. Presently, the vendors send their items in full trucks to save the cost of transportation, even when the items are not needed in that large quantity. In JIT environment, the vendors are required to supply the items in smaller lots with a greater frequency. Sometimes the items might have to be supplied in less than truck load (LTL). This causes an increase in the transport cost and thus motivates the vendors to hold back the shipment till it becomes a full truck load (FTL). These problems can, however, be minimised by using the concept of freight consolidation policy (FCP). *Consolidation of inbound freight involves grouping of shipments from different suppliers to form a single large shipment at the consolidation centre* (*CC*) *before shipping them to the final destination*(*s*).

The objective of FCP is (a) to convert the LTL of shipments into FTL, and (b) to reduce the transport cost due to the frequent deliveries in JIT supply. This will be beneficial to both the vendors and the buyer. The vendors will save on the cost of transportation, whereas the buyer will save on storage and multiple handling costs.

In Section 4 we propose some algorithms for freight consolidation which can be used in any process industry including the steel plant under study.

4. Algorithm for consolidation

Freight consolidation can be done on the basis of the following factors: (i) space needed by different components and subassemblies (if the space taken by different components is less, then large number of components from more number of vendors can be consolidated on the same trip but if the space needed is more, then even a single or a few components can be enough for the entire truck), (ii) nearness or the proximity of suppliers, (iii) delivery schedule and the need of the components at the buyers' place, and (iv) the capacity of the vehicle.

Notations

D_i demand of the ith item per year.
W_i weight per unit of the ith item (kg).
q_i quantity to be picked up per day for the ith item.
C_k capacity of the kth type of truck used to deliver the items to the plant.
n_k no. of trucks of kth type needed for delivering the item.
S_i space occupied by the ith item on the truck.
S_k space available on the kth type truck.
C_t cost of transportation with FCM.
C_T cost of transportation without FCM.
C_i cost of inventory carrying with FCM.
C_I cost of inventory carrying without FCM (It may be noted that $C_i = C_I$ for all the items.
C_{in} cost of inventory carrying for n days of consolidation either with FCM or without FCM $[W_{n-1} + W_{n-2} + W_{n-3} + \cdots + W_1]C_h$, where C_h = Cost of inventory/ton/day = Rs.100/ton/day.
TC_1 $(C_t + C_i)$ = total cost involved in transporting and delivery of items with FCM.
TC_2 $(C_T + C_i)$ = total cost involved in transporting and delivery of items without FCM.

We propose an algorithm to effect the FCP. This consists of solving this problem:

(a) Calculate q_i, q_iW_i and $\sum q_iW_i$ for all the JIT items i $(i = 1, 2, \ldots, n)$.
(b) Select a K type truck with the load-carrying capacity of C_k.
(c) Compute $\sum q_iW_i/C_k$ to find the number of trucks of kth type (n_k) needed to deliver the load.

Table 6
Capacity of various trucks and their cost per trip

K	Capacity of truck C_K (ton)	Cost of the kth type of truck per trip (Rs.)
1	0.5	75
2	1.0	150
3	2.0	225
4	3.0	275
5	5.0	300
6	10.0	480
7	15.0	620
8	20.0	760
9	40.0	1220

Table 7
Demand of items on daily basis and their weights

Items	Demand			W_i (kg)	q_iW_i (kg)	Σq_iW_i (kg)
	Items/yr	Items/m	Items/d (q_i)			
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	12 000	1000	34	15	510	510
2	20 000	1667	56	15	840	1350
3	8000	667	23	10	230	1580
4	18 000	1500	50	10	500	2080
5	9000	750	25	10	250	2330
6	16 000	1333	45	08	360	2690
7	8000	667	23	08	184	2874
8	1500	125	05	05	25	2899
9	900	75	03	05	15	2914
10	1000	83	03	02	06	2920

(d) If n_k is less than 0.75, then the trip is not feasible. But, if n_k is equal to or greater than 0.75 or its multiple, then the trip is feasible.
(e) For a given load to be delivered, select from the feasible trucks the one which has the least cost of delivery.
(f) Load the truck with last in first out (LIFO) concept in mind to facilitate unloading at various destination(s) at the plant.

We have to use the algorithm within the following constraints:

$$\sum S_i \leqslant n_k S_k \quad \text{(space constraint)}, \tag{i}$$

$$\sum q_i W_i \leqslant n_k c_k \quad \text{(load carrying capacity constraint)}. \tag{ii}$$

Illustrative example:

The demand pattern for the JIT items used in the steel plant under study and the capacity of different types of trucks used to collect and deliver these items are given in Tables 5 and 6, respectively. The cost per trip for different types of trucks is also given in Table 6.

Solution. The Table 5 shows the number of items required to be collected from different depots. In a JIT system the need for these items will be fixed for at least a month. So, this collection schedule can

Table 8
Calculation for different days of consolidation

Load for 1 day demand of buyer

Load (kg)	Truck (t)	C_t (Rs.)	C_i (Rs.)	TC_1 (Rs.)
510	1	150	0	900
840	1	150		
230	0.5	75		
500	0.5	75		
250	0.5	75		
360	0.5	75		
184	0.5	75		
25	0.5	75		
15	0.5	75		
06	0.5	75		
2920		900	0	900

Load for 2 days demand of buyer

Load (kg)	Truck (t)	C_t (Rs.)	C_i (Rs.)	TC_1 (Rs.)
1020	2	225	292	1492
1680	2	225		
460	0.5	75		
1000	1	150		
500	0.5	75		
720	1	150		
368	0.5	75		
50	0.5	75		
30	0.5	75		
12	0.5	75		
5840		12 000	292	1492

Load for 3 days demand of buyer

Load (kg)	Truck capacity (t)	C_t (Rs.)	C_i (Rs.)	TC_1 (Rs.)
1530	2	225	1168	2793
2520	3	275		
690	1	150		
1500	2	225		
750	1	150		
1080	2	225		
552	2	225		
75	0.5	75		
45	0.5	75		
18	0.5	75		
8760		1625	1168	2793

be provided to the logistics control department and to the vendors to be followed for the entire month. Table 7 shows the demand of items per day and the other details.The procedure of filling up different columns of the tables can be explained as follows:

From column 6 of Table 7 we have the total demand of items ($i = 1, 2, \ldots, 10$) for one day in terms of load. The total load per day (after consolidation) when all the items are needed by the buyer is 2920 kg. This can be transported by a 3 t capacity truck or by a combination of 2 t and 1 t trucks. Looking at the cost of transportation from Table 6 the two options give the costs equal to Rs. 275 and Rs. 375. Thus, the truck with 3 t capacity has been selected for transporting the load of 2920 kg for the first day of demand of all the items.

If the suppliers decide to deliver these items individually (i.e. without consolidation) then they will have to send each item in a separate vehicle (the choice of vehicle and the cost of transportation will vary depending on the load of individual item) and the total cost in doing so for the first day is Rs. 900. Thus, there is a saving of Rs. 625 on the first day of supply due to FCM [see Table 8 for sample calculation].

If the suppliers want to deliver the items after every two days then the best choice of trucks for the load 5840 kg (for two days of load of 10 items after consolidation) will be 5 and 1 t and the total cost will be equal to Rs. 450. On the other hand, if the loads are not consolidated and sent to the buyer after every two days by individual vehicle, then the cost will be Rs. 1200 (see Table 8). This will give a saving of Rs. 750. The same logic is followed for the rest of the days.

It should be noted, however, that when the suppliers decide to deliver the items not on daily basis but on every two days basis then the buyer will have to incur the cost of storage for the additional items for one day. Therefore, the total cost of supply of items will be the sum of transportation cost and the storage cost whether with FCM or without FCM. We call these two costs as TC_1 and TC_2, respectively. The same is true for other days of consolidation (i.e., for three days, four days, and so on). The savings in cost will be the difference of TC_1 and TC_2.

Table 9 shows the savings in the cost of transportation when different capacity trucks are used to collect and deliver the items.

5. Conclusions

(a) It is seen from Table 2 that about 7% of the 80 000 items fall in JIT items category. The corresponding cost of these items is Rs. 537 million.

(b) It is seen from Table 9 that the savings in the total cost due to consolidation of freight varies from 69.40 to 7.91% for one and ten days of supply at a time. The decrease in saving is due to the increase in inventory carrying cost as the number of consolidation days increases. Thus,

Table 9
Total cost by different types of truck with and without FCM

Day	Load (kg)	Optimal truck combination (t)	C_t	C_T	C_i	TC_1	TC_2	% Saving in cost (Rs.)
1	2920	3	275	900	0	275	900	69.4
2	5840	5 + 1	450	1200	292	742	1492	50.26
3	8760	10	480	1700	876	1356	2576	47.36
4	11 680	15	620	1700	1752	2372	3452	31.28
5	14 600	15	620	1900	2920	3540	4820	26.55
6	17 520	20	760	2125	4380	5140	6505	20.98
7	20 440	20 + 1	910	2225	6132	7042	8357	15.73
8	23 360	20 + 3 + 1	1185	2255	8176	9361	10 431	10.25
9	26 280	40	1220	2380	10 512	11 732	12 892	8.99
10	29 200	40	1220	2455	13 140	14 360	15 595	7.91

the study suggests that JIT delivery will give the maximum saving in total cost as compared to the larger lot size.

(c) It is also obvious that the cost of transportation and cost of inventory increase with the increase in the number of consolidation days, however the latter increases faster than the former which explains why the saving decreases as the interval of deliveries is increased.

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