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Service Charge in VMI Systems

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Abstract

This study investigates the role of the per unit payment made by the retailers to the manufacturer in VMI systems for managing their respective inventories. Hitherto, this has been assumed to be exogenously provided. It is shown that the manufacturer can use it to extract additional profit from the retailers. Implications of this charge have been investigated in both uniform pricing as well as retailer specific pricing scenarios. Various options available to the retailers in order to safeguard their respective interests have been discussed.

Keywords: Supply chain management, vendor managed inventory, pricing, service charge.

Service Charge in VMI Systems

1. Introduction

In today's economically challenging times, companies face unprecedented competition. They are exploring multitude of options to optimize their physical, information and monetary operations. Supply chain coordination is now widely believed to offer a path towards developing a sustainable competitive advantage. Within the context of supply chain management, major challenges faced by the companies include the pressure to lower costs, supplier development and management and development of differentiated customer service capabilities (SCM World, 2012).

Vendor managed inventory (VMI) is one of the myriad options being explored and implemented by a number of organizations to manage the aforementioned challenges. Under VMI, the supplier (manufacturer) manages the inventory of the customer (retailer) within a mutually agreed framework of performance criteria which are closely monitored and updated as required (Hines et al., 2000). The benefits of VMI include reduction in the bullwhip effect, decrease in inventory levels, overall cost reduction as well potentially closer buyer-supplier relationships (Marquès et al., 2010).

Stackelberg formulations of VMI systems have been in focus recently. Yu et al. (2006) were amongst the first to consider such a system. Yu et al. (2009a) studied an extended system incorporating raw material procurement stage in their analysis. Wong (2009) incorporated sales rebate in VMI systems, and found that retailer competition increased supplier profits. Yu et al. (2009b) presented a VMI system in which retailers did some advertisement expenditure to boost demand and determined the optimal pricing, advertising and inventory decisions. Yu and Huang (2010) analyzed how a manufacturer and multiple retailers can optimize the product marketing strategies, platform product configuration and inventory policies under VMI. Almehdawe and Mantin (2010) studied two different situations, first by assuming manufacturer to be the Stackelberg leader and then took one of the retailers as the leader and found that, in general, retailer dominance resulted in higher supply chain efficiency.

All the studies in this domain assume that under VMI, the manufacturer takes care of the operating costs of all the retailers who in turn pay a fee to him. This fee has hitherto been considered as exogenously provided. This inventory related payment is levied on per unit of product and thus presents an option to the manufacturer to charge extra. This charge could be different for different retailers. With this realization, we attempt to analyze three questions in this paper. First, we determine the role this inventory payment for services rendered plays in the SC in terms of the prices charged and profits made. Second, how the payment can be determined and how different parties can look after their respective interests. Third, we also study the impact of a retailer specific wholesale price on the VMI system and contrast it with a uniform wholesale price strategy.

The paper is organized as follows. In the next section, we provide the problem statement along with the associated assumptions. Section 3 contains all the models assuming a uniform wholesale price. Numerical analysis has been presented in section 4. The impact of a retailer specific wholesale price has been investigated in section 5. In section 6, we discuss the managerial implications of our study. Section 7 contains some concluding remarks and future research directions.

2. Problem statement

Consider a single product system with a single uncapacitated manufacturer who meets the demand of multiple retailers. Initially all the retailers are responsible for their respective replenishment decisions. Under this scenario, retailers bear the holding, transportation and ordering costs, while the manufacturer bears his holding and production (setup) costs.

The assumptions and notations used in the paper are listed below:

2.1 Assumptions

1. Demand at the retailers is assumed to be deterministic and is a function of the retail price.
2. There is no backordering.
3. There is no competition between the retailers.
4. Under VMI, a production batch is delivered to the retailers in multiple sub-batches.
5. All the retailers are supplied in the same replenishment cycle under VMI system.
7. Retailers are responsible for deciding the retail price.
6. The wholesale price charged by the manufacturer is the same for all the retailers.

2.2 Notation

S	Production setup cost ($ per setup)
n	Number of sub-batches delivered in a single production batch
r	Total number of retailers in the system
a_i	Ordering cost for the i^{th} retailer ($ per order)
h_i	Holding cost for the i^{th} retailer ($ per unit per year)
h_v	Holding cost for the vendor ($ per unit per year)
t_i	Transportation cost from the manufacturer to the i^{th} retailer ($ per order)
$D_i(p_i)$	Demand rate for the i^{th} retailer as a function of the retail price (units per year)
D	Total demand rate across all the retailers (units per year)
P	Production rate (units per year)
T_i	Replenishment cycle for the i^{th} retailer when operating independently (years)
T_v	Manufacturer's economic production cycle (years)
T	Common replenishment cycle for all the retailers in case of VMI (years)
δ	Transportation efficiency factor due to combined delivery to retailers ($0 \leq \delta \leq 1$)
w	Wholesale price charged by the manufacturer ($ per unit)
p_i	Retail price charged by the i^{th} retailer ($ per unit)
α_i	Market scale parameter of the i^{th} retailer
β_i	Price sensitivity parameter of the i^{th} retailer
θ_i	Per unit payment from the i^{th} retailer to the manufacturer under VMI ($ per unit)

3. Model formulation

In order to understand the dynamics of the SC under various operating conditions, we consider three basic modes of operations: (a) all the parties act independently, (b) they enter a VMI agreement in which the manufacturer is the Stackelberg leader, and (c) a cooperative contract is adopted across the SC. Specifically within the context of the VMI contract, we explore different options that can enable the retailers to safeguard their interests.

3.1 Model 1: Retailers place orders independently

Initially, it is assumed that all the retailers are operating independently. Thus, the decision variable for each retailer would be the length of the replenishment cycle and the retail price to be charged.

We assume the following relationship between the demand and the price for the i^{th} retailer:

$$D_i(p_i) = \alpha_i - \beta_i p_i \tag{1}$$

The yearly profit for the buyer can be written as the difference between its yearly revenues and its total cost, including the holding, ordering and transportation costs. Thus, the decision problem for the i[th] retailer can be written as:

$$Maximize\ NP_i = (p_i - w)(\alpha_i - \beta_i p_i) - \left[\frac{(a_i + t_i)}{T_i} + \frac{(\alpha_i - \beta_i p_i) T_i h_i}{2} \right] \tag{2}$$

$$S.t.\ Ti > 0$$

When each retailer is placing orders for himself, the optimal decision would be to place orders corresponding to the economic order quantity. The replenishment cycle corresponding to that is given by:

$$T_i^* = \sqrt{\frac{2(a_i + t_i)}{hi(\alpha_i - \beta_i p_i)}} \tag{3}$$

Using (3) in (2) and simplifying, we get:

$$NP_i = (p_i - w)(\alpha_i - \beta_i p_i) - \sqrt{2(a_i + t_i) h_i (\alpha_i - \beta_i p_i)} \tag{4}$$

The above expression can be rewritten as:

$$NP_i = (p_i - w)(\alpha_i - \beta_i p_i) - \sqrt{2(a_i + t_i) h_i \alpha_i} * (d_{0i} p_i^2 + d_{1i} p_i + d_{2i}) \tag{5}$$

where, $d_{0i} = (-8 + 4\sqrt{2})(\beta_i / \alpha_i)^2$, $d_{1i} = (12 - 7\sqrt{2})(\beta_i / \alpha_i)$, and $d_{2i} = (3\sqrt{2} - 4)$.

The optimal retail price can be obtained by differentiating (5) with respect to p_i, and equating it to zero. Solving, we get:

$$p_i^* = \frac{(\alpha_i + w\beta_i) - d_1 \sqrt{2(a_i + t_i) h_i \alpha_i}}{2\beta_i + 2d_0 \sqrt{2(a_i + t_i) h_i \alpha_i}} \tag{6}$$

Using the above value of the optimal retail price in (3), we can obtain the optimal replenishment cycle and using it in (5), we can obtain the total profit for the i[th] retailer.

Retailers place orders with the manufacturer as per their respective optimal replenishment cycles. In this scenario, it becomes difficult to determine the latter's cost. However, following Chan and Kingsman (2007), we assume that the vendor caters to a constant demand rate, which is equal to the total demand rate across all the retailers. At the same time, he carries extra stock equal to the sum of the economic order quantities of the retailers, in order to avoid stockouts. Thus, manufacturer functions as per his economic production quantity corresponding to the following time interval:

$$T_v = \sqrt{\frac{2S}{h_v D\left(1-\frac{D}{P}\right)}} \tag{7}$$

where, $D=\sum_{i=1}^{r} D_i(p_i)$ is the total demand across all the retailers.

Next, the total profit for the manufacturer can be written as:

$$NP_m = \sum_{i=1}^{r} wD_i(p_i) - \frac{S}{T_v} - h_v\left[\left\{\frac{DT_v}{2}\left(1-\frac{D}{P}\right)\right\} + \sum_{i=1}^{r} D_i(p_i)\mathrm{T}_\mathrm{i}\right] \tag{8}$$

3.2 Model 2: (Unconstrained) VMI

Under VMI, the manufacturer takes the responsibility of replenishing the retailers and bears all the costs involved. The retailers compensate the manufacturer through a service fee per unit of product handled (θ_i). Existing literature takes this fee to be exogenously provided and conducts the analysis of the VMI system. However, we consider this to be a decision variable of the manufacturer, as he is assumed to be the Stackelberg leader in our model. We also assume that the manufacturer replenishes all the retailers in the system in the same production cycle. However, he delivers *n* sub-batches from a single production batch.

Hence, the decision variables for the manufacturer would be the length of the replenishment cycle, number of sub-batches, service fee to be charged from the retailers and the wholesale price. Retailers would decide their respective retail prices.

Net profit for the ith retailer can be written as:

$$NP_i = (p_i - w - \theta_i)\left(\alpha_i - \beta_i p_i\right) \tag{9}$$

The net profit for the manufacturer can be written as:

$$NP_m = \left[\sum_{i=1}^{r}\left(w + \theta_i\right)(\alpha_i - \beta_i p_i)\right] - OC \tag{10}$$

OC is the total operating cost incurred by the manufacturer which includes the setup cost, ordering cost, transportation cost and inventory holding cost. The manufacturer transfers the production lot in 'n' batches of size $Q(=\sum_{i=1}^{r} q_i)$, where q_i is the size of the shipment sent to the ith retailer (Figure 1). Thus, we can get the average inventory cost related to all the retailers per year as:

$$= \sum_{i=1}^{r} \frac{D_i\left(p_i\right)h_i}{2}\left[\frac{T}{n} + \left(n-1\right)\left(\frac{1}{D} - \frac{1}{P}\right)\frac{DT}{n}\right]$$

Let δ represent the transportation cost under VMI, expressed as a fraction of the total cost incurred independently. Thus, the total setup, transportation and ordering costs will be:

$$= \frac{S + n\left(\delta\sum_{i=1}^{r} t_i + \sum_{i=1}^{r} a_i\right)}{T}$$

The total operating cost incurred by the manufacturer (OC) can be written as:

$$OC = \frac{S + n\left(\delta\sum_{i=1}^{r} t_i + \sum_{i=1}^{r} a_i\right)}{T} + \frac{h_v T D^2}{2nP} + \sum_{i=1}^{r} \frac{D_i\left(p_i\right)h_i}{2}\left[\frac{T}{n} + \left(n-1\right)\left(\frac{1}{D} - \frac{1}{P}\right)\frac{DT}{n}\right] \tag{11}$$

The Stackelberg game is generally solved through backward induction. We first determine the best response function of the retailers. Differentiating (9) with respect to p_i and equating it to zero, we get the critical value of retail price as:

$$p_i^* = \frac{\alpha_i + \beta_i\left(w+\theta_i\right)}{2\beta_i} \tag{12}$$

The demand faced by the retailers can then be written as:

$$D_i\left(p_i^*\right) = \frac{\alpha_i - \beta_i\left(w+\theta_i\right)}{2} \tag{13}$$

The decision problem for the manufacturer can be written as:

$$\begin{aligned} &Maximize\ NP_m \\ &s.t.\ n \in I^+ \\ &T, w \geq 0 \end{aligned} \tag{14}$$

After obtaining the optimal values of the manufacturer's decision variables, we can use (9), (12) and (13) to get the optimal retail price and the profits of the retailers.

3.3 Model 3: VMI with operating cost constraint

In this case, the retailers may try to safeguard their respective interests by insisting the total payment to the manufacturer for managing the inventory must not exceed the total operating cost (ordering, transportation and inventory holding costs) that retailers would have incurred when operating independently. Thus, the modified decision problem for the manufacturer can be written as:

$$\begin{aligned} &Maximize\ NP_m \\ &s.t.\ \theta_i D_i\left(p_i^*\right) \leq Operating\ cost\ incurred\ indepdenently\ \forall i \in \{1,2,\ldots,\mathrm{r}\} \\ &n \in I^+ \\ &T, w \geq 0 \end{aligned} \tag{15}$$

The value of the operating cost incurred by each retailer when he acts independently can be obtained from section 3.1, and this value will act as the upper limit to the payment that the retailer is willing to make to the manufacturer.

3.4 Model 4: VMI with net profit constraint

Another way in which the retailers can try to protect their interests is by insisting that irrespective of the service payment to the manufacturer, the VMI arrangement should not make them worse off, as compared to the situation when they acted independently. Thus, the modified decision problem for the manufacturer can be written as:

$$\begin{aligned}&Maximize\ NP_m\\&s.t.\ NP_i\left(p_i^*\right) \geq Net\ profit\ when\ acting\ indepdenently\ \ \forall i \in \{1,2,...,\mathrm{r}\}\\&n \in I^+\\&T, w \geq 0\end{aligned} \tag{15}$$

The net profit made by the retailers can be obtained from section 3.1, and this will act as a constraint on the VMI system.

3.5 Model 5: Cooperative VMI contract

The SC members may derive more cumulative benefit if they decide to cooperate in the decision making process. In this case, the total SC profits would obviously be independent of the wholesale price. The joint decision problem would thus be:

$$\begin{aligned}&Max\ NPSC = \left[\sum_{i=1}^{r}\left(\alpha_i - \beta_i p_i\right) p_i\right] - OC\\&s.t.\ n \in I^+\\&T, p_i \geq 0\ \ \forall i \in \{1,2,...,r\}\end{aligned} \tag{16}$$

Note that this joint optimization problem is independent of the wholesale price.

4. Numerical analysis

In this section, we present a numerical example in order to analyze a system with two retailers. The data for the numerical example is given in Table 1.

Table 1 Data for the numerical example

$S = 120$	$P = 1000$	$h_v = 5$	$a_1 = 15$	$a_2 = 15$	$h_1 = 6$	$h_2 = 7$
$\alpha_1 = 350$	$\alpha_2 = 600$	$\beta_1 = 11.5$	$\beta_2 = 13$	$t_1 = 20$	$t_2 = 25$	$\delta = 0.75$

In order to solve the optimization problem in different models, we use LINGO 13 on PC with a 2.8 GHz processor. For each problem instance, the solution was obtained within seconds.

In this paper our focus is on the pricing decisions in the VMI SC. In order to assess the impact of change in price sensitivity, we obtained the change in the decision variables and the profit made by different parties by changing the value of β_1. It would also help us in contrasting the benefits that can be derived from the five models developed under various scenarios. The results obtained are discussed below. In our analysis we use the notation Rk (k=1, 2) to refer to the k^{th} retailer.

In model 1, with an increase in price sensitivity, the profitability of the system went down across all the models (Table 2). In fact, this trend was observed across all the models. In case of model 1, R1 experienced a decline in profits, as an increase in β_1 meant that for the same market scale, it was able to service a lower demand. In order to hold his profits steady, the manufacturer reduced w. R2 turned out be the beneficiary in this scenario, as it was able to get better margins in spite of reducing p_2. The overall profits of the SC also went down.

The system wide profits went up under VMI compared to model 1, even though the downward trend with increase in β_1 continued (Table 3). As before, the manufacturer had to reduce w. However, R2 could not benefit under this setting as the manufacturer simultaneously increased the service payment from him, θ_2. NP_1 was higher as compared to model 1, as R1 benefited from reduced w. On the other hand, it was observed that NP_2 values were lower than the corresponding profits in case of model 1.

In case of model 3, the operating costs incurred by the two retailers in model 1 acted as the upper limit on the total payment that they were willing to make to the manufacturer (Table 4). Thus, while the manufacturer reduced w, he was unable to extract the same value of the inventory related payment from R2. As a result, NP_2 was higher. At the same time, a comparison of the values of w across model 1 and model 2 showed that the latter was always higher. NP_m was lower while NPSC went up. In the optimization problem in model 4, the system was constrained such that the profits made by R1 and R2 at least equaled that made in model 1 (Table 5). The total payment made by R2 ($w+\theta_2$) increased when compared to model 3, but it was still lower than model 2. NP_1 remained the same as in model 2, but NP_2 went up as compared to model 2 (though it was still less than that in model 3). NPSC went up as compared to the other three models. As expected, NPSC in model 5 was the maximum (Table 6). The values of p_1 and p_2 were lower than those under other VMI models.

Table 2 Model 1: Retailers act independently

β_1	w	p_1	p_2	NP_1	NP_2	NP_m	NPSC
10.0	20.69	28.46	33.81	452.34	1606.76	3747.58	5806.68
10.5	20.25	27.42	33.59	400.82	1637.28	3642.60	5680.69
11.0	19.82	26.47	33.37	354.90	1666.48	3541.90	5563.28
11.5	19.42	25.59	33.16	313.76	1694.43	3445.25	5453.44
12.0	19.03	24.77	32.96	276.71	1721.20	3352.41	5350.33
12.5	18.66	24.02	32.77	243.17	1746.86	3263.19	5253.21
13.0	18.31	23.32	32.59	212.64	1771.44	3177.38	5161.46

Table 3 Model 2: VMI

β_1	w	p_1	p_2	$w+\theta_1$	$w+\theta_2$	NP_1	NP_2	NP_m	NPSC
10.0	18.48	26.74	35.16	18.48	24.17	682.01	1570.25	4166.68	6418.94
10.5	17.65	25.49	35.16	17.65	24.17	645.65	1570.20	4094.00	6309.86
11.0	16.89	24.36	35.16	16.89	24.17	612.61	1570.16	4027.96	6210.72
11.5	16.20	23.32	35.16	16.20	24.17	582.45	1570.11	3967.68	6120.23
12.0	15.57	22.37	35.16	15.57	24.17	554.81	1570.06	3912.44	6037.31
12.5	14.98	21.49	35.16	14.98	24.17	529.38	1570.02	3861.64	5961.04
13.0	14.44	20.68	35.16	14.45	24.18	505.93	1569.97	3814.77	5890.66

Table 4 Model 3: VMI with operating cost constraint

β_1	w	p_1	p_2	θ_1	θ_2	$w+\theta_1$	$w+\theta_2$	NP_1	NP_2	NP_m	NPSC
10.0	20.67	27.83	34.39	0.00	1.96	20.67	22.63	513.46	1798.64	4127.29	6439.40
10.5	20.34	26.84	34.16	0.00	1.82	20.34	22.16	443.30	1870.56	4029.80	6343.67
11.0	19.96	25.89	33.96	0.00	1.80	19.96	21.76	386.40	1933.89	3938.20	6258.49
11.5	19.60	25.02	33.76	0.00	1.77	19.60	21.37	337.28	1995.88	3850.10	6183.26
12.0	19.26	24.21	33.58	0.00	1.74	19.26	21.00	294.72	2056.56	3765.30	6116.58
12.5	18.92	23.46	33.40	0.00	1.72	18.92	20.64	257.75	2115.91	3683.63	6057.29
13.0	18.59	22.76	33.22	0.00	1.70	18.59	20.29	225.54	2173.94	3604.94	6004.43

Table 5 Model 4: VMI with net profit constraint

β_1	w	p_1	p_2	θ_1	θ_2	$w+\theta_1$	$w+\theta_2$	NP_1	NP_2	NP_m	NPSC
10.0	18.48	26.74	35.04	0.00	5.44	18.48	23.92	682.19	1606.71	4166.26	6455.16
10.5	17.65	25.49	34.93	0.00	6.06	17.65	23.71	645.97	1637.28	4092.62	6375.86
11.0	16.88	24.35	34.83	0.00	6.63	16.89	23.51	613.06	1666.48	4025.12	6304.66
11.5	16.19	23.31	34.74	0.00	7.13	16.19	23.32	583.03	1694.43	3962.99	6240.44
12.0	15.56	22.36	34.65	0.00	7.58	15.56	23.14	555.50	1721.20	3905.57	6182.27
12.5	14.97	21.49	34.56	0.00	8.00	14.97	22.97	530.20	1746.86	3852.30	6129.35
13.0	14.43	20.68	34.48	0.00	8.37	14.44	22.81	506.84	1771.44	3802.73	6081.02

Table 6 Model 5: Cooperative VMI

β_1	p_1	p_2	NPSC
10.0	17.83	23.45	8793.81
10.5	16.99	23.45	8648.03
11.0	16.24	23.45	8515.50
11.5	15.54	23.45	8394.51
12.0	14.91	23.45	8283.60
12.5	14.33	23.45	8181.57
13.0	13.79	23.45	8087.39

6. Discussion and managerial implications

The numerical analysis in the previous sections highlights several interesting points about our system. NPSC followed the general trend: Cooperative contract > VMI (all options) > Independent ordering. However, this did not translate monotonically for the individual members.

For example, R2 lost out on adopting VMI (from model 1 to model 2). Thus, retailers entering into such an arrangement must be mindful of safeguarding their own interests.

The inventory payment is a powerful tool available to the manufacturer using which he can appropriate profits for himself. We analyzed two ways in which retailers can place a cap on such payments. The operating cost constraint increased system profits and benefited R2 but R1 lost out. On the other hand, the net profit constraint benefited R1 and reduced the profits for R2. Based on the cost structure of R1 and R2, our analysis suggested that a more cost efficient retailer with a large market scale (like R2) would probably prefer to operate under model 3 (with operating cost constraint), while a less efficient retailer like R1 would prefer model 4. This is because R2 would be able to service his demand at a lower cost and thus would enjoy higher margins.

Additionally, it must be pointed out that SC coordination can only be ensured only if all the parties gain by entering into the alliance, i.e. none of them should be better off alone (Cachon, 2003). Thus, the manufacturer as the leader must take into account the benefits of all the parties. Obviously, the cooperative contract provides the maximum total benefits. Dividing it however, would be a much tougher task. Different models can serve as negotiating benchmarks for the parties involved. As always, the success of the mechanism would depend on amicable resolution of the give and take problem. Dudek and Stadtler (2005) provide some guidelines on negotiation based collaborative planning.

This means that the presence of the inventory payment essentially transformed a prima facie uniform wholesale price regime into a retailer specific wholesale price regime, thereby hitting R2 the hardest. In this context, the safeguards in model 3 and model 4 no longer work. The manufacturer simply adjuststhe value of w_i, to counter any constraints imposed. As a consequence, the previous benefit of the coupled system vanished.

Our study should inform the decision making process in the adoption of VMI systems. Managers of all the members involved must be sensitive to the role the various parameters and decision variables involved. By being better informed on these issues, they can develop and adopt mechanism for an equitable distribution of the benefits and thus enjoy a sustainable mutually beneficial relationship.

7. Conclusions

In this paper we developed models for investigating the dynamics involved in the adoption of a VMI system SC with a single manufacturer and two retailers who faced price dependent demand. We studied the roles of inventory payment to the manufacturer and the impact of the retailer specific wholesale pricing strategy. It was found that the said payment was a useful tool available to the manufacturer for profit appropriation.

Increase in price sensitivity had an adverse impact on the total system profits. However, we found a great deal of divergence as to how such an increase was handled in different models. Safeguards for protecting the interests of the various parties involved were also highlighted.

Some extensions of this research might be of interest. One on them could be to study which kind of retailers (in terms of their cost structure etc.) would prefer which kind of safeguards (constraints). Moreover, modeling the dynamics of the negotiation might provide more practical insights. Analysis of the impact of competition between the retailers would also be useful.

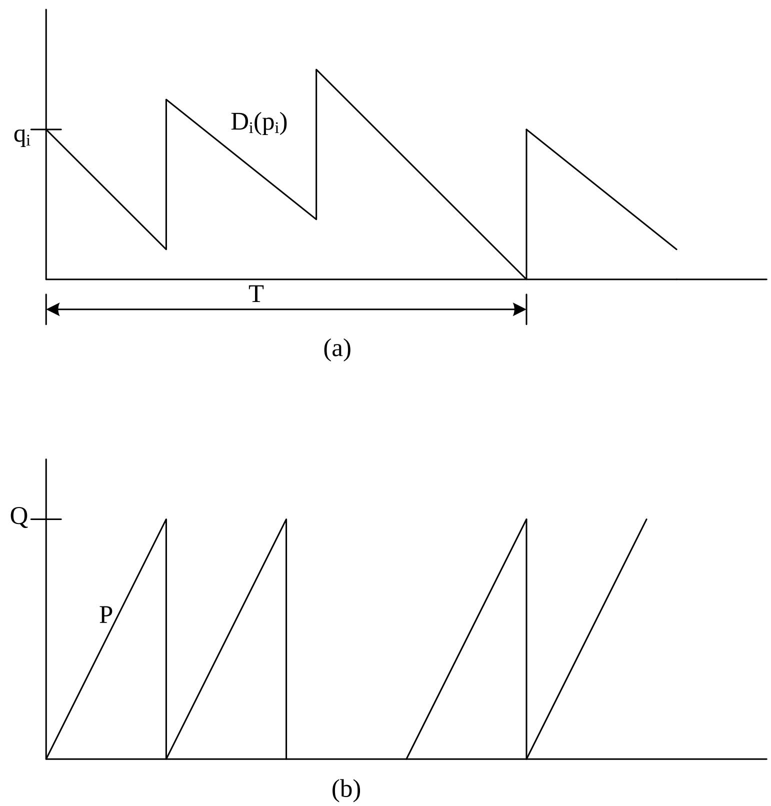

Figure 1. Stock level vs. time with n=3 for (a) Retailer *i* (b) Manufacturer

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