Journal of the Society of Korea Industrial and Systems Engineering
Vol. 35, No. 2, pp.45－51, June 2012.

불완전한 배송품질下 배송차량 복수化를 통한 기대수익함수 최대화전략

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Maximizing Expected Profit via Multiple Truck Operations under Imperfect Trucking Quality

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이 논문은 물류배송의 불확실성하에서의 생산자의 배송전략 문제를 다루고 있다. 즉 생산자의 배송수량이 전량 온전한 상태로 소매업체의 창고에 배송되지 못하는 상황을 고려한 것이다. 물류배송의 불확실성을 묘사하기 위해 물류배송을 위해 사용되는 개개의 트럭 또는 선박으로부터 발생되는 파손 제품의 수가 각각 독립적이며 동일한 확률분포를 따른다는 가정이 사용되었다. 또한, 최초 배송수량과 배송을 위해 사용된 전체 트럭 또는 선박의 대수를 기존의 단일구간 신문팔이 소년 문제에 적용하여 생산자의 이익함수를 구성하였다. 구성된 생산자의 이익함수를 이용하여 생산자의 기대 이익을 최대화하는 최적의 최초 배송수량 및 배송시 필요한 최적의 트럭 또는 선박의 대수를 계산해 내기 위한 최적해를 제시하였다. 마지막으로 이익함수 모델에서 사용된 다양한 파라미터 값의 조합에 따른 최적해의 움직임을 시뮬레이션을 통해 알아보았다.

Keywords : Logistics Quality, Single Period Inventory Problem, Newsvendor Model, Uncertain Supply

1. Introduction

In this era of global sourcing, to reduce material purchase costs and to attract a larger base of customers, the domestic manufacturers such as Samsung Electronics, Hyundai Motors, LG Electronics are constantly seeking suppliers with lower prices and finding them at greater and greater distances. According to this, most of their domestic production facilities and factories have been relocated to the developing countries like China, Vietnam, Mexico etc, to produce products in a more cost-efficient way. On the other hand, for products manufactured in these companies the actual market location is quite different from the production location. For Samsung Electronics, there are 35 production subsidiaries over 30 more countries and 47 sales subsidiaries over 40 more countries.

For many global companies, acquiring better logistics services has become one of the most important management strategy for last decade. The added distance introduced the significant uncertainty into the logistics operations in terms of both delivery time and successfully delivered number of sellable (or not damaged) products. One of the common practices to reduce overall transportation cost is to consolidate the orders from various customers and deliver the orders with

논문접수일 : 2012년 03월 05일　　논문수정일 : 2012년 04월 02일　　게재확정일 : 2012년 04월 27일
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reduced number of trucks or vessels at a lowest logistics cost as possible. This is why global companies strategically introduce regional logistics hub or central distribution center. For Samsung, ADC (America Distribution Center) in Chicago takes the role of hub for North America Region and ELS (European Logistics System) in Denmark is the hub for European Market.

But due to the various risks around supply chain the consolidated delivery should not always be favorable to the non-consolidated delivery option. In this research, we primarily investigate tradeoff between the logistics service (or trucking) quality and the logistics cost investment. According to our problem formulation, the more investment on logistics operation has been made, the better logistics performances can be guaranteed. The major goal of this research is to derive the optimal tradeoff between the number of products to ship to match customer demands and the number of trucks (or vessels) to fulfill the required delivery from the manufacturer's production factory to retailer's distribution center. In section 2, related research has been addressed and summarized. In section 3, we formulate the above question on the basis of the well-known newsvendor model followed by the analytical solution to the proposed model. In section 4, the computational study has been performed with the summarized results to deliver managerial insights. Finally we conclude our research in section 5.

2. Literature Review

Our research is closely related to traditional single period inventory problem where the supply process or operation including logistics service is not perfect. One of the earliest papers on the uncertain supply under economic order quantity (EOQ) framework was written by Silver [14]. He studied two cases, in the first case, the standard deviation of the amount received is independent of the lot size, while in second case the standard deviation is proportional to the lot size. The most interesting finding in Silver [14] was that the optimal order quantity depends only on the mean and the standard deviation of the amount received. Shih [13] studied the optimal ordering schemes in a case where the proportion of defective products in the accepted lots has a known probability distribution. The yield rate is thus between 0 and 1 and is assumed to be independent of the lot size. Similar to Silver's results he showed that the optimal order quantity depends only on the model parameters and the first two moments of the underlying yield distribution. As expected, the optimal order quantity is greater than that of the certain yield case, but it was less intuitive that the optimal lot size decreases when the variance of the yield rate distribution increases. Noori and Keller [10] extended Silver's model to obtain an optimal production quantity when the amount of products received at stores assumes probability distributions such as uniform, normal and gamma. They showed that for a uniform demand case the optimal ordering policy is independent of the yield distribution, but Rekik et al. [11] found out that the Noori and Keller's result is not always valid for all system parameters. They identified several cases defined by certain ranges of system parameters to investigate the validity of Noori and Keller's previous results. For the detailed survey of random yield literature, including exclusive random yield models, Yano and Lee [17] is the most popular reference.

Most of research presented above on the single-period inventory problem dealt with solutions for the optimal size of order which maximizes the expected total profits. But these research have weakness due to the 'flaw of average' in solving the single-period inventory problem. To overcome this 'flaw of average' many researchers tried to consider risk preferences, especially risk aversion of the decision maker. Lau [7], Spulber [15], Bouakiz and Sobel [2], Eeckhoudt et al. [5], Agrawal and Seshadri [1], Chen and Federgruen [3], Seifert et al. [12], Chen et al. [4], Haksoz and Seshadri [6]. Lau [7] examined newsvendor solutions which maximize expected utility under stochastic demand or stochastic supply situations. Eeckhoudt et al. [5] examined the risk and risk aversion in a single-period inventory problem where demand is stochastic while supply is deterministic. They show that the optimal order quantity decreases as decision maker's risk-aversion increases because a lower order amount definitely reduces the inherent risks of the outcome. In Bouakiz and Sobel [2], they explored the newsvendor problem with the exponential utility and showed that a base-stock policy is optimal when a multi-period newsvendor problem is optimized with an exponential utility criterion. Agrawal and Seshadri [1] also investigated the newsvendor problem with the objective being maximizing the expected utility. In their problem setting, both price and order quantity are decision variables for the risk-averse retailer. In Kim et al. [8] they introduced a constraint, so called 'Value-at-Risk', into the given model to reflect the decision makers risk preferences.

They investigated the various impacts of risk preference, which is specified by parameters of ‘Value-at-Risk’, on the optimal order quantity using relevant numerical examples.

In general, none of models described above do not link the supply chain and logistics decision processes together. They rather focus on the modeling of uncertain demand and supply processes with or without risk attitude of the decision maker. See Kim et al. [9] for the comprehensive analysis of the impact of logistics quality on the optimal product ordering decision processes of the retailer. Their research is similar to ours in that they assume k manufacturers to deliver products to single retailer. But they did not consider the logistics cost variable in their model. Without explicitly introducing the logistics cost variable it is not easy to analyze the behavior of the decision maker on the various status of the logistics investment.

In this paper, the topic of the uncertain supply situation in the single period inventory problem setting has been combined with the problem of determining the optimal logistics investment on the assumption that the quality of logistics can be improved via additional investment. This topic is different from that of Kim et al. [9] in that the logistics quality factor is introduced as a decision variable representing the number of transportation tools (or, trucks or vessels) while Kim et al. [9] do not implicitly use the additional variable but simply use the variables for the proportion of defective products (TPDP) along the supply chain network.

3. Model and Analysis

We consider the product-ordering decisions of manufacturer who is facing uniform demand from it’s retail customer. The retail customer purchases a single item of products from this single manufacturer. All orders from this retail customer is aggregate to the manufacturer’s a specific production center then shipped to the retailer using trucks (or vessels). The required number of trucks (or vessels), which will be denoted by m, is determined based on the reliability of the logistics operations of each channel. The reason why the manufacture should consider delivering using more than one truck (m > 1), even when one truck capacity is enough to carry the whole shipment of size Q, is in the reduction of the variability of the amount of defects among the original shipped quantity from the manufacturer’s site. We model this problem as a single period news-vendor problem where logistics cost is proportional to the number of appointed trucks (or vessels).

The following notation will be used in the formulation of our model :

- Q : Total order quantity requested by retailer (the first decision variable)
- r : Unit retail price
- m : Number of trucks to fulfill the delivery of Q products from manufacture’s warehouse to the retailer’s DC (the second decision variable)
- h : Unit holding cost per period for unsold products at the manufacturer’s warehouse
- π : Unit shortage cost for manufacturer per period per product short
- ξ : Demand rate of retailer’s DC per period, uniformly distributed with parameters a and b, ξ~U(a, b), where a < b
- Pj : r.v. representing total proportion of defects among shipped products using truck j, j = 1, ⋯, m
- Y : r.v. representing total proportion of defects among Q in transit, Y = (P1 + P2 + ⋯ + Pm)/m
- β : Logistics cost per each truck between DC and retailer.

We also make following assumptions for our model :

A1) The total order quantity is equally split into m trucks

A2) Pjs are i.i.d. with E[Pj] = μ and Var[Pj] = σ^2

A3) There is no capacity limit for each truck

A4) When m trucks are used, each truck carries same number of items

A5) Distribution of Pj and the size of shipment are independent amount of products

Even though we assume i.i.d. damage distribution for each truck, our model can be easily extended to the non i.i.d case by changing the logistics cost function. Suppose there are three logistics channels available to the manufacturer, e.g. trucks, rails, and planes from DC to the retailer. Then, the i.i.d. damage distribution assumption is not realistic to represent the damage process from each channel and so we need to use different unit logistics cost associated with each logistics channel. To choose or not to choose each channel can be modeled as decision variables by introducing binary variables. It is an interesting future research problem. On the other hand, in A3) we address the unlimited truck capacity. It sounds unrealistic but in certain situation such as when the size of products are so small, i.e. the computer memory related products or mobile phones, this assumption can be satisfied in general.

Using notations explained above, the manufacturer's profit function can be constructed as a function of decision variables, Q and m, respectively :

$$\begin{aligned}\Pi(Q,m) &= \mathrm{r}\min[(1-Y)Q,\xi] - h[(1-Y)Q-\xi]^+ \\ &\quad - \pi[\xi-(1-Y)Q]^+ - m\beta \\ &= r\xi - h[(1-Y)Q-\xi]^+ \\ &\quad - (r+\pi)[\xi-(1-Y)Q]^+ - m\beta\end{aligned}$$

Therefore, the manufacturer's expected profit can be expressed as

$$\begin{aligned}E\Pi(Q,m) &= \mathrm{r}\,E\min[(1-Y)Q,\xi] - hE[(1-Y)Q-\xi]^+ \\ &\quad - \pi E[\xi-(1-Y)Q]^+ - m\beta \\ &= ESR - ETIC - ETLC \qquad (1)\end{aligned}$$

where *ESR* (Expected Sales Revenue), *ETIC* (Expected Total Inventory Cost), and ETLC (Expected Total Logistics Cost) are as following :

$$\begin{aligned}ESR &= rEmin[\xi,(1-Y)Q] \\ &= rE\xi - r\int_0^1\int_{(1-y)Q}^{\infty}[\xi-(1-y)Q]f(\xi)g(y)d\xi dy, \\ ETIC &= h\int_0^1\int_0^{(1-y)Q}[(1-y)Q-\xi]f(\xi)g(y)d\xi dy \\ &\quad + \pi\int_0^1\int_{(1-y)Q}^{\infty}[\xi-(1-y)Q]f(\xi)g(y)d\xi dy, \\ ETLC &= m\beta.\end{aligned}$$

Under the assumption of uniformly distributed customer demand, it is not too hard to show

$$\int_0^{(1-y)Q} f(\xi)d\xi = \frac{(1-y)Q-a}{b-a},$$

$$\int_0^{(1-y)Q} \xi f(\xi)d\xi = \frac{(1-y)^2Q^2}{2(b-a)}$$

so that expected profit simplifies to :

$$\begin{aligned}E\Pi(Q,m) &= -\frac{(\mathrm{h}+\mathrm{r}+\pi)((1-\mu)^2+\sigma^2/\mathrm{m})}{2(\mathrm{b}-\mathrm{a})} \qquad (2) \\ &\quad \times (Q - \frac{(1-\mu)}{(1-\mu)^2+\sigma^2/m}[\frac{b(r+\pi)+ah}{r+\pi+h}])^2 \\ &\quad + r\frac{(a+b)}{2} - \frac{a^2h+b^2(r+h)}{2(b-a)} \\ &\quad + [\frac{(1-\mu)^2}{(1-\mu)^2+\sigma^2/m}]\frac{(b(r+\pi)+ah)^2}{2(b-a)(h+r+\pi)} \\ &\quad - m\beta\end{aligned}$$

where μ = EPj = EY, and σ^2 = V Pj. The optimal order quantity Q^* represents the boundary value where an increased order provides cost or benefit. And the optimal number of trucks m^* represents the threshold value where using an additional truck provides cost or benefit. In the following, we drive the closed form solution which maximizes the retailer's expected profit as in (2). The result is stated in the theorem 4.1 with the proof.

Theorem 4.1 *The optimal solution* (Q^*, m^*) *to the problem (2) exists and unique*. Furthermore

$$\begin{aligned}m^* &= \arg_{m\in\lfloor\tilde{m}\rfloor,\lfloor\tilde{m}\rfloor+1}\max\ E\Pi(Q^*,m), \\ Q^* &= \frac{(1-\mu)}{(1-\mu)^2+\sigma^2/m^*}\cdot Q^0\end{aligned}$$

where $Q^0 = \dfrac{b(r+\pi)+ah}{(r+\pi+h)}$ *is the optimal order quantity in the conventional news-vendor problem when there exist no damages occurring in the logistics operations (i.e.,* $\mu=\sigma=0$*),* $\tilde{m} = \dfrac{\sigma}{1-\mu}\sqrt{\dfrac{r+\pi+h}{2(b-a)\beta}}Q_0 - \dfrac{\sigma^2}{(1-\mu)^2}$, $\lfloor\tilde{m}\rfloor$ *is the largest integer less than or equal to* m.

Proof : Firstly, we prove the existence and uniqueness of the solution. Here, it suffices to show that the Hessian matrix of $E\Pi(Q,m)$ is negative definite (i.e., to show $E\Pi(Q,m)$ is a strictly concave function in both Q and m). Consider the function

$E\Pi(Q,m)$, with the corresponding Hessian matrix :

$$H = \begin{pmatrix} \dfrac{\partial^2 E\Pi(Q,m)}{\partial Q^2} & \dfrac{\partial^2 E\Pi(Q,m)}{\partial Q\partial m} \\ \dfrac{\partial^2 E\Pi(Q,m)}{\partial Q\partial m} & \dfrac{\partial^2 E\Pi(Q,m)}{\partial m^2}\end{pmatrix}$$

$$= \begin{pmatrix} -\dfrac{(r+h+\pi)((1-\mu)^2+\sigma^2/m)}{(b-a)} & \dfrac{(r+h+\pi)\sigma^2}{(b-a)m^2}Q \\ \dfrac{(r+h+\pi)\sigma^2}{(b-a)m^2}Q & -\dfrac{(r+h+\pi)\sigma^2Q^2}{(b-a)m^3}\end{pmatrix}$$

To check the negative definiteness of this Hessian matrix, we need to compute the determinants of the principal minors of the Hessian matrix H, $|H_1|$ and $|H_2|$:

$$\begin{aligned}|H_1| &= -\frac{(r+h+\pi)((1-\mu)^2+\sigma^2/m)}{(b-a)}, \\ |H_2| &= \frac{\partial^2 E\Pi(Q,m)}{\partial Q^2}\frac{\partial^2 E\Pi(Q,m)}{\partial m^2} - \left(\frac{\partial^2 E\Pi(Q,m)}{\partial Q\partial m}\right) \\ &= \frac{(1-\mu)^2(r+h+\pi)^2\sigma^2Q^2}{(b-a)^2m^3}\end{aligned}$$

and use the definition of the negative definiteness. In our case, it is not difficult to show that $|H_1| > 0$ and $|H_2| > 0$. Therefore, the solution (Q^*, m^*) uniquely exists. Secondly, to derive Q^* we can apply the first order condition to (2) to get :

$$\frac{\partial E\Pi(Q,m)}{\partial Q} = -\frac{(\mathrm{h+r}+\pi)((1-\mu)^2+\sigma^2/\mathrm{m})}{(\mathrm{b-a})} \times (Q-\frac{(1-\mu)}{(1-\mu)^2+\sigma^2/m}[\frac{b(r+\pi)+ah}{r+\pi+h}]) \approx (Q-\frac{(1-\mu)}{(1-\mu)^2+\sigma^2/m}[\frac{b(r+\pi)+ah}{r+\pi+h}]) = 0 \quad (3)$$

It is clear to see that $Q^* = \frac{(1-\mu)}{(1-\mu)^2+\sigma^2/m^*} \cdot Q^0$ satisfies the first order condition shown in (3). Now, from the first order condition of m on $E\Pi(Q,m)$ we have :

$$\frac{\partial E\Pi(Q,m)}{\partial m} \approx (m-\frac{\sigma}{1-\mu}\sqrt{\frac{r+\pi+h}{1(b-a)\beta}} Q^0-\frac{\sigma^2}{(1-\mu)^2}) = 0 \quad (4)$$

Considering the discreteness of m^* it is obvious that $m^* = \arg_{m\in \lfloor \tilde{m} \rfloor, \lfloor \tilde{m} \rfloor +1} \max E\Pi(Q^*, m)$ maximizes $m^* = E\Pi(Q^*, m)$ QED.

To prove m^* we can also use the logical intuition together with the concavity property of $E\Pi(Q, m)$. If we increase m to m+1 the first two components of (1) improve due to the reduced variability representing the increased sales revenue and decreased corresponding inventory costs. At the same time the additional truck incurs the additional investment on the logistics operation which is equivalent to β. Therefore m^* should satisfy the following :

$$E\Pi(Q, m^*-1) \leq E\Pi(Q, m^*) \leq E\Pi(Q, m^*+1) \quad (5)$$

In (5), at $m = m^*$ the benefit from the operational variability reduction surpasses the accompanying cost to appoint the additional truck. Theorem 4.1 addresses that there exists a optimal number of trucks which maximizes the manufacturer's expected profit when the service provided by each truck is not perfect to guarantee zero defect during delivery process.

In the following section we conduct some numerical analyses to draw useful managerial insights from the analytical result derived in this section.

4. Computational Study

To further understand the implication of results from the previous section, we consider an numerical example employing a variety of values of model parameters.

<Table 1> Parameter Values

Parameter	Value
r	\$50
h	\$10
π	\$30
a	100
b	150
μ	0.2, 0.3, 0.4, 0.5
σ	0.2, 0.3, 0.4, 0.5
β	\$400, \$800, \$1200, \$1600,

<Table 1> shows the various values of the input parameters that were considered in our numerical studies. In our numerical studies, even though there is no capacity limit on the truck, we found in certain cases that the expected profit is larger when two or more trucks are used to deliver the products to the retailer. This is because the increasement of the profit due to the reduced variability from the transportation operation, surpasses the additional investment cost, i.e. cost of using additional trucks.

According to our numerical example, the increase in profit using more than one truck ranges from 0% to over 1,188%. The results using various parameter values exhibit very similar pattern as shown in <Figure 1> ~ <Figure 3>. The percentage columns in Figures represent the percentage increase in manufacturer's expected profit when manufacturer uses more than one truck (channel). We used

$$|[E\Pi(Q^*, m^*) - E\Pi(Q_1, 1)]/E\Pi(Q_1, 1)| \times 100\%$$

to compute those values where Q_1 is the optimal order quantity when m is fixed at 1.

(1) μ=0.2, σ=0.2						
β	m^*	Q^*	$E\Pi(Q^*,m^*)$	$E\Pi(Q^*,1)$	Diff.	Diff %
400	2	180.34	4,851	4,734	118	2.49%
800	1	175.04	4,334	4,334	0	0.00%
1,200	1	175.04	3,934	3,934	0	0.00%
1,600	1	175.04	3,534	3,534	0	0.00%

(2) μ=0.3, σ=0.3						
β	m^*	Q^*	$E\Pi(Q^*,m^*)$	$E\Pi(Q^*,1)$	Diff.	Diff %
400	3	200.28	3,954	2,985	959	32.48%
800	2	194.67	3,074	2,585	490	18.95%
1,200	1	179.56	2,185	2,185	0	0.00%
1,600	1	179.56	1,785	1,785	0	0.00%

(3) μ=0.4, σ=0.4						
β	m^*	Q^*	$E\Pi(Q^*,m^*)$	$E\Pi(Q^*,1)$	Diff.	Diff %
400	4	223.17	2,786	216	2,570	1188.49%
800	3	215.97	1,459	- 184	1,643	893.99%
1,200	2	202.88	501	- 584	1,085	185.82%
1,600	2	202.88	- 299	- 984	685	69.61%

(4) μ=0.5, σ=0.5						
β	m^*	Q^*	$E\Pi(Q^*,m^*)$	$E\Pi(Q^*,1)$	Diff.	Diff %
400	5	247.97	1,176	- 3,274	4,450	135.92%
800	4	238.05	- 629	- 3,674	3,045	82.88%
1,200	3	223.17	- 1,937	- 4,074	2,138	52.47%
1,600	2	198.37	- 3,049	- 4,474	1,425	31.85%

<Figure 1> Effects of Logistics Cost, β

(1) σ=0.2, β=400						
μ	m^*	Q^*	$E\Pi(Q^*,m^*)$	$E\Pi(Q^*,1)$	Diff.	Diff %
0.2	2	180.34	4,851	4,734	118	2.49%
0.3	2	204.21	4,689	4,431	258	5.82%
0.4	2	234.92	4,446	3,986	460	11.53%
0.5	3	282.49	4,082	3,298	785	23.79%

(2) σ=0.3, β=800						
μ	m^*	Q^*	$E\Pi(Q^*,m^*)$	$E\Pi(Q^*,1)$	Diff.	Diff %
0.2	2	173.76	3,409	3,163	245	7.76%
0.3	2	194.67	3,074	2,585	490	18.95%
0.4	2	220.42	2,584	1,771	813	45.93%
0.5	3	265.68	1,856	596	1,260	211.23%

(3) σ=0.4, β=1200						
μ	m^*	Q^*	$E\Pi(Q^*,m^*)$	$E\Pi(Q^*,1)$	Diff.	Diff %
0.2	2	165.31	1,784	1,371	413	30.16%
0.3	2	182.71	1,254	533	720	135.11%
0.4	2	202.88	501	- 584	1,085	185.82%
0.5	3	245.24	- 590	- 2,082	1,492	71.65%

(4) σ=0.5, β=1600						
μ	m^*	Q^*	$E\Pi(Q^*,m^*)$	$E\Pi(Q^*,1)$	Diff.	Diff %
0.2	2	155.59	35	- 497	533	107.10%
0.3	2	169.34	- 688	- 1,531	843	55.06%
0.4	2	184.06	- 1,677	- 2,838	1,161	40.91%
0.5	2	198.37	- 3,049	- 4,474	1,425	31.85%

<Figure 2> Effects of Mean Damage Proportion, μ

In <Figure 1>, we investigate the effects of logistics cost β on the optimal number of trucks to be used, which is m^* as well as on the increase in expected profit. In each graph, holding the mean μ, and the standard deviation σ of proportion of defects from each truck, constant, we change the values of β. From various scenarios considered, it is shown that the number of trucks to be used increases as the uncertainty in logistics operations becomes larger and larger. The benefits of employing more than one truck $(m^* \geq 1)$ are getting bigger and bigger with more uncertainty in the performance of logistics channel. But, as β increases these benefits are becoming smaller and smaller due to the expensive total logistics cost (i.e., $m\beta$). Consider the first graph in Figure. 1 where the level of uncertainty is set at the minimum (i.e., $(\mu=0.2, \sigma=0.2)$). The only difference is when β = $400. In this case, the increase in profit by using additional truck is $518(= $400+$118), which is due to the reduced variability in logistics performance, bypasses the additional logistics cost, $400, by $118. The second column from the right in <Figure 1> ~ <Figure 3>, named ‘Diff.’, shows the total increase in profit when more than one truck are being used to carry products. Intuitively, one would expect an increased logistics cost to lead to decreased order quantities, which is the case in <Figure 1>. In general, order quantities increase as μ increases or as σ increases.

The mean of damage proportion, μ, is varying while the standard deviation, σ, and marginal logistics cost are fixed in <Figure 2>. As shown from all four graphs, it is clear to see that the manufacturer’s expected profits are always

(1) μ=0.2, β=400						
σ	m^*	Q^*	$E\Pi(Q^*,m^*)$	$E\Pi(Q^*,1)$	Diff.	Diff %
0.2	2	180.34	4,851	4,734	118	2.49%
0.3	2	173.76	4,209	3,563	645	18.11%
0.4	3	171.67	3,605	2,171	1,434	66.05%
0.5	4	169.43	2,986	703	2,284	325.06%

(2) μ=0.3, β=800						
σ	m^*	Q^*	$E\Pi(Q^*,m^*)$	$E\Pi(Q^*,1)$	Diff.	Diff %
0.2	1	196.5	4,031	4,031	0	0.00%
0.3	2	194.67	3,074	2,585	490	18.95%
0.4	2	182.71	2,054	933	1,120	120.06%
0.5	3	181.65	1,163	- 731	1,894	259.10%

(3) μ=0.4, β=1200						
σ	m^*	Q^*	$E\Pi(Q^*,m^*)$	$E\Pi(Q^*,1)$	Diff.	Diff %
0.2	1	223.17	3,186	3,186	0	0.00%
0.3	2	220.42	1,784	1,371	413	30.16%
0.4	2	202.88	501	- 584	1,085	185.82%
0.5	3	201.36	- 811	- 2,438	1,627	66.75%

(4) μ=0.5, β=1600						
σ	m^*	Q^*	$E\Pi(Q^*,m^*)$	$E\Pi(Q^*,1)$	Diff.	Diff %
0.2	1	256.52	2,098	2,098	0	0.00%
0.3	2	252.17	232	- 204	436	214.19%
0.4	2	225.42	- 1,399	- 2,482	1,083	43.64%
0.5	2	198.37	- 3,049	- 4,474	1,425	31.85%

<Figure 3> Effects of Standard Deviation of Damage Proportion, σ

greater when manufacturer deploys more than single truck and the marginal profit increase is becoming larger and larger as the uncertainties presented in the logistics service is getting bigger and bigger. Increase in μ will lead both the number of trucks to be used and the order quantities to increase.

Finally, in <Figure 3> the standard deviation is varying while the mean, μ, and the marginal logistics cost, β are held at constant. As similar to the result in <Figure 2> the increase in σ will lead to increased m^* and decreased Q^*. Benefits from using more than one truck are most significant when μ and β are set at minimum (μ = 0.2, β = 400).

5. Conclusion

In this paper we have reviewed the manufacturer's problem of seeking the optimal amount of delivery quantities to meet the retailer's stochastic demand as well as the optimal number of trucks to deliver products from the manufacturer's warehouse to retailer's distribution center. where the retailer's demand is assumed to follow the simple uniform distribution. From our study we showed that there always exist the optimal solution to this problem. And in certain cases where the quality of transportation process is not perfect the manufacturer is better off to invest on achieving better transportation quality by adopting multiple trucks to fulfill the delivery mission. It will be interesting future research topic to consider when the manufacturer has to ship to multiple distribution centers of retailer.

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