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# Applying a Just-in-Time Integrated Supply Chain Model with Inventory and Waste Reduction Considerations

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## ABSTRACT

Just-In-Time (JIT) has been playing an important role in supply chain environments. Countless firms have been applying JIT in production to gain and maintain a competitive advantage. This study introduces an innovative model which integrates inventory and quality assurance in a JIT supply chain. This approach assumes that manufacturing will produce some defective items and those products will not influence the buyer's purchase policy. The vendor absorbs all the inspection costs. Using a function to compute the expected amount of total cost every year will minimize the total cost and the nonconforming fraction. Finally, a numerical example further confirms this model.

**Keywords:** Supply Chain, Just-In-Time, Quality Assurance, Integrated Model

## 1. INTRODUCTION

In recent years, many firms in the Supply-Chain Management (SCM) environment have been applying Just-In-Time (JIT) in production to gain and maintain a competitive advantage. Miltenburg (2001) suggested that the term JIT could be adopted to signify techniques, which aim at improving products quality and reduce costs by eliminating all waste from the production system. JIT production focuses mainly on the purchasing and manufacturing items which belong to the products for immediate consumption. On the other hand, a single vendor that supplies products to a single buyer always creates interesting decision problems. The vendor must determine the most economical production batch quantity and the most economical number of shipments to supply a buyer's entire order quantity. For this reason, integrated inventory policy can help businesses to determine the best order quantity and shipment policy.

Within the last decade, countless firms have undergone unprecedented levels of change in response to global competition. Waste reduction and process improvement initiatives such as Total Quality Management (TQM), Business Process Reengineering (BPR), integrated supply-chain management and time-based competition have all been identified as critical to success in today's economy. A major new effort is now underway in corporate strategic planning boardrooms involving the environmentally-conscious, sustainable design of a 'green product'. The objective is to reduce all forms of waste, including solid waste and air pollution. Therefore, green manufacturing implementation requires that various factors must be prepared for and well controlled to ensure effectiveness. Hwang *et al.* (2001) considered the climate of increasingly strict regulations for energy efficiency, material composition, waste reduction and product recycling. These regulations have impacted various business types, especially in manufacturing.

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The principal focal point of JIT philosophy is the elimination of all waste within a system (Daugherty *et al*., 1994). Researchers have made many applications of this theory, emphasizing the importance in the waste reduction concept in various fields of industry. However, different studies followed varying approaches. The objective of this study is to introduce an innovative model to integrate inventory and waste reduction in a JIT supply chain.

Introduced by Shigeo Shingo and Taichi Ohno at the Toyota Motor plant in the mid-1970s, the JIT production system, both as a philosophy and disciplined method of production, has received much attention since its introduction. The JIT production philosophy was founded upon three fundamental principles: waste elimination, continuous quality improvement and worker participation incentives (Harber *et al.*, 1990).

According to Rawabdeh (2005); waste is "anything other than the minimum amounts of resources, which are essential to add value to the product". Moreover, waste also signifies any incurred costs such as inventory, set-up, scrap and reworks, which do not enhance the value added in the product (Svensson, 2001). Flinchbaugh *et al.* (2001) further suggested that waste refer to any objective beyond delivering the accurate product to the right customer at the right time at the right price. Waste reduction, therefore, is the priority of the JIT supply chain. The entire JIT concept consists based on the philosophy underpinning waste identification and its elimination (Karlsson and Ahlstrom, 1996; Rong *et al*., 2003). Waste allocation and elimination have recently become an important field of research. According to Rawabdeh (2005); waste can be categorized into three main groups related to man, machine and material. In the machine group, defective products are one form of waste.

Goyal (1977) proposed a joint economic lot size model of the objective of minimizing the total relevant costs between vendor and buyer when a contractual agreement enforces a cooperative arrangement. Banerjee (1986) assumed that the vendor produces to order on a lot-for-lot basis under deterministic conditions to determinate economic lot size model. Goyal (1977) generalized the model of Banerjee (1986) by relaxing the assumption of the vendor's lot-for-lot policy. Goyal's resulting joint economic lot size model, where the vendor's economic production quantity per cycle is an integer multiple of the buyer's purchase quantity, provides a lower or equal joint total relevant cost compared to Banerjee's model (Goyal, 1988; Banerjee, 1986). Goyal and Gupta (1989) reviewed the related literature on models, which provided a coordinating mechanism between the buyer and the vendor. Lu (1995) extended Goyal's assumption of completing a batch before a shipment is started and explored a model that allowed shipments to take place during the production cycle when the buyer's delivery quantity is known. Because of the frequent shipping policy proposed by the above model, transportation costs should be taken into account in the relevant costs to investigate the shipping relations between the number of shipments and inventory levels. Shi and Su (2004) suggested an integrated inventory model from the retailer's perspective only and thus ignored the fact that the manufacturer might have no incentive to accept returns. Ha and Kim (1997) proposed a single-buyer single-vendor integrated model under deterministic conditions for a single product with the multiple shipments strategy, including transportation costs. Hill and Omar (2006) contemplated a "vendor" who supplies a product to a 'buyer' in a supply chain.

However, it is impractical to suppose all production units are that common stock models of good products. Porteus (1986) incorporated the effect of defective items into the basic EOQ model and introduced the option of investing in-process quality improvement by reducing the process quality parameter and keeping the process under control. Lee and Rosenblatt (1987) considered the process inspection during the production run. In their model, a shift to an out-of-control state may be detected and corrected earlier than in the conventional EOQ models. Schwaller (1988) extended the EOQ model by adding the assumption that a known proportion of defective items is presented in incoming lots and that the fixed and variable inspection costs are incurred in finding and removing those items. Zhang and Gerchak (1990) considered a joint lot sizing and inspection policy in an EOQ model that a random proportion of units is defective. Cheng (1991) proposed an EOQ model with demand-dependent unit production costs and imperfect production processes. He formulated the inventory decision problem as a geometric program and solved it to obtain closed-form optimal solutions. Lee and Rosenblatt (1987) also investigated the effects of defective items in the lot sizing policy. Recently, Salameh and Jaber (2000) examined a joint lot sizing and inspection policy under an EOQ model when a random proportion of units are defective. Their study suggested that the poor-quality items should be sold as a single batch at the end of the 100% selection process. Goyal and Cardenas-Barron (2002) presented a simple approach to determine the economic production quantity for an item with imperfect quality.

Because of the above-mentioned arguments, this study incorporates the integrated single-vendor and single-buyer method and defective items into the production-inventory model. This study extends Ha and Kim (1997) model and incorporates the integrated vendor and buyer approach into the inventory model containing imperfect items. This approach deals with the imperfect items in the same way as proposed in Salameh and Jaber (2000). This model considers a simple and practical situation where each shipment to the buyer is the same size. The function of the expected annual integrated total cost can be found by trial and error and the solution procedure is developed to achieve the optimal solution.

In addition, some researchers still devote themselves to finding the optimal solutions or creating the modified model in supply chain management. For example, Manzouri *et al.* (2013) developed the model for securing sharing information across the supply chain and Chen *et al.* (2011) applied the fuzzy analytic hierarchy and grey relation analysis to evaluate the supply chain performance.

## 2. MATERIALS AND METHODS

To establish the proposed model, the following notations are used and some assumptions are made throughout this study.

### 2.1. Notations

- D : average demand per year
- P: production rate,
- Q : order quantity of the purchaser
- $h_v$: vendor's holding cost per unit per unit time
- $h_b$: buyer's holding cost per unit per unit time
- $S_v$: production cost paid by the vendor
- $S_b$: purchase cost paid by the purchaser
- $\delta$: percentage of defective items, a random variable
- g(y): probability density function of $\delta$
- m: the total number of shipments per lot from the vendor to the buyer, a positive integer
- $\beta$: reworking cost per unit
- $\alpha$: screening cost per unit
- L: length of lead time

### 2.2. Assumptions

- There is a single vendor and single buyer for a single product
- The demand for the item is constant over time
- The production rate is uniform and finite
- Successive deliveries are scheduled so that the next one arrives at the buyer when stock from previous shipment has just been finished
- Lead time L is deterministic and lead time demand $\xi$ has finite mean $\mu L$ and standard deviation $\sigma L^{1/2}$
- The reorder point r equals the sum of the expected demand during the lead time and the Safety Stock (SS), that is, $r = \mu L + k\sigma L^{1/2}$
- Shortages are not allowed
- Inventory is continuously reviewed
- Lead time is constant
- The extra costs incurred by the vendor will be fully transferred to the purchaser if shortened lead time is requested
- In a single batch at the end of the vendor 100% screening process, if defective items are found, duplicate costs must be paid
- Transportation cost per unit is constant. In order to simply purpose model, not considering transportation cost

### 2.3. Model Formulation

Based on the above notations and assumptions, the total expected joint annual cost is given by:

TEC (Q, m) = setup cost + screening cost
+reworking cost +ordering cost+ holding cost

For the vendor's inventory model, its total expected annual cost can be represented by:

$TC_v$ = setup cost + holding cost**+**
screening cost +reworking cost,

And the buyer's total expected annual cost is described as:

$TC_b$ = ordering cost+ holding cost.

Since the production quantity for the vendor in a lot can be denoted as mQ, the integrated inventory model is designed for a vendor's production situation in which, once an order is placed, the production begins and a constant number of units is added to inventory each day after the production run has been completed. The vendor will produce the item in the quantity of mQ and the purchaser will receive it in m lots with each having a quantity of Q. When the vendor produces one lot the entire quantity must be 100% screened. Bad items must be duplicated. The inventory pattern in the model is shown in **Fig. 1**.

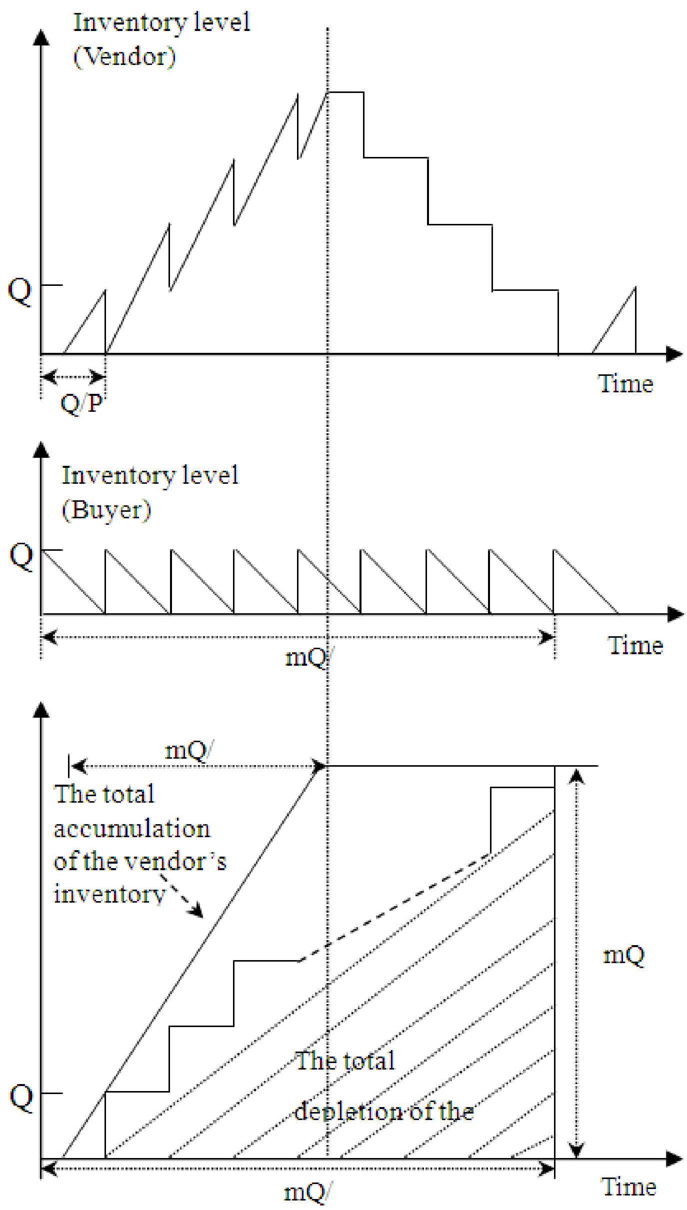


**Fig. 1.** Time-weighted inventory for vendor and buyer

For the vendor, its average inventory can be expressed as Equation 1:

$$\bar{I}_v = \frac{Q}{2}[m(1-\frac{D}{P})-1+\frac{2D}{P}] \quad (1)$$

It follows that the total expected annual cost for the vendor is Equation 2:

$$TC_v(Q,m) = \frac{Q}{2}[m(1-\frac{D}{P})-1+\frac{2D}{P}]h_v + \frac{S_v D}{mQ} + \alpha\, mQ + \beta\delta\, mQ \quad (2)$$

If the purchaser complies with the EOQ model, then its total excepted cost for the buyer can be written as follows Equation 3:

$$TEC_b(Q) = \frac{Q}{2}h_b + \frac{S_b D}{Q} + k\sigma\sqrt{L}h_b \quad (3)$$

Then the joint total expected annual cost is given by Equation 4:

$$\begin{aligned}
&JTC(Q,m) \\
&= TC_v(Q,m) + TC_b(Q,m) \\
&= \frac{D}{Q}[S_b + \frac{S_v}{m}] \\
&+\frac{Q}{2}\left\{[m(1-\frac{D}{P}) - 1 + \frac{2D}{P}]h_v + h_b\right\} \\
&+ \alpha mQ + \beta\delta mQ + k\sigma\sqrt{L}h_b
\end{aligned} \quad (4)$$

Since $\delta$ is a random variable with a known probability density function, $g(\delta)$, the expected value of JTEC(Q,m) is derived as:

$$\begin{aligned}
&JTEC(Q,m) \\
&= \frac{D}{Q}[S_b + \frac{S_v}{m}] + \frac{Q}{2}\left\{[m(1-\frac{D}{P}) - 1 + \frac{2D}{P}]h_v + h_b\right\} \\
&\qquad + \alpha mQ + \beta mQE[\delta] + k\sigma\sqrt{L}h_b
\end{aligned} \quad (5)$$

When all items are of perfect quality, that is, $\Pr(\delta = 0) = 1$ and $E[\delta] = 0$, then no need of screening process and Equation 5 can be reduced to Equation 6:

$$\begin{aligned}
&JTEC_{perfect}(Q,m) \\
&= \frac{D}{Q}(\frac{S_v}{m} + S_b) + \frac{Q}{2}[m(1-\frac{D}{P}) - 1 + \frac{2D}{P}]h_v \\
&+ (\frac{Q}{2} + k\sigma\sqrt{L})h_b
\end{aligned} \quad (6)$$

Taking the partial derivatives of JTEC (Q, m) with respect Q, we obtain:

$$\begin{aligned}
&\frac{\partial JTEC(Q,m)}{\partial Q} \\
&= \frac{1}{2}\{[m(1-\frac{D}{P}) - 1 + \frac{2D}{P}]h_v \\
&+ h_b\} - \frac{D}{Q^2}[S_b + \frac{S_v}{m}] + \alpha m + \beta mE[\delta]
\end{aligned} \quad (7)$$

For fixed m, we utilize the 2ND partial derivatives to prove that JTEC (Q, m) is convex, since Equation 8:

$$\frac{\partial^2 JTEC(Q,m)}{\partial Q^2} = \frac{2D}{Q^2}[S_b + \frac{S_v}{m}] > 0 \quad (8)$$

Now that setting Equation 7 to zero and solve for Q, it follows that:

$$Q^* = \left\{\frac{2D(\frac{S_v}{m} + S_b)}{[m(1-\frac{D}{P}) - 1 + \frac{2D}{P}]h_v + h_b + 2\alpha m + 2\beta mE[\delta]}\right\}^{½} \quad (9)$$

Substituting Equation 9 into Equation 5, the joint total expected annual cost is described by:

$$\begin{aligned}
&JTEC(m) \\
&= \left\{ 2D\left[S_b + \frac{S_v}{m}\right] \times \left[\begin{aligned}&[m(1-\frac{D}{P}) - 1 + \frac{2D}{P}]h_v \\ &+ h_b + 2\alpha m + 2\beta mE[\delta]\end{aligned}\right]\right\}^{1/2} \\
&+ k\sigma\sqrt{L}h_b
\end{aligned} \quad (10)$$

We can ignore the terms that are independent of m and take the square of Equation 10. Then, minimizing JTEC (m) is equivalent to minimizing as Equation 11:

$$\begin{aligned}
&(JTEC(m))^2 \\
&= 2D \times \left\{\begin{aligned}
&mS_b\left[(1-\frac{D}{P})h_v + 2\alpha + 2\beta E[\delta]\right] \\
&+\left[\frac{S_v}{m}\left(h_b - [1-\frac{2D}{P}]h_v\right)\right] \\
&+S_b\left[h_b - [1-\frac{2D}{P}]h_v\right] \\
&+S_v\left[h_v(1-\frac{D}{P}) + 2\alpha + 2\beta E[\delta]\right]
\end{aligned}\right\}
\end{aligned} \quad (11)$$

Once again, ignoring the terms that are independent of m, the minimization of the problem can be reduced to that of minimizing Equation 12:

$$\begin{aligned}
Z(m) = &\, mS_b\left[(1-\frac{D}{P})h_v + 2\alpha + 2\beta E[\delta]\right] \\
&+\left[\frac{S_v}{m}\left(h_b - [1-\frac{2D}{P}]h_v\right)\right]
\end{aligned} \quad (12)$$

The optimal value of m = m* is obtained when:

$$Z(m^*) \le Z(m^* - 1) \text{ and } Z(m^*) \le Z(m^* + 1) \quad (13)$$

On substituting relevant values in Equation 13, the following condition is obtained:

$$m^*(m^*-1) \le \frac{S_v\left(h_b - [1-\frac{2D}{P}]h_v\right)}{S_b\left[(1-\frac{D}{P})h_v + 2\alpha + 2\beta E[\delta]\right]} \le m^*(m^*+1) \quad (14)$$

Thus, we can use the following procedure to find optimal values of Q and m:

- Step 1. Compute the range of m by using Equation 14
- Step 2. Substitute $m=m^*$ into Equation 9, Compute $Q^*$ to obtain the optimal delivery of quantity by using Equation 9
- Step 3. Compute JTEC(Q*,m*). Then (Q*m*) is an optimal solution

## 3. RESULTS

To illustrate the results of the proposed models, consider an inventory system with the data (Yang and Pan, 2004) of annual demand D = 1000 unit/year, production rate P =3200 unit/year, purchaser's ordering cost per order $S_b$ =$25/order, vendor's set-up cost $S_v$ = $400/set-up, lead time L = 56/days, purchase cost $h_b$ = $25/unit, production cost $h_v$ = $20/unit, annual inventory holding cost per dollar invested in safety stock factor k = 2.33, variable $\sigma^2$ = 7 unit/week, duplicate cost $\beta$ = 2/unit. The percentage defective random variable, $\delta$, uniformly distributed according to the probability density function.

Both purchasers and vendors determine inventory policy independently. The purchasers always compute their economic order quantity by using Equation 3. In order to obtain the minimum cost lot size, we can take the first partial derivative of $TEC_b$ (Q) with respect to Q and set them to zero; as shown in Equation 15:

$$\frac{\partial TEC_b(Q,m)}{\partial Q} = \frac{h_b}{2} - \frac{S_b D}{Q^2} = 0 \quad (15)$$

Hence, $TEC_b$ (Q) is convex in Q, since Equation 16:

$$\frac{\partial^2 TEC_b(Q,m)}{\partial Q^2} = \frac{2S_b D}{Q^3} > 0 \quad (16)$$

Therefore, for fixed Q, the minimum total expected annual cost for the purchaser will occur at the end points of the interval. From Equation 14, we have Equation 17:

$$Q = \left(\frac{2S_b D}{h_b}\right)^{1/2} \quad (17)$$

## 4. DISCUSSION

### 4.1. Case 1

We can compute E[δ] and W expected value as follows:

$$g(y) = \begin{cases} 20, & 0 \le \delta \le 0.03 \\ 0, & \text{otherwise} \end{cases}$$

Therefore:

$$E[\delta] = \int_0^{0.03} 20y\,dy = 0.009$$

And:

$$W = E\left[\frac{1}{1-\delta}\right] = \int_0^{0.03} \frac{1}{1-\delta} 20dy = 0.609$$

We consult **Table 1** after trial and error selection of interval probabilities values and then we found that when δ values are increased, what is calculated out E[δ] will increase progressively too. On the other hand, we computed W value was decreased progressively to comply with E[δ]. We know fewer imperfect products is better, to reduce inspection and duplication cost. We discovered in **Table 1**, a curve protruding in the shape of W. If a probability point is taken on the curve, its defective products will be minimal and the cost will be lowest.

### 4.2. Case 2

After we computed different E[δ] and W to find constant ratio E[δ] values, we used Equation 13 to compute the optimization order batch and order quantity and to infer vendor appropriate production quantity. Cost variation in E[δ] from 0.009 to 0.02, costs went down and after E[δ] = 0.02, the joint total costs started to rise (**Fig. 2**).

### 4.3. Case 3

After combining point 1 and point 2, we want to treat whether the algorithm we built is superior to an independent model. For this reason, we use Equation 16's definition, we can compute the optimal order strategy in independent model Q = 44.72 and total cost is $2271.33. Using the buyer order strategy to determine Economic production quantity batch of time.

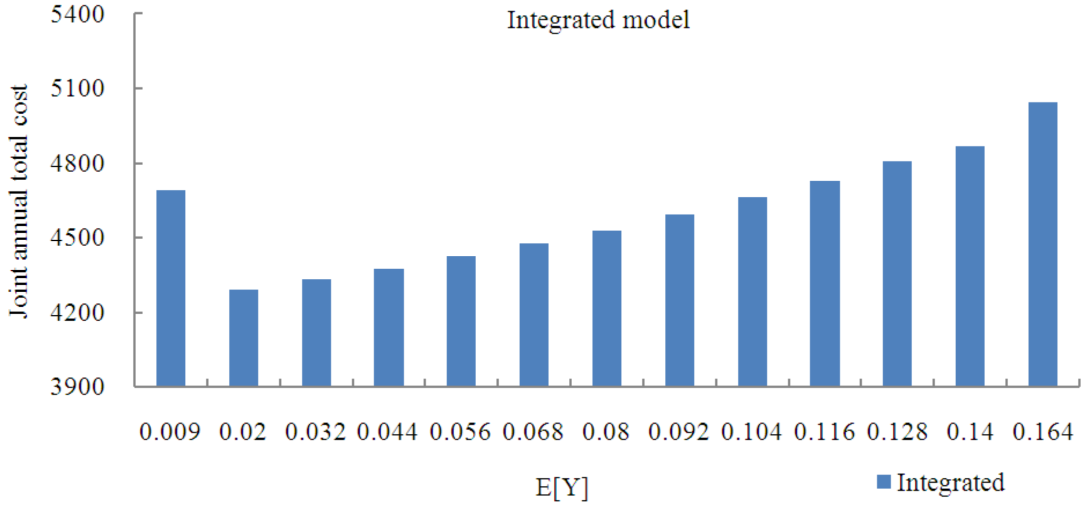


**Fig. 2.** Integrated model joint total costs

**Table 1.** Different interval probabilities value summaries table

| E[Y] | W | Q | m | mQ | Total cost |
|---|---|---|---|---|---|
| 0.009 | 0.609 | 48.68 | 4 | 194.72 | 4693.49 |
| 0.02 | 0.421 | 43.02 | 4 | 172.09 | 4289.34 |
| 0.032 | 0.435 | 43.47 | 4 | 173.88 | 4332.72 |
| 0.044 | 0.449 | 43.91 | 4 | 175.65 | 4376.43 |
| 0.056 | 0.465 | 44.41 | 4 | 177.65 | 4425.23 |
| 0.068 | 0.482 | 44.94 | 4 | 179.75 | 4476.76 |
| 0.08 | 0.5 | 45.49 | 4 | 181.94 | 4531.02 |
| 0.092 | 0.52 | 51.2 | 3 | 153.60 | 4595.43 |
| 0.104 | 0.541 | 51.89 | 3 | 155.68 | 4661.98 |
| 0.116 | 0.563 | 52.61 | 3 | 157.83 | 4731.39 |
| 0.128 | 0.588 | 53.41 | 3 | 160.23 | 4808.70 |
| 0.14 | 0.615 | 48.85 | 4 | 195.40 | 4867.03 |
| 0.164 | 0.678 | 50.6 | 4 | 202.39 | 5043.91 |

In Equation 2, m is unknown, so we let m = 1, 2, 3…, to minimize the cost in Equation 2. But we found find all m = 1 and vendor total costs and joint total cost were $7869.10 and $4693.49. We placed everything in **Table 2**.

Clearly, from **Fig. 2 and 3**, the cost trend rise slowly in E[Y] = 0.02. But it is not hard to see that the integrated model is superior to the independent model, when E[Y] increases, the cost difference between these models is distinct, it emphasizes the integrated model's advantage. E[Y] from 0.009 to 0.02 decreased; because the main factors δ computing E[Y] and W vary distinctly. Our model explains by transshipment time increase that setup costs are shared by each order period because the first period didn't achieve share cost function so that its setup cost was very high.

**Table 2.** Allocation of the total annual cost

| E[Y] | W | $Q_b$ | $Q_v$ | $TEC_b$ | $TEC_v$ |
|---|---|---|---|---|---|
| 0.009 | 0.609 | 44.72 | 44.72 | 2271.33 | 7,869.10 |
| 0.02 | 0.421 | 44.72 | 44.72 | 2271.33 | 6,193.46 |
| 0.032 | 0.435 | 44.72 | 44.72 | 2271.33 | 6,329.68 |
| 0.044 | 0.449 | 44.72 | 44.72 | 2271.33 | 6,466.57 |
| 0.056 | 0.465 | 44.72 | 44.72 | 2271.33 | 6,622.25 |
| 0.068 | 0.482 | 44.72 | 44.72 | 2271.33 | 6,787.77 |
| 0.08 | 0.500 | 44.72 | 44.72 | 2271.33 | 6,963.22 |
| 0.092 | 0.520 | 44.72 | 44.72 | 2271.33 | 7,157.78 |
| 0.104 | 0.541 | 44.72 | 44.72 | 2271.33 | 7,362.46 |
| 0.116 | 0.563 | 44.72 | 44.72 | 2271.33 | 7,577.32 |
| 0.128 | 0.588 | 44.72 | 44.72 | 2271.33 | 7,820.84 |
| 0.14 | 0.615 | 44.72 | 44.72 | 2271.33 | 8,084.01 |
| 0.164 | 0.678 | 44.72 | 44.72 | 2271.33 | 8,697.68 |
| Q | mQ | $TEC_b$+$TEC_v$ | JTEC | Ratio | |
| 48.68 | 194.72 | 10,140.43 | 4,693.49 | | |
| 43.02 | 172.09 | 8,464.79 | 4,289.34 | -8.61% | |
| 43.47 | 173.88 | 8,601.01 | 4,332.72 | -7.69% | |
| 43.91 | 175.65 | 8,737.90 | 4,376.43 | -6.76% | |
| 44.41 | 177.65 | 8,893.58 | 4,425.23 | -5.72% | |
| 44.94 | 179.75 | 9,059.10 | 4,476.76 | -4.62% | |
| 45.49 | 181.94 | 9,234.55 | 4,531.02 | -3.46% | |
| 51.20 | 153.60 | 9,429.11 | 4,595.43 | -2.09% | |
| 51.89 | 155.68 | 9,633.79 | 4,661.98 | -0.67% | |
| 52.61 | 157.83 | 9,848.65 | 4,731.39 | 0.81% | |
| 53.41 | 160.23 | 10,092.17 | 4,808.70 | 2.45% | |
| 48.85 | 195.40 | 10,355.34 | 4,867.03 | 3.70% | |
| 50.60 | 202.39 | 10,969.01 | 5,043.91 | 7.47% | |

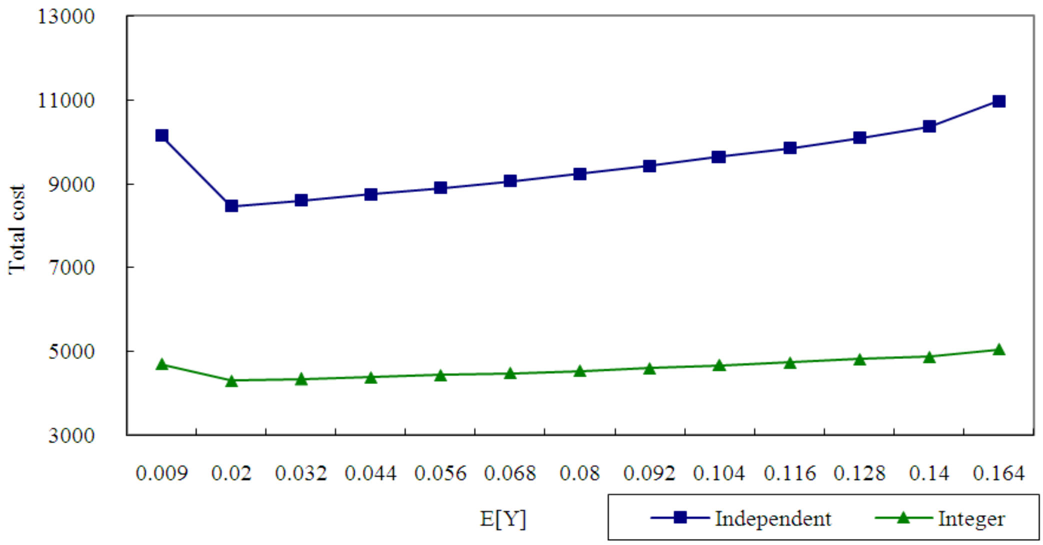


**Fig. 3.** Comparison of independent and integer models, joint total annual cost

Therefore, beginning at the second period, will cause costs to reduce. But after the second period, stock cost can increase following every period increase, so costs have the tendency to slowly rise.

## 5. CONCLUSION

This study combines two methods: the integrated model and the inspection of total unwholesome items. Both methods have not been mentioned in any studies before. The probability of the unwholesome items could help to analyze the total cost difference between the independent and integrated model. The numerical illustration presented throughout this study confirms that the integrated model is superior to the independent model. Therefore, this model can determine the best integrated model of unsuitable items stock in the JIT manufacturing environment with a single buyer and a single vendor. Furthermore, the model for this study can calculate the expected annual total costs. It thus improves the distinctness. Therefore, this model is superior to Pan and Yang (2002) broach algorithm model and fits with the green manufacturing concept by reducing waste in the supply chain and sustaining the company's competitive advantage.

## 6. REFERENCES

Banerjee, A., 1986. A joint economic-lot-size model for purchaser and vendor. Decis. Sci., 17: 292-311. DOI: 10.1111/j.1540-5915.1986.tb00228.x

Chen, Y.C., J.Y. Kuo and B.T. Luo, 2011. Applying fuzzy analytic hierarchy process and grey relation analysis to evaluate the supply chain performance of the wafer testing house. Am. J. Applied Sci., 8: 1398-1403. DOI: 10.3844/ajassp.2011.1398.1403

Cheng, T.C.E., 1991. An economic order quantity model with demand-dependent unit. IIE Trans., 23: 23-28. DOI: 10.1080/07408179108963838

Daugherty, P.J., D.S. Rogers and M.S. Spencer, 1994. Just-in-time functional model: Empirical test and validation. Int. J. Phys. Distr. Log., 24: 20-26. DOI: 10.1108/09600039410066150

Flinchbaugh, D.A., L.F. Crawford and D. Bradley, 2001. A model to set measurement quality objectives and to establish measurement uncertainty expectations in analytical chemistry laboratories using ASTM proficiency test data. Accredit. Qual. Assur., 6: 493-500. DOI: 10.1007/s007690100398-y

Goyal, S. K. and L.E. Cardenas-Barron, 2002. Note on: Economic production quantity model for items with imperfect quality-a practical approach. Int. J. Prod. Econ., 77: 85-87. DOI: 10.1016/S0925-5273(01)00203-1

Goyal, S.K. and Y.P. Gupta, 1989. Integrated inventory models: the buyer-vendor coordination. Eur. J. Oper. Res., 41: 261-269. DOI: 10.1016/0377-2217(89)90247-6

Goyal, S.K., 1977. An integrated inventory model for a single supplier-single customer problem. Int. J. Prod. Res., 15: 107-111. DOI: 10.1080/00207547708943107

Goyal, S.K., 1988. A joint economic-lot-size model for purchaser and vendor: A comment. Decis. Sci., 19: 236-241. DOI: 10.1111/j.1540-5915.1988.tb00264.x

Ha, D. and S.L. Kim, 1997. Implementation of JIT purchasing: an integrated approach. Prod. Plan. Control, 8: 152-157. DOI: 10.1080/095372897235415

Harber, D., D.A. Samson, A.S. Sohal and A. Wirth, 1990. Just-in-time: The issue of implementation. Int. J. Oper. Prod. Man., 10: 21-30. DOI: 10.1108/01443579010001681

Hill, R.M. and M. Omar, 2006. Another look at the single-vendor single-buyer integrated production-inventory problem. Int. J. Prod. Res., 44: 791-800. DOI: 10.1080/00207540500334285

Hwang, J.S., Z. Guo and H. Koenigsmann, 2001. A high-performance lead-free solder-the effects of In on 99.3Sn/0.7Cu, Solder. Surf. Mt. Tech., 13: 7-13. DOI: 10.1108/09540910110385194

Karlsson, C. and P. Ahlstrom,, 1996. Assessing changes towards lean production. Int. J. Oper. Prod. Man., 16: 24-41. DOI: 10.1108/01443579610109820

Lee, H.L. and M. J. Rosenblatt, 1987. Simultaneous determination of production cycle and inspection schedules in a production system. Manage. Sci., 33: 1125-1136. DOI: 10.1287/mnsc.33.9.1125

Lu, L., 1995. A one-vendor multi-buyer integrated inventory mode. Eur. J. Oper. Res., 81: 312-323. DOI: 10.1016/0377-2217(93)E0253-T

Manzouri, M., M.N.A. Rahman, F. Nasimi and H. Arshad, 2013. A model for securing sharing information across the supply chain. Am. J. Applied Sci., 10: 253-258. DOI: 10.3844/ajassp.2013.253.258

Miltenburg, J., 2001. U-shaped production lines: A review of theory and practice. Int. J. Prod. Econ., 70: 201-214. DOI: 10.1016/S0925-5273 (00)00064-5

Pan, J.C.H. and J.S. Yang, 2002. A study of an integrated inventory with controllable lead time. Int. J. Prod. Res., 40: 1263-1273. DOI: 10.1080/00207540110105680

Porteus, E.L., 1986. Optimal lot sizing, process quality improvement and setup cost reduction. Oper. Res., 34: 137-144. DOI: 10.1287/opre.34.1.137

Rawabdeh, I.A., 2005. A model for the assessment of waste in job shop environments. Int. J. Oper. Prod. Man., 25: 800-822. DOI: 10.1108/01443570510608619

Rong, C., K. Takahashi and J. Wang, 2003. Enterprise waste evaluation using the analytic hierarchy process and fuzzy set theory. Prod. Plan. Control, 14: 90-103. DOI: 10.1080/0953728031000096557

Salameh, M.K. and M.Y. Jaber, 2000. Economic production quantity model for items with imperfect quality. Int. J. Prod. Econ., 64: 59-64. DOI: 10.1016/S0925-5273(99)00044-4

Schwaller, R.L., 1988. EOQ under inspection costs. Prod. Invent. Manage. J., 29: 22-24.

Shi, C. S. and C.T. Su, 2004. Integrated inventory model of returns-quantity discounts contract. J. Oper. Res. Soc., 55: 240-246. DOI: 10.1057/palgrave.jors.2601676

Svensson, G., 2001. Just-in-time: the reincarnation of past theory and practice. Manage. Decision, 39: 866-879. DOI: 10.1108/EUM0000000006526

Yang, J.S. and J.C.H. Pan, 2004. Just-in-time purchasing: an integrated inventory model involving deterministic variable lead time and quality improvement investment. Int. J. Prod. Res., 42: 853-863. DOI: 10.1080/00207540310001632448

Zhang, X. and Y. Gerchak, 1990. joint lot sizing and inspection policy in an EOQ model with. IIE Trans., 22: 41-47. DOI: 10.1080/07408179008964156