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Modeling of Supply Chain for Defective Goods Using Jit-Logistics

Salah Alden Ghasimi[a*], Rizauddin Ramli[a], Nizaroyani Saibani[a]

[a]*Department of Mechanical and Materials Engineering, Faculty of Engineering and Built Environment Universiti Kebangsaan Malaysia, 43600 UKM, Bangi, Selangor, Malaysia*

*Corresponding author: salahzoh@yahoo.com

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Graphical abstract

No. problem	Dimension of problems					$\sum Sc$	$\sum Def$	$\sum Co$	$\sum TCo$	$\sum B$	$\sum Q$	$Z_{\min}$
	I	*J*	*K*	*L*	*T*							
1	1	1	1	1	1	3	30	2973	3000	27	3003	61917
2	1	2	2	1	1	5	55	5450	5500	50	5505	113515
3	2	1	2	2	1	108	330	12677	12900	222	13009	304115
4	2	2	1	1	2	55	141	5444	5500	85	5555	117788
5	2	2	3	1	2	87	445	20842	21200	357	21287	674836
6	1	1	2	2	1	32	193	12638	12800	161	12832	252260
7	2	2	1	2	1	13	80	5432	5500	67	5513	131262
8	1	2	2	4	1	70	363	20532	20800	288	20875	422083
9	2	2	2	2	1	32	193	12639	12800	161	12832	304266
10	1	1	2	1	4	236	1568	22768	24100	1331	24336	931172
11	2	1	2	1	3	255	1277	16978	18000	1021	18255	685078
12	1	2	2	1	3	212	1060	20152	21000	848	21212	662360

Abstract

Supply chain management (SCM) is a field of study which covers a wide range of research issues involving strategic to operational models. In the past two decades, SCM has drawn much attention from manufacturers and organizations for optimizing their operations. In this paper, a mathematical model to optimize costs of the supply chain for defective and repairable goods through the application of just-in-time (JIT) logistics is proposed. The hypothesis is that the defective goods are repairable and some of them are considered as scraps. The aim of this model is to minimize the total cost of production, maintenance, freight, reworking, scrap goods and shortage to retailers. The proposed model is novel and LINGO has been used to solve it. The validity of the model was proven by testing 12 sample problems and the results showed correctness and fine function of the model. Based on the data parameters, this model can also determine which manufacturer or distributor in the particular period of the production needs to be active. The model is applicable for all producers that are encountering with problem of producing of defective goods.

Keywords: Supply chain management, defective goods, JIT- logistic, LINGO

1.0 INTRODUCTION

In the past two decades, the issue of supply chain management (SCM) has drawn a great deal of attention from manufacturers and organizations for optimizing their operations [1]. One part of a supply chain is known as logistics. It is responsible for planning, execution, goods storage and flows with effective and efficient control, the required services and information from the beginning to the consumption point in order that consumer needs will be met. By logistics, it is meant that several parameters are involved including transportation, inventory, displacement of material, storage, packing and solidarity of information and especially providing security in this respect. It is a connecting means between supply chains whose value of time and place is crucial to each process. The suitable use of situations and the proper application of knowledge of logistics is a good opportunity for many companies to boost their business.

Just-in-time (JIT) in its simplest form refers to a method of inventory control with a focus on waste elimination. The visible performance improvements of some firms adopting JIT led to a great deal of excitement. Implementing JIT at the operational level and creating competitive advantage through JIT became topics of widespread interest. Manufacturers needed to search for alternative ways to extend their goods provision and employ appropriate strategies to meet various market demands properly and on time.

In any production system manufacturing of some defective goods can result, due to various factors such as imperfect quality and defective raw materials. Therefore, there is the need for some facilities for reworking of the defective goods produced. In most cases, reworking can be very profitable if the cost of production is too high or the raw materials are limited and costly.

In recent years, numerous methods have been proposed for improving the efficiency of production systems. Vijay and Keah correlated the three features of TQM, SCM, JIT and their impacts on the efficiency of the business [2]. Their findings showed that their simultaneous application brings synergy which can enhance the effectiveness of companies. Simme et al. considered the defective products by the single-item manufacturers who use the same facilities and production machines for reworking [3]. Abdollah and Gultekin presented a model that considered defective goods and the ordered amounts which were returned as shortage [4]. The results derived in solving the model by means of a numerical example showed that the defective and useless goods lowered overall profits. Kun et al. proposed a two-warehouse inventory model with imperfect quality production processes [5]. Wahab and Jaber investigated the economic order quantity model for products with imperfect quality, different holding costs and learning effects [6]. Salameh *et al*. reported that a warehouse was used for the storage of the defective and non-defective products [7]. However, in a real situation, it is not possible to allocate only one warehouse for the storage of the defective and non-defective products because the profit rates of these products are different.

Mondal et al. investigated the inventory model for single-item production with a defective production process [8]. Also, they studied relationship between the rate of production with cost and the total profit. On the other hand, Hong et al. considered the relationship between the process quality and the investment to reduce set up time [9]. Sarker et al. proposed an EPQ inventory model include of two operational inventory policies for a multi-stage manufacturing system with rework process. Their research contains mathematical expressions which are corrected and the solution to the numerical example. It also established the forms for the optimal total inventory cost [10]. Ruilin Guo and Qi Tang studied a supply chain model that was integrated with logistics planning [11]. The results showed the logistics planning is an important factor to reduce the costs and to provide the market demands permanently. Furthermore, Reza and Mahsa solved the JIT distribution in supply chain management by presenting a model that has two target functions which were designed for a three-level distribution network of the supply chain [12].

In this paper, we present a mathematical model for optimizing defective goods supply chain. The advantages of our model toward to previous models are in our model we considered the contribution of JIT-logistic, economic production quantity, defective goods maintenance costs, scrap goods, production costs and cost of shortage for retailers due to delays in defective goods production comprehensively.

■2.0 PROBLEM STATEMENT

With the current vigorous competition in markets and increasing number of manufacturers, factors of cost and time play significant roles in the success of manufacturers. Many researchers have worked on the supply chain of defective goods [3-8], but there were very few who had presented a comprehensive mathematical model for supply chain of defective goods, and most of them did not include factors of just-in-time logistics, available time constraints, maintenance cost of the defective goods, cost of production of scrap products and the cost of shortages to retailers due to production of the defective goods.

■3.0 MODELING

In this research, we considered a three-level model for defective goods supply chain. The first level was of manufacturers, the second level distributors and the third level was retailers. The proposed model can be adapted to optimize costs such as, production, maintenance, shipping, reworking of the defective goods, scrap goods and shortage in retailers due to the production of defective goods.

3.1 Model Assumptions and Limitations

In order to develop the proposed model, the following assumptions were made:

First, the amount of demand was given to manufacturers at the beginning of the period and the duration of each period was fixed and clear. Second, the duration of each period was equal to total of production time and rework time and shortage was allowed. Third, the model was designed for multi-manufacturer, multi-distributor and multi-retailer situations. Fourth, the parameters used were fixed; i.e. the demand rate, reworking time, production time, percentage of defective products, percentage of scrap products and prices. Finally, we assumed that the inspection operation was perfect and the intended inspection time was zero.

Also, several limitations were considered. First, the manufacturers supply capacity, total warehouse capacities are limited. Second, for each product, the storage allocated capacity is limited. Third, for each defective goods, the store capacity and the storage allocated capacity is limited. Fourth, for each period, the customer demand should be provided. Finally, we considered the limitations of production time and reworking time.

3.2 Indices and Sets

The following indices and sets were introduced:

Manufacturer’s index	$i=1,2,3,...I$
Distributor’s index	$j=1,2,3,...J$
Product’s index	$l=1,2,3,...L$
Period’s index	$t=1,2,3,\ldots T$
Retailer’s index	$k=1,2,3,\ldots K$

3.3 Decision Variables and Parameters

In this model, we defined the decision variables and parameters to be used in cost optimization by LINGO in Table 1.

Table 1 The explanation of decision variables and parameters

p_{ilt}	Percentage of defective goods l produced by manufacturer i during period t
γ_{ilt}	Rework cost of per defective goods l by manufacturer i during period t
h_{jlt}	Holding cost of product l in distributor j during period t
h'_{ilt}	Holding cost of product l in defective goods store inside the manufacturer i during period t
θ_{ilt}	Time required to production of per goods l by manufacturer i during period t
$T\theta_t$	Total of production time during period t
μ_{ilt}	Time of reworking required for goods l by manufacturer i during t
$T\mu_t$	The total of reworking time during period t
Pc_{ilt}	Production cost of per item by manufacturer i during period t
TC_{ijlt}	Shipping cost each product l from manufacturer i to distributor j during period t
$T''C_{ilt}$	Shipping cost each product l from distributor j to retailer k during period t
$T''C_{ilt}$	Shipping cost each defective goods l inside manufacturer I during period t (from production process to defective goods store and inverse)
α_{ilt}	Percentage of scrap product l produced by factory i during period t
f_{ilt}	Production cost of per scrap goods l by factory i during period t
β_{klt}	shortage cost for each product l in retailer k during period t
B_{klt}	amount of the shortage of product l in retailer k during period t
X_{ijlt}	Amount of product l transported from factory i to distributor j during period t
Q_{ilt}	Economic production quantity of product l by factory i during period t
Def_{ilt}	Amount of defective goods l produced by factory i during period t
Sc_{ilt}	Amount of scrap goods l produced by factory i during period t
Co_{ilt}	Amount of perfect products l produced by factory i during t before reworking.
TCo_{ilt}	Amount of perfect products l produced by factory i during t after reworking.
Y_{jklt}	Amount of product l transported from distributor j to retailer k during period t.

3.4 The Mathematical Model

The objective function of this model is to minimize the global cost of defective goods supply chain as shown in the following equation:

$$Z_{\min} = \sum_{i=1}^{I}\sum_{l=1}^{L}\sum_{t=1}^{T} Pc_{ilt}.Q_{ilt} + \sum_{j=1}^{J}\sum_{l=1}^{L}\sum_{t=1}^{T} h_{jlt}.\left(\sum_{t'=1}^{t'\neq T}\sum_{i=1}^{I} X_{ijlt'} - \sum_{t'=1}^{t'\neq T}\sum_{k=1}^{K} Y_{jklt'}\right) + \sum_{i=1}^{I}\sum_{l=1}^{L}\sum_{t=1}^{T} h'_{ilt}.Def_{ilt} + \sum_{i=1}^{I}\sum_{l=1}^{L}\sum_{t=1}^{T} \gamma_{ilt}.Def_{ilt} + \sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{l=1}^{L}\sum_{t=1}^{K} TC_{ijlt}.X_{ijlt} + \sum_{j=1}^{J}\sum_{k=1}^{K}\sum_{l=1}^{L}\sum_{t=1}^{T} T'C_{jklt}.Y_{jklt} + \sum_{i=1}^{I}\sum_{l=1}^{L}\sum_{t=1}^{T} T''C_{ilt}.Def_{ilt} + \sum_{i=1}^{I}\sum_{l=1}^{L}\sum_{t=1}^{T} f_{ilt}.Sc_{ilt} + \sum_{k=1}^{K}\sum_{l=1}^{L}\sum_{t=1}^{T} B_{klt}.\beta_{klt} \qquad (1)$$

The objective function include the costs of production, maintenance in warehouse and defective goods store, reworking of defective goods, shipping from manufacturers to distributors, shipping from distributors to retailers and transfer of defective goods from production line to defective goods store and vice versa, cost of scrap goods and shortage in retailers is shown by Eq.(1).

The constraints of the model and explanation of them

$$Q_{ilt} \le S_{ilt} \qquad \forall \quad i,l,t \qquad (2)$$

Eq.(2) Shows the restriction of production capacity

$$\sum_{i=1}^{I}\sum_{l=1}^{L} X_{ijlt} \le W_{jt} \qquad \forall \quad j,t \qquad (3)$$

Eq(3) shows the limitation of delivery capacity of distributors

$$\sum_{i=1}^{I} X_{ijlt} \le W_{jlt} \qquad \forall \quad j,l,t \qquad (4)$$

Limitation of delivery capacity of distributors for each product type is shown by Eq(4)

$$\sum_{j=1}^{J}\sum_{l=1}^{L} Y_{jklt} \le W'_{kt} \qquad \forall \quad k,t \qquad (5)$$

Eq(5) shows the limitation of delivery capacity of retailers

$$\sum_{j=1}^{J} Y_{jklt} \le W'_{klt} \qquad \forall \quad k,l,t \qquad (6)$$

Eq(6) shows the limitation of delivery capacity of retailers for each product type

$$Def_{ilt} = p_{ilt}.Q_{ilt} \qquad \forall \quad i,l,t \qquad (7)$$

Eq(7) shows the amount of defective goods

$$Sc_{ilt} = \alpha_{ilt}.Def_{ilt} \qquad \forall \quad i,l,t \qquad (8)$$

Eq(8) shows the amount of scrap goods

$$Co_{ilt} = 1 - p_{ilt} \; .Q_{ilt} \qquad \forall \quad i,l,t \qquad (9)$$

Eq(9) shows the amount of perfect goods before reworking

$$TCo_{ilt} = Co_{ilt} + Def_{ilt} - Sc_{ilt} \qquad \forall \quad i,l,t \qquad (10)$$

Eq(10) shows the total of perfect goods after reworking

$$Q_{ilt} = Co_{ilt} + Def_{ilt} \qquad \forall \quad i,l,t \qquad (11)$$

Eq(11) shows the total of production

$$\sum_{k=1}^{K} d_{klt} + \sum_{i=1}^{I} Sc_{ilt} \le \sum_{i=1}^{I} Q_{ilt} \qquad \forall \quad l,t \qquad (12)$$

$$\sum_{k=1}^{K} d_{klt} \le \sum_{i=1}^{I} TCo_{ilt} \qquad \forall \quad l,t \qquad (13)$$

Eqs(12) and (13) Show the supply amount of demand

$$\sum_{k=1}^{K} B_{klt} = \sum_{k=1}^{K} d_{klt} - \sum_{i=1}^{I} Co_{ilt} \qquad \forall \quad l,t \qquad (14)$$

$$\sum_{i=1}^{I} Co_{ilt} \le \sum_{k=1}^{K} d_{klt} \qquad \forall \quad l,t \qquad (15)$$

The amounts of shortage because of defective goods are shown by Eqs.(14) and (15).

$$\sum_{i=1}^{I} X_{ijlt} = \sum_{k=1}^{K} Y_{jklt} \qquad \forall \quad j,l,t \qquad (16)$$

Eq(16) shows the inventory in warehouses are zero at the last period

$$\sum_{j=1}^{J} Y_{jklt} = d_{klt} \qquad \forall \quad k,l,t \qquad (17)$$

Eq.(17) The inventory of retailers are not more than the demand

$$\sum_{k=1}^{K}\sum_{t'=1}^{t'\neq T} Y_{jklt'} \le \sum_{i=1}^{I}\sum_{t'=1}^{t'\neq T} X_{ijlt'} \qquad \forall \quad j,l,t \neq T \qquad (18)$$

The inventory of warehouses before the last period are shown by (18)

$$\sum_{j=1}^{J} X_{ijlt} \le Q_{ilt} \qquad \forall \quad i,l,t \qquad (19)$$

Eq.(19) The exit of scrap products from system

$$\sum_{i=1}^{I}\sum_{l=1}^{L} \theta_{ilt}.Q_{ilt} \le T\theta_{t} \qquad \forall \quad t \qquad (20)$$

Eq.(20) The limitation of available times for all production

$$\sum_{i=1}^{I}\sum_{l=1}^{L} \mu_{ilt}.Def_{ilt} \le T\mu_{ilt} \qquad \forall \quad t \tag{21}$$

Eq.(21) The limitation of available times for reworking

$$T\theta_t + T\mu_t = T_t \qquad \forall \quad t \tag{22}$$

Eq.(22) The length of each period t

$$X_{ijlt}, Y_{jklt}, Q_{ilt}, B_{klt}, Def_{ilt}, Sc_{ilt}, Co_{ilt}, TCo_{ilt} \ge 0 \qquad \forall \quad i, j, k, l, t \tag{23}$$

Eq.(23) The amount of delivery to warehouses and retailers, productions shortage in retailers, defective goods, scrap goods, perfect goods before reworking and perfect goods after reworking should all have positive values

4.0 RESULTS AND DISCUSSION

In this research, a solvable mathematical model using linear programming software has been proposed and the LINGO has been used to solve it. The LINGO is a comprehensive tool designed to solve linear, nonlinear, quadratic, stochastic, and integer optimization models, the aim of using LINGO was because it can solve faster and was efficient in terms of calculation time. The findings of the model were the amount of scrap goods, defective goods, perfect goods before repair, perfect goods after repair which are equal to the amount of demand, shortage in retailers, economic production quantity and global optimized costs. Twelve sample problems with different dimensions were considered. The results are presented in Table 2, where the first column indicates the numbers of sample problems, the second column shows dimensions of the problems, where *I* is the number of manufacturers, *J* is the number of distributors, *K* is the number of retailers, *L* is product types that are produced by manufacturers and *T* is the number of production periods. The remaining columns indicate the amount of scrap goods ($\sum Sc$), defective goods ($\sum Def$), perfect goods before reworking ($\sum Co$), total perfect goods after reworking ($\sum TCo$), shortage in retailers ($\sum B$) due to defective goods produced, economic production quantity ($\sum Q$) and global optimal cost ($Z_{\min}$) in each time horizon respectively.

Table 2 Results of twelve sample problems solved using the LINGO software

No. problem	Dimension of problems					$\sum Sc$	$\sum Def$	$\sum Co$	$\sum TCo$	$\sum B$	$\sum Q$	$Z_{\min}$
	I	*J*	*K*	*L*	*T*							
1	1	1	1	1	1	3	30	2973	3000	27	3003	61917
2	1	2	2	1	1	5	55	5450	5500	50	5505	113515
3	2	1	2	2	1	108	330	12677	12900	222	13009	304115
4	2	2	1	1	2	55	141	5444	5500	85	5555	117788
5	2	2	3	1	2	87	445	20842	21200	357	21287	674836
6	1	1	2	2	1	32	193	12638	12800	161	12832	252260
7	2	2	1	2	1	13	80	5432	5500	67	5513	131262
8	1	2	2	4	1	70	363	20532	20800	288	20875	422083
9	2	2	2	2	1	32	193	12639	12800	161	12832	304266
10	1	1	2	1	4	236	1568	22768	24100	1331	24336	931172
11	2	1	2	1	3	255	1277	16978	18000	1021	18255	685078
12	1	2	2	1	3	212	1060	20152	21000	848	21212	662360

Table 3 Details of sample problem 5

B_{klt}	Q_{ilt}	Def_{ilt}	Sc_{ilt}	Co_{ilt}	TCo_{ilt}	X_{ijlt}	Y_{jklt}
B_{111}=130	Q_{111}=5699	Def_{111}=57	Sc_{111}=6	Co_{111}=5642	Tco_{111}=5693	X_{1111}=993	Y_{1111}=3000
B_{112}=0	Q_{112}=5700	Def_{112}=114	Sc_{112}=23	Co_{111}=5586	Tco_{112}=5677	X_{1112}=177	Y_{1112}=2000
B_{211}=0	Q_{211}=4541	Def_{211}=113	Sc_{211}=34	Co_{112}=4427	Tco_{211}=4507	X_{1211}=4700	Y_{1211}=2500
B_{212}=0	Q_{212}=5347	Def_{212}=161	Sc_{212}=24	Co_{211}=5187	Tco_{212}=5323	X_{1212}=5500	Y_{1212}=3500
B_{311}=0						X_{2111}=4507	Y_{1311}=0
B_{312}=227						X_{2112}=5323	Y_{1312}=0
						X_{2211}=0	Y_{2111}=0
						X_{2212}=0	Y_{2112}=0
							Y_{2211}=0
							Y_{2212}=500
							Y_{2311}=4700
							Y_{2312}=5000
$\sum B$=357	$\sum Q$=21287	$\sum Def$=445	$\sum Sc$=87	$\sum Co$=20842	$\sum Tco$=21200	$\sum X$=21200	$\sum Y$=21200

Table 4 Details of sample problem 10

B_{klt}	Q_{ilt}	Def_{ilt}	Sc_{ilt}	Co_{ilt}	TCo_{ilt}	X_{ijlt}	Y_{jklt}
$B_{111}=362$	$Q_{111}=5740$	$Def_{111}=402$	$Sc_{111}=40$	$Co_{111}=5338$	$TCo_{111}=5700$	$X_{1111}=5700$	$Y_{1111}=3000$
$B_{112}=278$	$Q_{112}=6193$	$Def_{112}=371$	$Sc_{112}=93$	$Co_{112}=5821$	$TCo_{112}=6100$	$X_{1112}=6100$	$Y_{1112}=3500$
$B_{113}=0$	$Q_{113}=5980$	$Def_{113}=538$	$Sc_{113}=80$	$Co_{113}=5443$	$TCo_{113}=5900$	$X_{1113}=5900$	$Y_{1113}=2500$
$B_{114}=234$	$Q_{114}=6423$	$Def_{114}=257$	$Sc_{114}=23$	$Co_{114}=6166$	$TCo_{114}=6400$	$X_{1114}=6400$	$Y_{1114}=3300$
$B_{211}=0$							$Y_{1211}=2700$
$B_{212}=0$							$Y_{1212}=2600$
$B_{213}=457$							$Y_{1213}=3400$
$B_{214}=0$							$Y_{1214}=3100$
$\sum B=1331$	$\sum Q=24336$	$\sum Def=1568$	$\sum Sc=236$	$\sum Co=22768$	$\sum TCo=24100$	$\sum X=24100$	$\sum Y=24100$

For a more detailed explanation, the details of sample problem 5 with dimensions *I=2, J=2, K=3, L=1, T=2* and sample problem 10 with dimensions *I=1, J=1, K=2, L=1, T=4* are illustrated in Tables 3 and 4. The first column shows the amount of shortages in retailers, for example in sample problem 5, $B_{111}=130$ means that the shortages of retailer 1 in period 1 for kind of product 1 are 130 products. The second column shows the economic production quantity, for instance, $Q_{112}=5700$ means the most appropriate amount of production of product 1 in manufacturer 1 in second period are 5700, and similarly for columns 3, 4, 5 and 6. Finally, columns 7 and 8 show the amounts of products that must be transferred from manufacturers to distributors (X_{ijlt}), and from distributors to retailers (Y_{jklt}).

From our results, it can be ascertained that in order to reach the best optimal value of total cost (Z_{min}) of the supply chain, the output of this model specifies every single manufacturer, distributor and retailer in any particular time period that must be active and the amount of goods that needs to be traded. Finally the model is able to determine the amount of the shortage in retailers and identify the retailers concerned.

■5.0 CONCLUSION

In this research, a solvable mathematical model using linear programming software is proposed for the optimization of costs of the supply chain of defective goods with special attention to just-in-time logistics. The proposed model helps to optimize costs such as, production, maintenance, shipping, reworking on the defective goods, scrap products and shortage in retailers due to the production of defective goods. The model also determines which manufacturer and distributor should be active during a specified period of production. Finally, the model also shows the amount of goods that must be exchanged in order to optimize the costs. The model is applicable for all producers that are encountering with problem of producing of defective goods.

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References

[1] Sana, S. S. 2011. A Production-inventory Model of Imperfect Quality Products in a Three-Layer Supply Chain. *Decision Support Systems.* 50: 539–547.

[2] Kannan, R. V. and C. T. Keah. 2005. Just in Time, Total Quality Management, and Supply Chain Management: Understanding Their Linkages and Impact on Business Performance. *International Journal of Management Science*. 33: 153–162.

[3] Flapper, P. S. D. and T. H. Ruud. 2004. Logistic Planning of Rework with Deteriorating Work-in-Process. *International Journal of Production Economics*. 88: 51–59.

[4] Iroglu, A. and O. Gultekin. 2007. An Economic Order Quantity Model with Defective Items and Shortages. *International Journal Of Production Economics*. 106: 544–549.

[5] Chung, K. J., H. Chao-Chun and L. Shy-Der. 2009. A Two-warehouse Inventory Model with Imperfect Quality Production Processes. *Computers & Industrial Engineering*. 56: 193–197.

[6] Wahab, M. I. M. and M. Y. Jaber. 2010. Economic Order Quantity Model for Items with Imperfect Quality , Different Holding Costs, and Learning Effects: A Note. *Computers & Industrial Engineering*. 58: 185–190.

[7] Salameh, M. K., and M. Y. Jaber. 2000. Economic Production Quantity Model for Items with Imperfect Quality. *International Journal of Production Economics*. 64: 59–64.

[8] Mondal, B., A. K. Bhunia and M. Maiti. 2009. Inventory Models for Defective Items Incorporating Marketing Decisions with Variable Production Cost. *Applied Mathematical Modeling.* 33: 2845–2852.

[9] Hong, J., S. H. Xu and J. C. Hayya. 1993. Process Quality Improvement and Setup Reduction in Dynamic Lot-Sizing. *International Journal of Production Research*. 31: 2693–2708.

[10] Sarker, B. R., A. M. M. Jamal and S. Mondal. 2008. Optimal Batch Sizing in a Multi-Stage Production System with Rework Consideration. *European Journal Operational Research*. 184: 915–929.

[11] Guo, R., and T. Qi. 2008. An Optimized Supply Chain Planning Model for Manufacture Company Based on JIT. *International Journal of Business and Management.* 3: 129–133.

[12] Farahani, R. and E. Mahsa. 2008. A Genetic Algorithm To Optimize the Total Cost and Service Level for JIT Distribution in a Supply Chain. *International Journal of Production Economics.* 111: 229–243