ISSN: 0971-1260
Vol-22-Issue-16-August-2019

A Dual Channel Coordinated Supply Chain With SSMD Policy and Shortages

Ruchi Chauhan, DeepikaKhurana, ArunavaMajumder*,Varun Kumar

Department of Mathematics, School of Chemical Engineering and Physical Sciences, Lovely Professional University, Phagwara 144411, Punjab, India.

*Corresponding author: ArunavaMajumder,Phone: +91 9883179340, Email: am.arunavamajumder@gmail.com

Abstract

Recently, industries are more concerned about more than one supply channel as dependency on only one channel may not be profitable in modern business environment. In this paper, a dual channel supply chain management is considered with single-manufacturer and single-retailer. The industry manager incorporates two different strategies as traditional retail channel and online channel. In traditional channel, manufacturer uses single-setup multiple-delivery policy to transport items to the retailer whereas, in online channel, only customized product is sold directly to the customers. The online channel follows make-to-order policy which considers shortages. The mathematical model is constructed to maximize the profit of the centralized chain. The model is analysed with numerical experiments and graphical analysis.

Keywords: Supply chain management; dual channel supply chain; SSMD policy; make-to-order policy; shortages

1. Introduction

This paper is focused on channel coordination. If in business, manufacturer and retailer collaborate or work jointly for making economic policies then profit can be done in supply chain management as it is logistic functioning in the network involved in supply chain model. The advent of the e-commerce has significantly influenced the purchasing custom of the people which emanates in increasing the number of manufacturer's redesigning, their selling, and supply distribution. With the pace of IT and advancement in manufacturing system, manufacturer is now able to provide made-to-order product to the customer directly, because of which the competition between the traditional and online channels has been increased. Service levels of both channels that is delivery lead time in case of online channel and availability of the

ISSN: 0971-1260
Vol-22-Issue-16-August-2019

product in the retailer's channel do affect the customers. Introduction of made-to-order products by online and improvement in retail services in case of centralized system increased the profit of the system.

Kevin Chiang and Monahan [1] and Andy Tsayand Agrawal [2] developed a supply chain model with direct channel where the efficiency of direct channel was measured compared to indirect channel and gives us ways to adjust relationship between the manufacturer and reseller like paying reseller's commission for diverting the customers to direct channel. Another part of research was related with competition between the two channels of the manufacturer. Battling between the two, clearly depends upon the service levels of both channels, customer's choice, and shopping experience of the customer as indicated by Chen et al. [3]. Further, Yan and Pei [4] proposed that the ameliorated retail service effectively alleviates the channel's efficiency which automatically ameliorates the supply chain performance. By the same aspect, Dan et al. [5] suggested that overall profit of the system and channel's efficiency in dual supply can be improved effectively by planning the pricing strategies of the manufacturer and the traditional channel. To increase the customer's, introduction of online channel was needed [6]. The work of this paper is also related with the concept of Xia and Rajagopalan [7] which states that product variety and lead time plays a judicious role in the competition, after studying the standardization and customization of the two firms.

Shao [8] found that in case of the centralized decision-making situations, make-to-order dominates the dual channel's strategy in comparison with single channel and increases the profit of the system. In the study of manufacturer–retailer supply chain model, Li et al.[9] analyzed that the manufacturer's decision on offering the customized product through online channel depends on the acceptance level of the customer's and their shopping experience. Moreover, there is no decrease in the price of the standard product with the introduction of online channel price. Supply chain management basically manages a network which relates the customer with all other parties involved in the network as given by Sadraoui et al. [10] and for all this an integrated system is demanded. Supply chain management gives us a way that how traditional purchasing and advanced technology can be merged in modern era [11].

ISSN: 0971-1260
Vol-22-Issue-16-August-2019

Further he quoted that supply chain management is basically the synonym of purchasing and supply activities of the manufacturer to satisfy the demand of the customer. Initially, the mathematical model of this concept was coined by Goyal [12] whereas later different assumptions like-number of lot size and manufacturer produces as much as integer multiple of retailer's demand were added in the model by Banerjee [13] and Goyal [14]. According to Schiraldi et al. [15], Economic production quantity (EPQ) is optimal quantity produced by the manufacturer so that demand of the customer and cost of the manufacturer is managed. Chu[16] and Habib et al. [17] mentioned that shortage of customized product generally results into two situations, either the customer will wait for the product that should be backordered or impatient customer shifts to other shop and manufacturer will lose the sale. A significant number of papers focusing on the supply chain with multi-delivery policy and multi-retailer under shortage appeared in the literature in recent days [18, 19, 20].

2. Mathematical model

The model is developed based on the following assumptions and notation.

Assumption

1. Dual channel supply chain is considered containing a traditional retail channel and an online channel. Through online channel,vendor directly contacts to the buyer.
2. In retail channel, vendor uses multiple delivery policy (SSMD) [18] to transport product to the buyer and in online channel vendor uses make-to-order policy for manufacturing and delivering items.
3. Customers order only customized items through online channel.
4. There is a fixed cost for each individual customized feature added to the core product.
5. There is a fixed same cost for each individual core product for both retail and online channel.
6. No lead time is assumed for transporting goods from vendor to buyer or vendor to customer in traditional and online channel, respectively.

ISSN: 0971-1260
Vol-22-Issue-16-August-2019

Notation

P_t Production rate per unit time for traditional channel

D_t Average demand for traditional channel

S_t Set up cost of manufacturer for traditional channel per setup

Q_t Quantity ordered by the buyer for traditional channel

r_v Holding cost of the vendor per unit per unit time per unit item

C_{v_t} Manufacturing cost per unit for traditional channel

C_b Purchase cost per unit for retailer

m Number of lots delivered from vendor to the buyer in one production cycle

A_t Ordering cost of buyer for traditional channel

r_b Holding cost of the buyer

Sp_t Selling prize for traditional channel

p_{c_i}Selling price of each customized product

P_cProduction rate per unit time for online channel

D_c Average Demand per unit time for online channel

S_c Setup cost of manufacturer for online channel

C_s Shortage cost for online channel

Q_c Quantity ordered by customer for online channel

Q_s Shortage quantity in case of online channel

v_{c_i} Production cost of each i th customized feature

φ_{c_i}Fraction of core product which are utilized to make the customized product i

The supplychain is composed of two channels traditional and online.

Traditional channel

The total profit for the buyer can be expressed as

$$PR_b(Q_t) = \text{Total Revenue} - (\text{Ordering Cost} + \text{Holding Cost} + \text{Purchase Cost})$$

ISSN: 0971-1260
Vol-22-Issue-16-August-2019

The revenue can be presented as $p_t D_t$ and the total cost of buyer in classical EOQ model without shortages and lead time can be shown as

$$T = \frac{A_t D_t}{Q_t} + \frac{r_b Q_t}{2} + c_b D_t$$

Based on this, the profit of the buyer becomes

$$PR_b(Q_t) = p_t D_t - \frac{A_t D_t}{Q_t} - \frac{r_b Q_t}{2} - c_b D_t \tag{1}$$

The total profit for the vendor is

$$PRV_t(Q_t, m) = \text{Total Revenue} - (\text{Setup Cost} + \text{Holding Cost} + \text{Manufacturing Cost})$$

The vendor follows SSMD policy. Thus, the average inventory calculation shown in Figure 1 is obtained by $\frac{Q_t}{2}\left[m\left(1 - \frac{D_t}{P_t}\right) - 1 + \frac{2D_t}{P_t}\right]$ (Sarkar and Majumder, 2013).

Therefore, the holding cost of vendor becomes $\frac{r_v Q_t}{2}\left[m\left(1 - \frac{D_t}{P_t}\right) - 1 + \frac{2D_t}{P_t}\right]$ and the total cost of the vendor becomes $\frac{S_t D_t}{m Q_t} + \frac{r_v Q_t}{2}\left[m\left(1 - \frac{D_t}{P_t}\right) - 1 + \frac{2D_t}{P_t}\right] + C_{v_t} D_t$ whereas, the revenue is $C_b D_t$.

According to the above inference, the total profit of the vendor becomes

$$PRV_t(Q_t, m) = C_b D_t - \frac{S_t D_t}{m Q_t} - \frac{r_v Q_t}{2}\left[m\left(1 - \frac{D_t}{P_t}\right) - 1 + \frac{2D_t}{P_t}\right] - C_{v_t} D_t \ (2)$$

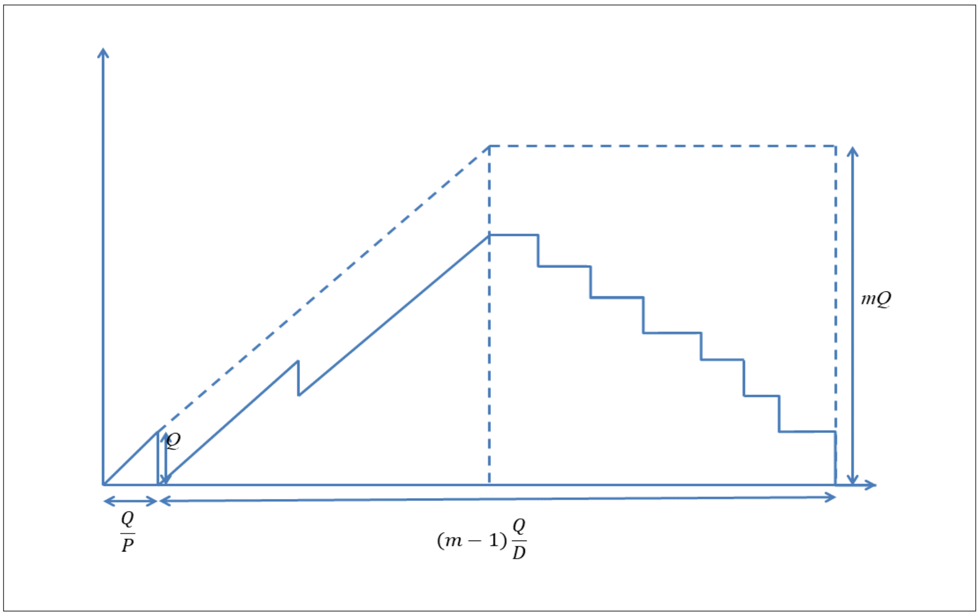

Figure 1: Inventory position of vendor for retail channel

ISSN: 0971-1260
Vol-22-Issue-16-August-2019

Online channel

In this channel, vendor directly communicates to the customers without having any intermediate party. The delivery policy adopted by the buyer is make-to-order. This article considers economic production model with shortages which is illustrated in Figure 2. As, each customization is composed of a production cost v_{c_i}, total production cost of the vendor will be $\sum_{i=1}^{n} v_{c_i} \varphi_{c_i} D_c$. Now, p_{c_i} is the selling price of each customized item *i*. therefore, total revenue will be $\sum_{i=1}^{n} p_{c_i} D_c$.

The total profit for the vendor is

$$PRV_c(Q_c, Q_s) = \text{Total Revenue} - (\text{Setup Cost} + \text{Holding Cost} + \text{Shorage cost} + \text{Production Cost})$$

The vendor's profit becomes, after simplification,

$$PRV_c(Q_c, Q_s) = \sum_{i=1}^{n} p_{c_i} D_c - \frac{S_c D_c}{Q_c} - \frac{1}{2Q_c}\left(\frac{P_c}{P_c - D_c}\right)\left[r_v\left\{\left(\frac{P_c - D_c}{P_c}\right)Q_c - Q_s\right\}^2 + {Q_s}^2 C_s\right] - \sum_{i=1}^{n} v_{c_i} \varphi_{c_i} D_c \quad (3)$$

Supply chain coordination

The supply chain coordination can be achieved by implementing the centralized decision for both vendor and buyer. Therefore, the joint profit for traditional and online channel is

$$JPR(Q_t, Q_c, Q_s, m) = PR_b(Q_t) + PRV_t(Q_t, m) + PRV_c(Q_c, Q_s)$$

$$= p_t D_t - \frac{A_t D_t}{Q_t} - \frac{r_b Q_t}{2} - c_b D_t + C_b D_t - \frac{S_t D_t}{m Q_t} - \frac{r_v Q_t}{2}\left[m\left(1 - \frac{D_t}{P_t}\right) - 1 + \frac{2D_t}{P_t}\right] - C_{v_t} D_t + \sum_{i=1}^{n} p_{c_i} D_c - \frac{S_c D_c}{Q_c} - \frac{1}{2Q_c}\left(\frac{P_c}{P_c - D_c}\right)\left[r_v\left\{\left(\frac{P_c - D_c}{P_c}\right)Q_c - Q_s\right\}^2 + {Q_s}^2 C_s\right] - \sum_{i=1}^{n} v_{c_i} \varphi_{c_i} D_c \quad (4)$$

ISSN: 0971-1260
Vol-22-Issue-16-August-2019

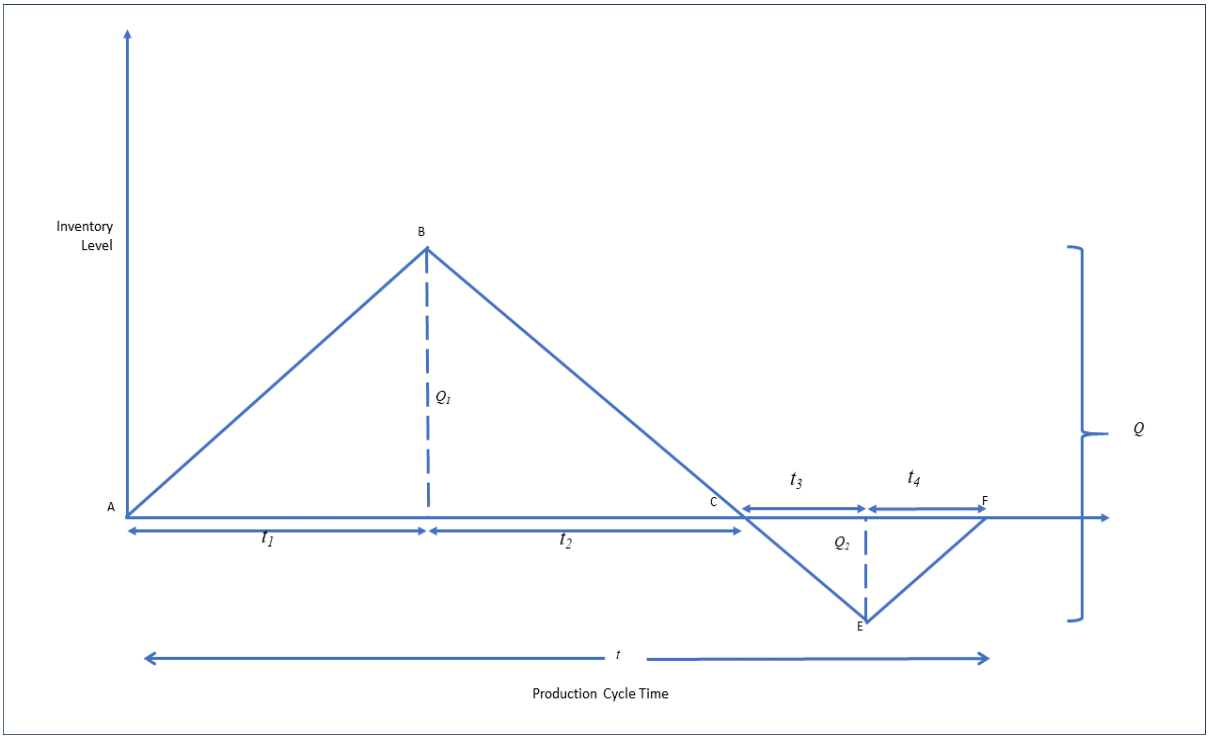

Figure 2: Inventory position of vendor for online channel

Theproblem becomes

Max $JPR(Q_t, Q_c, Q_s, m)$=$p_t D_t - \frac{A_t D_t}{Q_t} - \frac{r_b Q_t}{2} - C_b D_t + C_b D_t - \frac{S_t D_t}{m Q_t} - \frac{r_v Q_t}{2}\left[m\left(1 - \frac{D_t}{P_t}\right) - 1 +\right.$

2DtPt−CvtDt+i=1npciDc−ScDcQc−12QcPcPc−DcrvPc−DcPcQc
−Qs2+Qs2Cs −i=1nvciφciDc

Solution methodology

The solution is obtained by taking the partial derivatives of $JPR(Q_t, Q_c, Q_s, m)$ with respect to Q_t, Q_c and Q_s and equating to zero, we obtain the decision variables.

$$\frac{\partial JPR\,(Q_t, Q_c, Q_s, m)}{\partial Q_t} = \frac{A_t D_t}{Q_t^2} - \frac{r_b}{2} + \frac{S_t D_t}{m Q_t^2} - \frac{r_v}{2}\left[m\left(1 - \frac{D_t}{P_t}\right) - 1 + \frac{2D_t}{P_t}\right] \tag{5}$$

$$\frac{\partial JPR(Q_t, Q_c, Q_s, m)}{\partial Q_c} = \frac{S_c D_C}{Q_c^2} - \frac{r_v}{2}\left(\frac{P_c}{P_c - D_c}\right) + \frac{Q_s^2 C_s}{2Q_c^2}\left(\frac{P_c}{P_c - D_c}\right) + 2\left(\frac{P_c}{P_c - D_c}\right)^2 - \frac{2Q_s}{Q_c}\left(\frac{P_c}{P_c - D_c}\right) - \left[\left(\frac{P_c - D_C}{P_c}\right) - \frac{Q_s}{Q_c}\right]^2 \tag{6}$$

$$\frac{\partial JPR\,(Q_t, Q_c, Q_s, m)}{\partial Q_s} = r_v - \frac{2r_v Q_s}{Q_c}\left(\frac{P_c}{P_c - D_c}\right) - \frac{Q_s C_s}{Q_c}\left(\frac{P_c}{P_c - D_c}\right) \tag{7}$$

ISSN: 0971-1260
Vol-22-Issue-16-August-2019

The values of Q_t, Q_c and Q_s are obtained by equating Eqs. (5)-(7) to zero as

$\frac{\partial JPR\,(Q_t,Q_c,Q_s,m)}{\partial Q_t} = 0$implies

$$Q_t^* = \left[\frac{2P_tD_t(mA_t+S_t)}{(r_b-1)P_t+r_vm(P_t-D_t)+2D_t}\right]^{\frac{1}{2}} \quad (8)$$

Which is a closed form solution itself.Now,

$\frac{\partial JPR\,(Q_t,Q_c,Q_s,m)}{\partial Q_s} = 0$which is not a closed form. Because, $Q_s = f(Q_c)$. Again, $\frac{\partial JPR\,(Q_t,Q_c,Q_s,m)}{\partial Q_c} =$ 0implies $Q_c = f(Q_s)$.

Thus, simplifying these two forms, we have the closed form expression of Q_s and$Q_s$as

$$Q_s^* = \left(\frac{r_v}{2r_v+C_s}\right)\left(\frac{P_c-D_c}{P_c}\right)\left\{\frac{S_cD_c}{\left(\frac{P_c-D_c}{P_c}\right)^2\left(\frac{r_v}{2r_v+C_s}\right)^2\left[\left(\frac{2r_v+C_s}{r_v}\right)^2-\frac{C_sP_c}{2(P_c-D_c)}+1\right]+\left(\frac{P_c}{P_c-D_c}\right)^2\left[\frac{r_v(P_c-D_c)}{2P_c}-2\right]}\right\}^{\frac{1}{2}} \quad (9)$$

$$Q_c^* = \left\{\frac{S_cD_c}{\left(\frac{P_c-D_c}{P_c}\right)^2\left(\frac{r_v}{2r_v+C_s}\right)^2\left[\left(\frac{2r_v+C_s}{r_v}\right)^2-\frac{C_sP_c}{2(P_c-D_c)}+1\right]+\left(\frac{P_c}{P_c-D_c}\right)^2\left[\frac{r_v(P_c-D_c)}{2P_c}-2\right]}\right\}^{\frac{1}{2}} \quad (10)$$

Now, as m, the number of shipments is a discrete decision variable, thus, discrete optimization technique will be used which depends on the following condition

$$JPR(m^*-1) \leq JPR(m^*) \geq JPR(m^*+1)$$

If the above condition is satisfied, then we say, for some $m = m^*$, the maximum total profit is obtained foroptimal Q_t^*, Q_s^*, and Q_c^*.

3. Numerical experiments

We use the following data values described in Table 1.

Table 1: Data set of parameters

P_t	5000	p_{c_3}	300
D_t	2000	P_c	5000
S_t	2000	D_c	250
r_v	40	S_c	2000
C_{v_t}	30	C_s	30
C_b	50	v_{c_1}	60
A_t	200	v_{c_2}	120
r_b	20	v_{c_3}	200
Sp_t	75	φ_{c_1}	0.3
p_{c_1}	100	φ_{c_2}	0.3
p_{c_2}	200	φ_{c_3}	0.3

ISSN: 0971-1260
Vol-22-Issue-16-August-2019

Table 2: Optimal results				
m	Q_t^*	Q_c^*	Q_s^*	*JPR*
1	448.23	170.47	58.89	249049.64
2	**376.28**	**170.47**	**58.89**	**249267.41**
3	336.58	170.47	58.89	247647.81
4	310.99	170.47	58.89	245638.70

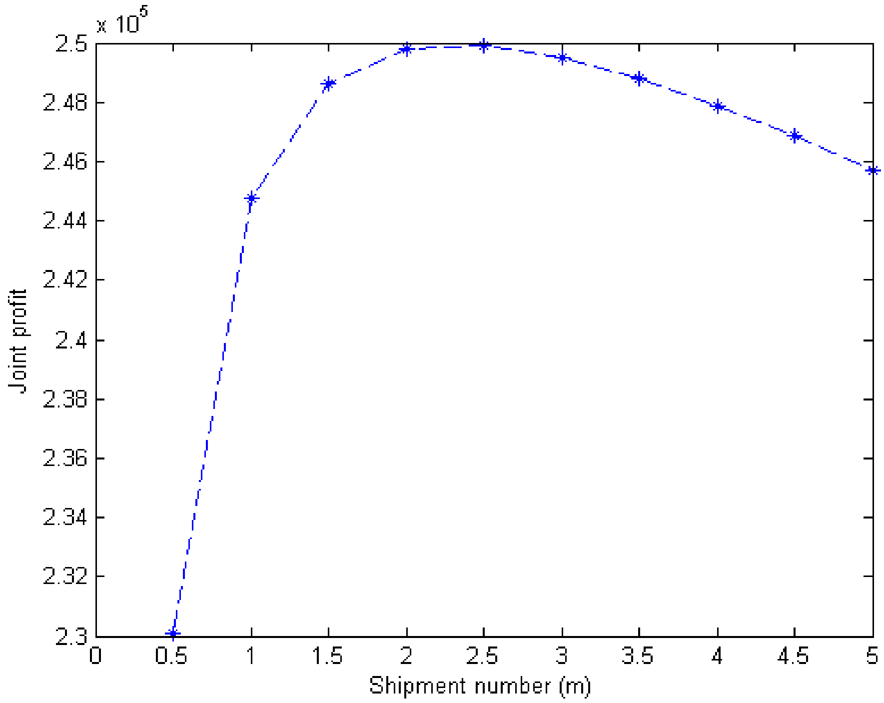

Figure 3: Graphical representation of *m* vs. JPR

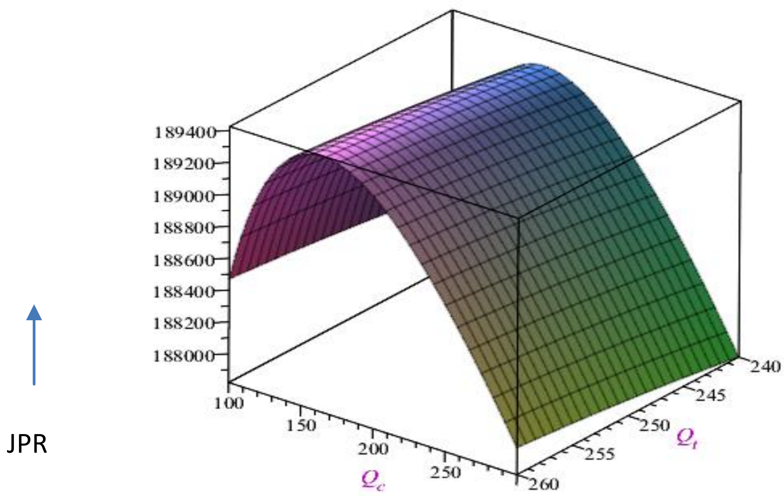

Figure 4: Graphical representation of *JPR* vs. Q_c and Q_r

ISSN: 0971-1260
Vol-22-Issue-16-August-2019

Discussion

Table 1 presents the data for all parameters for numerical validation of the model. Table 2 gives the optimal values of all decision variables. It is observed that maximum profit is 249267.41 which is achieved for m=2. Moreover, the values of other decision variables like optimal order quantity of traditional, online, and optimal shortages are obtained as 376.28, 170.47, and 58.89, respectively. Figure 3 presents the changes in total cost with shipments and Figure 4 shows the changes in total cost with the changes in lot-size for traditional and online channels through a 3D plot.

4. Conclusions

This article developed a dual chain supply chain model containing a traditional vendor-buyer channel and an online channel. In traditional system, the supply chain employs a multi-delivery policy with single-vendor and single-buyer. In online channel, there is no intermediate party between vendor and customer. Vendor adopted make-to-order policy to deliver merchandise to the customer. This study analysed the effect employing of dual channel in the centralised supply chain management. As, in online channel, only ordersfor customised products are entertained by the vendor, thus this paper obtained the managerial decisions for every customization incorporated to the core product. Finally, four individual decisions were achieved as order quantity (retail channel), number of lots, and order quantity (online channel), shortages (online channel) in centralized manner.

Conflict of interest: Authors do not have any conflict of interest with anyone.

References

[1]W. Kevin Chiang, G.E. Monahan, “Managing inventories in a two-echelon dual-channel supply chain”, Eur. J. Oper.Res.,vol. 162, pp. 325–341, 2005.

[2] A. A. Tsay, N. Agrawal, “Channel conflict and coordination in the E-commerce age”, Prod. Oper.Manage.,vol. 13, pp. 93–110, 2004.

ISSN: 0971-1260
Vol-22-Issue-16-August-2019

[3] K. Y. Chen, M. Kaya, Ö. Özer, “Dual sales channel management with service competition”, Manufact. Serv. Oper. Manage., vol. 10,pp. 654–675, 2008.

[4] R. Yan, Z. Pei, “Retail services and firm profit in a dual-channel market”, J. Retail.Consum.Serv., vol. 16, pp. 306–314, 2009.

[5] B. Dan, G. Xu, C. Liu, “Pricing policies in a dual-channel supply chain with retail services”, Int. J. Prod. Econ., vol. 139, pp. 312–320, 2012.

[6] N. M. Modak, P. Kelle, “Managing a dual-channel supply chain under price and delivery-time dependent stochastic demand”, Euro. J. Oper. Res., vol. 272(1), pp. 147-161, 2019.

[7] N. Xia, S. Rajagopalan, “Standard vs. custom products: variety, lead time, and price competition”, Mark. Sci., vol. 28, pp. 887–900, 2009.

[8] X.F. Shao, “Integrated product and channel decision in mass customization”, IEEE Trans. Eng. Manage., vol. 60, pp. 30–45, 2013.

[9] G. Li, F. Huang, T.C.E. Cheng, P. Ji, “Competition between manufacturer’s online customization channel and conventional retailer”, IEEE Trans. Eng. Manage, vol. 62, pp. 150–157, 2015.

[10] T.Sadraoui, N.Mchirgui, “Supply chain Management optimization within

informationsystem development”, Int. J. Econ. Fin. Manag., vol. 2(2), pp. 59-71, 2014.

[11] K. C. Tan, “A framework of supply chain management literature”, Euro. J. Pur. Supp. Manag., vol. 7, pp. 39-48, 2001.

[12] S. K. Goyal, “An integrated inventory model for a single supplier-single customer problem”. Int. J. Prod. Res., vol. 15(1), pp. 107–111, 1976.

[13] A. Banerjee, “Joint economic-lot-size model for purchaser and vendor”. Decis.Sci.,vol. 17(3),pp. 292–311,1986.

[14] S. K. Goyal, “A joint economic-lot-size model for purchaser and vendor: a comment.” Decis. Sci., vol. 19(1), pp. 236–241,1988.

[15]M. Schiraldi, L. Baciarello, M. D'Avino, R. Onori, “Lot Sizing Heuristics Performance”, Int. J. Eng. Bus. Mannag., vol. 5(6), pp. 1-10, 2013.

[16] P. Chu, “On inventory models with partial backlogging”, J. Stat. Manag.Sys., vol. 4(1), pp. 41-52, 2001.

[17]N. A. Habib, S. Ghosh, “Inventory optimization for combined stock-dependent and stochastic demand”, Amer. J. Indus. Eng., vol. 5(1), pp. 1-11, 2018.

ISSN: 0971-1260
Vol-22-Issue-16-August-2019

[18] B. Sarkar, A. Majumder, “Integrated vendor-buyer supply chain model with vendor’s setup cost reduction”. Appl. Math. Comput, vol. 224, pp. 362–371, 2013.

[19] A. Majumder, B. Sarkar, and C. K. Jaggi, “A multi-retailer supply chain model with backorder and variable production cost”, RAIRO- Oper.Res., vol. 52(3), pp. 943-954, 2018.

[20] B. Sarkar, A. Majumder, M. Sarkar, N. Kim, M. Ullah, “Effects of variable production rate on quality of products in a single-vendor multi-buyer supply chain management”, Int.J.Advan.Manu.Tech., vol. 99, pp.567-581, 2018.