Building a Supply Chain Flexibility Model for Fast Fashion Industry

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Abstract

Supply chain flexibility refers to the capability of a supply chain in response to diversified customer demands and market changes. Since most of previous works regarding flexibility focus mainly on production level and intra organizational environment rather than take into account multiple aspects of flexibility in the entire supply chain. This study proposes an integrated supply chain flexibility model to incorporate supply flexibility, product mix flexibility, distribution flexibility and responsiveness flexibility in different phases of the supply chain. Also provided is a case example of the fast fashion industry to illustrate the applicability and effectiveness of the proposed model. The research result and findings can be used to guide the development of a supply chain flexibility model suitable for meeting the needs of various industries and ultimately attaining better profits.

Keywords: Supply chain flexibility, Supply flexibility, Product mix flexibility, Distribution flexibility, Responsiveness flexibility, Fast fashion industry

1. Introduction

Supply chain flexibility refers to the promptness of a supply chain in response to customer demands as well as to the degree a supply chain can adjust its speed, destinations, and volume to deal with various market changes (Duclos, Vokurka, & Lummus, 2003). As global competition rapidly intensifying and shifting to the supply chain level, flexibility issues related to supply chain modeling have become increasingly important and attracted growing attentions from both academic and business sectors (Das & Abdel-Malek, 2003; Chuu, 2011). Although the concept and issues of supply chain flexibility have been addressed by several studies in the literature, different perspectives and goals were taken in the identification of flexibility dimensions as well as in the building of flexibility models. Moon, Yi, & Nagi (2012) consider supply chain flexibility as the capability of an organization to respond to internal and external changes in order to gain or maintain a competitive advantage. They indicate that most research works on flexibility concern only flexibility of specific types and domains such as on intra organizational flexibility and manufacturing systems. Flexibility studies from the entire supply chain perspective have far been limited. On the other hand, identified types of supply chain flexibility in various research models and applications include supply flexibility, product flexibility, market flexibility, distribution flexibility, information system flexibility, responsive flexibility, etc (Kumar, Fantazy, Kumar, & Boyle, 2006; Duclos, Vokurka, & Lummus, 2003; Moon, Yi, & Nagi, 2012) . Besides, the objectives of formulating a supply chain flexibility model range from evaluating the impacts of adopting flexibility measures in the supply chain, to assisting in supplier selection, or leveraging responsiveness and quality levels. To the best of our knowledge, most supply chain flexibility relevant studies belong to qualitative research, very few are quantitative research, and even lesser are mathematical models for supporting optimal decision making (Schutz & Tomasgard, 2011; Gosling, Purvis, & Naim, 2010; Ramizani, Bashiri, & Tavakkoli-Moghaddam, 2013). For filling the research gap, the goal of this paper is to propose an integrated supply chain flexibility model that incorporates supply flexibility, product mix flexibility, distribution flexibility, and responsiveness flexibility into the supply chain network design for better fitting the characteristics of the fast fashion industry and for achieving the objective of profit optimization. A case example will be used to demonstrate the feasibility and effectiveness of the proposed supply chain flexibility model in terms of making better economic performance. The rest of this paper is organized as follows. Section 2 reviews the relevant literature and outlines the theoretical background. Section 3 presents a supply chain flexibility model focusing on the fast fashion industry. In Section 4, a brief example is provided to illustrate the applicability of the proposed model. Section 5 is the conclusion of this study.

2. Literature Review

From reviewing the literature related to supply chain flexibility, it can be noted that the scope and components of flexibility adopted in the supply chain model are diversified (Das, 2011; Gong, 2008; Duclos, Vokurka, & Lummus, 2003; Moon, Yi, & Nagi, 2012; Gosling, Purvis, & Naim, 2010; Schutz & Tomasgard , 2011; Zhang & Tseng, 2009; Shen, 2006; Chuu, 2011). Vickery, Calantone & Droge (1999) stated that supply chain flexibility should be examined from an integrative, customer-oriented perspective, and then identified five supply chain flexibilities including product flexibility, volume flexibility, new product flexibility, distribution flexibility, and responsiveness flexibility. Kumar & Linguri (2006) also defined five supply chain flexibilities comprising product flexibility, sourcing flexibility, delivery flexibility, new product flexibility, and responsive flexibility. Arguing that the identification of flexibility dimensions should take into account the requirements of all supply chain participants and meet the customer demands, Duclos, Vokurka, & Lummus (2003) outlined six components of the supply chain flexibility as operations systems flexibility, market flexibility, logistics flexibility, supply flexibility, organizational flexibility, and information systems flexibility. Considering the need of supply chain participants in developing superior responsiveness to meet the challenges of a volatile marketplace, Moon, Yi, & Nagi (2012) identified four flexibility dimensions consisting of sourcing flexibility, operating system flexibility, distribution flexibility, and information system flexibility.

As for formulating supply chain flexibility as part of a mathematical model, Shen (2006) presented a profit-maximizing supply chain design model in which the demand-choice flexibility is used to help business companies in determining which customers to serve. Zhang & Tseng (2009) presented a mixed-integer programming model that integrates customer flexibility and manufacturing flexibility in supporting optimal order commitment decisions. The proposed model sets up various elements of customer flexibility in constraints, and specifies decision variables in product configuration, resource allocation and due date assignment categories with the aim to maximize manufacturer’s profit. Das (2011) developed a mixed-integer supply chain planning model to integrate capacity, product mix, customer service level and input supply flexibilities for addressing demand and supply uncertainty, as well as for improving market responsiveness. The research model took a view of the whole supply chain and specified the following measures: supplier flexibility for solving supply uncertainty; capacity flexibility for solving demand uncertainty; product mix flexibility for ensuring market responsiveness, and input supply flexibility and customer service level flexibility for improving the overall supply chain performance. Esmaeilikia (2013) developed a tactical supply chain planning model incorporating the supply flexibility, manufacturing flexibility, distribution/logistics flexibility options for a three-echelon supply chain environment. The model is used to solve problems with different scenarios that are characterized by having different number of identified flexibility options and various impact levels on the overall supply chain performance. Schutz & Tomasgard (2011) studied the effect of volume flexibility, delivery flexibility, operational decision flexibility and storage flexibility in operational supply chain planning under uncertain demand. Based on real-world data from the Norwegian meat industry, they adopted a two-stage stochastic programming model to the deterministic expected value problem and compared the annual operating results in order for discussing the impact of flexibility in the supply chain. A brief summary of the supply chain flexibility models proposed in the literature is illustrated in Table 1.

Table 1 A summary of supply chain flexibility models

Items / The studies	Flexibility dimensions	Objective function	Model	Network
Zhang & Tseng (2009)	Customer, Volume	Max profit	MILP	Non-supply chain network
Das (2011)	Capacity, Product mix, Customer service level, Supply	Max profit	MINLP	Three-echelon supply chain
Shen (2006)	Demand choice	Max profit	LP-relaxations	Two-echelon supply chain
Esmaeilikia (2013)	Supply, Delivery, Manufacturing	Min Cost	MINLP	Three-echelon supply chain
Schutz & Tomasgard (2011)	Volume, Delivery, Operational decision, Storage	Max profit	Two-stage stochastic programming model	Three-echelon supply chain

3. Model Formulation

In this section, an integrated supply chain flexibility model suitable for the fast fashion industry is presented with an illustrative example. The proposed model helps the planning, design, and evaluation of a flexible supply chain. Due to the specific characteristics of the fast fashion industry such as high mix low volume production, quick delivery to the target market, and quick response for customer needs, we integrate four related flexibilities in multiple phases of the supply chain to form the proposed supply chain flexibility model. These four supply chain flexibilities include supply flexibility, product mix flexibility, distribution flexibility, and responsiveness flexibility. The supply flexibility refers to the ability of reconfiguring the supply chain, and altering the supply of product in line with customer demand. The product mix flexibility refers to the ability of supply chain partners to produce a mixed set of related products economically and with no additional time to meet the market demand. The distribution flexibility refers to the company’s ability to control the movement and storage of materials, components, finished goods, and/or services under constantly evolving marketplace conditions. And then the responsive flexibility refers to the capability of supply chain partners to respond economically and with no additional time to the market changes for satisfying customer demands. The detail definitions of the supply flexibility and product mix flexibility, the distribution flexibility, and the distribution flexibility can be checked in the references of Das (2011), Esmaeilikia (2013), and Pishvaee, Farahani, & Dullaert (2010) respectively. If other industries own the similar characteristics, this proposed flexible model can be a suitable reference for building their flexible supply chain model.

3.1 Problem statement

The fast fashion industry is a case that needs to build a flexible supply chain for quickly responding to the changing and uncertain demand. According to the study by Zhelyazkov (2011), many researchers explain a fashion company's success with its efficient agile supply chain in four parts: procurement and production, product organization and design, product distribution, as well as sales and feedback. Concerning key characteristics of the agile supply chain, this study builds a supply chain flexibility model to cover four flexibility aspects, namely supply flexibility, product mix flexibility, distribution flexibility, and responsiveness flexibility. An illustrative example of such a supply chain network is described as follows:

The suppliers are divided into two areas, European, Asia and others. The company adopts nearing sourcing policy, so the selection priority is European, Asia and others. There are two kinds of products including the high uncertainty products for the innovative and fashionable products and the low uncertainty products for the basic products. The company produces the high uncertainty products in-house, but outsources low uncertainty products to external plants. In order to offer new products for their customer, the company's designers create 40000 new designs annually, from which 11000 are selected for production. Production is generally carried out in smaller batches in order to avoid oversupply and to facilitate rapid delivery of highly demanded styles to the customers. The company has nine distribution centers. The products are distributed to the European market by trucks, and to the rest of the world by air cargo. The company follows strict periodic delivery schedules, and the distribution has a constant lead time. The leadtimes of products distributed to the sale zones in the European region is 48 hours, and is 72 hours to other regions.

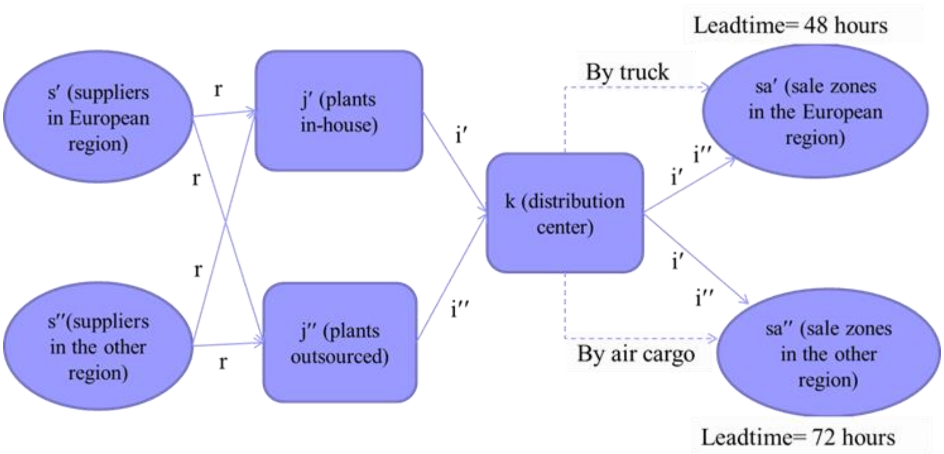

Figure 1 Supply chain network model

3.2 Model Formulation

Indices:

s'	supplier in the European region, $s' \in \{1, 2, ..., g\} = S1$
s''	supplier in the other region, $s'' \in \{g + 1, g + 2, \cdots, S\} = S2$
s	supplier (in the total supply pool), $s \in \{1, 2, \cdots, S\} = SA$; $SA = S1 \cup S2$
r	material supplied for production, $r \in \{1, 2, \cdots, R\}$
i'	high uncertainty product, $i' \in \{1, 2, . . . , a\} = IH$
i''	low uncertainty product, $i'' \in \{a+1, a+2, . . . , I\} = IL$
i	full product range, $i \in \{1,2,\cdots,I\}=IA$; $IA=IH \cup IL$
j'	in-house plant, $j \in \{1, 2, . . . , b\} = J1$
j''	plant outside, $j \in \{b+1, b+2, . . . , J\} = J2$
j	plant, $j \in \{1,2,\cdots,J\}=JA$; $JA=J1 \cup J2$
sz'	sale zone in the European region, $sz' \in \{1, 2, ..., h\} = SZ1$
sz''	sale zone in the other region, $sz'' \in \{h + 1, h + 2, \cdots, SZ\} = SZ2$
sz	sale zone (in the total sale zones), $sz \in \{1, 2, \cdots, SZ\} = SZA$; $SZA = SZ1 \cup SZ2$
k	distribution center (DC), $k \in \{1,2,\cdots,K\}$
tm	transportation mode, $tm \in \{1$:truck,2:air cargo$\}$

Parameters:

$SC_{rs'}$	supply capacity of supplier s′ to supply material r
$SC_{rs''}$	supply capacity of supplier s″ to supply material r
BN	a large number
$PC_{i'j'}$	production capacity of plant j′ for product i′
$PC_{i''j''}$	production capacity of plant j″ for product i″
NP_{nt}	new product type n to be produced in period t
NDP_{nt}	demand quantity of new product type n to be produced in period t
KC_{ik}	the distribution capacity of DC k for product i
$DR_{i'szt}$	demand quantity of product i′ from sale zone sz in period t
$DR_{i''szt}$	demand quantity of product i′′ from sale zone sz in period t
DR_{iszt}	demand quantity of product i from sale zone sz in period t
DT_{risj}	distribution time of material r for product i from supplier s to plant j
DT_{ijk}	distribution time of product i from plant j to DC k
DT_{iksz}	distribution time of product i from DC k to sale zone sz
CR_{rs}	cost of supplying material r by supplier s
$P_{isz't}$	unit price of product i to sale zone sz′ in period t
$P_{isz''t}$	unit price of product i to sale zone sz′′ in period t
$FS_{s'}$	fixed cost for taking material supply from supplier s′
$FS_{s''}$	fixed cost for taking material supply from supplier s″
$SU_{j'}$	fixed cost for setting up in-house plant j′
$SU_{j''}$	fixed cost for setting up outsourced plant j″
TC_{ijk}	cost of distributing product i produced in plant j to DC k
$TC1_{iksz}$	cost of distributing product i from DC k to sale zone sz by truck
$TC2_{iksz}$	cost of distributing product i from DC k to sale zone sz by air cargo
FD_k	fixed cost for opening DC k
CP_{ij}	cost to produce one unit of product i at plant j
EXDT1	expected distribution time for product i from DC k to sale zone sz′
EXDT2	expected distribution time for product i from DC k to sale zone sz′′

$EXDT_{riksz}$ expected total distribution time for product i from supplier r to sale zone sz

$DFDT_{sz}$ $= \{k | DT_{risj} + DT_{ijk} + DT_{iksz} \le EXDT_{riksz}\}$

ResLev the basic responsiveness level

AvgLev the average number of product types for the industrial level

MaxLev the maximum number of product types for the industrial level

α a multiple number which describes the unit price of products in the other areas higher than the unit price of products in the European region

Decision variable:

$SI_{rs't}$ equals 1, if supplier in the European region supplies material r in period t, otherwise 0

$SI_{rs''t}$ equals 1, if supplier in the other region supplies material r in period t, otherwise 0

$SR_{irs't}$ material r for product i supplied by supplier s′ in period t

$SR_{irs''t}$ material r for product i supplied by supplier s″ in period t

SR_{irst} material r for product i supplied by supplier s (s = s′ + s″) in period t

$SP1_{rt}$ 0, 1 variable to formulate if-then condition in the supply flexibility formulation

$SP2_{rt}$ 0, 1 variable to formulate if-then condition in the supply flexibility formulation

$I_{i'j't}$ equals 1 if product i′ produced by plant j′ in period t, otherwise 0

$I_{i''j''t}$ equals 1 if product i″ produced by plant j″ in period t, otherwise 0

KI_{kt} equals 1 if distribution center k is open in period t, otherwise 0

$JI_{j't}$ equals 1 if plant j′ is open in period t, otherwise 0

$JI_{j''t}$ equals 1 if plant j′′ is open in period t, otherwise 0

$I_{i't}$ equals 1 if product i′ produced in period t

$I_{i''t}$ equals 1 if product i′′ produced in period t

x_{ijkt} quantity of product i produced in plant j for sending to DC k in period t

y_{ikszt} quantity of product i to be distributed to sale zone sz from DC k in period t

$y_{i'kszt}$ quantity of product i′ to be distributed to sale zone sz from DC k in period t

$y_{i''kszt}$ quantity of product i′′ to be distributed to sale zone sz from DC k in period t

$y_{iksz't}$ quantity of product i to be distributed to sale zone sz′ from DC k in period t

$y_{iksz''t}$ quantity of product i to be distributed to sale zone sz″ from DC k in period t

y_{iktmt} quantity of product i to be distributed from DC k by transportation mode tm in period t

KI_{ikt} equals 1 if product i is distributed from DC k in period t, otherwise 0

$IT1_{iksz}$ equals 1 if product i from DC k to sale zone sz by truck, otherwise 0

$IT2_{iksz}$ equals 1 if product i from DC k to sale zone sz by air cargo, otherwise 0

Objective functions

Maximize profit=Total revenue – Supply cost – Production cost – Distribution cost (1)

$$\text{Total revenue} = \sum_{i=1}^{I}\sum_{t=1}^{T}\sum_{sz'=1}^{h} P_{isz't}\sum_{k=1}^{K} y_{iksz't} + \sum_{i=1}^{I}\sum_{t=1}^{T}\sum_{sz''=h+1}^{SZ} P_{isz''t}\sum_{k=1}^{K} y_{iksz''t} \quad (1.a)$$

$$\text{Supply cost} = \sum_{r=1}^{R}\sum_{s=1}^{S} CR_{rs}\sum_{i=1}^{I}\sum_{t=1}^{T} SR_{irst} + \sum_{s'\in S1} FS_{s'}\sum_{r=1}^{R}\sum_{t=1}^{T} SI_{rs't} + \sum_{s''\in S2} FS_{s''}\sum_{r=1}^{R}\sum_{t=1}^{T} SI_{rs''t} \quad (1.b)$$

$$\text{Production cost} = \sum_{i=1}^{I}\sum_{j=1}^{J} CP_{ij}\sum_{k=1}^{K}\sum_{t=1}^{T} x_{ijkt} + \sum_{j'\in J1} SU_{j'}\sum_{t=1}^{T} JI_{j't} + \sum_{j''\in J2} SU_{j''}\sum_{t=1}^{T} JI_{j''t} \quad (1.c)$$

Distribution cost$=\sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{k=1}^{K}TC_{ijk}\sum_{t=1}^{T}x_{ijkt}+$

$$\sum_{i=1}^{I}\sum_{k=1}^{K}\sum_{sz=1}^{h}(IT1_{iksz}\times TC1_{iksz})\sum_{t=1}^{T}y_{ikszt}+\sum_{i=1}^{I}\sum_{k=1}^{K}\sum_{sz=h+1}^{SZ}(IT2_{iksz}\times TC2_{iksz})\sum_{t=1}^{T}y_{ikszt}+\sum_{k=1}^{K}FD_k\sum_{t=1}^{T}KI_{kt} \quad (1.d)$$

Constraints:

(1)Supply Flexibility

$$SC_{rs'}\leq BN\times SI_{rs't} \quad \forall\, r,s'\in S1,t \quad (2)$$

$$\sum_{i=1}^{I}SR_{irs't}\leq SC_{rs'}\times SI_{rs't} \quad \forall\, r,s'\in S1,t \quad (3)$$

$$\sum_{i=1}^{I}SR_{irs''t}\leq SC_{rs''}\times SI_{rs''t} \quad \forall\, r,s''\in S2,t \quad (4)$$

$$\sum_{i=1}^{I}SR_{irst}=SR_{irs't}+SR_{irs''t} \quad \forall\, r,s'\in S1,s''\in S2,t \quad (5)$$

$$\sum_{s'\in S1}SC_{rs'}-\sum_{i=1}^{I}\sum_{s=1}^{S}SR_{irst}\leq SP1_{rt}BN \quad \forall\, r,t \quad (6)$$

$$SI_{rs''t}\leq(1-SP1_{rt})BN \quad \forall\, r,s''\in S1,t \quad (7)$$

$$\sum_{i=1}^{I}\sum_{s=1}^{S}SR_{irst}-\sum_{s'\in S1}SC_{rs'}\leq SP2_{rt}BN \quad \forall r,\, t \quad (8)$$

$$\sum_{s'\in S1}SC_{rs'}-\sum_{i=1}^{I}\sum_{s=1}^{S}SR_{irs't}\leq(1-SP2_{rt})BN \quad \forall r,t \quad (9)$$

(2)Product Mix Flexibility

$$\sum_{i'=1}^{A}y_{i'kszt}=I_{i't}DR_{i'szt} \quad \forall i',sz,t \quad (10)$$

$$\sum_{i''=1}^{A}y_{i''kszt}=I_{i''t}DR_{i''szt} \quad \forall i'',sz,t \quad (11)$$

$$DR_{i'szt}+DR_{i''szt}=DR_{iszt} \quad \forall i=i'+i'',sz,t \quad (12)$$

$$y_{i'kszt}+y_{i''kszt}=y_{ikszt} \quad \forall i=i'+i'',k,sz,t \quad (13)$$

$$I_{i't}+I_{i''t}\geq AvgLev \quad \forall i'\in IH,i''\in IL \quad (14)$$

$$I_{i't}+I_{i''t}\leq MaxLev \quad \forall i'\in IH,i''\in IL \quad (15)$$

$$\sum_{sz=1}^{SZ}DR_{i'szt}\leq\sum_{j'=1}^{b}PC_{i'j'}\times I_{i'j't} \quad \forall i',t \quad (16)$$

$$\sum_{sz=1}^{SZ}DR_{i''szt}\leq\sum_{j'=b+1}^{J}PC_{i''j''}\times I_{i''j''t} \quad \forall i'',\ t \quad (17)$$

(3)Distribution Flexibility

$$DT_{iksz}=IT1_{iksz}\times\ EXDT1\ +\ IT2_{iksz}\times EXDT2 \quad \forall\, i,k,sz \quad (18)$$

$$\sum_{sz=1}^{h}DR_{iszt}=\sum_{k=1}^{K}\sum_{tm=1}y_{iktmt} \quad \forall i,t \quad (19)$$

$$\sum_{sz=h+1}^{SZ}DR_{iszt}=\sum_{k=1}^{K}\sum_{tm=2}y_{iktmt} \quad \forall i,t \quad (20)$$

$$\sum_{sz=1}^{SZ}y_{ikszt}\leq KC_{ik}\times KI_{ikt} \quad \forall i,k,t \quad (21)$$

$$\sum_{i=1}^{I}\sum_{j=1}^{J}x_{ijkt}=\sum_{i=1}^{I}\sum_{sz=1}^{SZ}y_{ikszt} \quad \forall k,t \quad (22)$$

$$\sum_{i=1}^{I}DR_{iszt}=\sum_{i=1}^{I}\sum_{k=1}^{K}y_{ikszt} \quad \forall sz,t \quad (23)$$

(4)Responsiveness Flexibility

$$\sum_{k=1}^{K}\sum_{sz\in DFDT_{sz}} y_{ikszt} \div \sum_{sz=1}^{SZ} DR_{iszt} \geq ResLev \qquad \forall i,t \qquad (24)$$

(5)others

$$P_{isz''t} = P_{isz't} \times \alpha \qquad \forall i,sz',sz''t \qquad (25)$$

$$SI_{rs't}, SI_{rs''t}, I_{i'j't}, I_{i''j''t}, KI_{kt}, JI_{j't}, JI_{j''t}, I_{i't}, I_{i''t}, KI_{ikt}, IT1_{iksz}, IT2_{iksz}, SP1_{rt}, SP2_{rt} \in \{0,1\} \qquad (26)$$

$$SR_{irs't}, SR_{irs''t}, SR_{irst}, x_{ijkt}, y_{ikszt}, y_{i'kszt}, y_{i''kszt}, y_{iksz't}, y_{iksz''t}, y_{iktmt} \geq 0 \qquad (27)$$

The objective function in Eq. (1) maximizes profit, which is computed by subtracting supply cost, production cost, distribution cost from total revenue. The total revenue Eq. (1.a) is acquired by supplying the products to the sale zones at an acceptable price. Eq. (1.b)-Eq.(1.d) include acquiring material cost from suppliers, the production related cost, and the distribution related cost between facilities. Supply flexibility constraints Eq. (2)-(9) are referenced by Das (2011). Constraint (2) describes the selection of suppliers. Constraint (3) and (4) describes the capacity limitations for suppliers. Constraint (5) ensures the total supply from the suppliers in two regions. Constraints (6)-(9) present the supply restriction from the two regions. Product mix flexibility constraints Eq. (10)-(15) are also referred to Das (2011). Constraint (10) and (11) balance the demand quantity of products and the distribution quantity to sale zones. Constraint (12) balances the total demand. Constraint (13) balances the total quantity of products distributed from DCs to sale zones. Constraint (14) and (15) ensure the number of product types being greater than the base level while not exceeding the maximum level. Constraint (16) and (17) ensure the capacity restrictions of the plants. Distribution flexibility includes constraints Eq. (18)-(23). Constraint (18) sets the distribution time of products from DCs to sale zones. Constraint (19) and (20) ensure the distribution type of products from two regions. Constraint (21) limits the capacity of DCs. Constraint (22) balances the product flows of DCs. Constraint (23) ensures that the demand quantity of products from sale zones equal to the quantity of products distributed to sale zones from DCs. Responsiveness flexibility constraint Eq. (24) ensures the quantity distributed from DCs to sale zones meet the basic responsiveness level (referenced by Pishvaee, Farahani, & Dullaert 2010). Constraint (25) sets the unit price of products for sale zones. Constraint (26) and (27) enforce the binary and non-negativity restrictions on the decision variables.

4. Illustrative Example

To demonstrate the applicability of the proposed supply chain flexibility model, we consider a case example to compare the optimal profit between the traditional supply chain planning model and the proposed flexible supply chain planning model. In order to simplify the problem, we suppose there are three suppliers, two materials, two products, four plants, four sale zones, and one distribution center in the example supply chain network. For simplicity, only one time period is considered. The case data is illustrated in Table 2-11.

Table 2 Supplier data

Materials	Parameters	Suppliers in the European region		Supplier in the other region
		1	2	3
	Fixed cost $	10	8	5
1	Capacity/ Cost$	100/7	200/5	100/3
2	Capacity/ Cost$	300/3	100/5	200/5

Table 3 Plant data

Products	Parameters	In-house Plants		Plants outsourced	
		1	2	3	4
	Set up fixed cost / Distribution cost to DC $	4/10	6/6	4/20	3/15
1	Capacity/ Cost$	70/8	50/7	20/7	10/5
2	Capacity/ Cost$	20/7	30/7	50/4	50/4

Table 4 Distribution center data

DC	Products	Parameters	Sale zones in the European region		Sale zones in the other region	
			1	2	3	4
1		Fixed cost$	4	4	4	4
	1	Capacity/ Unit price$	50/130	50/130	40/390	40/390
		Cost$ by truck/ air cargo	10/30	5/15	40/60	30/45
	2	Capacity/ Unit price$	60/100	60/100	30/300	30/300
		Cost$ by truck/ air cargo	25/40	10/20	50/70	45/60

Table 5 the value of parameters

Parameters	Value	Parameters	Value	Parameters	Value	Parameters	Value
EXDT1	2	EXDT2	3	$EXDT_{riksz}$	100	ResLev	0.9

Table 6 Product demand data

		High uncertainty product 1		Low uncertainty product 2	
		Traditional model	Flexible Model	Traditional model	Flexible Model
Total Quantity of demand		70	100	60	100
Sale zones	1/2/3/4	20/10/10/30	30/20/20/30	10/30/20/0	20/40/20/20

Table 7 Material data

	High uncertainty product 1		Low uncertainty product 2	
	Traditional model	Flexible Model	Traditional model	Flexible Model
Total quantity for material 1	140	200	0	0
Quantity from supplier 1/2/3	-/40/100	100/100/-	-/-/-	-/-/-
Total quantity for material 2	70	100	120	200
Quantity from supplier 1/2/3	70/-/-	100/-/-	120/-/-	200/-/-

Table 8 Distribution time of material data

	Materials	Suppliers	(Suppliers→)Plants			
			1	2	3	4
Traditional model	1	1/2/3	20/25/40	18/20/35	40/35/20	40/35/20
	2	1/2/3	20/25/40	18/20/35	40/35/20	40/35/20
Flexible Model	1	1/2/3	6/8/15	6/8/15	10/12/10	10/12/10
	2	1/2/3	6/8/15	6/8/15	10/12/10	10/12/10

Table 9 Distribution time of product data

	Products	Plants(→DC)				(DC→)Sale zones			
		1	2	3	4	1	2	3	4
Traditional model	1/2	8/8	7/7	30/30	25/25	10/10	6/6	20/20	15/15
Flexible Model	1/2	2/2	1/1	7/7	6/6	2/1	1/1.5	2.5/2	3/3

Table 10 the quantity of production and distribution data

	High uncertainty product 1		Low uncertainty product 2	
	Traditional model	Flexible Model	Traditional model	Flexible Model
Total quantity of DC	70	100	60	100
Quantity of production				
Plant 1/2/3/4	-/40/20/10	70/30/-/-	-/-/10/50	-/-/50/50
Quantity of distribution				
Sale zone 1/2/3/4	20/10/10/30	30/20/20/30	10/30/20/0	20/40/20/20

Table 11 the comparison of the traditional model and the flexible model data

	Optimal profit	Total Revenue	Supply cost	Production cost	Distribution cost
Traditional model	22840	29500	1093	723	4844
Flexible Model	31701	44000	2128	1167	9004

From the result above, we can claim that the proposed supply chain planning model with supplier flexibility, product mix flexibility, distribution flexibility, and responsiveness flexibility is capable of improving the performance of the supply chain with better profit.

5. Conclusions

In this study, we review the relevant supply chain flexibility literature, and propose a supply chain flexibility model to fill the research gap and to achieve better profit in practice. Considering the needs of the fast fashion industry, four types of flexibility including supply flexibility, product mix flexibility, distribution flexibility, and responsiveness flexibility are integrated to form the supply chain flexibility model. A brief illustrative example is presented to demonstrate the conduction of the mathematical model and the evaluation of performance for showing the feasibility and applicability of the proposed model. The supply chain flexibility model and the example of profit optimization can serve as a guide to support the building of supply chain flexibility models suitable for different businesses and industries for sustaining benefits, and thus contribute to both domains of the research and practices.

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