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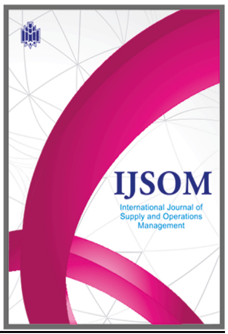

Competitive Supply Chain Network Design Considering Marketing Strategies: A Hybrid Metaheuristic Algorithm

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Abstract

In this paper, a comprehensive model is proposed to design a network for a multi-period, multi-echelon, and multi-product inventory controlled supply chain. Various marketing strategies and guerrilla marketing approaches are considered in the design process under the static competition condition. The goal of the proposed model is to efficiently respond to the customers' demands in the presence of the pre-existing competitors and the price inelasticity of demands. The proposed optimization model considers multiple objectives that incorporate both market share and total profit of the considered supply chain network, simultaneously. To tackle the proposed multi-objective mixed-integer nonlinear programming model, an efficient hybrid meta-heuristic algorithm is developed that incorporates a Taguchi-based non-dominated sorting genetic algorithm-II and a particle swarm optimization. A variable neighborhood decomposition search is applied to enhance a local search process of the proposed hybrid solution algorithm. Computational results illustrate that the proposed model and solution algorithm are notably efficient in dealing with the competitive pressure by adopting the proper marketing strategies.

Keywords: Supply Chain Management; Marketing Strategies; Hybrid Metaheuristic; Non-dominated sorting genetic algorithm-II; Particle swarm optimization; Variable neighborhood decomposition search.

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1. Introduction

As a rapid globalization continues to affect the competition in business environment, supply chain management is becoming the main concern for many corporations to be more successful(Hasani and Zegordi, 2015).Therefore, a considerable shift in what is expected of functions of the supply chain is seen. Nowadays, business leaders are demanding more agility from their supply chains as a consequence of dealing with more intense global competition(Hasani and Khosrojerdi, 2016).To address these issues, supply chain network design (SCND) problem deals with various decisions of strategic and tactical levels(Fattahi et al., 2015).While the global concerns about business competition have increased considerably, the main players in the business environment are stimulating the corporations to increase their competitive advantages and consider the competitive condition in their business decisions(Costantino et al., 2012, Goh et al., 2007).Business owners aim to consistently beat the competition and gain competitive advantage with a strong marketing strategy(Paksoy and Chang, 2010). Considering the marketing strategy planning in the network design could increase the competitive advantage of the supply chain under the competition condition. Therefore, in this paper, marketing strategies under competition condition to gain higher market share are considered in design of the strategic supply chain network. To address these issues properly, a comprehensive mathematical model and an efficient solution algorithm are proposed.

The remainder of this paper is structured as follows. In section 2, the literature review of the SCND problem from various major aspects is presented. In section 3, the problem definition is introduced. In section 4, the proposed mathematical model for designing a competitive SCND is presented. In section 5, a proposed hybrid meta-heuristic method is introduced. In section 6, computational experiments and obtained results are presented. Finally, the paper is concluded in section 7 and some of the future research directions are highlighted.

2. Literature review

Studying the evolution of previous studies on the SCND indicates that the main trend of these studies is affected by real-world conditions. Therefore, various aspects, which are affected by decision-making environment, are regarded in the proposed SCND models. A dynamic or multi-period SCND formulation is developed from the SCND problem(Rezapour et al., 2011). The structure of the SCND problem is extended to multiple echelons as well as multiple facilities in each echelon. To satisfy more sustainable issues in designing the supply chain network, a reverse flow of materials is considered in reverse and closed-loop SCND problems(Eskandarpour et al., 2014). In addition, various types of facilities are considered to manage the reverse flow of materials in the design of supply chain network(Hasani et al., 2012).A complex flow of materials affected by considering multiple commodities and their bill of materials is regarded to satisfy the customers' demands(Eskandarpour et al., 2013). There are various and major challenges that supply chain managers are facing for gaining more competitive advantages such as capacity restrictions of supplier(Thanh et al., 2008), manufacturer, distributor, technology selection, inventory storage, and investment budget(Hasani and Khosrojerdi, 2016).In addition, there could be some uncertain factors that influence the design and planning of the supply chain network (Goh et al., 2007).The uncertainty of parameters has been handled in some studies using various approaches such as fuzzy programming(Moghaddam, 2015), stochastic programming(Goh et al., 2007)and robust programming(Hasani et al., 2012).Nowadays, complexities of supply chain characteristics have led to the need of more integration of various strategic and tactical planning decisions in SCND problems. In accordance with the related literature, determining the amount of required capacity, supplier selection, and technology selection decisions are involved as strategic planning decisions in the SCND problems. In addition, some decisions such as material shipment, production planning, and inventory control decisions are involved as tactical planning decisions in the SCND problems(Eskandarpour et al., 2014).According to the requirements of the business environment, different objective functions have been proposed in the literature such as cost minimization(Wilhelm et al., 2013), profit maximization, and customer's demand responsiveness maximization(Hasani and Hosseini, 2015).To consider various objectives concurrently, several studies examined the multiple objectives problem (Hasani and Hosseini, 2015).Guerrilla marketing as one of the recent marketing strategies is introduced by Jay Conrad Levinson in 1984. The guerrilla marketing is an unconventional marketing method which has specific features in preference to high marketing budgets(Paksoy and Chang, 2010). Guerrilla marketing strategy is suitable for small and medium-sized firms. The main concentration of guerrilla marketing is increasing the amount of a total profit gained and not on the total sales(Levinson, 1998).The guerrilla marketing strategy focuses on growing business geometrically by conducting more transactions with existing consumers of firms. it offers allied products and services instead of concentrating on growing linearly by adding new consumers and offering diversified products(Navrátilová and Milichovský, 2015).One of the tools used in the guerrilla marketing is establishing short-lived pop-up stores as a kind of temporary shops in major customer zones to attract the interest of the customers more and more. Today, many companies, especially those that are related to fashion industry, are using short-lived pop-up stores to take advantages of the market opportunities(Bigat, 2012).Paksoy and Chang (2010) proposed a goal programming model for an inventory controlled supply chain model considering pop-up store establishment to satisfy customer's demands. The supply chain management is becoming themain issue for many firms, as a competitive condition continues to affect the business environment(Costantino et al., 2012, Goh et al., 2007).Business leaders are demanding more agility from their supply chains to gain a further competitive advantage(Farahani et al., 2014).This phenomenon has caused the real competition to be between supply chains not companies. Assessment of the impact of the competition on the design of the supply chain is sophisticated because of facing with highdynamics in the competitive business environment. Generally, there are three kinds of competition, which exist in the context of competitive facility location, including the following: static(Aboolian et al., 2007, Rezapour et al., 2011), foresight, and dynamic(Farahani et al., 2014). Rezapour et al., (2011)proposed a single objective deterministic mathematical model for SCND considering an inelastic demand in the presence of pre-existing competing chains. Rezapour et al., (2011)considered a probabilistic customer behavior based on an attraction function depending on both the location and quality of the retailers for providing customers' demands. Zegordi and Hasani (2015) proposed a robust mathematical model to design a global supply chain network under static competition condition for a medical device industry. Zegordi and Hasani (2015)consider the impact of capacity disruption on the attractiveness of facilities and then on the considered static competition condition.

In this study, a new comprehensive multi-objective mathematical model for designing a competitive supply chain network incorporating marketing strategy is presented. This study is different from the previous studies on SCND problem in considering the static competition condition as well as guerrilla marketing strategy concurrently in the design of the supply chain network. In addition, to tackle with the proposed complex multi-objective mixed-integer nonlinear programming model, an efficient hybrid meta-heuristic algorithm is developed.

3. Problem definition

The goal of this study is to design an efficient network structure of a multi-echelon supply chain as a new entrant into the new competitive markets. The aim of this company is to capture a more market share in the presence of competitors. An efficient guerrilla marketingis adopted for providing customers' demands of multiple products. A pre-existing set of competitors with pre-known competitive characteristics is considered in this highly competitive business environment. The attractiveness and the utility of each service provider are affected by the considered characteristics of the considered products and markets. The customers' demands in this study are price-inelastic. In addition, the competition condition between the considered supply chain network as a new entrant to a market and the other pre-existing competitors are pre-known and fixed during the planning horizon. Therefore, the static competition condition is regarded in this study. The considered company deals with various strategic and tactical decisions for designing the supply chain network, including supplier and distributor location selection, pop-up store establishment, parts of product procurement, inventory holding, semi-manufactured and final product production, material shipment, and pop-up store capacity determination. Finally, the aim of the proposed model is to maximize the total profit of the supply chain network as well as maximize the total responsiveness to customers' demands concurrently.

4. Mathematical model

In this section, the proposed MINLP model for designing the competitive supply chain networks by considering the Guerrilla marketing strategy is explained.

4.1. Notation

- Indices

I, *J*, *K*, *L*,*M*, and C: Sets of suppliers, manufacturers, wholesalers, pop-up stores, customer zones, and pop-up stores controlled by competitors, respectively,
P,*N*, *T*, and *A*: Sets of products, parts, periods, and attractiveness attributes, respectively,

- Parameters

C_{ijnt}: Transportation cost of part *n* from supplier *i* to manufacturer *j* in period *t*,
C_{jkpt}: Transportation cost of product *p* from manufacturer *j* to wholesaler *k* in period *t*,
C_{klpt}: Transportation cost of product *p* from wholesaler *k* to pop-up store *l* in period *t*,
C_{lmpt}: Distribution cost of product *p* from pop-up store *l* to customer zone *m* in period *t*,
C_{mpt}: Cost of not satisfying demand of product *p* at customer zone *m* in period *t*,
V_{pn}: Number of part *n* used in one unit of product *p*,
A_{it} and B_{jt}: Supplying capacity of supplier *I* and production capacity of manufacturer *j*, respectively,
E_{kt} and C_{lzt}: Storage capacity of wholesaler *k* and pop-up store *l*, respectively,
D_{mpt}: Amount of demand of product *p* at customer zone *m* in period *t*,
δ_{kt}, Fs_{it}, andFw_{kt}: Fixed cost of establishing pop-up store *k*, selecting supplier *i*, and selecting wholesaler *k* in period *t*, respectively.
α_p: Cost of holding a unit of product *p* in wholesaler *k* in period *t*,
β_p: Backordering cost of product *p*,
μ_{mpt}: Level of customer demand satisfaction at point *m* for product *p* in period *t*,
B_{jpt}: Total backordered amount of product *p* to manufacturer *j* in period *t*,
A_t: Maximum number of available potential pop-up stores in period *t*,
Pr_{mpt}: Selling price of product *p* at customer zone *m* in period *t*,
Vs_{in}, Vm_{jp}, and V_p: Occupied capacity of supplier *k* for supplying part *n*, occupied capacity of

manufacturer j for producing product *p*, and amount of occupied space by product *p*, respectively,
λ_p, β, Θ_z: Product *p* elasticity, capacity sensitivity, and utility function, respectively,

- Variables

yp_{lt}: 1 if pop-up store *l* is established in period t; 0 otherwise,
ys_{il}: 1 if supplier *i* is selected in period t; 0 otherwise,
yw_{kl}: 1 if wholesaler *k* is selected in period t; 0 otherwise,
q_{pkt}: Inventory of product *p* in wholesaler *k* at the end of period *t*,
qs_{pk} and si_{pk}: Safety stock and initial inventory level of product *p* in wholesaler *k*, respectively,
x_{ijnt}: Amount of part *n* transferred from supplier *i* to manufacturer *j* in period *t*,
w_{jkpt}: Amount of product *p* transferred from manufacturer *j* to wholesaler *k* in period *t*,
y_{klpt}: Amount of product *p* transferred from wholesaler *k* to pop-up store *l* in period *t*,
z_{lmpt}: Amount of product *p* distributed from pop-up store *l* to customer *m* in period *t*,
nd_{mpt}: Amount of demand of product *p* at customer zone *m* which is not satisfied in period t,
u_{lmpt} and ms_{lmpt}: Utility of providing product *p* and captured market share of the demand of product *p* by pop-up store *l* for customer zone *m* in period *t*, respectively,
tms_{mpt} and tu_{mpt}: Total market share of product *p* and total utility of providing product *p*, respectively,
at_{lpt}: Attractiveness of pop-up store *l* for delivering product *p* in period *t* (i.e.,at_{lpt}>0),
fu_{mpt} (*S*) and fu_{mpt}(*C*): Total utility of the customer zone *m* to get supplied with product *p* via facilities which are controlled by the considered supply chain and competitors in period *t*, respectively,
y_{lzpt}: Improvement level over the basic design of pop-up store *l* regarding the *z*th design attributes,

4.2. Mathematical model formulation

The aims of Obj. (1) and Obj. (2) are to maximize the total net present value of the profit and the total demand responsiveness of the supply chain network, respectively.

$$Max \sum_{l,m,p,t} pr_{mpt}.z_{lmpt} - \left(\begin{array}{l} \sum\limits_{i,j,n,t} C_{ijnt}.x_{ijnt} + \sum\limits_{j,k,p,t} C_{jkpt}.w_{jkpt} + \sum\limits_{k,l,p,t} C_{klpt}.y_{klpt} + \sum\limits_{l,m,p,t} C_{lmpt}.z_{lmpt} \\ + \sum\limits_{k,t} \delta_{kt}.yp_{lt} + \sum\limits_{i,t} Fs_{it}.ys_{it} + \sum\limits_{i,t} Fw_{kt}.yw_{kt} + \sum\limits_{t} \alpha_p.q_{pkt} + \sum\limits_{j,t} \beta_p b_{jpt} + \sum\limits_{m,p,t} C_{mpt}.nd_{mpt} \end{array} \right) \quad (1)$$

$$Max \sum_{m,p,t} tms_{mpt} \quad (2)$$

$$\sum_{n,j} Vs_{in}.x_{ijnt} \le A_{it}.ys_{it} \quad \forall i,t \quad (3)$$

$$\sum_{k,p} Vw_{jp}.w_{jkpt} \le B_{jt} \quad \forall j,t \quad (4)$$

$$\sum_{l,p} V_p.y_{klpt} \le E_{kt}.yw_{kt} \quad \forall k,t \quad (5)$$

$$\sum_{k,p} V_p.y_{klpt} \le C_{lt}.yp_{lt} \quad \forall l,t \quad (6)$$

$$\sum_{j} w_{jkpt} + q_{pk,(t-1)} - \sum_{j} b_{jp,(t-1)} - \sum_{l} y_{klpt} - q_{pkt} \ge 0 \quad \forall k,p,t \quad (7)$$

$$\sum_{i,j} x_{ijnt} = \sum_{j,k} v_{pn}.w_{jkpt} \quad \forall p,t \quad (8)$$

$$\sum_{k} y_{klpt} = \sum_{m} z_{lmpt} \quad \forall l,p,t \quad (9)$$

$$\sum_{l} z_{lmpt} + nd_{mpt} \ge \mu_{mpt}.D_{mpt} \quad \forall m,p,t \quad (10)$$

$$q_{pkt} \geq qs_{pk} \quad \forall p,k,t \tag{11}$$

$$\sum_{p} v_{p}.q_{pkt} \leq E_{kt} \quad \forall k,t \tag{12}$$

$$q_{pk0} = si_{pk} \quad \forall p,k \tag{13}$$

$$\sum_{k} \delta_{kt}.yp_{kt} \leq A_{t} \quad \forall t \tag{14}$$

$$u_{lmpt} = \frac{at_{lpt}}{C_{lmpt}{}^{\beta}} \quad \forall m,p,t,l \in (S \cup C) \tag{15}$$

$$ms_{lmpt} = \frac{u_{lmpt}}{\sum_{l \in S \cup C} u_{lmpt}} \quad \forall m,p,t,l \in (S \cup C) \tag{16}$$

$$tms_{mpt} = \frac{\sum_{l \in S} u_{lmpt}}{\sum_{l \in S} u_{lmpt} + \sum_{l \in C} u_{lmpt}} = \frac{\sum_{l \in S} u_{lmpt}}{\sum_{l \in S \cup C} u_{lmpt}} \quad \forall m,p,t \tag{17}$$

$$g(tu_{mpt}) = 1 - e^{-\lambda_p \times \sum_{l \in S \cup C} u_{lmpt}} \quad \forall m,p,t \tag{18}$$

$$at_{lpt} = yp_{kt} \times \alpha_i \times \prod_{z=1}^{|ZA|} \left(1 + Y_{lzpt}\right)^{\theta_z} \quad \forall l,p,t \tag{19}$$

$$Y_{lzpt} = \begin{cases} \dfrac{(C_{lt})\big|_{l \in C}}{Min\left(C_{lt}\big|_{l \in C}, (C_{lt} + RC_{lt} \times yrc_{lt})\big|_{l \in S}\right)} \\ \dfrac{(C_{lt} + RC_{lt} \times yrc_{lt})\big|_{i \in S}}{Min\left(C_{lt}\big|_{l \in C}, (C_{lt} + RC_{lt} \times yrc_{lt})\big|_{l \in S}\right)} \end{cases} \quad \forall l,z,p,t \tag{20}$$

Eqs. (3)- (6) demonstrate the capacity of each supplier, manufacturer, wholesaler, and a pop-up store. Eq. (7) ensures that quantities of products shipped from a wholesaler to pop-up stores in each time period are less than or equal to the total quantity of incoming products from other manufacturers within the same time period and the remaining products from the previous time period. Eq. (8) ensures the parts usage according to the each product BOM.A balance between the total incoming and outgoing products, to and from the pop-up store is set up in Eq. (9).Eq. (10) states that the demand of each customer zone should be fulfilled through the incoming products. Eq. (11) and (12) ensure that the total inventory level in the wholesaler in each period should be between ‘‘greater than or equal to safety stock”, and ‘‘less than or equal to wholesaler capacity”. The initial inventory of the wholesaler is regarded in Eq. (13). The number of pop-up stores to be opened is restricted in Eq. (14). The utility of each customer zone for each pop-up store is calculated in Eq. (15).The market share, which is captured by a specific pop-up store, is calculated in Eq. (16). The total captured market share is calculated in Eq. (17). The exponential form of the demand function is shown in Eq. (18).The attractiveness of each pop-up store is calculated in Eq. (19).Eq. (20) indicates that they_{lzpt} is a function of the total available capacity of each pop-up store.

5. Proposed hybrid solution algorithm

Due to the NP-hard nature of the SCND problem, solving large-size instances efficiently within a reasonable time is a challenging task (Fahimnia et al., 2013). To tackle this challenge in this study, an efficient hybrid meta-heuristic is proposed (Figure 1).Solution chromosome of the proposed hybrid solution algorithm is represented using a two-dimensional binary array. The size of the proposed binary array is $(|I|+|K|+|L|).|T|$. Using values of solution chromosome's genes, the binary decision variables are generated and the mixed integer non-linear problem transforms into a single weighted objective non-linear programming one which is solved by LINDOGLOBAL in GAMS 24.1.2 optimization software. The initial population of the proposed hybrid solution algorithm is generated randomly. The next populations are generated in three ways. In the first method, a predefined number of solutions are generated using the Taguchi-based crossover(Hasani and Zegordi, 2015). In the second method, a multi-point mutation operator is used to generate a specific number of solutions. Finally, a customized operator of the PSO is utilized to improve the two sets of the Pareto optimal solution, including the Pareto optimal solutions of each generation and the overall generations. This operator is a kind of a multi-point crossover, which is applied on decision variables as follows: if both genes of selected parents are equal to one or zero, then a related gene of a child has an equal value to its related genes of the parents; otherwise, the binary value of the child's gene is determined randomly. A roulette wheel selection scheme is adopted to select the fittest individual prior to the others into the next generation. Steps of the proposed VNDS are demonstrated in Figure 2. Various neighborhood structures of the proposed VNDS are listed in the following.

- Single random Pairwise interchange in which two departments are selected randomly and their positions are swapped.
- Multi Pairwise interchanges in which for a specific number of iterations departments are selected randomly and their positions are exchanged.
- Subsequence moving operator in which a group of departments are moved to another position altogether.
- Insertion mechanism in which a randomly selected department is omitted from its position and inserted between two other positions selected randomly.
- Subsequence shuffling operator in which a group of departments are selected and jumbled up.
- Inversion structure in which a group of departments are selected and positioned inversely.
- Subsequence moving and inversion operator in which a group of departments are positioned inversely and moved to another position altogether.
- Shifting neighborhood structure in which two random positions are selected depending on the first position, the department located in the position of the first random number is shifted backward or forward, respectively.
- Adjacent swap operator in which a department is selected randomly and replaces its position probabilistically with its left or right position.

6. Computational experiments and results

In this section, the effectiveness of the proposed hybrid meta-heuristic solution algorithm, namely HNSG-PSO, is investigated using a series of extensive computational experiments. 16 test problems are defined based on the experts' opinions of the considered medical device company and the test problems that are proposed by Paksoy and Change (2010) (Tables 1 and 2). Parameters of the proposed hybrid meta-heuristic solution algorithm are set using an offline parameter tuning based on the Taguchi experimental design method (Table 3).Firstly, the quality of the best-obtained solution using a single-objective version of the proposed hybrid solution algorithm and GAMS optimization software are compared. In this test, only the first objective function is considered. The maximum allowed CPU time for GAMS was limited to 200 hours. Results indicate that the performance of the proposed hybrid solution algorithm using variable neighborhood decomposition search is superior to GAMS for medium and large-sized test problems. Due to the solution algorithm restrictions and capabilities, GAMS was unable to prove optimality of the optimum solutions for all test problems, even after the permitted runtime limitation. The average gap between solutions of aforementioned algorithms is 10.09 percent (Table 4). In addition, the effectiveness of employing the proposed solution algorithm versus the NSGA-VNS and NSGA-II is investigated. The quality of the Pareto solutions is examined by two common performance measures, including an average number and a ratio of Pareto-optimal solutions. The results of Table 5 demonstrate that the proposed HNSG-PSO found superior Pareto solutions for all test problems. Systematic changes in the neighborhood in the descent and escape from local optimum phases using capable operators of the PSO algorithm could be the main reasons for the superiority of the proposed HNSG-PSO to other comparable solution algorithms. The conflict between the two considered objective functions is investigated using a successive procedure (Figure 4). The results of applying this procedure to the test problem 16, as a large-sized problem, is presented in Figure 5. The obtained results show that by increasing demand responsiveness, total profit decreases due to increasing cost of satisfying more demand. The impact of changes in competition condition is presented in Figure 6. The obtained results indicate that the total profit and demand responsiveness of the supply chain will decrease as a consequence of enhancing the competition condition. Limitation in the number and capacity of pop-up stores due to access constraint to appropriate locations could be some of the most important reasons for this phenomenon.

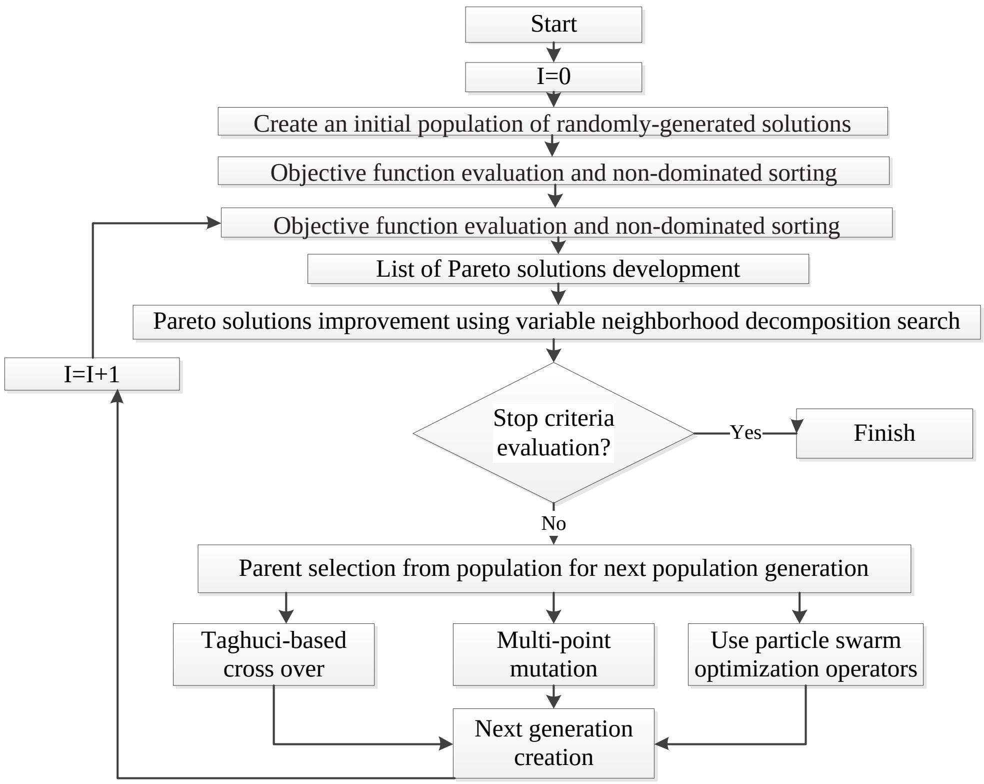

Figure 1. The schematic overview of the proposed hybrid solution algorithm structure

Initialization. Select the set of neighborhood structures $N_k, k = 1,...,k_{\max}$; Find an initial solution x;
Choose a stopping condition; Repeat the following sequence until the stopping condition is met:

(1) Set $k \leftarrow 1$;

(2) Until $k = k_{\max}$, repeat the folowing steps:

(a) Shaking: Generate a point x' at random from the k^{th} neighborhood of x

(b) Local search: Find the best solution in the space of y either by inspection or by some heuristic;

(c) Move or not: If the solution thus obtained is better than the incumbent,
move there $(x \leftarrow x'')$, and continue the search with $N_1(k \leftarrow 1)$; otherwise, set $k \leftarrow k+1$;

Figure 2. The pseudo-code of the proposed VNDS heuristic

Table 1. Proposed test problems

Parameters											Parameters										
Testproblems	I	K	L	M	P	N	T	β	λ	μ	Testproblems	I	K	L	M	P	N	T	B	λ	M
1	10	20	40	50	3	4	5	1	1	0.45	9	20	30	50	70	9	8	10	1	1	0.45
2	10	20	40	50	3	4	5	1	1	0.5	10	20	30	50	70	9	8	10	1	1	0.5
3	10	20	40	50	3	4	5	2	2	0.45	11	20	30	50	70	9	8	10	2	2	0.45
4	10	20	40	50	3	4	5	2	2	0.5	12	20	30	50	70	9	8	10	2	2	0.5
5	15	25	45	60	6	6	5	1	1	0.45	13	25	35	55	80	12	10	10	1	1	0.45
6	15	25	45	60	6	6	5	1	1	0.5	14	25	35	55	80	12	10	10	1	1	0.5
7	15	25	45	60	6	6	5	2	2	0.45	15	25	35	55	80	12	10	10	2	2	0.45
8	15	25	45	60	6	6	5	2	2	0.5	16	25	35	55	80	12	10	10	2	2	0.5

Table 2. Generation scheme of parameters of the proposed model

Parameter	Generation scheme	Parameter	Generation scheme	Parameter	Generation scheme
C_{ijnt}	[500,600]	E_{kt}	[1.6E+6,2.2E6]	Pr_{mpt}	[800,900]
C_{jkpt}	[300,500]	C_{lzt}	[1.6E+4,2.2E4]	Vs_{in}	1
C_{klpt}	[300,500]	D_{mpt}	[2.4E+6,3.3E6]	Vm_{jp}	1
C_{lmpt}	[300,500]	δ_{kt}	[1.0E+7,1.5E+7]	V_p	1
C_{mpt}	[900,1000]	Fs_{it}	[1.0E+10,1.5E+10]	α_p	[5E+5,7.5E+5]
θ_z	1	Fw_{kt}	[2.5E+11,3.0E+11]	β_p	[900,1000]
A_{it}	[3.2E+6,4.8E+6]	B_{jt}	[8E+5,1.2E6]		

Table 3. The design and noise factors for parameters tuning using the Taguchi method

Design Factors	Algorithms	Levels		
	HNSG-PSO	Level1	Level2	Level3
NSGA-II iteration number	✓	300	400	500
NSGA-II population size	✓	50	75	100
Mutation rate	✓	30	20	10
Crossover rate	✓	50	60	70
VNDS iteration number		5	10	15
PSO1 operator rate	✓	50	70	30
PSO2 operator rate	✓	50	30	70
Fraction of full designed factorial experiments in Taguchi-based crossover	✓	¼	1/2	1
Orthogonal array	$L_{27}(3^8)$			

Table 6. Results of investigating the solution quality of the proposed solution algorithm

Solution quality				Solution quality			
Test problem	HNSG-PSO	GAMS	Gap (%)	Test problem	HNSG-PSO	GAMS	Gap (%)
1	134653.01	131003.58	03.22	9	143233.10	394840.40	12.48
2	140035.47	126203.85	06.95	10	150071.10	385379.66	11.82
3	148816.33	129479.20	05.35	11	145446.16	373697.27	10.60
4	136256.04	134548.86	03.19	12	131029.09	388721.68	11.81
5	142576.76	255106.16	07.40	13	146327.95	494450.41	16.02
6	135262.57	264155.29	06.22	14	138280.27	462777.94	15.94
7	130982.17	257002.31	09.31	15	141763.69	468060.38	16.24
8	134034.75	250163.48	08.93	16	139149.57	441356.23	15.96

Table 4. Results of investigating the efficiency of the proposed HNSG-PSO

Test problem	HNSG-PSO		NSGA-VNS		NSGA-II		Test problem	HNSG-PSO		NSGA-VNS		NSGA-II	
	C1	C2	C1	C2	C1	C2		C1	C2	C1	C2	C1	C2
1	0.5421	32.12	0.2641	13.03	0.2047	9.81	9	0.9527	56.45	0.4642	22.90	0.3639	17.40
2	0.5834	34.57	0.2843	14.02	0.1882	10.19	10	0.8256	48.92	0.4023	19.85	0.2808	13.60
3	0.5811	34.43	0.2831	13.97	0.2251	11.08	11	0.7919	43.08	0.4718	24.09	0.3213	18.38
4	0.7279	32.97	0.3495	13.70	0.2377	10.06	12	0.9318	19.25	0.4519	8.89	0.3231	6.43
5	0.5484	18.26	0.3192	8.52	0.2477	5.74	13	0.8527	50.52	0.4155	20.50	0.3170	15.25
6	0.6507	38.56	0.3170	15.64	0.2349	11.89	14	0.8603	50.97	0.4192	20.68	0.3077	14.60
7	0.6812	40.36	0.3319	16.37	0.2363	13.03	15	0.8736	51.76	0.4257	21.00	0.3244	14.95
8	0.6531	41.72	0.3402	16.12	0.2324	11.32	16	0.7843	43.91	0.4708	24.18	0.3136	17.89

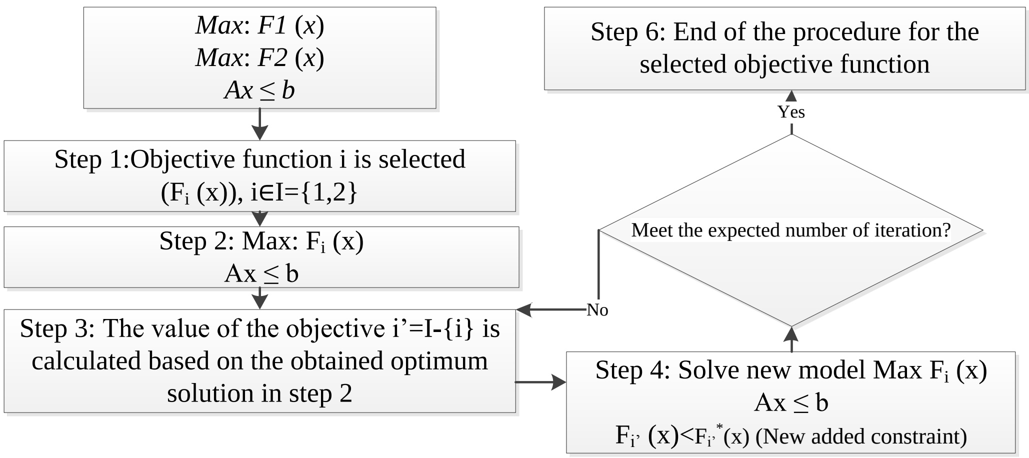

Figure 4. Procedure for investigating the behavior of optimizing one objective function against another one

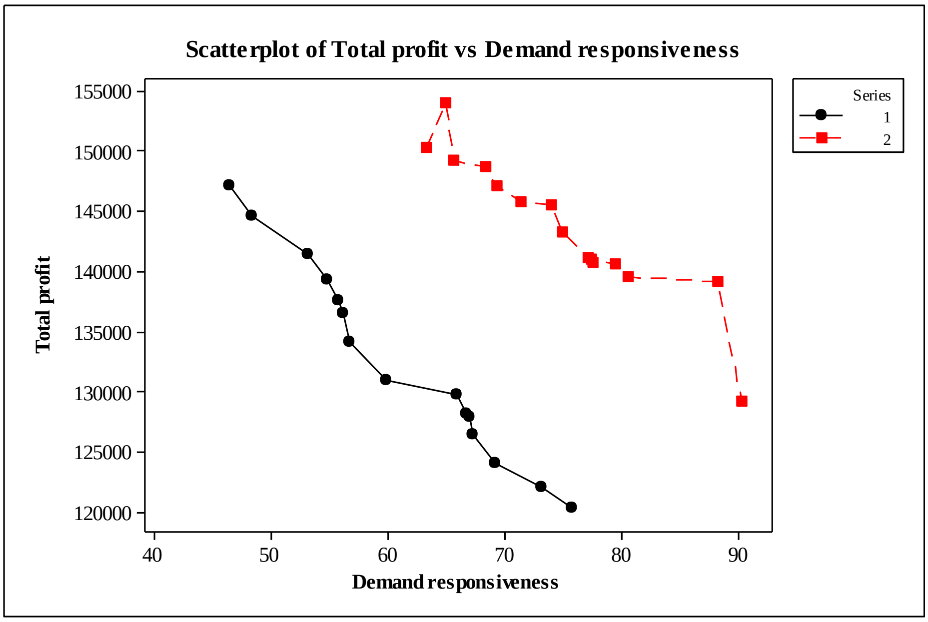

Figure 5. Conflict demonstration between two objective functions via optimizing the first and second objective function

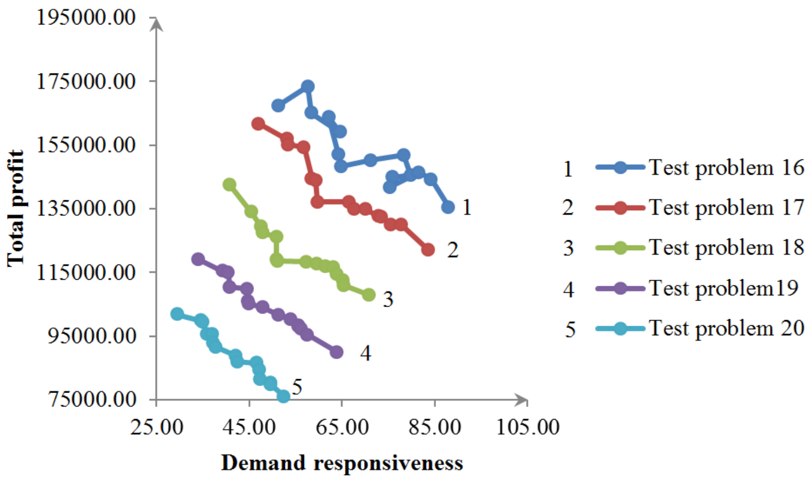

Figure 6. Pareto solution results of large-sized test problems 16-20

7. Conclusion

The SCND is a powerful modeling approach with potential of delivering a significant reduction in the supply chain costs and improvements in the service levels by better aligning strategies of supply chain management. In this study, to acquire the more and sustainable competitive advantages versus competitors, the guerrilla marketing strategy is considered in the strategic design of the supply chain network. Due to the characteristics of the marketplace such as the state of pre-existing competitors, a static competition is considered in the network design. The competition condition and attractiveness of facilities of the service providers are affected by the total demand, which is supplied by the pop-up stores. The aim of the proposed model is to maximize the total profit of the supply chain as well as the demand responsiveness concurrently. To tackle the proposed multi-objective model, a hybrid meta-heuristic algorithm incorporating the Taguchi-based NSGA-II and VNDS is proposed. The results of extensive experiments indicate the superior competitive advantages of considering the marketing strategies in the proposed SCND. In addition, the superiority of the proposed hybrid solution algorithm is investigated via comparing its performance with the other meta-heuristics. For further research, considering the other competition conditions, including foresight and dynamic competition, as well as considering the impact of the product price on the attractiveness of a service provider in the network design is proposed. Additionally, the uncertainty of the key parameters can be considered in the network design process. Finally, an efficient solution algorithm can be developed to tackle such a complex problem.

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