International Journal of Mathematics and Computational Science
Vol. 2, No. 1, 2016, pp. 20-33
http://www.aiscience.org/journal/ijmcs
ISSN: 2381-7011 (Print); ISSN: 2381-702X (Online)

Integrated Supply, Production, Distribution Planning in Supply Chain with Regard to Uncertain Demand and Flexibility in Capacity, Supply and Delivery

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Abstract

In this paper a mathematical model will be presented for the integrated planning of supply, production and distribution problem in a multi-level supply chain which consists of producer, warehouse and customer (retailer) in uncertainty of demand situation. The proposed model provides decision making on uncertain and varying markets with regards to capacity, supply and delivery flexibility. Demand is considered to be a random variable with normal distribution and market frequencies have been incorporated into the model within various scenarios. Planning perspective, in the proposed model, has been divided into a series of strategic decision making periods with them each includes a number of tactical decision making periods and time value of money have been inserted into the model with regard to interest rate. Due to model's complexity in large scales, to solve the model we deployed particle swarm meta-heuristic optimization algorithm.

Keywords

Distribution Planning, Strategic and Tactical Planning, Flexibility in the Supply Chain, Demand Uncertainty

Received: November 12, 2015 / Accepted: December 6, 2015 / Published online: February 1, 2016

1. Introduction

Today the traditional production management approaches which offered lower integrity in their processes have lost the ground, and supply chain is capable of handling the situation as an integrated approach to flow of material, products, information and financial management. Furthermore, the key to the organization's survival relies in customer satisfaction, and supply chain management not only is concerned about final balance of the customer who receives the final product, but also considers the sequence of suppliers and investigate the role of incorporated organizations integration and coordination of material, information and financial flow in service of a better supply chain competitiveness. Therefore, supply chain management is a set of approaches which are deployed to efficiently integrate suppliers, producers, warehouses and retailers so that the required product is produced in a certain amount, within the proper time and specified place and is delivered to the customers. In this way, the cost is minimized and the gain is maximized and the customer is serviced accordingly better. The supply chain's

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flexibility against the uncertain markets and the ability to adapt to conditions, also, are key aspects of supply chain discussion.

2. Literature Review Integrated Supply – Production- Distribution Models

Integrated model of supply-production - distribution are included three categories, supply–production, production-distribution and supply-production-distribution.

It is necessary to know the production aggregation and production timing in order to determine how order of raw material. Hence the raw material aggregation specification problem could not be isolated from aggregation amount and production timing problem. Significant papers on supply-production integration are Goyal & Deshmukh (1997) regarding the fixed demand and single-product condition and Boulaksil et al. (2011) which regard a supply chain with dynamic demand and single product with several time periods.

Also managers have found that without careful planning in purchase and distribution, they would fail in their competition against the rivals. The followings are most reliable production and distribution models. Bilgen (2010) incorporated the fuzzy discussion into his multi-products and multi-periods exclusive model. Naso at el. (2007) has suggested production-distribution models for unclear supply chains routing.

The high complexity of the mentioned models lead to fewer researches in this group which compared to the other groups is more comprehensive. Below are some of the most significant papers in this domain: Torabi & Hassini (2008) have suggested a multi - objective three-level concerning the discount in a Fuzzy condition. To summarize the information and for an easier analysis, we will compare the foresaid papers in table (1). Furthermore, we will more give more explanation on some of these papers, specifically those with the focus around the uncertainty of data.

Aliey et al. (2007) have discussed integrated production-distribution planning a model as well as objective function of interest maximization, unlike most of fuzzy models which considers production and distribution plans as two separate entities, while demand, production capacity, and process timing is uncertain and unclear. Liu et al. (2013) have proposed a model which simultaneously follows the total cost of chain, service quality and total time flow and lost sales as an objective. Liang (2008) proposed a linear multi-objectives model for integrated production-distribution planning with a regard to simultaneous minimization of all costs and total delivery time which in turn are associated with the budget level, capacity-access of all devices and performance level of each resource, demand anticipation, accessible warehouse space and total budget.

Liang (2011) proposes a model targeting demand estimation and production and distribution total cost minimization. Zhang et al. (2011) discuss modeling in an environment with supply and demand uncertainty and have established a connection between inventory, production cost and customer services level. Kenne et al. (2012) investigated single-product closed loop supply chain where the machineries maintenance or break is random. Feili & Hassanzadeh Khoshdooni (2011) elaborated fuzzy linear planning model in a multi-level, multi-products, multi-periods supply chain tactical planning which has taken into account the uncertainty of supply, demand and the process simultaneously. Mirzapour et al. (2011) proposed a multi-objectives model for an uncertain condition whose objectives are total cost minimization and customers' satisfaction maximization. Bashiri et al. (2011) also, proposed a mathematical model for tactical and strategic planning based on collective net interest in which dynamic and certain demand is taken. They have taken into account the flexibility of their models. Gebennini et al. (2009) recommended an integrated model to allocation, transportation management, reverse logistic activities. Mohammadi Bidhandi et al. (2009) presented a combined integral linear planning model and solution algorithm for designing supply chain network in certain and multi-products level with single period.

3. Flexible Production Planning Models of Supply Chain

Some of the most important researches are listed below which in addition to flexibility, discussion about decision making levels is also investigated.

Sabri & Beamon (2000) proposed a multi-objectives model for supply chain decisions. There is objective of maximization of flexibility in time and amount of raw materials and products delivery. Bashiri et al. (2011) presented a mathematical model based on the collective net interests which have been taken into account in dynamic and certain demand. They have considered the capacity flexibility in their model. Das (2011) developed combined integral integrated planning model for supply chain which have taken into account the flexibility of capacity, supply and mix product and service level in order to optimize the response to market. Schutz & Tomasgard (2011) studied volume flexibility, demand flexibility and operational decision making flexibility effects on supply chain planning under an uncertain demand condition. Tang & Tomlin (2008), have emphasized indicated the effects of flexibility on supply risk reduction to show how it is important. Dos & Abdulmalek (2003) concentrate on delivery time and order quantity flexibility in a supply chain planning. Garavelli (2003) have considered a limited flexibility in case that such flexibility does not increase its cost, and his model leads suppliers to allocation to the factories. Gong (2008) developed a supply chain flexible model in which machines flexibility, routing flexibility, workforce and information technology flexibility and the whole system's flexibility is measured against economic indexes.

Table 1. Classification of supply chain integrated production planning models.

line	research	Year	Supply Chain levels	demand		Raw material		product		Period of time	
				Fixed	Dynamic	one	Several	one	Several	one	Several
1	Goyal	1997	S-P	●			●	●			
2	Boulaksil	2011	S-P		●		●	●			●
3	Bilgen	2010	P-D		●		●		●		●
4	Naso	2007	P-C		●	●		●		●	
5	Aliev	2007	P-D-C		●	●			●		●
6	Liu	2013	P-D-C		●		●		●		●
7	Liang	2008	P-C		●		●		●		●
8	Liang	2011	P-C		●				●		●
10	Zhang	2011	S-P-D-C		●		●		●		●
11	Noorul Haq	2006	S-P-D-W-C		●		●		●		●
12	Torabi	2008	S-P-D		●		●		●		●
13	Kenne	2012	S-P-D-C-M		●		●	●			●
14	Feili	2011	S-P-D		●		●		●		●
15	Mirzapour	2011	S-P-C		●				●		●
16	Bashiri	2011	S-P-W-C		●		●		●		●
17	Mohammadi	2009	S-P-W-C		●		●		●	●	

Table 1. Continue.

line	research	Year	Objective function	fuzzy	Discount	location	allocation	Routing	inventory	outsourcing
1	Goyal	1997	TC							
2	Boulaksil	2011	TNP				●			●
3	Bilgen	2010	TC	●			●			
4	Naso	2007	TC					●		
5	Aliev	2007	TNP	●						
6	Liu	2013	TC-SL				●		●	
7	Liang	2008	TC-TDT	●						
8	Liang	2011	TC-LD	●					●	
10	Zhang	2011	TC- TNP-SL	●					●	
11	Noorul Haq	2006	TC							
12	Torabi	2008	TC -DVSC	●	●					
13	Kenne	2012	TC						●	
14	Feili	2011	TC-OP	●			●		●	
15	Mirzapour	2011	TC-SH-SL						●	
16	Bashiri	2011	TNP			●	●			
17	Mohammadi	2009				●	●			

S: Supplier P: Plant D:Distibutor W:Warehouse C: Customer M: Remanufacturer SH: Shortage R: Retailer DVSC: Warehouse Limits TNP: Total Net Profit SL: Service Level TC: Total Cost OP: Optimum Production TVP: Total Value of Purchases DT: Lead Time

Lin & Chen (2009) presented a model to random demand estimation with regard to current inventory flexibility which helps to an optimal routing and loading and transportation coordination in a distribution system. Shen (2006) developed a model to maximize interest in a supply chain in which the company is flexible enough to satisfy customers with quality services and the company might lose one customer due to the competition on pricing.

Gebennini et al. (2009) presented a model to allocate chain's components to each other and for transportations, warehousing and reverse logistic activities management in order to elaborate the control of current inventory, production quantity and service level determination in random situations.

Ahlert et al. (2009) presented a new approach to capacity flexibility in which the flexibility is provided by increasing the degree of freedom, and thus treats demand uncertainty. Ka-Leung Moon et al. (2012) attempted to evaluate supply, production, distribution, and information system flexibility of a textile and garment company.

Chen & Kasikitwiwat (2011) assessed quantitatively the capacity flexibility of traveler transportation network, using two-leveled network capacity model. Bjo & Carlsson (2007) presented two sets from mixed linear integral model with a fixed time perspective: first is a mix production and inventory model (manufacturer) with a fixed delivery time and another is with a flexible delivery time. Erhan Kesen et al. (2010) employed the flexibility in supplier selection to handle the demand uncertainty and inventory cost reduction, using the two methods of order to supplier below the allowed amount and pay fines or regular orders and accepting the lost orders. Charnsirisakskul et al. (2006) presented decision-making model which includes price integration and product decision-making for the cases where the manufacturer aims at providing pricing, delivery time, asset amount flexibility in different conditions. The main objective of the under-study-company is the product mixture flexibility with regard to capacity, installation, automation level and several capabilities of the resources.

Table 2. Classification of supply chain integrated flexible production planning models.

line	research	Supply chain level	Decision level	amount and time of delivery of raw material	amount and time of deliveries	capital	supply	Production time	delivery
1	[2011]. Bashiri	s-p-w-c	S-T			●			
2	[2000]. Sabri	s-p-w-d	S-O	●	●				
3	[2011]. Das	s-p-d-c	S			●	●		
4	[2011]. Schutz	s-p-d	O	●	●	●			
5	[2008]. Tang	s-p-r	S						
6	[2003]. Das	s-r	S	●	●				
7	[2003]. Garavelli	s-a-c	S						
8	[2008]. Gong	s-p-d	T-O						
9	[2009]. Lin	p-d	S-O						
10	[2006]. Shen	p-d-c	S						
11	[2009].Gebennini	p-d-c	S-T-O						
12	[2009]. Ahlert	s-d-c	T-O			●			
13	[2012].Leung Moon	s-p-d	S-T-O				●	●	●
14	Chen.[2011]	d-c	-			●			
15	Bjo.[2007]	p-d	O		●				
16	Erhan Kesen.[2010]	s-p	T				●		
17	Charnsirisakskul. [2006]	p-c	T		●				
18	Merzifonluoglu. [2006]	s-p	T-O	●					
19	Propose model	s-p-w-c	S-T			●	●		●

Table 2. Continue.

line	research	Supply chain level	Decision level	Customer Specified	Information system	Mixed product	Service level	Work force	inventory	routing	machine
1	[2011]. Bashiri	s-p-w-c	S-T								
2	[2000].Sabri	s-p-w-d	S-O								
3	[2011]. Das	s-p-d-c	S			●	●				
4	[2011]. Schutz	s-p-d	O								
5	[2008]. Tang	s-p-r	S						●		
6	[2003]. Das	s-r	S								
7	[2003]. Garavelli	s-a-c	S							●	
8	[2008]. Gong	s-p-d	T-O		●			●		●	●
9	[2009]. Lin	p-d	S-O						●		
10	[2006]. Shen	p-d-c	S	●							
11	[2009].Gebennini	p-d-c	S-T-O								
12	[2009]. Ahlert	s-d-c	T-O								
13	[2012].Leung Moon	s-p-d	S-T-O		●						
14	Chen.[2011]	d-c	-							●	
15	Bjo.[2007]	p-d	O								
16	Erhan Kesen. [2010]	s-p	T								
17	Charnsirisakskul. [2006]	p-c	T						●		
18	Merzifonluoglu.[2006]	s-p	T-O	●							
19	Propose model	s-p-w-c	S-T								

Strategic: S tactical: T operation: O

Merzifonluoglu & Geunes (2006) attempt to specify optimal levels of demand, production and inventory for each planning period, due to demand coming from different customers, when there is flexibility in demand selection and their delivery timing.

According to table 1 & 2, we can draw this conclusion, that an integrated four-level planning model (supply, production, warehouse, customer) that includes allocation and supply chain network design, while a multi-period, multi-product model with uncertain demand which also has supply, production and distribution in three level, has not been yet presented. We will present such model in following parts.

4. Defining the Problem

In this research, supply chain problem with multi products, multi suppliers, multi production centers, multi warehouses and multi customer is investigated and is applied with an integrated planning for tactical and strategic periods. The whole prospect of planning is divided into several strategic periods with each period including several tactical periods. In objective function the loan and its payment is to be discussed.

In the strategic level, first suppliers and then distribution centers will be detected. Then the effective criteria and sub-criteria are specified and paired comparisons between different suppliers and distribution centers is accomplished, based on the experts' analysis. In the end, the suppliers and distribution centers are ranked. In this period, the decisions related to contracts with suppliers and distribution centers and also the amount of capital of each period, the quality of accessing the centers and the unit price of each product and other decision are make. Also in a tactical level, the decisions regarding the capacity specifications, transportation amount between suppliers, plants, warehouses and customer, demand estimation, production amounts in various periods and other decisions will be made.

In this problem the customer demands are considered to be uncertain and probable, and customer demands follow different scenarios of normal distribution and the demand of each product in each period is raised with a specified amount and probability.

Our suppliers consist of two categories: producer with high quality raw materials and producer with mid-quality raw materials. Up to the time that suppliers are capable of supplying materials, no order is given to the suppliers of category two. When capacity of suppliers of first category becomes full, we will order suppliers of second category but the received raw material would be controlled.

Several capacity options considered for each factory and warehouse that will be added the initial capacity of these facilities proportional to demand fluctuating. Each center has a certain amount of installed capacity. Utilization rate of production and distribution centers will not to exceed a minimum and a maximum.

To satisfy this item, each of the stocks in a particular fleet capacity is considered and Special handling procedures are carried. Since the customer demands be supplied in each period (even with more transportation cost), if the transported amount toward customers for each warehouse in each period, is less than the fleet's mass transportation capacity of that warehouse, it would be transported as regular, while if it exceeded, it would be transported in a special way which costs more.

5. Proposed Model

In this section we will provide a mathematical model following introduce the indices, parameters and variables displayed in Table 3.

Table 3. Indices, parameters, and variables of the proposed model

• Indices.	
k: Strategic periods, $k=\{1,2,\ldots,K\}$	t: Tactical periods, $t=1,2,\ldots,T$
s : Suppliers sets, $s \in S^*=\{1,2,\ldots,S\} = S_1 \cup S_2$	o : Options for increasing capacity, $o=1,2,\ldots,O$
s': Suppliers of high quality material, $s' =\{1,2,\ldots,g\} \in S_1$	
s'': Suppliers of acceptable quality materials, $s'' =\{g+1,\ldots,S\} \in S_2$	
j : Plants, $j=1,2,\ldots,J$	w : Warehouses, $w \in W^*=\{1,2,\ldots,W\}= W_2 \cup W_1$
W_1: Private warehouses, $W_1 \in \{1,2,\ldots,a\}$	W_2: Public warehouses, $W_2 \in \{a+1,\ldots,W\}$
r :Raw materials, $r =1,2,\ldots,R$	i : Final products, $i=1,2,\ldots,I$
c : Customers (retailers), $c=1,2,\ldots,C$	sc : Different scenarios of demand, $sc \in \{1,2,\ldots,SC\}$
• Parameters.	
INV^k: Capital of period k	IR : Interest rates

TR : Tax rate

SH : Stakeholder shares

BN : A big number

e: A small number

F: Total profit

A_j^k: Availability of plant j in period k

B=DL^0: The loan amount at the beginning of the first strategic period

$R_{r,s'}^{k,t}$: Capacity of supplier s' for supply of raw material r

$R_{r,s''}^{k,t}$: Capacity of supplier s'' for supply of raw material r

$MK_{i,j}$: The initial capacity of plant j for product i

MU_{ij}: Minimum rate of plant j use for product i

$NK_{i,j}$: The maximum installed capacity of plant j for product i

NU_{ij}: Maximum rate of plant j use for product i

$CK_{j,i,o}$: Capacity of option o for product i

$CKW_{w,i,o}$: Capacity of option o in the warehouse for product i

$MKW_{i,w}$: Primary capacity of warehouse w for product i

$NKW_{i,w}$: Maximum installable capacity for warehouse w for product i

$B_{r,i}$: The amount of raw material r required to produce one unit of product i

$ID_{i,c}^{k,t,sc}$, $PD_{i,c}^{k,t,sc}$: Estimated percentage and probability of increasing in demand of product i from the customer c in period t, k based on scenario sc

$\mu_{i,c}^{k,t}$, ${\sigma^2}_{i,c}^{k,t}$: The average and variance of demand of product i from the customer c in period k, t

$MO_{r,s}$: The minimum allowable value for the order raw material r to the supplier s

$WL_{i,j}$: Workload required for producing one unit of product i in plant j

VW_i: Workload required for maintaining one unit i in warehouse

$INS_{r,s''}$: Inspection costs of raw material r supplied by the supplier s''

$CR_{r,s}$: The price of per unit of raw material r supplied by supplier s

FS_s: Fixed cost of Supply of from the supplier s (cost of contract)

CO_j: Fixed cost of setting up the plant j

FD_w: Fixed cost of activated warehouse w

$CA_{j,o}$: Fixed cost of adding options o to plant j

CU_j: Fixed cost of operating in the plant j

$CAW_{w,o}$: Cost of adding options o to warehouse w

CU_w: Fixed cost of operating in the warehouse w

FR_c: P percentage of service level of customer c

MT_w: Normal carrying capacity of warehouse w

$COP_{j,o}$: Fixed cost of operating in capacity option o in the plant j

$COP_{w,o}$: Fixed cost of operating in capacity option o in the warehouse w

$CP_{i,j}$: Variable cost of production per unit of product i in plant j

$CS_{i,w}$: Variable cost of per unit of storage product i in warehouse w

$PR_{i,c}^k$: The sell price of per unit of product i to customer c in period k

$CD_{r,s,j}$: Transportation costs per unit material r from supplier s to plant j

$CT_{i,j,w}$: Transportation costs of product i from plant j to warehouse w

$dis_{w,c}$: The distance between the warehouse w and the customer c

$CF1_w$: Normal transportation cost of product from warehouse w

$CF2_w$: Special Transportation cost of product from warehouse w

$SLT_{w,c}$: Delivery time of raw materials from the warehouse w to the customer c

- Variables.

INC^k: Income of k period

DL^k: Net income of strategic periods 1 to k

$Aq_{r,s''}^{k,t}$: It is Equal to 1 if supplier s'' provides raw material r in period k, t, otherwise it is zero

$q_{r,s'}^{k,t}$: It is Equal to 1 if supplier s' provides raw material r in period k, t, otherwise it is zero

x_j^k: It is equal to 1 if plant j in period k is enabled, otherwise it is zero

u_w^k: It is equal to 1 if warehouse w in period k is enabled, otherwise it is zero

$y_{j,o}^k$: It is equal to 1 if the capacity option o is added to plant j in period k, otherwise it is zero

$v_{w,o}^k$: It is equal to 1 if the capacity option o is added to warehouse w in period k, otherwise it is 0

$sp1_r^{k,t}$ & $sp2_r^{k,t}$: Binary variables for formulating flexibility of supply of material *r* in period *k, t*

$kp_w^{k,t}$: Binary variables for formulating flexibility of delivery from warehouse *w* in period *k, t*

$DS_{i,c}^{k,t}$: The average fluctuations (increase) in demand of product *i* from customer *c* in period *t, k*

$h_{i,w}^{k,t}$: The inventory of product *i* in warehouse *w* at the start of period *t, k*

$b_{i,j}^{k,t}$: The amount of product *i* in plant *j* in period *k, t*

$f1_{r,s',j}^{k,t}$: The amount of raw material *r* carried form supplier s' to plant *j* in period *k, t*

$f2_{r,s'',j}^{k,t}$: The amount of raw material *r* carried form supplier s'' to plant *j* in period *k, t*

$f3_{r,s,j}^{k,t}$: The amount of raw material *r* carried form supplier *s* to plant *j* in period *k, t*

$f4_{i,j,w}^{k,t}$: The amount of product *i* carried form plant *j* to warehouse *w* in period *k,*

$f5_{i,w,c}^{k,t}$: The amount of product *i* carried by normal way form warehouse *w* to customer *c* in *k, t*

$f6_{i,w,c}^{k,t}$: The amount of product *i* carried by particular way form warehouse *w* to customer *c* in *k, t*

$f7_{i,w,c}^{k,t}$: The amount of product i carried from warehouse w to customer c in period k, t

- Objective function

$$maximum\ F = \sum_{k=1}^{K} \frac{INC^k}{(1+IR)^{k-1}} \quad (1)$$

- Constraints

$$DS_{i,c}^{k,t} = \mu_{i,c}^{k,t} . \sum_{sc=1}^{SC} PD_{i,c}^{k,t,sc} . ID_{i,c}^{k,t,sc}\ \forall i,c,k,t \quad (2)$$

$$\sum_{w=1}^{W} f7_{i,w,c}^{k,t} = \mu_{i,c}^{k,t} + DS_{i,c}^{k,t} + FR_c * \sqrt{\left(0.5\ (SLT_{w,c}^{max} + SLT_{w,c}^{min})\right) . \sigma 2_{i,c}^{k,t}}\ \forall i,c,k,t \quad (3)$$

$$h_{i,w}^{(k-1),T} + \sum_{j=1}^{J} f4_{i,j,w}^{k,t} = \sum_{c=1}^{C} f7_{i,w,c}^{k,t} + h_{i,w}^{k,t}\ \forall i,k \neq 1, w, t = 1 \quad (4)$$

$$h_{i,w}^{k,(t-1)} + \sum_{j=1}^{J} f4_{i,j,w}^{k,t} = \sum_{c=1}^{C} f7_{i,w,c}^{k,t} + h_{i,w}^{k,t}\ \forall i,k,w \in W^*, t \neq 1 \quad (5a)$$

$$\sum_{j=1}^{J} f4_{i,j,w}^{k,t} = \sum_{c=1}^{C} f7_{i,w,c}^{k,t} + h_{i,w}^{k,t}\ \forall i,k,t = 1 \quad (5b)$$

$$\sum_{j=1}^{J} \sum_{s=1}^{S} f3_{r,s,j}^{k,t} = \sum_{i=1}^{I} B_{r,i} . (\sum_{j=1}^{J} b_{i,j}^{k,t}\ \forall k,t,r \quad (6)$$

$$h_{i,w}^{k,t} = 0\ \forall k = K, t = T, i, w \quad (7)$$

$$b_{i,j}^{k,t} = \sum_{w=1}^{W} f4_{i,j,w}^{k,t}\ \forall i,j,k,t \quad (8)$$

$$\sum_{k=1}^{K} \sum_{t=1}^{T} WL_{i,j} . b_{i,j}^{k,t} \leq NU_{i,j} . \sum_{k=1}^{K} (MK_{i,j} . x_j^k + \sum_{o=1}^{O} CK_{j,i,o} . y_{j,o}^k)\ \forall i,j \quad (9)$$

$$\sum_{k=1}^{K} \sum_{t=1}^{T} WL_{i,j} . b_{i,j}^{k,t} \geq MU_{i,j} . \sum_{k=1}^{K} (MK_{i,j} . x_j^k + \sum_{o=1}^{O} CK_{j,i,o} . y_{j,o}^k)\ \forall i,j \quad (10)$$

$$b_{i,j}^{k,t} \leq (MK_{i,j} . x_j^k + \sum_{o=1}^{O} CK_{j,i,o} . y_{j,o}^k) . A_j^k \quad \forall i,j,k,t \quad (11)$$

$$\sum_{t=1}^{T} \sum_{i=1}^{I} VW_i . (h_{i,w}^{(k-1),T} + \sum_{j=1}^{J} f4_{i,j,w}^{k,t}) \leq \sum_{i=1}^{I} MKW_{i,w} . u_w^k + \sum_{i=1}^{I} \sum_{o=1}^{O} CKW_{w,i,o} . v_{w,o}^k\ \forall w,k \quad (12)$$

$$MK_{i,j} . x_j^k + \sum_{o=1}^{O} CK_{j,i,o} . y_{j,o}^k \leq NK_{i,j}\ \forall i,j,k \quad (13)$$

$$MK_{i,w} . u_w^k + \sum_{o=1}^{O} CKW_{w,i,o} . v_{w,o}^k \leq NKW_{i,w}\ \ \forall k,i,w \quad (14)$$

$$\sum_{j=1}^{J} f1_{r,s',j}^{k,t} \leq R_{r,s'}^{k,t} . q_{r,s'}^{k,t}\ \forall r,s',k,t \quad (15)$$

$$\sum_{j=1}^{J} f2_{r,s'',j}^{k,t} \leq R_{r,s''}^{k,t} . Aq_{r,s''}^{k,t}\ \forall r,s'',k,t \quad (16)$$

$$\sum_{j=1}^{J} f1_{r,s',j}^{k,t} \geq MO_{r,s'}^{k,t} . q_{r,s'}^{k,t}\ \ \forall r,s',k,t \quad (17)$$

$$\sum_{j=1}^{J} f2_{r,s'',j}^{k,t} \geq MO_{r,s''}^{k,t} . Aq_{r,s''}^{k,t}\ \forall r,s'',k,t \quad (18)$$

$$\sum_{s=1}^{S} f3_{r,s,j}^{k,t} = \sum_{s'=1}^{g} f1_{r,s',j}^{k,t} + \sum_{s''=g+1}^{S} f2_{r,s'',j}^{k,t}\ \ \forall r,j,k,t \quad (19)$$

$$\sum_{s'=1}^{g} R_{r,s'}^{k,t} - \sum_{j=1}^{J} \sum_{s=1}^{S} f3_{r,s,j}^{k,t} \leq (sp1_r^{k,t} . BN)\ \ \forall r,k,t \quad (20)$$

$$\sum_{s'=1}^{g} R_{r,s'}^{k,t} - \sum_{j=1}^{J} \sum_{s=1}^{S} f3_{r,s,j}^{k,t} \geq (-sp2_r^{k,t} . BN)\ \forall r,k,t \quad (21)$$

$$\sum_{s'=1}^{g} R_{r,s'}^{k,t} - \sum_{j=1}^{J} \sum_{s'=1}^{g} f1_{r,s',j}^{k,t} \leq (1 - sp2_r^{k,t}) . BN\ \ \forall r,k,t \quad (22)$$

$$Aq_{r,s''}^{k,t} \leq (1 - sp1_r^{k,t})\ \forall r,s'',k,t \quad (23)$$

$$Aq_{r,s''}^{k,t} \geq e - (sp1_r^{k,t})\ \forall r,s'',k,t \quad (24)$$

$$f7_{i,w,c}^{k,t} \leq NKW_{i,w} . u_w^k\ \ \forall i,k,t,c,w \quad (25)$$

$$w_{w,c}^k \leq u_w^k\ \forall k,c,w \quad (26)$$

$$y_{j,o}^k \leq x_j^k\ \forall k,o,j \quad (27)$$

$$v_{w,o}^k \leq u_w^k\ \forall k,o,w \quad (28)$$

$$x_j^{k-1} \leq x_j^k\ \forall j,k \quad (29)$$

$$u_w^{k-1} \leq u_w^k\ \forall k,w \quad (30)$$

$$\sum_{o=1}^{O} y_{j,o}^k \leq 1\ \forall k,j \quad (31)$$

$$\sum_{o=1}^{O} v_{w,o}^k \leq 1\ \forall k,w \quad (32)$$

$$y_{j,o}^k \leq 1 - (x_j^k - x_j^{k-1})\ \forall k,o,j \quad (33)$$

$$v_{w,o}^k \leq 1 - (u_w^k - u_w^{k-1})\ \forall k,w \quad (34)$$

$$v_{w,o}^{k} = 0 \ \forall w \in W_2 \tag{35}$$

$$f7_{i,w,c}^{k,t} = f5_{i,w,c}^{k,t} + f6_{i,w,c}^{k,t} \ \forall i,w,c,k,t \tag{36}$$

$$MT_w - \sum_{i=1}^{I}\sum_{c=1}^{C} f7_{i,w,c}^{k,t} \le kp_w^{k,t}.BN \ \ \forall w,k,t \tag{37}$$

$$\sum_{i=1}^{I}\sum_{c=1}^{C} f7_{i,w,c}^{k,t} - MT_w \le (1-kp_w^{k,t}).BN \ \forall w,k,t \tag{38}$$

$$f6_{i,w,c}^{k,t} \le (1-kp_w^{k,t}).BN \ \ \forall i,w,c,k,t \tag{39}$$

$$f5_{i,w,c}^{k,t} \le MT_w \ \ \ \forall i,w,c,k,t \tag{40}$$

$$Aq_{r,s''}^{k,t}, q_{r,s'}^{k,t}, x_j^k, y_{j,o}^k, v_{w,o}^k, u_w^k, kp_w^{k,t}, sp1_r^{k,t}, sp2_r^{k,t} \in \{0,1\} \ \ \forall i,j,c,k,t,r,p,o,w,s \tag{41}$$

$$f3_{r,s,j}^{k,t}, f1_{r,s',j}^{k,t}, f2_{r,s'',j}^{k,t} \ge 0 \ \forall r,j,k,t,s',s'',s \tag{42}$$

$$f4_{i,j,w}^{k,t}, b_{i,j}^{k,t} \ge 0 \ \ \forall i,j,k,t,w \tag{43}$$

$$f5_{i,w,c}^{k,t}, f6_{i,w,c}^{k,t}, f7_{i,w,c}^{k,t}, h_{i,w}^{k,t} \ge 0 \ \ \ \forall i,c,k,t,w \tag{44}$$

Equation (1) defines the objective function based on a cumulative net profit maximizing strategic course. Equation (2) determines fluctuations in the amount of (increased) demand in different periods under various scenarios. The constraints (3) The total amount of product *i* in period *k, t* be sent from warehouse to customer demand, the average periods equal to *k, t* as well as periods of fluctuating demand *k, t* for product *i*. These constraints also are to determine inventories to ensure that it satisfies delivered service levels.

According to equations (4) & (5) (including 5a and 5b) the amount of inventory in each warehouse i at the end of the previous tactical period plus the total amount of product *i* received to that warehouse in the current tactical period is equal to the value of product *i* shipped to customers in the current tactical period plus inventory of product *i* at the end of the current tactical period in the warehouse. Other limitations of the model equations are as follows: (6), sufficient quantities of raw materials required to produce the final product delivers to factories. (7), There will not be excess inventory at the end of the course. Equation (8), the amount product produced in a plant must be equal to the amount of delivered to the warehouse. (9), production rate in total period should not be less than the minimum possible rate of operation of the plant. (10), production rate in total period should not be less than the maximum possible rate of operation of the plant. (11), at the tactical level of product i at plant j for product i is less than the total capacity of the plant. (12), greater storage capacity can hold the product. (13) & (14), with a total installed capacity of each facility is equal to the initial capacity and added capacity options.

Equations (15)-(18) are limits of the amount of suppliers' capacities. The amount of material *r* is provided by the suppliers should not be greater than the suppliers' capacities and less than minimum allowable amount for the order to the suppliers. (19), the amount of raw material *r* from supplier *s* to plant in period *k, t* is equal to the sum of raw material *r* received by manufacturers of both the supplier s' and s'' in period *k, t*. Constraints (20) and (24) guarantee that as long as *s* suppliers s' have capacity to supply raw material *r* in period *k, t*, the suppliers s'' will not be selected to supply raw material *r*.

Equation (25), each storage customer sends the product, provided that the cache enabled and the maximum size of the installed capacity in the warehouse. (26), each stock *k* during the active will be assigned to the customer *c*. (27) & (28), the option will add capacity only to active facility. (29) & (30) disabled facilities, it cannot be disabled. (31) & (32), one option in each period k is the maximum capacity that can be added to the distribution centers or plants. (33) & (34) in the first period of an activity does not have the capacity to add options. (35) That can be added is the option to add capacity to only public warehouse. (36) The total amount of transported goods using both ordinary and special is equal to the total amount of shipping products from warehouse to customer .Special transport (direct), which is more expensive. (37)-(40) guarantees that if the transported amount toward customers for each warehouse in each period, is less than the fleet's mass transportation capacity of that warehouse, it would be transported as regular, while if it exceeded, it would be transported in a special way (direct) which costs more. Constraints (41)-(44) are taken as indicative of the type of the variable.

6. Calculation of Components of the Objective Function

$$\mathrm{INC}^k = \sum_{t=1}^{T}\sum_{w=1}^{W}\sum_{i=1}^{I}\sum_{c=1}^{C} \mathrm{PR}_{i,c}^k . f7_{i,w,c}^{k,t} \tag{45}$$

$$-\sum_{j=1}^{J} \mathrm{CO}_j . (x_j^k - x_j^{k-1}) \tag{46}$$

$$-\sum_{w=1}^{W} \mathrm{FD}_w . (u_w^k - u_w^{k-1}) \tag{47}$$

$$-\sum_{j=1}^{J}\sum_{o=1}^{O} \mathrm{CA}_{j,o} . (y_{j,o}^k - y_{j,o}^{k-1}) \tag{48}$$

$$-\sum_{w=1}^{W}\sum_{o=1}^{O} \mathrm{CAW}_{w,o} . (v_{w,o}^k - v_{w,o}^{k-1}) \tag{49}$$

$$-\sum_{j=1}^{J}(\mathrm{CU}_j . x_j^k + \sum_{o=1}^{O} \mathrm{COP}_{j,o} . y_{j,o}^k) \tag{50}$$

$$-\sum_{w=1}^{W}(\mathrm{CU}_w . u_w^k + \sum_{o=1}^{O} \mathrm{COP}_{w,o} . v_{w,o}^k) \tag{51}$$

$$-\sum_{t=1}^{T}\sum_{i=1}^{I}\sum_{j=1}^{J} \mathrm{CP}_{i,j} . b_{i,j}^{k,t} \tag{52}$$

$$-\sum_{t=1}^{T}\sum_{i=1}^{I}\sum_{w=1}^{W} \mathrm{CS}_{i,w} . (h_{i,w}^{k,t} + \sum_{j=1}^{J} f4_{i,j,w}^{k,t}) \tag{53}$$

$$-\sum_{t=1}^{T}\sum_{r=1}^{R}\sum_{s=1}^{S}\sum_{j=1}^{J} \mathrm{CD}_{r,s,j} . f3_{r,s,j}^{k,t} \tag{54}$$

$$-\sum_{t=1}^{T}\sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{w=1}^{W} \mathrm{CT}_{i,j,w} . f4_{i,j,w}^{k,t} \tag{55}$$

$$-\sum_{t=1}^{T}\sum_{i=1}^{I}\sum_{w=1}^{W}\sum_{c=1}^{C} CF1_{i,c} . dis_{w,c} . f5_{i,w,c}^{k,t} \quad (56)$$

$$-\sum_{t=1}^{T}\sum_{i=1}^{I}\sum_{w=1}^{W}\sum_{c=1}^{C} CF2_{i,c} . dis_{w,c} . f6_{i,w,c}^{k,t} \quad (57)$$

$$-(\sum_{t=1}^{T}\sum_{r=1}^{R}\sum_{s'=1}^{g}\sum_{j=1}^{J} CR_{r,s'} . f1_{r,s',j}^{k,t} + \sum_{t=1}^{T}\sum_{r=1}^{R}\sum_{s''=g+1}^{S}\sum_{j=1}^{J} CR_{r,s''} . f2_{r,s'',j}^{k,t} + + \sum_{t=1}^{T}\sum_{r=1}^{R}\sum_{s'=1}^{g} FS_{s'} . q_{r,s'}^{k,t} + \sum_{t=1}^{T}\sum_{r=1}^{R}\sum_{s''=g+1}^{S} FS_{s''} . Aq_{r,s''}^{k,t} + + \sum_{t=1}^{T}\sum_{r=1}^{R}\sum_{s''=g+1}^{S}\sum_{j=1}^{J} INS_{r,s''} . f2_{r,s'',j}^{k,t}) \quad (58)$$

$$- DL^{0}/_{K} \quad (59)$$

Relations (45)-(59) describe the different parts of the objective function. The equation (45) represents a total investment of proceeds from the sale of products in period *k*, equation (46) & (47) the fixed costs of setting up factories and warehouses, relations (48) & (49) the fixed costs rise capacity of plants and warehouses, relations (50) & (51) the fixed costs of operating in factories and warehouses, (52) the cost of production in factories, (53) the cost of inventory in warehouses, (54) & (57) the cost of transport between suppliers, manufacturer, warehouses and customers, (58) the fixed and variable costs of materials and inspection costs of materials supplied by suppliers s′, (59) repayment of principal loans are each period. Fixed costs and inventory costs are not considered reliable for stock companies. The following constraints were added to the model clearer:

$$DL^{k} = (1 - TR).(1 - SH).INC^{k} - TR \ .(B - ((k-1).^{B}/_{K}))\ \forall k \quad (60)$$

$$\sum_{j=1}^{J} CO_{j} . (x_{j}^{k} - x_{j}^{k-1}) + \sum_{w=1}^{W} FD_{w} . (u_{w}^{k} - u_{w}^{k-1}) + \sum_{o=1}^{O}\sum_{j=1}^{J} CA_{j,o} . (y_{j,o}^{k} - y_{j,o}^{k-1}) + \sum_{o=1}^{O}\sum_{w=1}^{W} CA_{w,o} . (v_{w,o}^{k} - v_{w,o}^{k-1}) \leq DL^{k-1} + INV^{k}\ \forall k \quad (61)$$

Equation (60) Net income strategy 1 to calculate k. Constraint (61) ensures that the necessary capital to launch the facility at any time during that period does not exceed the total amount of funds available. Also, we have:

7. Solution Method

Since the number of constraints and decision variables, and zero and one decision variable is causing the problem and given the complexity of the issue in articles such as work NP_HARD, Jolai et al. (2010) demonstrated, as well as high method of calculation time required for exact solution algorithms, meta- heuristic optimization of dense particles (PSO) was proposed to solving the model enlarge.

8. Particle Swarm Optimization Algorithm

PSO algorithm is an algorithm for social search that is modeled on the social behavior of birds clubs. Particles move in the search space is affected by the experience and knowledge of themselves and their neighbors. The foundation of PSO is based on this principle that in each moment, each particle sets its space according to the best location ever being placed in and the best place ever its neighbors being placed in. In this research, this algorithm is written heterogeneously. Particle swarm optimization algorithm's chart is shown in Figure 1.

The following symbols and parameters have been used in particle swarm optimization algorithm:

Iter: Algorithm iteration's counter

pp Particle counter

x^{i}: Particle i position

V^{i}: Particle i velocity

Swarm: Total Population in the each iteration

W: The inertia coefficients

Wdamp: reduction rate of inertia coefficients in the each iteration

ri: Uniform random number between zero and one

C1: Coefficient of individual learning

C2: Coefficient of collective learning

Velmin: The minimum rate of speed

Velmax: The maximum rate of speed

Pbest: The best individual answer

Gbest: The best collective answer

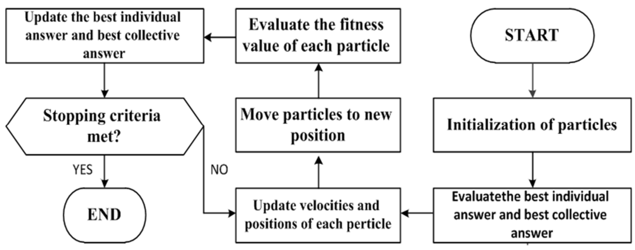

Figure 1. Article swarm optimization algorithm's char.

First step: generate random binary variables, taking into account the limits of (23) & (24), (28)-(35) and (41) in the model that includes the variable *x, y, u, v, kp, sp1, sp2, q, Aq* are. Variable x, which played a decisive role in the likely or unlikely is it, at first, to prevent the production of non-feasible solution, for all its index value is taken.

Second step: generate variables *f1, f2, f3,* based on the values of the binary variables in the first step. This variable determines amounts of raw materials supplied by the Suppliers. To Supply constraints (15)-(18), *f1* and *f2* values are generated based on desired interval constraints. Then *f3* limits are set by (19). This means that the sum of *f3* per *s* and 19 limits are calculated and the accident is divided between s to *f3*.

Step three: Restoring the values *f1, f2* and *f3* to supply constraints (20)-(22). In this step, the limits of previous steps that have been taken in violation of binary variables may be changed accordingly.

Step Four: variable amounts *f5, f6, f7,* which is related to the amount of goods from warehouse to customer. The total amount of the limit w *f7* for (2) & (3) are calculated by taking the limit of (25), the value of the sum should be divided between w. Supply constraints are also considered to be (37) & (38). Then according to the limit (36), the values of *f5* is divide between variables *f6 & f7* taking the limit (39) & (40) will be discussed.

Step Five: It is set to b. The first, second, third step is calculating and determining the limits of the same (6) values $((\sum_{i=1}^{I}(B_{r,i}.(\sum_{j=1}^{J} b_{i,j}^{k,t}))))$ and then divide this amount between *b* and taking (9)-(11) and (13) & (14) will continue. For example, in every answer, *b* and *h* are considered as matrices four dimension with size of their index if relationships (62) & (63).

$$H= [k, w, t, i] \quad (62)$$

$$B= [i, j, k, t] \quad (63)$$

Intermediate variables are also in the matrixes with the size of their indexes.

Step Six: This step consists of a set of values *h* and then the *f4* means product in the production centers. First, the amount of *b* from Equation (8) divides and then *f4* values calculated from equations (4), (5) & (12) *h* values. If any of the h or *b* Negative values are set to return to the first step. Otherwise, the seventh step. The algorithm is written so that it allows the partial non- response in the first accepted iterations. For example, when the matrix *b* contains the value 400, in the first iterations, solutions that contain 20 negative values, will be accepted. And gradually more of the repeater, this value goes to zero, until the negative amount will not be produced.

Step Seven: Calculate the objective function based on equations 1 and (45)-(61).

For PSO iterations, first step: binary variables are initialized by binary PSO.

Here, step 2 to7 are similar to the steps of generating an initial solution.

For the initialization of particle, each particle has a random answer and the above procedure will produce. The answer is known as the position of the particle. Fitness function value obtained for each particle as well as the best person to answer that particle is considered.

Each of these particles searches with a certain velocity and direction in solution space. This move, takes place according to the best previous position of the particle, the current state of the particle and the best position among all the particles. Function (64) is used to determine the velocity of each particle. The first part of the ratio of the velocity of the previous iteration is considered. The second part moves towards the best answer to the third part of the individual and the collective in the comments is the best answer.

$$V^i[t+1] = w \times V^i[t] + C_1 \times r_1 \times (x^{i,Pbest}[t] - x^i[t]) + C_2 \times r_2 \times (x^{Gbest}[t] - x^i[t] \quad (64)$$

To prevent excessive motion of a particle, velocity is limited by the values of *Velmin* and *Velmax*. After determining the velocity of each particle, the position of each particle is obtained as a function of (65). Also, the new position of each particle is restricted to values between zero and one.

$$x^i[t+1] = x^i[t] + V^i[t+1] \quad (65)$$

Right-hand side of equation (64) is composed of three parts: the first parts, is the current velocity of the particle and the second and third parts are responsible for the particle velocity and spin it the best personal experience and the experience of the group.

After updating the velocity and position of each particle, the fitness function for each particle is calculated. The improvement in the fit function, the best individual solution is updated to the new value. Also, the collective works best if the change is updated. The inertia coefficient decreases with offered reduced rates.

The proposed algorithm, stops if only come to a termination condition. The termination condition is the first to reach a certain number of iterations. The number of iterations of the algorithm and the code can be pre-determined. Another condition to stop the iteration solution is characterized by lack of the optimal change. That is, if after a certain repetition optimal solution is unchanged, the algorithm is stopped.

9. Numerical Examples and Validation of Model

IN order to illustrate the application of the proposed model, a numerical hypothetical example with the following structure has been proposed and some computational results is presented in this section to solve by MIP CPLEX software GAMS.

Number Prime suppliers: 3	uppliers of second degree: 3
Number of plants available: 4	umber of warehouse: 4
Number of strategic period: 5	
Number of customer: 40	umber tactical periods: 4
Number of raw material 6	umber of final product: 5
Number of Capacity options: 4	

The input data for example the generation of random numbers using a uniform distribution is obtained.The proposed model in each period selects the best suppliers, manufacturing centers, warehouses deals. Expanding the capacity is done in the second cycle. There are 4 potential locations for production facilities and 2 private places for storing and 3 candidates for general warehouse in the hypothetical example. Table 4 represents Status of construction or rental of facilities and capacities associated with each strategy in each indicated period.

According to Table 4 in the first strategy, two factories (Sites 3 & 4) are set up and 2 General Warehouse (Warehouses 3 & 4) is leased. Private warehouse storage period 2 will be launched. It was observed that the capacity of the production facilities established increases in the second or third period.

Table 4. Capacity of plants and warehouses in strategic period.

		Strategic periods				
		1	2	3	4	5
factories	1	-	261370	342760	342760	342760
	2	-	245430	245430	245430	308650
	3	277570	353310	353310	353310	353310
	4	266080	266080	338460	266080	266080
Private warehouses	1	-	398580	398580	398580	398580
	2	413500	413500	413500	413500	413500
Public warehouses	3	114100	146640	146640	146640	146640
	4	132370	162960	132370	132370	162960

Table 5. Selected suppliers for each raw material.

raw	First rate supplier			Second rate supplier		
material	1	2	3	4	5	6
1	-	-	✓	-	-	-
2	-	-	-	✓	✓	✓
3	-	✓	✓	-	-	-
4	-	-	-	✓	✓	✓
5	✓	✓	✓	✓	✓	✓
6	✓	✓	✓	✓	-	-

The model Suppliers have been selected based on the required amount of raw material prices and transportation costs. Raw materials in present example are provided six suppliers over the planning horizon. For example, Table 5 shows the materials supplied by any provider in the first strategic and second tactical period. In considering this issue, the proposed model is essential to meet the demand of all customers, table 5 6epresent the amount of each product per tactical course.

In the proposed model, it is assumed that the units of products cannot be transported directly to the customer areas, such those warehouses, are distribution centers in which the products can be stored. Table 7 shows Value of inventory of each of the products in warehouse in each strategic period. Figure 2 also shows changes in inventory levels in warehouses in the strategic periods.

Table 6. The amount of each product produced during each of the tactical periods.

product	Tactical	Strategic periods				
	period	1	2	3	4	5
1	1	83093	3821	57899	22673	28895
	2	10527	3778	-	-	-
	3	-	34097	-	3979	-
	4	4107	-	-	-	-
2	1	63738	77038	6350	-	49294
	2	33029	-	-	-	-
	3	-	-	-	25627	-
	4	4225	-	2859	-	-
3	1	63760	58422	26860	-	-
	2	35489	-	-	-	-
	3	-	-	-	32280	45994
	4	-	-	-	-	-
4	1	38096	78304	27989	-	49812
	2	61266	-	-	-	-
	3	-	5161	-	116540	-
	4	-	-	505	-	-
5	1	82786	93672	24865	25393	24351
	2	82310	-	-	-	-
	3	-	-	-	-	-
	4	-	-	-	-	-

Table 7. Value of inventory in warehouses at the end of each strategic period.

warehouse	Strategic periods				
	1	2	3	4	5
1	-	95054	102370	88982	85325
2	123780	74841	96399	56955	137500
3	203760	316590	287320	267580	286030
4	211620	237710	327670	345370	224770

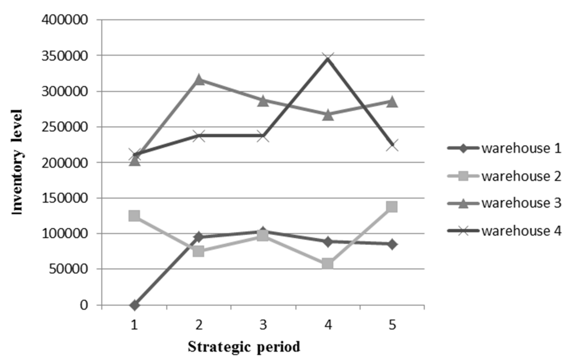

Figure 2. Trend of inventory level in warehouses.

9.1. Numerical Results of the Model

To evaluate the performance of the proposed model, we provide some examples of the problem in this section. The sample problem started small size and gradually increasing its dimensions by adding to the parameters (p1 to p15). Some computational results of these examples are solved by the MIP CPLEX and GAMS software on a computer with a 2.30 GHz Core i5 processing power and 4GB of memory installed, and are presented in this section. In all instances the 5 strategic planning period are assumed that each period is tactical strategy includes four courses. Table 8 shows the structure of this sample issues.

Table 8. Structure of Problems.

Problem	Strategic period	Tactical period	Suppliers	Production sites	warehouses private	warehouses public	Customer	Raw material	product	Number of Capacity of options
1	5	4	3	2	2	0	20	3	6	1
2	5	4	4	3	2	1	30	4	7	1
3	5	4	5	4	2	2	40	5	8	2
4*	5	4	6	4	2	2	40	6	5	4
5	5	4	5	5	2	3	50	6	9	3
6	5	4	6	6	2	4	60	7	10	3
7	5	4	7	7	2	5	70	7	12	3
8	5	4	8	8	2	6	80	8	14	3
9	5	4	8	8	2	7	90	9	16	3
10	5	4	8	9	2	8	100	9	18	4
11	5	4	8	7	2	7	110	11	18	3
12	5	4	8	8	2	7	120	10	17	3
13	5	4	8	8	2	7	130	11	18	3
14	5	4	9	8	2	8	140	11	18	3
15	5	4	9	9	2	8	150	10	18	3

Having solved examples, due to the complexity of the model and the inability to solve problems with large Software Gomez, here we consider only the output of the first five issues. Total number of variables, the total number of discrete variables, number of constraints, and the processing time to reach the optimal solution is recorded. The computational results of problems have shown in Table 9. All that matters is the total number varies from 18,871 to 251,571 different.

Table 9. Results of the calculations for examples.

problems	variable	Discrete Variable	Constraint	Process time (s)	Gap
1	18871	380	26140	3.36	0.000047
2	46631	600	62554	305.72	0.000256
3	91951	900	120800	3760.78	0.000297
4*	159251	1140	201371	14100.06	0.000263
5	251571	1480	324356	43200	NFS

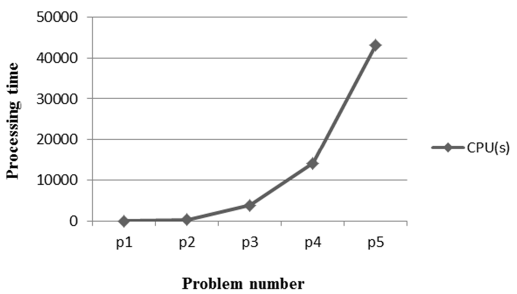

Figure 3. Trend of increasing processing time problems.

Process time ranges from 3.36 seconds to 10 hours. The number of variables, the number of discrete variables and constraints that increase .It makes the processing time significantly increased. In the first instance, the processing time of less than 6 seconds and this value is more than 1 hour in Example 3 & 5 is more than 10 hours. (Figure 3)

9.2. Numerical Results of the Algorithm

In This section problems are classified into two categories: small size and large size. PSO Parameter setting is done by Taguchi method, and with the help of MINITAB software and appropriate parameters was obtained. Graphs of the Taguchi parameter setting results is displayed in Figure 4. But is necessary to mention that because the suggested algorithm approaches a right solution with an optimal solution gained from GAMS and low risk, although the parameter settings recommends more iterations, but the answers optimization improves a little in iterations.

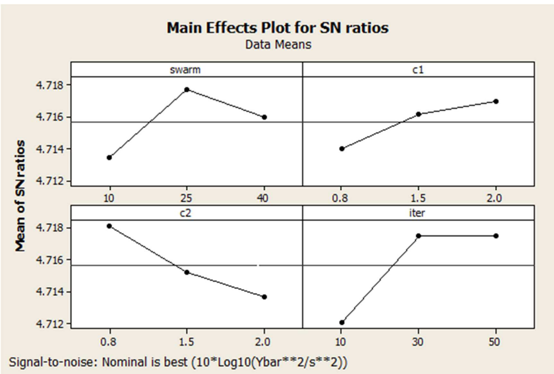

Figure 4. Results of tuning parameters by Taguchi method.

For small-sized problems, solutions obtained to mathematical programming and optimization software GAMS. It also uses the PSO algorithm to enforce these addressed items and the results of its optimality are shown in Table 10.

Table 10. Results evaluation of small size problems.

Error (%)	PSO	Best solution	Problem size							Problem
			o	c	i	r	w	j	s	
0.06	5.2839+e10	5.6303+e10	1	20	6	3	2	2	3	1
0.04	9.4505+e10	9.8533+e10	1	30	7	4	3	3	4	2
0.2	1.4642+e11	1.5062+e11	2	40	8	5	4	4	5	3
1	8.9767+e10	9.9741+e10	4	40	5	6	4	4	6	4

For large size problems due to the increasing size of the problem and lack of solution at this size by software GAMS, PSO method which is used in Table 11 are presented the results for 11 issues. In this table, the best response time performance of the algorithm is shown in seconds.

10. Conclusions and Suggestions for Future Research

This paper presents a mathematical model for supply planning - production - distribution chain. Strategic and tactical planning decisions are taken during the strategic period of several tactical courses. In this model, the capacity flexibility, providing flexibility and delivery flexibility are considered that makes it possible to apply the decisions in accordance with market changes in the intended conditions of uncertainty. The proposed model is a linear programming model. The results of this model help us make decisions about the allocation of each chain components such as the allocation of suppliers to plants, factories, warehouses, etc.

Table 11. PSO algorithm performance and results evaluation of large size problems.

PSO		Problem size							Problem
Time(s)	Best solution	o	c	i	r	w	j	s	
220	2.0695+e11	3	50	9	6	5	5	5	5
320	2.7653+e11	3	60	10	7	6	6	6	6
433	3.8830+e11	3	70	12	7	7	7	8	7
865	4.5410+e10	3	80	14	9	8	8	8	8
980	6.6990+e11	3	90	16	9	9	8	8	9
1060	7.8886+e11	4	100	18	10	9	8	10	10
1256	9.2163+e11	3	110	18	11	9	7	8	11
967	9.4642+e11	3	120	17	10	9	8	8	12
1922	1.0917+e12	3	130	18	11	9	8	8	13
2018	1.1753+e12	3	140	18	11	10	8	9	14
2422	1.3421+e12	3	150	18	10	10	9	9	15

The feature of this model, first, it deals with suppliers based on the demand, and then according to the results gained from supply section, does plan the production planning for working stations and in the end operates the distribution planning and produced amount allocation among the customers (selling centers). Flexibility makes the model to be applied in order to better respond to the changes in our market.

However, research can improve in various fields, including discussions and lack of inventory and the possibility of future research. Also, because of the increased time and solve increasingly complex problems, following its dimensions increase, the use of meta- heuristic methods for achieving better solutions in less time for larger problems is proposed. Considering the increased rebate policy, not so much complexity in solving the model, looks good idea. Use an actual model Instead of random problems or adding routing phase in the integrated supply chain, are some suggestions for future research.

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