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Integrated production, inventory, and distribution model under MTS/MTO strategy.

M. S. Abass[a], A.M. Gaafer[b], A. R. Saad[b].

a Faculty of Engineering, Modern University, Egypt.
b Mechanical Department , Faculty of Engineering, Benha University, Egypt.

a b s t r a c t

Hybrid Make-To-Stock (MTS)-Make-To-Order (MTO) manufacturing is a well-known policy that captures the benefits of both MTS and MTO policies. This paper presents an integrated single objective production, inventory and distribution planning in a multi-product, multi period under hybrid MTS/ MTO strategy. The objective of the model is to minimize the total cost involved in running the supply chain SC via Fuzzy Goal Programming (FGP) approach. The model is tested with a set of realistic data and the optimal results show the validation of the model. It was concluded that the total cost of the SC was minimized and the decision variables were obtained.

من المعروف ان سياسة التصنيع المختلط بين الانتاج للتخزين و الانتاج حسب الطلب تجمع بين مزايا كل منهما ولذلك هذا البحث يقدم تخطيط التكامل للتصنيع و التخزين و التوزيع لدالة ذات هدف واحد فى حالة تعدد المنتجات خلال فترات زمنية متعددة فى ظل هذه السياسة. وهدف هذا النموذج هو تقليل التكلفة الإجمالية لسلسلة التوريد باستخدام منهج برمجة الأهداف الفازية. و قد تم اختبار النموذج بواسطة بيانات واقعية و تم الحصول على الحل الامثل حيث حققت النتائج صحة النموذج و تم تقليل التكلفة الكلية لسلسلة التوريد و تم تحديد قيم متغيرات القرار.

Keywords: Supply Chain, Production-Inventory-Distribution, Hybrid MTS/MTO.

1. Introduction

A manufacturing system can be defined as an arrangement of tasks or processes to transform a selected group of raw materials or semi-finished products into a set of finished products. From the viewpoint of the relationship between production release and order arrival, production systems can be classified into Make-To-Stock (MTS) and Make-To-Order (MTO) or Hybrid one. Hybrid Make-To-Stock (MTS)/ Make-To-Order (MTO) deals with a combination of two extreme production contexts; MTS and MTO.MTS production environments are planned and implemented based upon forecasts of demands and coming orders. Hence, products are accomplished before entrance of any order and with respect to forecasted specifications from customers. In contrary to MTS, products are manufactured exactly as dictated by actual orders in MTO production context.

The objective of this paper is to minimize the SC total cost over multiple time periods under hybrid

information flow among various business entities such as suppliers, manufacturers, distributors, third party logistic providers, retailers and customers [2].

MTS/MTO strategy to provide a universal platform for the decision makers to take and implement their managerial decisions.

In today's dynamic business environment, many companies are expanding, merging, contracting, or otherwise redesigning their supply chain. Due to the rapid advancements of technology such as pervasive or ubiquitous wireless and internet networks, the basic supply chain is rapidly evolving into what is known as a Supply Chain Network. The supply chain network is a dynamic and integrated system in which all firms integrated to increase the value of every chain. Integration is a process of redefining and connecting parts of a whole in order to form a new one [1].

A supply chain (SC) can be defined as an integrated system synchronizing a series of interrelated business processes in order to: (1) acquire raw materials and parts, (2) transform these raw materials and parts into finished products, and (3) distribute these products to either retailers or customers. A SC facilitates
In the context of supply chain management (SCM), planning, controlling and optimization of Production–inventory-distribution (P–I–D) have raised significant interest for both researchers and practitioners over the past few years. The drivers for

the extensive literature addressing the modeling and optimization of integrated P–I–D plans in SCs are (1) positively affecting the profitability of the SC through the global integration of production, inventory and distribution activities and (2) reducing the lead-times and offering quicker response to market changes and hence reducing the propagation of unexpected and undesirable events through the network.

For practical manufacturing/ inventory/ distribution planning decisions integration problems in supply chains, a decision maker (DM) typically attempts to achieve the following goals: (1) set overall production and inventory levels for each product category for each source (manufacturer) to meet fluctuating or uncertain demands for various destinations (distributors) over the intermediate planning horizon and, (2) generate suitable strategies regarding regular and overtime production, subcontracting, inventory, backordering and distribution levels, thereby determining the appropriate resources to be utilized.

A P–I–D planning problem is the problem of simultaneously optimizing the decision variables of different functions that have traditionally been optimized sequentially in the sense that the optimized outputs of the production stage have become the input to the inventory stage and the optimized outputs of the inventory stage have become the input to the distribution stage.

Jonathan and Narameth[3] analyzed a single production facility that serves a set of customers with time varying demand over a finite and discrete planning horizon and focus on the production, inventory, distribution, routing problem (PIDRP).They use a branch-and-price algorithm to solve this problem. Computational testing on standard data sets showed that the a branch-and-price algorithm can solve instances with up to 50 customers and 8 time periods within 1 h, While **Armentano** [4] et al. considered a capacity-constrained plant that produces a number of items distributed by a fleet of homogenous vehicles to customers with known demand for each item in each period. The objective is to minimize production and inventory costs at the plant, inventory costs at the inventory costs at the customers and distribution costs. They proposed two tabu search variants for this problem, one that involves construction and a short-term memory, and one that incorporates a longer term memory used to integrate a path relinking procedure to the first variant. The results shown that tabu search and path relinking can be successfully applied to the addressed problem and more generally to planning problems with a discrete time horizon.

On the other hand mills, **Kullapapruk** [5] studied a case of multiple feed multiple farms, and multiple products problem, which resembled a multi-facility, multi customer, and multi-product of an integrated feed swine company as a real life case study. In order to determine the most suitable feed delivery cycle, number of trucks used, feed order quantities for individual farms, and production batch size of the feed mill such that the cost from mill to feed is minimized the database management coupled with a mathematical modeling method is proposed to cope with the industrial-scale feed production– distribution planning.

Krishna and Tiwari [6] incorporated a risk pooling effect, for both safety stock and running inventory (RI), in the system to minimize the supply chain cost along with determining facility location and capacity. They formulated the model as mixed integer nonlinear problem and divided it into two stages. **Miguel et al. [**7] combined the use of mathematical programming based optimization and Game Theory as an effective way to solve SC planning problems in competitive/ collaborative scenarios. The system developed is tested in a case study based in previously proposed Supply Chain, adapted to consider the operation of two different Supply Chains (multi-product production plants, storage centers, and distribution to the final consumers).

To solve the problem of production/ distribution to determine an efficient integration of production, 5distribution and inventory system in order to minimize system wide costs while satisfying all demand required, **Mitsuo and Syarif** [8] proposed a new technique called spanning tree-based genetic algorithm (hst-GA) which is hybridized with the fuzzy logic controller (FLC) concept for auto-tuning the GA parameters, In order to improve its efficiency. This problem can be viewed as an optimization model that integrates facility location decisions, distribution costs, and inventory management for multi- products and multi-time periods. The proposed method is compared with traditional spanning tree-based genetic algorithm approach.

Liang [9] applied a fuzzy linear programming approach based on the possibility theory to solve multi-product and multi-time period MDPD problems with imprecise goals and the proposed approach attempts to minimize the total manufacturing and distribution costs forecast demand by considering the time value of money of related operating cost categories. by considering the levels of inventory, subcontracting and backordering, the available machine capacity and labor levels at each source, forecast demand and available warehouse space at each destination. The study utilized an industrial case study to demonstrate the feasibility of applying the proposed approach to practical MDPD problems. The proposed approach yields a more efficient solution and several significant managerial implications for practical application. In particular, the proposed computational methodology can easily be extended to any other situation and can handle real-life MDPD decisions in uncertain environments. Also **Liang and Cheng** [10] applied fuzzy sets to integrating manufacturing/distribution planning decision (MDPD) problems with multi-product and multi-time period in supply chains by considering time value of money for each of the operating cost categories. Total costs and total delivery time with reference to inventory levels, available machine capacity and labor levels at each source, as well as market demand and available warehouse space at each destination, and the constraint on total budget were attempted to simultaneously minimize by the proposed fuzzy multi-objective linear programming model (FMOLP). An industrial case demonstrates the feasibility of applying the proposed model to a realistic MDPD problem and several significant management implications are presented based on computational analysis and comparisons with the existing MDPD methods. The main advantage of the proposed model is that it presents a systematic framework that facilitates fuzzy decision-making for solving the multi-objective MDPD problems with multi-product and multi-time period in supply chains under an uncertain environment, enabling the decision maker to adjust the search direction during the solution procedure to obtain a preferred satisfactory solution.

Cóccolaa et al. [11] presented a novel optimization approach to the integrated operational planning of multi-echelon multiproduct production and transportation networks. In multi-site systems, products are usually manufactured in one or more factories, moved to warehouses for intermediate storage, and subsequently shipped to retailers or final consumers. They proposed an integrated MILP-based framework for production and distribution scheduling in supply chains to optimally manage such complex networks. The model addresses the problem of managing single-stage parallel-line multiproduct batch plants together with multi-echelon distribution networks transporting multiple products from factories to customers through direct shipping and/or via intermediate depots using warehousing and cross docking strategies. While **Bashiri et al. [**12] presented a new mathematical model for strategic and tactical planning in a multiple-echelon, multiple-commodity production–distribution network. In the proposed model, different time resolutions are considered for strategic and tactical decisions. Also they planned expansion of the network based on cumulative net incomes. To illustrate applications of the proposed model as well as its performance based on the solution times, some hypothetical numerical examples have been generated and solved by CPLEX. **Ashoka et al.** [13] generated an integrated production–distribution plan by a simulation based heuristic discrete particle swarm algorithm. They considered a renowned bearing manufacturing industry producing three types of products at three locations and the demand was assumed to vary uniformly .In addition to the bearing manufacturing industry data set, two other test data sets are also solved. The simulation based optimization approach gives good approximate solutions for the stochastic demand problems.

The major challenge in today's industry is how to increase product variety and at the same time decrease cost and lead time. Manufacturing systems are usually categorized into Make-To-Stock (MTS) systems and Make-To-Order (MTO) systems. In a MTS system, the facility produces according to a forecast of customer demand, and completed jobs enter a finished goods inventory, which in turn serves customer demand. In a MTO system, the facility produces according to customer requests and no finished goods inventory is kept. The main advantage of MTS over the MTO system is that it allows for immediate satisfaction of customer demand. The main drawback for MTS system is the high inventory costs incurred for holding finished goods inventory, especially when there are a high variety of products offered to customers. Thus, MTS systems are usually suitable for high volume and low variety products, while MTO systems are suitable for low volume and high variety products. The advantage of the MTO policy is that there is no need to carry inventory of finished products, and hence, no inventory cost is incurred.

Some researches on the combined MTO-MTS planning used the Decoupling Point (DP) approach to distinguish the MTS and the MTO stages of a production system. Olhager [14] investigates the impact of the position and role of the CODP on issues of concern for production and supply chain management. He proposes a dual design approach for production and supply chain planning systems; one type of system for operations upstream the CODP and another type of system for downstream operations in order to fully support the characteristics and objectives of each respective part of the supply chain. He also[15] discusses the impact of having the decoupling point at different positions, and the distinguishing features for value chain operations upstream the decoupling point versus those downstream the decoupling point.

Some other researches deal with end-products which having a common component, i.e: semi-finished product. Lmehdawe and Jewkes [16] consider a stochastic two-stage hybrid manufacturing system for a single product where semi- finished goods are Made-To-Stock (MTS) and then differentiated when demand is realized through a Make-To-Order (MTO) stage. They introduce a batch ordering policy to permit economies of scale in ordering due to a cost associated with each order placed. They use the Matrix-analytic method to evaluate system performance under this ordering policy. After wards, they develop an optimization model to find the optimal intermediate buffer size and the optimal replenishment order quantity for the system. They show that a base stock policy is sub- optimal in the presence of a replenishment cost for semi-finished goods. The idea of switching between MTS and MTO production has been discussed by other researchers. Zhan et al. [17] develop an analytical model of a multiple-machine dynamic hybrid MTS–MTO facility which is capable of efficient standardized production and mass customization. They propose a simple policy for switching a select group of flexible machines between MTS and MTO production.

Lower inventory cost and better customer service is the target of all approaches, although different approaches are used to control the production of hybrid MTO-MTS systems. This objective is achieved by integrating production planning and inventory control decisions. Soman et al. [18] test the conceptual production planning and inventory control framework for combined make-to-order (MTO) and make-to-stock (MTS) production mode. They apply the framework in the case of a firm that produces 230 products on a single line with limited capacity. Jeong [19] propose a dynamic model to simultaneously determine the optimal position of the decoupling point and production–inventory plan in a supply chain such that the total cost of the deviation from the target production rate and the target inventory level is minimized using the optimal control theory.

Based on the above literature review, it is clear that there has been a lot of research done in the areas of supply chain modeling and MTS/MTO planning and a few papers combining both. It is noted that few papers deal with integrated production – inventory problems along with MTS/MTO production strategy and these papers concern with minimizing the inventory holding cost only, while there is no papers that integrates the inventory, production and distribution problems under MTS/MTO strategy aiming to minimize the total cost.

2. Model Formulation

Although the importance of a hybrid MTS/MTO strategy which combine the advantages of MTS and MTO strategies, the researchers focus on decoupling point and which product will the firm decide to produce according to MTS or MTO strategy and few of them study this strategy with aggregate production planning. No one make attention to the importance of the integration of various stages of SC under hybrid strategy. Also the supplier selection problem with the integration under this strategy is neglected, so our research focus on these two points as follows.

2-1- Case study description

The case study considered here consists of a number of suppliers (3) which supply manufactures with raw material, one plant which produce four items; two of them produced under MTS strategy and the other two items under MTO strategy, with a limited capacity over time, three distribution centers which receive, distribute finished products and store excess production. The manufactured products are directly delivered to distribution centers (DCs).The firm owns the manufacturing plant and DCs. Therefore, the manufacturers are responsible for the sales of their products in DCs outlets.

In this paper, an integrated production, inventory and distribution model under MTS/MTO strategy was investigated using FGP approach. The objective is to minimize the total cost of the SC. Lingo 11 is used to obtain the optimum solution.

2-2- Model Assumptions

The following are the underlying assumptions for each stage that needs to be stated before we proceed with the model formulation.

2-2-1- Manufacturers:

- Manufacturing site follows MTS/ MTO production strategy.

- For MTO production strategy the manufacturing process is instantaneous, i.e., the plant can produce and ship immediately when the order arrives without any time delay.
- Backorders are not considered.
- The plant has a capacity limit for producing finished products.
- The plant has a limited capacity for storing finished products.
- The plant has a limited capacity for storing raw material.
- For MTS products there is safety stock inventory in each time period.
- Inventory in any period t represents the inventory level at end of the time period t.
- Initial inventories are assigned.
- Set up cost is neglected because there is not any information about it.
- Unit transportation cost of finished products from the plant to DC k is independent on the type of finished product.

2-2-2- Distribution centers:

- Inventory in any period t is the inventory level at end of the time period t.
- Initial inventories are assigned to each DC.
- Backorders are not considered because there is not any information about the cost of these backorders.
- Each DC has a limited storage capacity for finished products.
- Unit holding cost for finished products is independent on the type of the finished product at DC k.

2.3 Integrated production, inventory, and distribution model under MTS/MTO strategy.

Here the problem consisted of one plant and three distribution centers. Our objective is to minimize the total cost for the supply chain.

2.3.1 Definitions of Symbols

x_s Set of products based upon MTS strategy (1, 2, 3 ,X_S).

PI_{xs0} Initial Inventory level for item S at the plant.

$D\ I_{xskt}$ Inventory level for item S at DCs k in period t.

$D\ I_{xsk0}$ Initial Inventory level for item S at DC_s k.

DIO_{xokt} Inventory level for item O at DCs k in period t.

DIO_{xok0} Initial Inventory level for item O at DC_s k.

x_o Set of products based upon MTO strategy (1, 2, 3 ,X_O).

k Set of distribution centers (1, 2,..K)

t Time period index (t = 1, 2, 3 …T)

Maxsup The maximum capacity of the supplier for raw material.

Minsup Minimum quantity supplied by the supplier for raw material.

$CSUP_t$ The unit transportation and purchasing cost for raw material from the supplier to the plant in period t

D Available capacity of the plant.

Cs_{xs} Unit processing cost of product S produced under MTS Strategy.

Co_{xo} Unit processing cost of product O produced under MTO strategy.

Cd_k Unit transportation cost of products (S and O) from the plant to DC_k

HR Unit holding cost per period for raw material.

HS_{xs} Unit holding cost per period for item S at the plant.

Hd Unit holding cost per period for Item (S and O) at DCs k.

W_R Storage capacity for row material at the plant.

W_S Storage capacity for item S at the plant.

Wd_k Storage capacity at DC k.

S_{xst} Amount of item S produced in period t.

O_{xot} Amount of item O produced in period t.

Q_{xskt} Amount of item S delivered from the plant to DCs k in period t.

QO_{oxkt} Amount of item O delivered from the plant to DCs k in period t.

R_t The quantity of raw material shipped from supplier to the plant in time period t.

IR_t Inventory level for raw material at the plant in period t.

IR_0 Initial Inventory level for raw material at the plant.

PI_{xst} Inventory level for item S at the plant in period t.

F Demand for item S at DCs outlet k in period t

FO Demand for item O at DCs outlet k in period t

2.3.2 Model Formulation

Min total cost =purchasing cost+ production cost + inventory cost from suppliers to factory and factory to DCs + transportation cost for product from factory to DCs.

$$Min = \sum_t CSUP * R_t + \sum_{xst} CS_{xs} * S_{xst} + \sum_{xot} CO_{xo} * O_{xot} + \sum_t HR * IR_t + \sum_{xst} HS_{xs} * PI_{xst} + \sum_k Hd_k * (\sum_{xskt} DI_{xskt} + \sum_{xokt} DIO_{xokt}) + \sum_k Cd_k * (\sum_{xskt} Q_{xskt} + \sum_{xokt} QO_{xokt}) \quad (2.1)$$

2.4 Model Constraints

2.4.1 RAW MATERIAL CONSTRAINTS

The capacity of the supplier for raw material must be high enough to meet the quantity of raw material ordered from the supplier in each time period t:

$R_t \leq$ Maxsup $\quad \forall \quad (t) \qquad (2.2)$

The order quantity of raw material must meet the minimum purchase requirement of supplier in every time period t:

$R_t \geq$ Minsup $\quad \forall \quad (t) \qquad (2.3)$

The order quantity of raw material shipped to the plant must meet the quantity of raw material needed for producing all types of products in every time period.

$$R_t \geq (\sum_{xst} S_{xst} + \sum_{xot} O_{xot}) \qquad \forall\ x_s, x_o, t \qquad (2.4)$$

2.4.2 PLANT CONSTRAINTS

The quantity of raw material which used to produce any product (S or O) in any period cannot exceed the inventory of raw material in that period.

$$IR_{(t-1)} + R_t - (\sum_{xst} S_{xst} + \sum_{xot} O_{xot}) \leq IR_t \qquad \forall x_s, x_o, t \qquad (2.5)$$

The inventory of raw material stored at the plant must be within the storage capacity limits for each time period t:

$IR_t \leq$ WR $\quad \forall \quad (t) \qquad (2.6)$

For MTO items, the following constraint presents the inventory balance at the DC_s outlet.

$$DIO_{xo(t-1)} + \sum_k QO_{xokt} - DIO_{xot} = FO$$

$$\forall\ x_o, k, t \qquad (2.13)$$

For MTS products, the inventory of the products in any period must exceed the demand for each time period t:

$$PI_{xs(t-1)} + S_{xst} - \sum_k Q_{xskt} \leq PI_{xst} \qquad \forall\ x_s, t \qquad (2.7)$$

The inventory of MTS products stored at the plant must be within the storage capacity limits of the products for each time period t:

$$\sum_{xs} PI_{xskt} \leq WP \qquad \forall \quad (t) \qquad (2.8)$$

The inventory of MTS products should exceed the safety stock value.

$PI_{xst} \geq$ SSV $\quad \forall \quad (t) \qquad (2.9)$

For MTO products, the quantity produced of these products equal its demand.

$$O_{xot} = \sum_K QO_{xot} \qquad \forall \quad x_o, t \qquad (2.10)$$

The quantity of all products produced at any time period must not exceed the production capacity.

$$\sum_{xs} S_{xst} + \sum_{xo} O_{xot} \leq D \qquad \forall \quad (t) \qquad (2.11)$$

2.4.3 DISTRIBUTION CENTERS CONSTRAINTS

The actual demand for MTS items at DCs outlet in any period cannot exceed the forecasted demand in that period for.

$$DI_{xs(t-1)} + \sum_k Q_{xskt} - DI_{xst} \geq F \qquad \forall\ x_s, k, t \qquad (2.12)$$

The inventory of MTS and MTO products stored at the DCs must be within the storage capacity limits for each time period t:

$$\sum_{xs} DI_{xskt} + \sum_{xo} DIO_{xokt} \leq Wd_k \qquad \forall\ k, t \qquad (2.14)$$

The restrictions of non-negativity on the decision variables.

$S_{xst} \geq 0$, $O_{xot} \geq 0$, $Q_{xskt} \geq 0$, $QO_{xokt} \geq 0$, $IR_t \geq 0$, $PI_{xst} \geq 0$, $DI_{xskt} \geq 0$, $DIO_{xokt} \geq 0$ (2.15)

3. Model Implementation and Analysis

The model formulated earlier is tested for a set of realistic data and the results are discussed.

3.1 Given Data

Number of suppliers, Z =3
Number of DC_s, k = 3
Number of time periods, t = 6 (t = 1, 2, 3,.., 6)

Table (3-1) summarizes the data for the raw materials and suppliers. Table (3-2) contains plant data and Table (3-3) includes the data for the DC_s items.

3-1-1- Raw materials and Supplier data

Table(3-1) Raw materials and Supplier data

The Supplier	
Maximum capacity (ton)	670
Minimum order quantity (ton)	80
Cost per unit for 6 time periods (LE/ton)	8300,8400,8100,8200,8300,8150

3-1-2- Plant data

Production capacity (Tons), D = 100Ton

Production cost for MTS products, CS_{xs} = 5000 LE/Ton, 4000 LE /Ton

Production cost for MTO products, CS_{XO} = 10832 LE/Ton, 4880 LE /Ton

Raw material initial inventory, IR0 = 20 Ton

MTS products initial inventory, PI10=10 Ton, PI20=5 Ton,

Raw material storage capacity, WR = 20 Ton

MTS products storage capacity, WS = 10 Ton

MTS products inventory holding cost per unit time period, HS_{xs} = 140LE/Ton,120 LE /Ton

Raw material inventory holding cost per unit time period, HR = 130 LE/Ton

Safety stock value, SSV = 1 Ton

For simplicity, we assume that the unit transportation cost of the finished products from the plant to the DC_s is independent of the product type.
Cd_1 = 50 LE/Ton, Cd_2 = 75 LE/Ton, Cd_3 =100 LE/Ton.

3-1-3- DC_s data

Table (3-2) DC_s Demand data

Time period	Customer's demand at the DC_s (Ton)											
	DC 1				DC 2				DC 3			
	MTS		MTO		MTS		MTO		MTS		MTO	
	S1	S2	O1	O2	S1	S2	O1	O2	S1	S2	O1	O2
Time period1	7	20	5	15	4	15	6	10	4	20	7	12
Time period2	10	9	10	3	14	10	8	3	10	11	10	5
Time period3	7	8	6	2	7	11	10	2	5	13	8	2
Time period4	6	7	15	0	6	4	7	0	7	2	11	0
Time period5	1	2	5	0	1	3	5	0.5	1	2	4	0
Time period6	9	8	2	5	6	7	2	4	9	8	2	5

Table (3-3) DC_s data

	DC1				DC2				DC3			
	MTS		MTO		MTS		MTO		MTS		MTO	
	S1	S2	O1	O2	S1	S2	O1	O2	S1	S2	O1	O2
Initial inventory,$DI_{(xs\ or\ xo)\ 0}$	10	25	0	0	8	20	0	0	20	30	0	0
Maximum inventory capacity,	50 Ton				40 Ton				30 Ton			
Inventory holding cost per unit time period	140 LE				150 LE				130 LE			

3.2 Results and discusion

3.2.1 Model Results

The optimization software, LINGO is used to generate the fuzzy goal linear program and solve it. The total cost incurred for running the supply chain is 5,260,968 LE. The results obtained in the solution report are tabulated as follows;

It is clear from table (3-4) that the ordered quantity for each time period covers the production quantity needed for produce all items. Another interesting observation is that the quantities ordered for the first four periods are very close to the minimum order quantity values for each raw material as seen in Table (3-1).

From Table (3-4), it is to be noted that there is inventory stored during all time periods and the stored quantity at the fifth and end periods is very close to the maximum storage capacity for raw material.

Table (3-4) Raw material inventory quantity.

Time period	Quantity ordered	inventory
Time period 1	55	50
Time period 2	53	50
Time period 3	76	50
Time period 4	64	50
Time period 5	50	58.5
Time period 6	50	58.5

From table (3-5), It can be seen that the plant produce hybrid products (MTS-MTO products) all over the time periods and the sum of the quantity of the fourth products is less than the plant capacity for each time period. Another notation that there is no production of the MTS products at the first time period that is due to the initial inventory stored before the start of the time horizon is shipped immediately during this time period itself to satisfy the shipping quantity of the this type of products from the plant to the DCs which in turn satisfy the DCs demands. It can also be seen that there is no production of MTO second item at the fourth period because there is no demands for this item from all three DC_s at that period.

Table (4-6), indicated that the inventory for the two products for all time periods is equal to the SSV except for the first period. The initial inventory stored before the start of the time horizon is shipped immediately during this time period itself to satisfy the shipping quantity of the this type of products from the plant to the DCs, which in turn satisfy the DCs demands. Another observation that the inventory for the second product exceed the SSV at the fifth period this is due to the inventory stored at the previous period covers the demand at that period.

Table (3-5) MTS and MTO items production (Ton)

Time period	MTS		MTO	
	1	2	1	2
Time period 1	0	0	18	37
Time period 2	8	6	28	11
Time period 3	14	32	24	6
Time period 4	18	13	33	0
Time period 5	3	20	14	4.5
Time period 6	24	10	6	10

From table (3-7), it can be seen that there is no shipment from the plant to the DCs at the first period for all MTS products this is due to the initial inventory stored before the start of the time horizon is shipped immediately during this time period itself to satisfy the DCs demands. It is also noted that for the DC3 there is no shipment of the first MTS item during the first three periods because the initial inventory stored before the beginning of the time horizon and the inventory for the second and the third periods cover the demand at these periods. On the other hand for all MTO items there is shipment for each time period to the three DC_s except for the second MTO item at the DC1for periods 4, 5 that is because there is no demand at these periods. The same thing can be used for the second item at DC_2 and at the fourth period at DC_3, since there is no demand at the fourth period.

Table (3-6) MTS products inventory quantity

Time period	MTS products inventory	
	MTS1	MTS2
Time period1	10	5
Time period2	1	1
Time period3	1	1
Time period4	1	1
Time period5	1	14
Time period6	1	1

From table (3-8), it can be seen that the first for MTO products there is no inventory at all time horizon for the three DC_s and this agreed with their production strategy except the second MTO item at DC3 at the fifth period because there is no demand for this item at the fourth period and there is shipment quantity equal 4 Ton so there is an inventory at this period. Second for MTS products there is inventory at the first period for some items and extended to the third period for another items this is due to the inventory as explained before but for the remaining periods its zero and that's to minimize the cost of holding inventory aiming to make the inventory at the plant this is from one view point. From the other view point, since in MTS (Make to Stock), products are manufactured based on demand forecasts, so the actual demand will be less than or equal the expected demand and this will result in inventory at the DC_s.

Table (3-7) finished products quantity transported from the plant to DCs

Time Period	DC1				DC2				DC3			
	MTS		MTO		MTS		MTO		MTS		MTO	
	Q11	Q21	QO11	QO21	Q12	Q22	QO12	QO22	Q13	Q23	QO13	QO23
Time Period1	0	0	5	15	0	0	6	10	0	0	7	12
Time Period2	7	4	10	3	10	5	8	3	0	1	10	5
Time Period3	7	8	6	2	7	11	10	2	0	13	8	2
Time Period4	6	7	15	0	6	4	7	0	6	2	11	0
Time Period5	1	2	5	0	1	3	5	0.5	1	2	4	4
Time Period6	9	8	2	5	6	7	2	4	9	8	2	1

Table (3-8). DCs inventory quantity

Time Period	DC1				DC2				DC3			
	MTS		MTO		MTS		MTO		MTS		MTO	
	DI11	DI21	DIO11	DIO21	DI12	DI22	DIO12	DIO22	DI13	DI23	DIO13	DIO23
Time Period1	3	5	0	0	4	5	0	0	16	10	0	0
Time Period2	0	0	0	0	0	0	0	0	6	0	0	0
Time Period3	0	0	0	0	0	0	0	0	1	0	0	0
Time Period4	0	0	0	0	0	0	0	0	0	0	0	0
Time Period5	0	0	0	0	0	0	0	0	0	0	0	4
Time Period6	0	0	0	0	0	0	0	0	0	0	0	0

4. Concolusions

Some conclusions and recommendations for further research are discussed.

It was concluded that previous work was done in the area of supply chain integration modeling but they did not address this problem under hybrid MTS/MTO strategy. The goal of this paper was to develop a supply chain integrated model. The model is under hybrid MTS/MTO strategy and involves most of the strategic and tactical decisions faced by a real world, such as assignment of production quantities, inventory levels, and shipment amounts.

The objective of the problem was to minimize the total cost incurred across the SC over multiple time periods under hybrid MTS/MTO strategy. The involved costs were procurement cost which was incurred for the raw material ordered by the manufacturing, production cost, and inventory holding cost. Costs were also incurred for holding inventory at the DC_s and transportation costs to DC_s. The finished products were shipped to the DC_s to satisfy the customer's demand.

The underlying assumptions, variables and constraints were defined as per the problem description. This resulted in a fuzzy goal linear programming problem. The problem was solved with a set of actual real world data using the optimization software, LINGO. The results obtained were tabulated and thus the models implementations were validated accordingly.

The whole idea behind this research was to provide a universal platform for the decision makers running a firm to take and implement their managerial decisions.

There is a lot of scope for further research for this work. The single objective model can be extended to a multi-objective problem as most of the supply chain models nowadays.

The cost structure in the plant considers only the production costs based on the number of units manufactured but there are also some other fixed and variable costs associated with plants in real world situations such as, machinery set-up cost, maintenance and repair costs, plant labor cost and other miscellaneous costs.

The supply chain modeled here has the provision for one raw material. But generally in practical conditions, there are two or more raw materials. Also the demand at the DCs is assumed as deterministic in nature but generally even after extensive market research and forecasting, customer's demand usually ends up being stochastic in nature.

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