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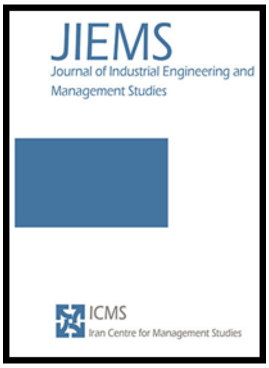

Simulation based optimization of multi-product supply chain under a JIT system

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Abstract

It is scientifically challenging to determine the inventory level all through the supply chain in such a way that the desired objectives such as effectiveness and responsiveness of the supply chain system can be obtained. Simulation is a means for solving various problems which cannot be solved by regular exact models such as mathematical ones due to their complexity. The present paper is aimed at simulating lean multi-product supply chain system as well as optimization of the objectives of supply chain. Variables of the simulation model include two types of Kanbans namely withdrawal, and production to determine the inventory level, and batch size of delivery parts for each stage of supply chain. So, in this paper simulation model was developed for supply chains, taking into consideration the different production scenarios and were modeled and compared. A production scenario is adopted for each level of the chain in order to achieve the objectives. The use of meta-heuristic techniques leads us to optimization of these variables which helps decrease delay of both product delivery and inventory level of supply chain. In this case, Genetic Algorithm has applied to find the best variable values of each scenario (included in the right number of each Kanbans), aimed at decreasing the costs and delivery delays. An example based on a case study is given to illustrate the efficiency of the proposed approach. Considering each level of supply chain, the ratio between and among cost, inventory, and delivery delay variables were obtained.

Keywords: supply chain management; genetic algorithm; optimization; just in time; discrete event simulation.

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1. Introduction

Lean Production recently has become one of the most effective manufacturing approaches in plenty industrial countries. The motivation to apply these agile methodologies in multi-

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organizational multi-level environments is focused on lean principles that encourage increased visibility of work in progress, limited inventory level, and recognition of problems causing blocked work (Tregubov and Lane, 2015). The in-process inventory costs in manufacturing systems have been a huge concern for companies and managers. Just-in-time (JIT) procedure using kanban (card) controls was first introduced in Japan to rein the in-process inventory costs (Azadeh et al. 2005) which designed in the 1950's (Wang et al. 2005). On the other hand, analyzing the SCM field in the literature become more interested, from supplier selection (sajedinejad et al., 2018; Parsaeifar et al., 2019) to customer segmentation and pricing and marketing decisions (Naimi Sadigh et al., 2011; 2016). As an achievement the benefits or results of Lean system, JIT performs a significant pattern to apply the Lean totally (Chaharsooghi et al., 2010) and many case studies have been modeled so far (Cheng, 1990). As inventory control is one of the challenges of the supply chain management. Managers are on the one hand engaged in strategic decision makings of the chain as well as various kinds of cooperation among members, and on the other hand, it is engaged with the quantities of inventory all through the chain. However, in recent years, it seems that this concept has increased due to the increasing complexity of business environments and the need for companies to gain competitive advantage in order to gain more market share. There is certainly a supply chain in the supply and delivery of any product or service, but for reasons such as lack of competition, market exclusivity and so on it may not be considered. In the late 20th century, supply chain management was recognized as one of the most widely used operational strategies for organizational competition. Different scholars and writers have presented different attitudes and definitions of the supply chain. Some have constrained the supply chain in the relationship between buyer and seller, which focuses solely on first-tier purchasing operations in an organization. Another group extends the concept of supply chain and considers it to include all sources of supply for the organization. In addition to discussing the complexities and competitiveness that have increased the need for attention to supply chain collaboration and coordination between members of the chain, always and under all circumstances, even in non-competitive and non-competitive circumstances, attention to cooperation and coordination of supply chain leaders has led to improved performance. The process and customer satisfaction will be greater in terms of quality, cost and time. Supply chain management involves integrating organizational units across the supply chain and coordinating material, information and financial flows. A brief overview of litreture can easily find the growing trend of supply chain studies in various areas of organizational literature, and a significant portion of these studies have been done in the areas of supply chain mathematical modeling, supply chain simulation as well as case studies, indicating the importance of These are from the researchers' point of view.

So, this paper is attempted to present the serial multi-stage supply chain system considering all the possible complexity, under stochastic demands with the Kanban base philosophy. Based on a research, it was determined that two kinds of Kanbans be used, each being attached on a batch in supply chain. The model is designed to simulate the multi-product SC. Delay of the product delivery as well as the inventory level of SC are to be minimized in this model. Five production scenarios in firms of SC are presented and a multi-objective analysis is provided for each scenario. Optimum results for each scenario are compared with one another. Following, a review of literature concerning inventory control has been provided. It will be followed by the previously mentioned model as well as an algorithm developed to achieve this objective. Later, Scenarios will be discussed and finally the model will be illustrated by a case example.

2. Review of the related literature

There are so many researchers conducted with the goal of optimizing the decisions made to control the level of inventory considering stochastic demands. This is normally done with the purpose of minimizing the total cost of a chain using different technique and methods.

In 1998, Kim conducted a study which compared the following scenarios for modeling serial production system (Kim et al., 1998).

- CONWIP
- WR (workload regulating)
- SA (starvation avoidance)

Akturk and Erhun (1999) had a review of investigations concerning JIT issues and Kanban systems. They defined JIT as having the obligatory amount of material where and when it is indispensable. They described JIT as a pull system of coordination between stages of production. They also apprehend that Kanban is the senior element of JIT incorporeity and pull mechanism.

Shah and Ward (2007) studied that pull system in the form of JIT construction structure including Kanban Cards which serves as a mark to outset or suspend production is one of the 10 most influential matters of accomplishment a lean order.

Matsui (2007) analyzed the function of JIT derivation in Japanese companies and claimed that the system will improve the competitive performance state for each company. Matsui (2007) also implied that the JIT systems act a key role of operation ordering and management. He believed the JIT production strongly dominate manufacturing implementation strategy, organizational behaviors, and technology development activities.

Within the framework of JIT system, Ohno and his colleagues (1995) presented the very first non-deterministic request for a solo stage factory using two types of kanbans, one to withdraw the parts called supplier Kanban and another for triggering the production, called production-ordering Kanban. They proposed the mentioned model for stable conditions. In the above-mentioned research, each Kanban was attached to one product without assuming any batch size.

Hu et al. (2008) represented a model in which a penalty for shortcoming was set on downstream in a chain system. The penalty was also allocated to the upstream stages and thus the cost would come to be an increasing linear function of shortage of time. They claimed to have found the best policy for the SC members without the use of JIT rules and principles.

Kojima et al. (2008) applied the Ohno's framework to multi stage Supply Chain integration with the same assumption of the original research such as stochastic demands as well as usage of two kinds of Kanbans. They didn't take into consideration the role of batches in total cost of the model either.

By Mirzapour et al. (2011) a research has been conducted in a multi-objective robust optimization model for multi-site aggregated production planning in a multi-product form, under uncertainty of supply chain without having taken into consideration the delay of product delivery. As a popularity of this paper aspect, Negahban and Smith (2014) have conducted a literature review and analysis of simulation for manufacturing system scheme and operation. Due to their comparison of contributions from 2002 to 2013, a general shift in the usage of discrete event simulation from production and manufacturing system design to function and operation has been emerged. In 2016, many controlling strategies consist of CONWIP have been compared with each other by Lee and Seo (2016). As mentioned in this section, a little amount of studies have been carried on the various uncertainties of the chain, as this paper aimed to model, in the different scenarios. Also many researches like Alinaghian and Goli (2017) has been focused on applying the problem on real cases or apply the SC principals in other field of researches like Sajedinejad (2019) or Sajedinejad and Naimi-Sadigh (2018) researches.

The problem of multi-stage inventory adjustment remain complicated and multi method application dealing with finding the suitable solution are developing in the literature. Tirkolaee et al. (2019) proposed a robust mixed integer linear programming (MILP) to model the multi-echelon capacitated location–allocation–inventory problem under uncertainty by the aid of a self-learning particle swarm optimization (SLPSO) algorithm in order to find the appropriate solution. Using Robust Mixed-Integer Linear Programming (RMILP) in order to model the SC also take into consideration in Goli et al. (2019). In their research, the comparison analysis demonstrated the superiority of our proposed model against the previous Non-Linear Programming (NLP) model in the literature also has been taking into account. The mention nonlinear programming of the supply chain can also be observed in many researches like Sangaiah et al. (2019). Darestani and Hemmati (2019) Modelled a closed-loop supply chain for perishable products solving with robust optimization. The proposed model also considered two sub-objectives included in minimizing the total network costs, and minimizing greenhouse gas emissions. For solving a two-objective model, three multi-criteria decision-making methods, namely overall weighting method, and Torabi-Hassini method were employed. Using metaheuristic algorithms for solving SC mathematical model also considered in Goli and Davoodi (2018) research to integrate closed loop supply chain with open-shop manufacturing and economic lot and delivery scheduling problem (ELDSP). Assuming that the ELDSPR is an NP-hard problem, they proposed a simulated annealing (SA) algorithm and a biography-based optimization (BBO) algorithm to deal with the problem. The numerical results show the suites of applying these algorithms to solve the considered problem.

Regards to the reviewed literature, the lack of modeling the SC and controlling the inventory level by the means of simulation modelling has been recognized which is the main focus of this paper. Also the use of optimization as a tool to be enabled inside the simulation model integrate to achieve the multi-objective goals is provided in presented research.

3. Problem definition

In JIT systems, a mass of cards called “Kanban” cards is exploited to give an authorization of production. These cards are used to control the transfer and production of products between each supply chain level. In other words, kanbans is used as a sign and authorization for each production plant. A station is only authorized to start the process of parts if a kanban of those parts is available.

JIT production system fulfills with two kinds of kanbans (withdrawal and supplier) explored and discussed by Ohno et al. (1995) has been improved and modified for the supply chain system and its multi-product conditions in this paper. Following notation is presented in order to clarify the problem.

n: Plant or factory number
i: Index of plant or factory from 1 to n,
j: Type of products from 1 to m,
A_{ij} : Storage of product *j* which placed before each plant,
B_{ij}: Backlogged demand and request of product *j* (which placed after each plant),
Al_{ij}: Inventory cost for parts and product j in one period in inventory A_i (which placed before each plant),
Bl_{ij}: Inventory cost for parts and product j in one period in inventory B_i (which placed after each plant),
Ab_{ij}: Backlogged cost (if shortage occurs) for a part per period,
Cb_j: Backlogged cost for product *j*,
Ao_{ij}: Setup (ordering) cost for product *j*,
Aw_j: Withdrawal cost for product *j*,
L_{ij}: Delivery lead time of each batch product at stage *i*,
As_i: Salvage cost and the end of each period,
$AE_{ij}(h)$: Salvage cost and the end of each period elapsed *h* period after ordering product *j*,
Qw_{ij}: Batch size number the plant *i* delivers the product *j*,
$T_{ij}(Qw_{ij})$: Transportation and material handling cost from plant *i* for batch of product *j*,
Km_i: Number of production kanbans at plant *i*,
Kn_i: Number of supplier kanbans at plant *i*,
$Cow_i(Km, Kn)$: Fix cost per period for kanban area if the numbers of kanbans are Km, Kn,
$Ak_{ij}(Qw_{ij}, Qw_{i-1j})$: Setup (packing and unpacking) cost of product *j* placed if the input and output batch sizes are Qw_i, Qw_{i-1},
C_{ij}: The max production amount and quantity of product *j* in plant *i*,
C_i: The maximum production amount and quantity plant *i*,
$D_j(k)$: Demand of product *j* occurred in period *k*,
$B_{ij}(k)$: The backlogged demand and request at the beginning of period k in plant *i* of product *j*,
$I_{ij}(k)$: Level of inventory at the beginning of period *k* (in batch) of product *j*,
$J_{ij}(k)$: Number of production kanbans in kanban post at the beginning of stage *k* in plant *i* of product *j*,
$P_{ij}(k)$: Production of product *j* at the period *k* in plant *i*,
$Q_{ij}(k)$: Quantity of batches of product *j* delivered in period *k* by plant *i*,
$X_{ij}(k)$: Total backlogged demand of product *j* at the beginning of period *k* in plant *i*,

$$X_{ij}(k) = B_{ij}(k) + J_{ij}(k) * Qw_{ij} \quad (1)$$

M_i: Total number of Products can be stored after plant *i*,

$$M_i = \sum_{j=1}^{m} Qw_{ij} * Km_i \quad (2)$$

N_i: Total number of parts can be stored before plant *i*,

$$N_i = \sum_{j=1}^{m} Qw_{i-1j} * Kn_i \quad (3)$$

In order to universalize the model to general format of each supply chain, some new variables have been defined. The chain begins at stage 1 (the supplier) to stage n (final customer). Demand in every period is stochastic but processing time of each plant is assumed parametrical (Figure 1). Following relations in the JIT SC model have been formed.

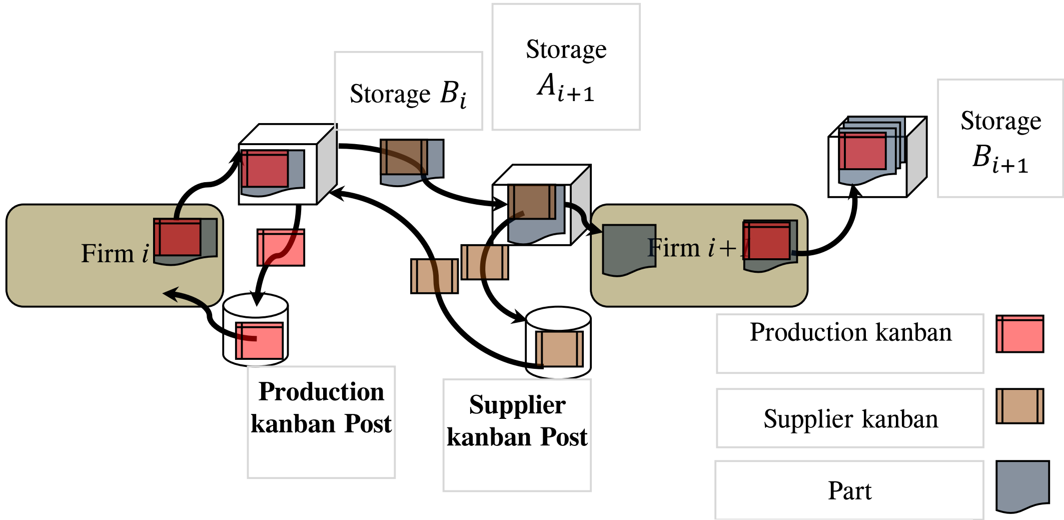

Figure 1. Kanbans operations between two firms.

In Figure 1, the presented workout of the Kanbans in SC has been provided. A supply chain system usually consists of a series of independent organizations or companies and a set of efficient business practices to take full advantage of suppliers, manufacturers, distribution centers, warehouses, vendors and ultimately customers. In order to minimize total cost, production and distribution at the right time and in the right places, and to implement JIT philosophy, the Kanban technique has been introduced as an efficient operating mechanism (Figure 1).

As such, the Kanban mechanism ensures that organizations follow a timely policy to implement supply chain systems. If the supply chain system is taken as above and steps *i* and *i + 1* are separated, the Kanbans usually contains information such as segment number, segment description, piece palette, unit load (quantity per Kanban), warehouse location, end process and some other information such as package size, number of cannabis packages, and so on. Kanban's role in supply chain system presented in Figure 1 is not only as an information carrier, but also as a material (or transport) carrier.

As showed in figure 1, in period k, numbers of supplier Kanbans set and placed in Kanban Post are $Q'_{i-1j} = Qw_{i-1j} * Q_{i-1j}$, so the numbers of withdrawal kanbans can be determined as bellow:

$$Kn_i = \sum_{j=1}^{m}(I_{ij}(k) + \frac{P_{ij}(k-1)}{Qw_{i-1j}} + B_{i-1j}(k) + \sum_{h=k-L_i+1}^{k-1} Q_{i-1j}(h)) \qquad (4)$$

And $Q_{i-1j}(h)$ for h from 0 to L_{i+1} are given.

Inventory level of a plant and factory in each time period defined as the difference between the inventory level of last period and received batches from previous plant and the amount of batches produced in the plant, therefore:

$$I_{ij}(k+1) = I_{ij}(k) + Q_{i-1j}(k - L_{i+1}) - \frac{P_{ij}(k)}{Qw_{i-1j}} \qquad (5)$$

As the JIT system stands on, each factory should produce equal to production– ordering kanbans existing in the bin (post), or more than parts available in store before the plant, so

$$P_{ij}(k) = min\left(I_{ij}(k) * Qw_{i-1j}, J_{ij}(k) * Qw_{ij}, C_{ij}\right) \qquad Eq. (A.6)$$

Also it is obvious that the plant can't produce more than its capacity, therefore:

$$\sum_{j=1}^{m} P_{ij}(k) \le C_i \quad (7)$$

Because the demand in period k is determined and known at the beginning of the period k, backlogged demand at the beginning of period $k+1$ is:

$$B_{ij}(k+1) = max\left(0, B_{ij}(k) + J_{ij}(k) * Qw_{ij} + P_{i+1j}(k-1) - P_{ij}(k) - Qw_{ij} * Km_i\right) \quad (8)$$

The number of released production-ordering Kanbans put in Kanban post at the beginning of period $k+1$ is the minimum between total production-ordering Kanbans ($B_{ij}\ Capacity$) and total backlogged demand,

$$J_{ij}(k+1) = \min\left(Km_i, \frac{B_{ij}(k)}{Qw_{ij}} + J_{ij}(k) + \frac{P_{i+1j}(k-1)}{Qw_{ij}} - \frac{P_{ij}(k)}{Qw_{ij}}\right) \quad (9)$$

The number of delivery quantity of goods and products in period k equals to the minimum between the term of sum of the request of the next plant at previous time period and backlogged demand, and the term of sum of the production quantity and level of inventory:

$$Q'_{ij} = Qw_{ij} * Q_{ij}(k) = min(P_{i+1j}(k-1) + B_{ij}(k), P_{ij}(k) + max\left(0, Qw_{ij} * Km_i - X_{ij}(k)\right) \quad (10)$$

And total backlogged in each period is based on backlogged in previous time period and production of present and next factory:

$$X_{ij}(k+1) = X_{ij}(k) + P_{i+1j}(k) - P_{ij}(k) \quad (11)$$

3.1. Scenarios

Many modified push and pull strategies within the SC or production systems are explored and discussed by Puchkova et al., (2016). Some Kanban selecting rules and regulations in each factory are employed to find and evaluate the performance of chain under different circumstances. Simulation models were explored and developed to evaluate the delay of orders as well as WIP for each solution. All solutions are generated by optimizing sub-system of the model. Many scenarios have been proposed so far to control of WIP as a performance indicator which some of them is addressed by Lee and Seo (2016).

A. FCFS Scenario

Each Production Kanban received by the firm, triggers the production of the related batch. Therefore, Kanbans are arranged and sorted in the kanban post in the order that they reach the plant. The length of time each kanban related batch spends in queue for production, determines the priority of its production.

B. Random Order

It is possible that the factory choose randomly from among the available kanbans. In this case, each factory will produce any batch for the available kanban in the bin.

C. Priority scenario

In this scenario, the authorization is given to each production Kanban that is already available and at the same time is of higher priority. In case there are more than one Kanban with high priority available, they are produced in the order they arrived at the factory.

D. Maximum Number of Kanbans

In this scenario, each Kanban of the product is collected in a different bin and the factory gives priority to the production of the parts which have greater number of Kanbans waiting in its bin.

E. Ratio of Kanbans Scenario

The ratio of Kanban (RKB) rule has the advantage of considering the likelihood of parts shortages. This ratio is based on the number of Kanbans of a particular part type waiting for processing relative to the total number of Kanbans of that part type that the system started out with in that firm and its pulling firm. The RKB rule gives priority to the part type that has the largest ratio (Hum and Lee, 1997).

4. Proposed Approach

Many algorithms including GA's were invented, applied and developed to model the reality problems, originally by mimic some of the themes placed in natural selection, and the first on, GA initially developed by J. Holland and absolutely his associates in 1960s and 1970s.

GAs use to represent a complex structure by means of a vector structure, and the idea relies on biology in which the chromosome and its genetic formation overturned. (Li et al., 1998) In this paper, both simulation and optimization procedure are implemented in Enterprise Dynamics (ED).

The optimization segment is meant to minimize delay time of all products delivery as well as providing the best way to minimize the inventory level respectively, costs of inventory and transportation. The procedure takes place under certain constrains as follows:

- Production capacity of each plant
- Order distribution
- Transfer time between plants
- Warehouse capacity before production of each plant is controlled by ordering kanbans
- Warehouse Capacity after production of each plant is determined by production Kanbans
- Scenarios for selecting the production parts
- Batch size for each factory

The manner of all optimization process is determined by Genetic Algorithm strategies on the basis of simulation model mentioned above. The basic GA operators are:

- Encoding
- Recombination
- Crossover, and
- Mutation

GA has been applied recently in order to solve various optimization models and problems. It has been shown to be recommended effective in searching a large, poorly defined area of search. To do so, the present paper defines each chromosome (of the model) to consist in batch sizes and production and order Kanbans for each factory. The genetic model is illustrated bellow.

Table 1. Proposed Genetic Algorithm

0 start
1 Generate X Random initial chromosomes (solution)
2 GEN:=1 (Generation counter) , ITT:= 1 (Iteration counter)
3 Simulate the ITT solution and record the objectives
4 ITT := ITT + 1
5 IF ITT < X go to 3
6 sort the answers by their fitness. Save Bests
7 If GEN = finish condition go to 11
8 Cross Over
9 Mutation
10 GEN := GEN + 1, go to 3
11 sort the best answers by their first objective and move to FC (0) population
12 FC:=1 (front counter)
13 If second objective of the first answer is better than the second answer in FC (0), move the second answer to FC+1 Population else move the first answer to FC population
14 If all chromosomes in FC -1 not compared go to 13
15 If FC = FCLIMIT , go to 18
16 FC := FC + 1
17 Got 13
18 END

The designed Chromosomes consisted in the number of Kanbans (withdrawal or production) of each level of SC. For example the string bellow shows the number of Kanbans in firm sequenced *n*.

…	Gene no *2n-1*	Gene no *2n*	Gene no *2n +1*	…
	Number of withdrawal Kanban in the post before Firm *n*	Number of Production Kanban in the post after Firm *n*	Number of withdrawal Kanban in the post before Firm *n+1*	

Figure 2. Proposed Chromosome Formation

The first generation has been produced randomly through the minimum and maximum limited area and the fitness values has been calculated by the simulation. Next, genetic operators are applied to ensure that all chromosomes in a generation are modeled and found to fit all. In the first step, the answers are arranged separately in both proportions and better answers in both objectives are stored. Then the chromosomes that are better suited are selected with a higher chance and the model performs the crossover operation. Then by selecting from the randomly selected chromosome genes, the mutation is performed and the chromosomes are stored in the new community, followed by the next round of cloning. It should be noted that ten percent of the elites of the previous generation are also added directly to the new generation. Next, the model starts automatically from scratch and at the end of the task, the answers that override the other answers are replaced with older ones.

5. Model

The model was applied for one of the Turbine Blade Engineering and Manufacturing Chains of country. The main company was founded with the aim of mass production of heavy duty industrial gas Turbine Blades and Vanes for industrial and power generation applications. In this case, due to the lack of transportation information, it assumes that most cost terms are generated in inventory terms and one of objective functions simplified to quantity of WIP. Another objective function aims to minimize the delay respect to the due time.

5.1. Model Assumptions

The SC produces 4 kind of different products. The distribution of order in this paper is estimated as Poisson with the mean of 1000 blades per mount. Blades are ordered in batches each including 100 blades. To do so, every product in simulation represents 100 blades. This should mean that every 100 blades are shown as 1 product. The output batch size of each plant can be 100, 200 or 300 which in the process of simulating, are indicated as 1, 2, or 3 products for simplicity. Orders are given to the end supplier at the end of each month. In order to simplify the process, every month in reality is taken as one period in simulation. The chain consists in 3 different levels and each level has the maximum production capacity exactly equal to 1200 blades per month (C_i). The SC was modeled in Enterprise Dynamics (ED) as mentioned above. A view of the simulation model could be seen in figure 3.

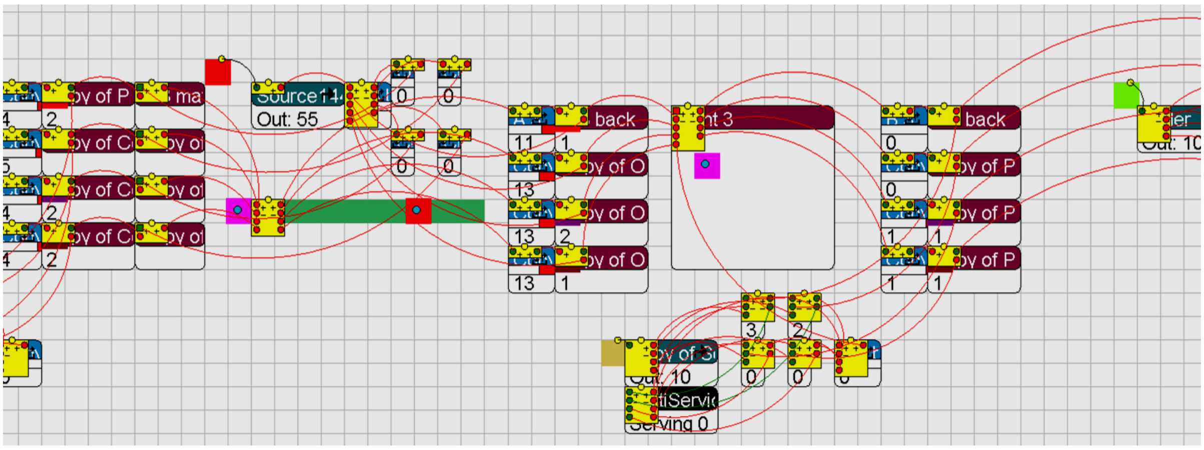

Figure 3. Proposed Simulation Model of the case

In this research optimization segment and simulation model are combined and optimization segment controls the simulation variables for achieving the objective values.

5.2. Limits of Kanbans

Minimum numbers of both Kanbans for each plant are considered as 1 but the upper limit also has to be evaluated. The range of different generations' response genes in the optimization algorithm affects the speed and sensitivity of the model. High upper bound in many cases can reduce the optimization speed and by the same idea, low upper bound can result in ignoring some of the good possible answers. If the initial response time is high and the algorithm-based mutation results are too high, the optimal solution speed will be reduced. At the same time, however, if the response interval is greatly reduced, the likelihood of appropriate responses will increase. Therefore, at the beginning of the process, the response interval is very large and the model moves to the optimal solution.

For this purpose, initial solutions of up to 500 units are selected for the inventory capacity (which is more than orders along many periods). To avoid overloading the answers, multiples of 10 are created. In this case, after 300 generations, no trace of chromosomes with more than 100 genes (Kanban size) is found. Therefore, the upper limit of each gene is chosen for initial responses - as well as for generating different responses in mutations – was 100. The answer columns that do not have an answer above 100 (such as the tensile cannabis column at the second plant or the size of the product batch at the third plant) are listed below.
A simulation analysis was conducted with unlimited upper limit to evaluate the estimated bound. As can be seen in the table 2, number of genes upper than 100 is going to vanish after 300 generations. Based on the present research the selected upper bound of Kanban numbers will stand at 100.

Table 2: Number of genes upper than 100 in each generation

Number of Generations	1	2	8	32	64	176	256	300
Number of genes upper that 100	87	86	75	70	60	30	9	0

5.3. Run Time Period

For acquiring the run time period, same chromosomes are put in the simulation model. Probable order in every period makes the outcome of each process different even though the chromosomes are the same. So, for different run times, the t-test of outcome similarity among answers are conducted, as a result of which 3000 run time periods are determined as standard (Table 3).

Table 3. t-test of similarity for different Run Times

Run Time	Average Production	Standard Deviation	t-test
200	0.51	0.252	-3.78
1000	0.665	0.0833	-1.65
2000	0.668	0.083	-1.44
3000	0.696	0.0571	0.78
			$t(\infty)$ 90% = 1.3

5.4. Warm up period

Warm up period is considered to cover the proportion of time in which the SC is blank or there is no WIP, at the beginning of each simulation run. In warm up period, neither one of the delay and WIP is calculated for each chromosome. Warm up period is standardized at 10 percent of the total run time (300 simulation period) for the model.

6. Results

Having conducted the present research helped the researchers find out that optimization algorithm has led to determining different fronts. The best four fronts for each scenario are as follow:
In FIFO Scenario, the four best fronts for FIFO scenario are shown below. Two objectives are illustrated in the form of two axes. One axis presents the amount of WIP and the other

one presents sums of the delay occurring in orders delivery. The lower front dominates other fronts as shown in figure 3.

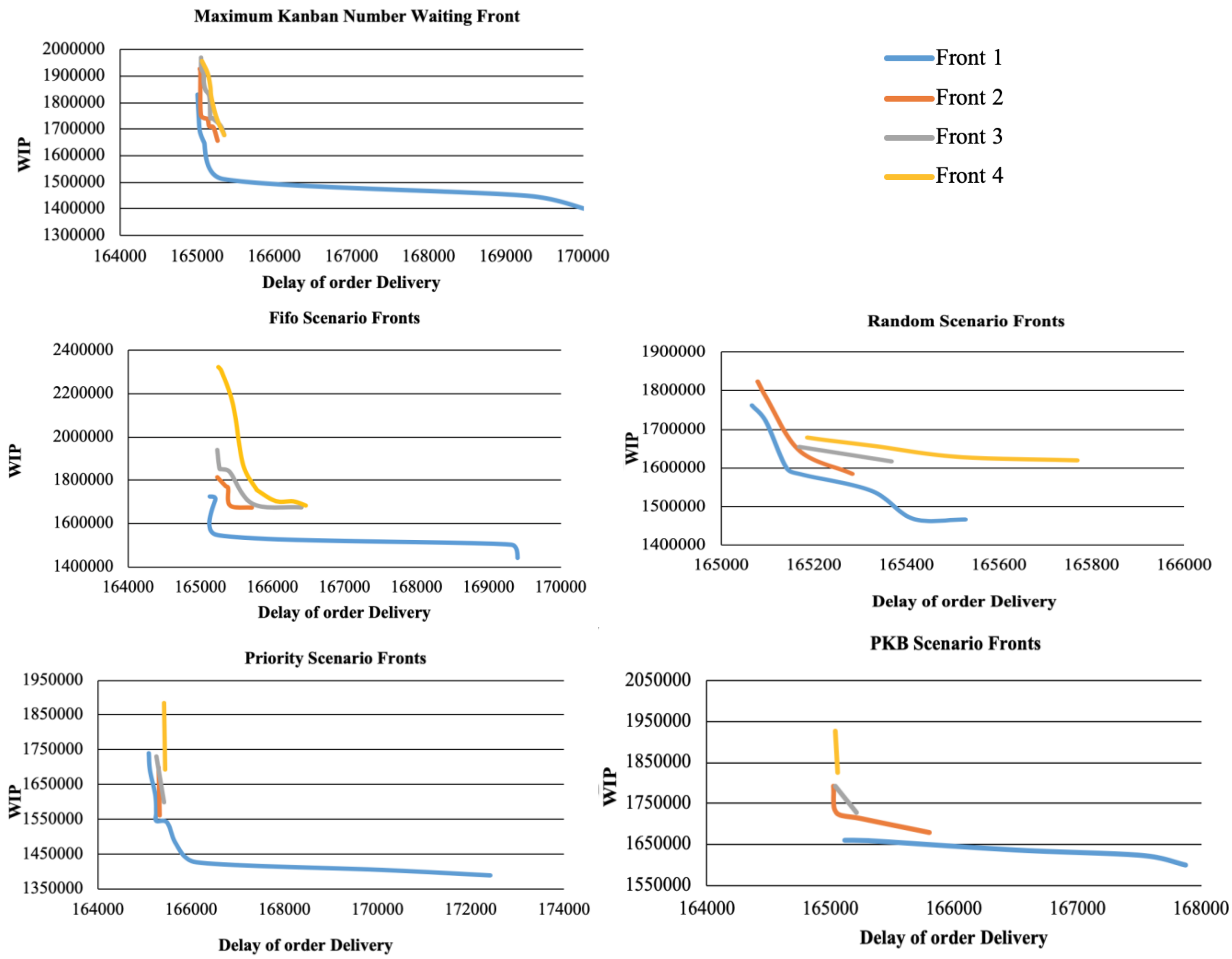

Figure 4. Scenarios Fronts

For each different ratio of objectives, the SC has to pick the best production scenario from among the best fronts. For example, if the SC decides to minimize the WIP without taking into consideration delivery delay of orders, the 'Maximum Kanban Number Waiting' scenario has to be chosen (Figure 5).

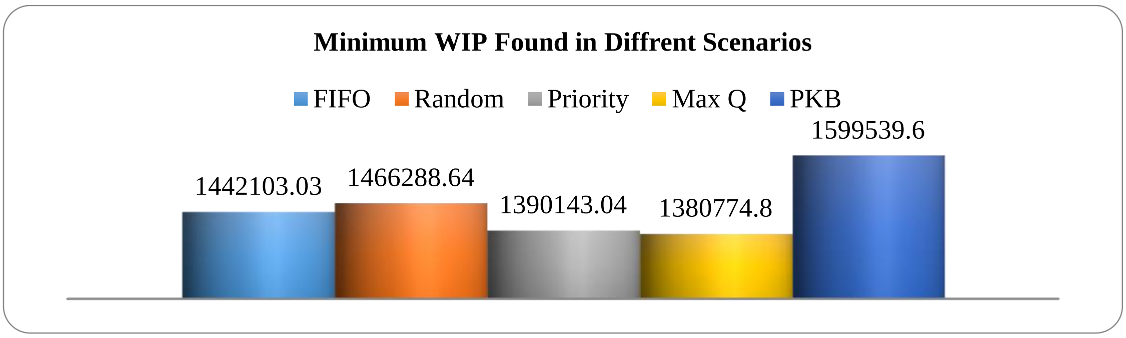

Figure 5. Minimum WIP for different scenarios

Table 4. Best solution for minimum delay variables and objectives

Production Kanban for plant 1: 15	Production Kanban for plant 2: 15	Production Kanban for plant 3: 20
Ordering kanban before plant 1: 5	Ordering kanban before plant 2: 10	Ordering kanban before plant 3: 80
Batch size of plant 1: 2	Batch size of plant 2: 1	Batch size of plant 3: 1
Delays (s): 165000.23	**WIP (s): 1830234.51**	

If the firms decide to lower the delivery delay and regardless of the probable significance of WIP, the best solution will be found in FIFO scenario with the variables that are estimated by optimization algorithm mentioned in table 4. In this solution, WIP estimates equal to 80774 parts in 3000 time period. Best fronts can be depicted in one plot which helps the managers select the best choice from among scenarios with regards to different ratios of minimizing the delivery delay and minimization of the WIP. Figure 6 includes the best front for each scenario.

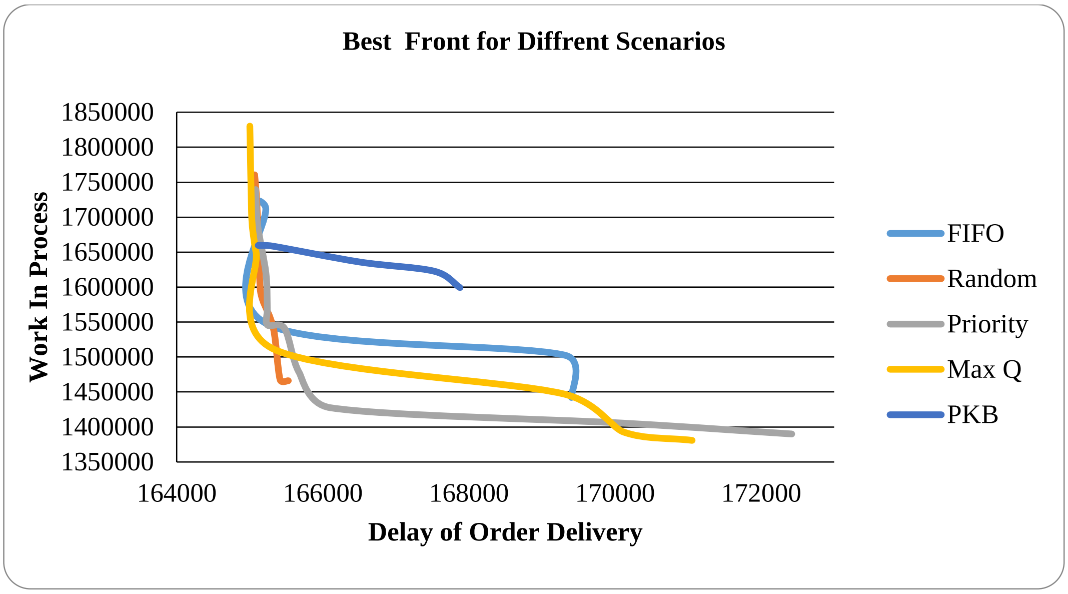

Figure 6. Objectives for different scenarios

As can be seen in figure 9, the SC can pick the different scenarios with regard to the WIP or delay of order. It helps company to decide which strategy to choose in order to find the best solution for predefined ratio of its WIP and delays. The SC used to make use of the FIFO rule. However, it prefers to have the minimum WIP regardless of delay that may occur. Figure 8, indicates that the SC could lower the WIP level of the chain to 4.25 percent using the Max Waiting scenario. Other savings are illustrated in following table.

Table 5. Percentage of SC Savings regards to select different scenarios

Scenarios	WIP	Lower WIP Percentage
Fifo	1442103	0.00
Random	1466289	1.68
Priority	1390143	-3.60
Max Q	1380775	-4.25
PKB	1599540	10.92

6.1. Comparison results

Due to the lack of access to financial coefficients and indicators, supply chain monitoring has been identified as one of the most influential production parameters in the case study. Therefore, one of the goals for optimizing this system has been to reduce inventory levels.

By optimizing the system based on the production scenario, the levels of inter-chain inventory will be significantly reduced, according to the order of requests (FIFOs) on which supply chain members operate. However, by creating the answer layers in this system, to achieve the above objective, the production scenario based on the most pending cannabis will be more cost effective than other scenarios.

The following figure shows the percentage of inventory reductions that are one of the goals of the system, in both the maintenance and change scenario of the production scenario:

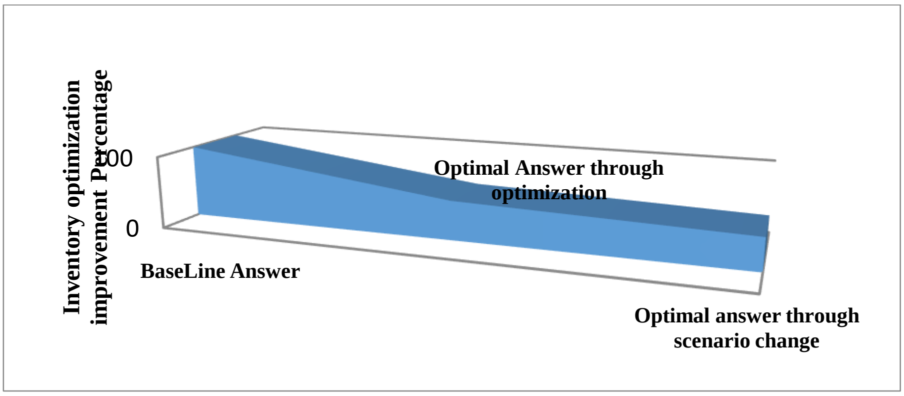

Figure 7. Decrease inventory level during optimization process

As shown in the figure above, with the improvement of the FIFO scenario used and only by changes in supply chain variables including batch size and number of production Kanbans, the inventory level reached 54% of the initial state with no change of scenario. By selecting and modelling other scenarios the SC will reach 43% of the initial stock and cost respectively.

Also the percentage of improvement in reduction of delay in supply chain ordering in the improved cases is shown in the following chart:

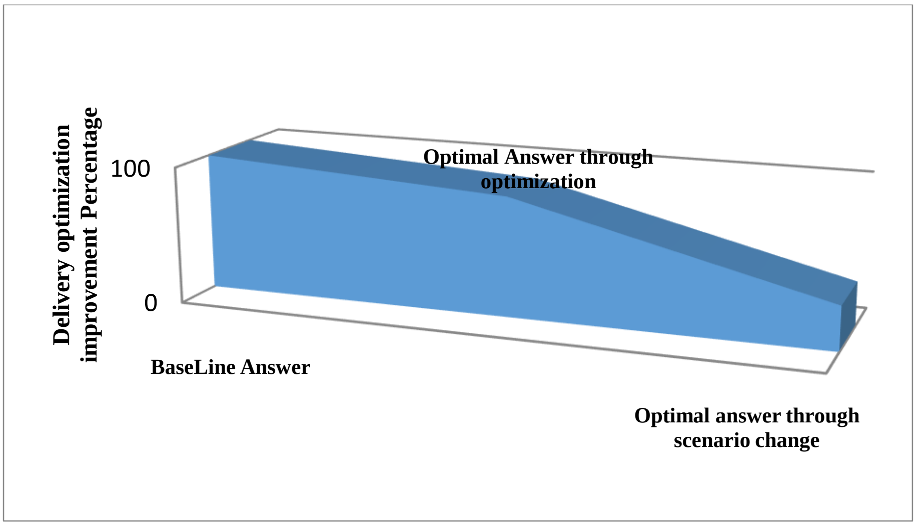

Figure 8. Reduce order delays in order delivery

As can be seen in the above picture, by changing the decision-making and scenario maintenance components, the model achieve 13% and 67% improvement respectively, compared to the baseline scenario.

6.2. Model verification

Applied templates have parameters to fit all scenarios. These parameters often affect the performance of a model. Therefore, they also affect the performance of the simulation algorithm. On the other hand, model parameters must also be designed to search for all possible behavior of the models (Kelton et al., 2004).

For this purpose, model parameters, including cost parameters and orders interval parameter, were evaluated parametrically. In this model, the value of inventory maintenance cost coefficient from 0 to 32 was investigated and the cost of different model responses were compared. The following diagram shows the amount of cost obtained by the simulation model:

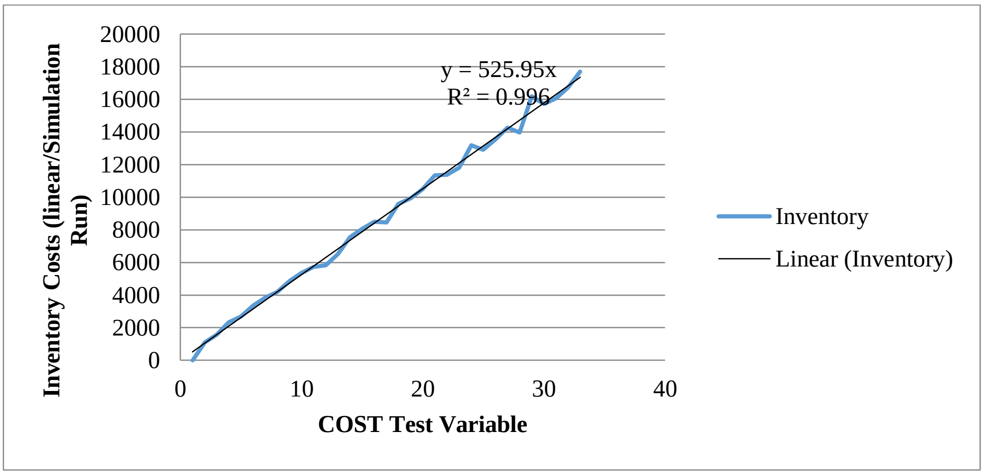

Figure 9. Inventory costs due to different test cost variable

As can be seen in the figure above, the cost of the chain increases linearly with 99% confidence as the cost coefficient increases, which shows the effectiveness of the algorithm.

In another analysis, alternative scenarios are simulated and compared when ordering from one order per month to one order within 2 months. As can be seen in the figure below, the delay in the delivery of orders decreases sharply as the time of order creation.

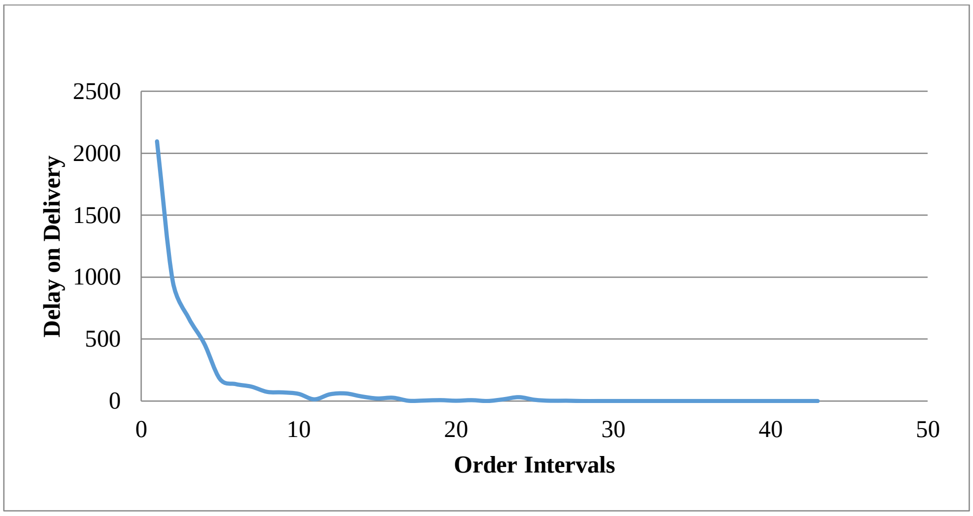

Figure 10. Delay on delivery on different order intervals test scenario

Applied templates are often not sufficiently complete to fully study performance. This is of great importance when we introduce new algorithms for simulation in case study (Sawer & Brann, 2008).

In this framework, with two separate algorithms, the model optimization was pushed to the optimization, which, despite the differences in the time of convergence of the solutions, had the same trend as discussed in the optimization section of this chapter. In this phase, to compare the model results with the limit state, the same test results of the model with their limit state are performed. For this purpose, 30 identical solutions were used in two time periods of maximum simulation time and limit time (20,000 units of time). According to the t-test, the following statistic is made up:

$t = (\bar{y}-\mu) / (s / \sqrt{n})$

Where s and $\bar{y}$ mean and standard deviation of the values obtained for the same solutions at the upper limit of the simulation and μ, the mean values obtained from the simulation at the limit state.

According to the obtained values, the test statistic value is 0.87, which is less than t_ ($\propto$ = 95%, n = 30) and the same results are accepted. In the real world, functional models are more complex than simulated models. In comparison, the hybrid experimental model should be as simple as possible. This potential can facilitate defect correction, verification of simulation accuracy, and interpretation of performance test results (Sawaya, 2007).

Due to the likelihood of orders being made, the same test of output responses was performed in the long run. The test was tested with the following three types of data, one of which yielded the optimal solution, and the same results were proved by statistical testing. The following solutions were examined in the model:

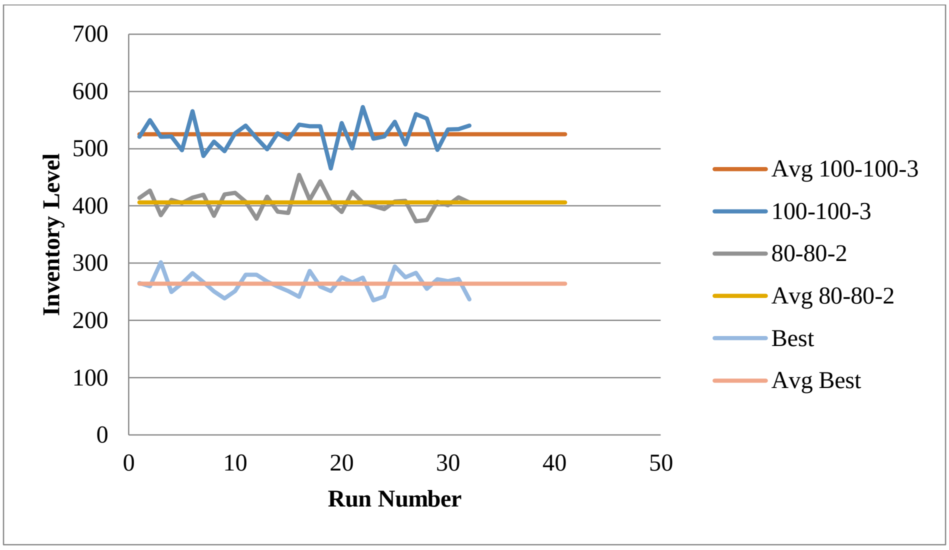

Figure 11. Same output test for identical solutions results

For this purpose, as can be seen in Figure 11, for each of the 32 batches of identical answers, the amount of inventory in the chain was measured and the same test of answers was used. According to the chi-square test with a degree of freedom of 30 and a 5% error, a statistic lower than 43.773 indicates compliance of the output data with the same value.

7. Conclusion

In this paper, the researchers have dealt with the multi-stage supply chain which performs based on the philosophy of JIT production environment. The supply chain management (SCM) in JIT environment with two kinds of kanbans (production-ordering and supplier kanbans) has been considered in the present paper, under stochastic demand. Furthermore, deterministic processing time of each plant align with withdrawal process and lead time consideration as well as batch size constraints in multi-product firms are also taken into consideration. So long as the demand rate becomes stochastic, one of the very influential logistic parameters in the chain total cost is the size of batches delivered to or produced by a plant. Another objective could be the order delivery delay. The batch size and two kinds of kanbans were integrated with the chain and were played a significant role in determining the cost of SC more feasibly.

The algorithm was applied to find the optimal cost of a chain regarding constrains which batches brought. The algorithm makes use of simulation to find the objectives for different scenarios so as to estimate the best scenario for every goal. After in all, an example is exhibited to illustrate the effect of the five strategies on the WIP of supply chain as well as delay of delivery and find the performance optimal state.

The following considerations are needed to implement this framework in the country's supply chains:

- Verification the accuracy of the information collected and the exact timing for estimating the chain parameters
- To further fit the model with the supply chain under investigation, accurately data collection and estimation their probability distribution are means of focus.

- Some parameters, such as demand, may have seasonal effects, etc., which need to be used by regression methods to estimate them.
- Discovery of the relationships in the model requires careful study and observation of the actual system.
- The model validation steps must are carefully examined and the simulation mode compared to the current state of the system.
- At the modeling stage, consider all environmental conditions such as layout, transportation, breakdown and preventive maintenance, etc.
- Paying more attention to detail may add to the complexity of the modeling and slow down the optimization process.
- The implementation phase can be very challenging, such as lack of collaboration between staff and others.

At last of the chapter, the following research possibilities are suggested for future research:

- Develop a mathematical model taking into account the diversity of products
- Development of mathematical model to non-serial supply chain
- Development of mathematical model from discrete to continuous time
- Development of a simulation model taking into account more realistic and probabilistically parameters such as production process time with probability distribution
- Considering separate scenarios for each plant
- Consider the risk of supplying materials and products in the supply chain simulation model
- Using several heuristic optimization algorithms and comparing their performance

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