

A NEW MODEL FOR LOGISTICS AND TRANSPORTATION OF FASHION GOODS IN THE PRESENCE OF STOCHASTIC MARKET DEMANDS CONSIDERING RESTRICTED RETAILERS CAPACITY

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Abstract. In today's world, using fashion goods is a vital of human. In this research, we focused on developing a scheduling method for distributing and selling fashion goods in a multi-market/multi-retailer supply chain while the product demands in markets are stochastic. For this purpose, a new multi-objective mathematical programming model is developed where maximizing the profit of selling fashion goods and minimizing delivering time and customer's dissatisfaction are considered as objective functions. In continue due to the complexity of the problem, a number of metaheuristics are compared and a hybrid of Non-dominated Sorting Genetic Algorithm II (NSGAI) and simulated annealing is selected for solving the case studies. Then, in order to find the best values for input parameters of the algorithm, a Taguchi method is applied. In continue, a number of case studies are selected from literature review and solved by the algorithm. The outcomes are analyzed and it is found that using multi-objective models can find more realistic solutions. Then, the model is applied for a case study with real data from industry and outcomes showed that the proposed algorithm can be successfully applied in practice.

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1. INTRODUCTION

The use of fashion goods in the real world is inevitable. According to statistics released by the World Trade Organization and information posted on the fashionunited.com website, the global apparel industry has 3 trillion-dollar worth of money which has assigned 2% of the world's gross weight product. Watches, perfumes, clothing, bags, mobile phones, sports suits and so on can be considered as fashion goods. Due to the high share of this industry in the world markets, studies in this field should be taken into consideration more than ever, because providing a model that can achieve even one percent savings in this market, brings a significant benefit for supply chain components (including: suppliers of raw materials, manufacturers, distributors, wholesalers,

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retailers, final customers or consumers). Unfortunately, lack of enough attention in planning of fashion goods can result huge financial harms in this industry. In order to solve this problem in recent years, researchers have presented extensive research on the planning of various aspects of the supply chain management (SCM), including supplying materials, production, sales and distribution. This study focuses on the distribution of fashion goods from manufacturer to retailers in different markets. For this purpose, by studying the literature review (discussed in the second part), a multi-objective mathematical model for planning the sale of fashion goods in different markets of Malaysia will be addressed. The purpose of this research is to compensate for the shortcomings in multi-objective decision-making in supply chain sales. The focus of this research is on simultaneous consideration of several goals. In the real world, decision makers do not generally rely on optimizing just one goal (such as delivery time to a customer or cost of production), but by considering a set of simultaneous goals such as delivery time and cost of delivery, customer satisfaction, etc. they take decisions.

This research tries to answer this question that how an appropriate product distribution plan can reduce the product-lost sale in a multi-market/multi-retailer supply chain while the product demands are not fixed and can be varied from period to another. The objectives of this research is increasing the profit of selling fashion goods and minimizing delivering time and customer's dissatisfaction in a dynamic closed loop supply chain. A brief overview on fashion goods scheduling models shows that the scheduling of fashion goods in a multi-market/multi-retailer supply chain in the presence of market demand uncertainty has not been addressed before. Therefore, the purpose of this study is to exclusively discuss the effects of possible market demand on the product distribution of fashion goods in the markets to maximize the profit of a supply chain.

2. LITERATURE REVIEW

A classical supply chain involves supplying raw materials from suppliers, producing products, sending to warehouses, distributing to wholesalers and retailers, and ultimately to the customer. In other words, a typical supply chain consists of suppliers, depots of raw materials, production centres, distributors, retailers and final customers. Each supply chain is guided by multiple components. These six components are: inventory, transportation, facilities, information, source finding, pricing. Such a chain requires a comprehensive view of the links in the chain that work together efficiently to create customer satisfaction at the end point of delivery to the consumer. Figure 1 shows a classic supply chain.

Fashion goods refers to items that lose their value over time due to rapid technological changes or the production of a new product by a rival. Fashion goods may lose their value over time and may be outdated.

Today, the attention of many scholars and researchers has focused on the topic of fashion or obsolete goods. With the growth of fashion industry over the past few years, it has a significant share of the economy of the countries.

Abecassis-Moedas [1], factors such as changing the trend of the fashion industry, short life cycle of products associated with this industry, the intense competition for countries with low-cost labor, the unprecedented growth of emerging markets have brought about significant changes in the traditional models of this Industry.

Nagurney and Yu [36] presented a new model of exclusive competition for the supply chain of multi-product fashion goods with consideration of environmental issues. Chen and Chang [6] conducted a study in which an analytical decision framework was presented, in conditions that each sale market varies both in terms of product type and in terms of sales time. Mehrjoo and Pasek [30] developed a modelling method for long-term and dynamic management in the fashion commodity industry, the focus of their model was on the interaction between physical processes, information flows, and the management of the clothing supply chain to create dynamic variables such as diverse products, inventories, costs, and profits. In the following, Zhou *et al.* [52] presented two models of optimal pricing methods for fashion product companies by which the optimal strategy style was determined. Brito *et al.* [3] conducted two data mining methods for customer segmentation. Macchion *et al.* [28] analyze the adoption of environmental sustainability practices and collaboration along the supply chain in order to achieve better innovation performance.

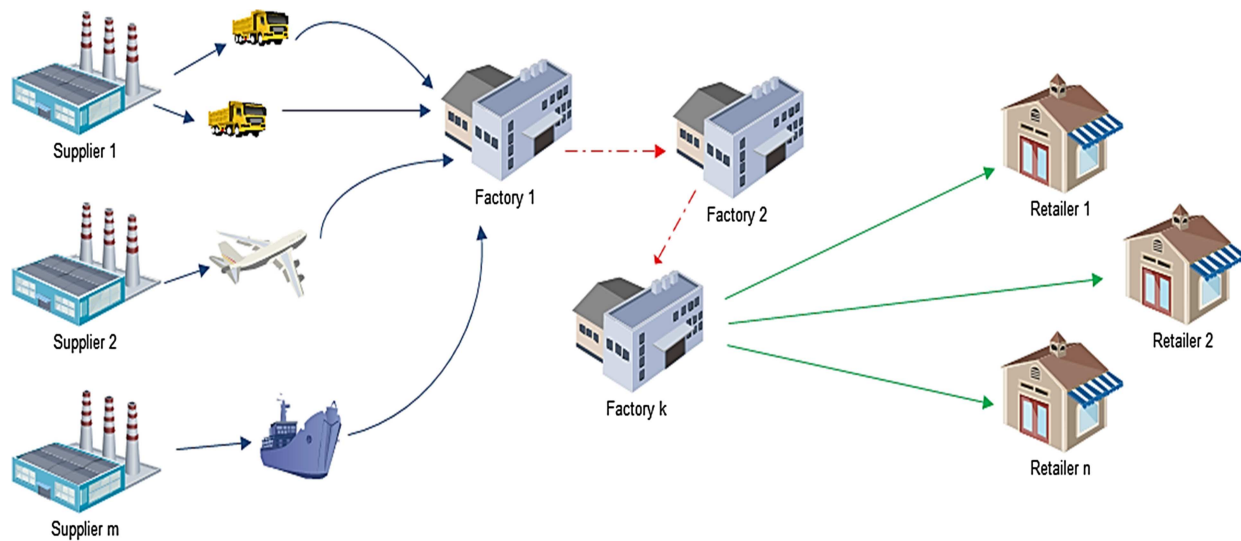


FIGURE 1. A classic supply chain.

In supply chain models, product distribution is considered as a significant parameter in the success of the supply chain.

In many cases, products were provided to retailers by various transmission methods, as well as through various routes.

Levner [18] carried out a risk/cost analysis in a supply chain based approach for sustainable management of wastewater for irrigation. For this purpose, an economic mathematical model is developed to mitigate the integrated risk to population and society under economic, technological and social constraints.

Sen [45] showed that by using a field study, the communication between manufacturers and retailers in the fashion industry would improve supply chain performance. Levner *et al.* [20] addressed a supply chain approach for the coordination of the ecological risks of all stakeholders in a transboundary river basin. Mula *et al.* [34] conducted a comprehensive research on a variety of mathematical programming models in the supply chain focusing on production and transportation. Peidro *et al.* [40] presented a linear programming model for intelligent planning of a supply chain system that was multi-product multi-level and in a number of time periods with the goal of simultaneous decision-making. There also some research that focused on quick response to customer demand [5] and also the coordination of the fashion supply chain [48]. Ni and Fan [37] provided a model for short-term and long-term dynamic sales forecasts for fashion products. He *et al.* [14] made a solution to optimize the use of raw materials and replenishment of these materials on corrosive products. In multi market issues, due to different parts of sales in different markets, production planning and inventory control are very complicated. Z. Qin *et al.* [43] used a selective control system for the transmission of products. Jia and Bai [17] introduced an approach in 2011 to develop a production strategy based on qualitative parameters. In the following, they used fuzzy theory to integrate the model in order to reduce the ambiguity in decision making. Liang *et al.* [22] used mathematical programming to solve the problem of integrated production planning, which in their model variety of products and different production periods would work in a fuzzy environment with the goal of reducing overall system costs and taking into account available inventory levels, the level of available human resources, the capacity of machinery, stockpile, and budget. El-Baz [12] presented the decision-making approach to measure the supply chain performance by combining fuzzy theory and Analytic Hierarchy Process. Olugu and Wong [38] used an expert system to evaluate closed loop supply chain management in terms of parameters such as efficiency, effectiveness, and economic strategies. Lo *et al.* [24] presented a study on the

impacts of environmental management systems on profits and the improvement of the performance of fashion-producing factories. Li *et al.* [21] focused on the issue of returning fashion goods among members of the supply chain model for cost optimization and ordering policies. Dye and Hsieh [11], provided an inventory model with variable rate of deterioration and a slight downgrade which considered the amount of capital involved in the product conservation technology that would measure the maximum profit. Basu and Nair [2] presented a multi-period inventory control formula in 2013 in a dynamic random programming model. MacCarthy and Jayarathne [25] argued that there are differences between the components of the distribution chain in apparel retailers and significant consistency between the type of retailer and the distribution chain is visible. The focus of the strategy of geographical diversity in the fashion industry has been identified by many authors. Caniato *et al.* [4] also expanded the scope of studies by designing a comprehensive framework for examining the integration of the new product development plan and international retailing in the fashion industry with a probable approach. Iannone *et al.* [16] focused on the relationships between the decision making variables of a fashion supply chain to integrate the retailer network. The model provided by them was able to assist in the process of pre-purchase decision, delivery, and replenishment steps. Macchion *et al.* [26] by carrying out statistical analysis on the information of 132 Italian factories producing fashion goods, identified three different branches of factories in which different ways were found to organize production and distribution network with specific competitive preferences. Delgoshaei *et al.* [8] focused on machine-load variation as a major shortcoming in manufacturing systems. For this purpose, a new method is proposed for scheduling dynamic manufacturing systems in the presence of bottleneck and parallel machines. They showed that the condition of dynamic costs affects the routing of materials in process and may induce machine-load variation. Delgoshaei *et al.* [10] presented a new method for short-term period scheduling of dynamic manufacturing systems in a dual resource constrained environment. The aim of this method is to find best production strategy of in-house manufacturing using worker assignment (both temporary and skilled workers) and outsourcing, while part demands are uncertain and can be varied periodically. Macchion *et al.* [27] addressed an original analytical approach to analyze whether the adoption of e-commerce improves company business, innovation and operational performance and whether sales internationalization might moderate this relationship. Lion *et al.* [23] focused on sustainability of drivers and practices within the Italian fashion industry. They proposed a taxonomy of these approaches by adopting the supplier perspective, a novelty in the sustainability literature.

While uncertain product demands come into consideration, mathematical models are divided into two main parts. The first part of the model is the demand level of the predefined various products, and the second set of models is that the demand for products which can be predicted with regard to past data or market existing analyses.

Ouyang *et al.* [39] by presenting an inventory model for corrupt items, focusing on determining repository replenishment optimal policies and proposing practical solutions to reduce annual inventory costs. Another form of definite demand is the price-based demand. Y. Qin *et al.* [42] in their study, concentrated on those corruptive items whose demand was price-dependent. Levner and Proth [19] focused on ecological factors that affect supply chains. They argued that a global management is required for protecting oceans from pollution and overexploitation. Pishvaei *et al.* [41] presented an integer programming model for designing a direct and reverse logistics integrated network. Hsu *et al.* [15] provided a model to determine the optimal level of inventory control. In this study, the researchers focused on investing in new technologies to improve the maintenance of corrosive items. Zhao *et al.* [51] focused on the uncertainty and dynamic changes of supply chain models. They found that issues such as machine failures, special sales orders, and some similar items could affect the increase in uncertainty and emphasized that the presented models require specific coordination to establish mechanisms for allocating available resources in order to achieve production goals. Tong *et al.* [47] used an Adaptive Fuzzy Method in 2009 to investigate the uncertainty estimation in supply chain logistics systems. Regulwar and Gurav [44] introduced a fuzzy multi-objective programming model to examine the uncertainty in supply chain systems. Widyadana and Wee [49] considered a constant demand inventory control model for corruptive items in a production system with constant production rates and the possibility of machine failure. Musa and Sani [35] presented the mathematical model for the inventory system of corruptive items with the ability of products

TABLE 1. Comparing the opted research with similar targets in terms of the contribution.

Row	Research	The contribution of the research
1	MacCarthy and Jayarathne [25]	Focused on differences between the components of the distribution chain in apparel retailers and significant consistency between the type of retailer and the distribution chain
2	Nagurney and Yu [36]	A model for a supply chain of multi-product fashion goods with consideration of environmental issues
3	Macchion <i>et al.</i> [26]	A practical research on distribution of Italian factories producing fashion goods
4	Zhou <i>et al.</i> [52]	Proposing pricing methods for fashion goods
5	Chen and Chang [6]	Proposing a framework for sale fashion goods in markets in order to decrease lead time
6	Şen [45]	Focused on the relationship between manufacturers and retailers in the fashion industry
7	Iannone <i>et al.</i> [16]	Dealt with pre-purchase decision, delivery, and replenishment in SCM
8	He <i>et al.</i> [14]	Optimizing the use of raw materials and replenishment of them on corrosive products in SCM problem
9	Pishvaei <i>et al.</i> [41]	designing a direct and reverse logistics integrated network
10	Li <i>et al.</i> [21]	returning fashion goods among members of the supply chain model
11	Current research	Addressing a multi-objective distribution model for Multi-market/ Multi-retailer Stochastic SCM

credit purchase. Mishra *et al.* [31] focused on the effect of time on demand, maintenance costs, and rate of corruption. So, they provided a model for backlog deficiency with the goal of minimizing costs. Sicilia *et al.* [46] presented an inventory model for corrosive goods. Montagna [32] and Delgado and Albuquerque [7] looked at cultural issues and its relationship with the fashion industry. Yang and Ng [50] have presented a strategy model with variable capacity and a multi-period market for uncertain demand and investment constraints. Delgoshaei *et al.* [9] compared different material transferring models that are developed by scientists in the scheduling manufacturing systems. In modern production systems, planning and scheduling are integrated to achieve the fastest response to customer demand. Fornasiero *et al.* [13] proposed an approach for customizing SCM according to historical data and a configuration model of supply chain based on discrete-event simulation. Macchion *et al.* [29] focused on strategic approaches to sustainability used in fashion supply chain management. Moretto *et al.* [33] designed a sustainability roadmap for fashion companies. They offered a five-step roadmap, characterized in terms of practices and main goal.

A review over the opted research shows that the idea distributing products in the multi-market/multi-retailer supply chain while the product demands are not fixed and may be varied in the different periods, has been less developed. Table 1 compares a number of opted research with similar targets.

The contribution of this research is proposing a new scheduling model for the distributing of fashion goods in order to increase profit and minimizing delivering time and customer's dissatisfaction while product demands are varied from a period to another.

3. PROPOSE A NEW METHOD FOR DISTRIBUTING AND TRANSPORTING IN DYNAMIC SUPPLY CHAIN

In this section, the logic of the problem under study will be investigated first. In the following, a mathematical model that can follow the research objectives will be developed. Suppose a main manufacturer. This manufacturer has s wholesaler in different provinces. Each wholesaler in each market i has several k retailers. The demand for each market is uncertain and can be estimated by the normal distribution function (Fig. 2). Distribution of goods

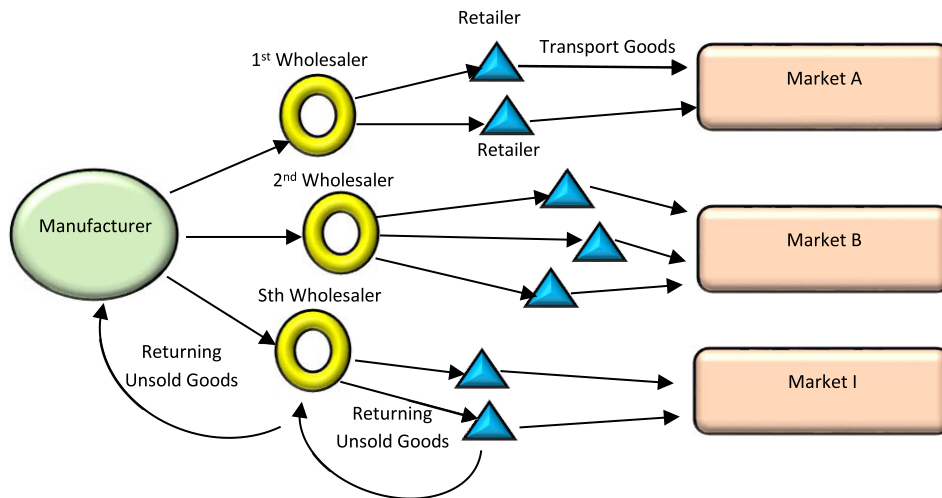


FIGURE 2. Graphical representation of the mathematical model.

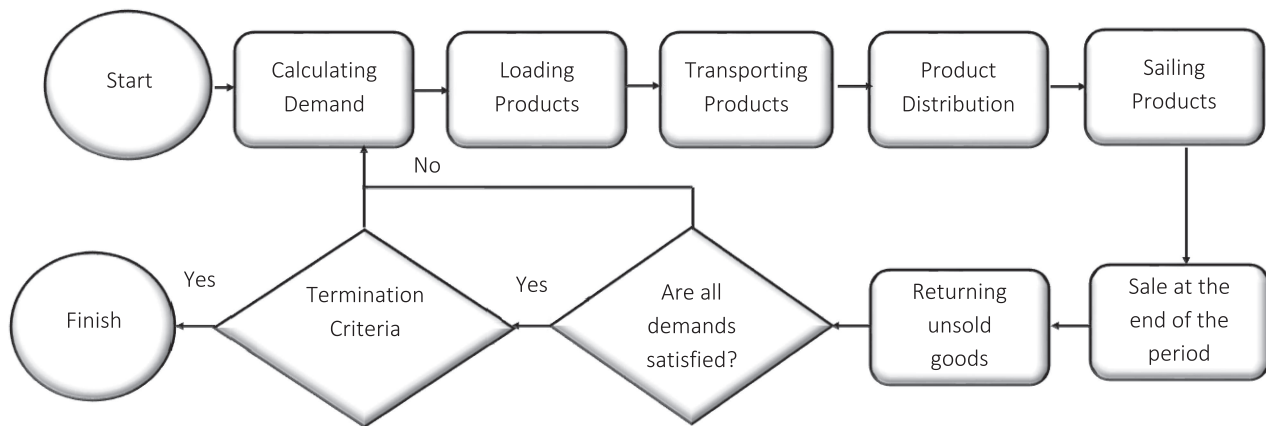


FIGURE 3. Flow diagram of the mathematical model of research.

from the manufacturer to wholesalers, and then from wholesalers to retailers, is performed by several vehicles j . The capacity of each vehicle is pre-determined. The cost of carrying any unit of goods by any type of vehicle also varies according to the speed and capacity of the vehicle (the first and second objective functions of the model will be formed for this purpose). If during the time period the rate of goods presentation in a market be higher than the market demand, due to the fashion of the goods, the additional amount will be auctioned at the end of the period. Conversely, if the demand for a product be higher than the offer over a period of time, this will result in lost sales, which will be due to customer dissatisfaction (the function of the third objective of the model will be created for this purpose). In addition, a percentage of the goods are considered defective when they are bought by customers, which should be returned to wholesalers and then to the manufacturer.

3.1. Flowchart of the model

In this section, the research method flowchart will be displayed (Fig. 3). This flowchart shows that in this model, the wholesalers delivers the goods to retailers in different provinces. It is worth mentioning that the

duration of transportation and the amount of capacity of cars are effective in the amount of goods offered, because the number of vehicles is limited. The product is presented to the customers in the following. If the demand for a product in a market be less than the amount of product received, the surplus product will be sold at auction. At the end of each section, the remaining products are returned to the supplier.

Therefore, in the model a variable must be defined to determine the amount of goods that will be delivered to the whole seller in each of the periods (let's say X). Similarly, the next variable must be defined to show the number of goods that are received by retailers in the markets (Y). The next sets of variables will show the amount of the sold goods (Z). There are also variables needed to show the goods that are sold in a sale, returned goods to whole seller and returned goods to the manufacturer (W , U and V , respectively). The last variable must be defined to show the amount of the lost sale in each of the markets (L).

As it is clear from the history of sales planning literature review, many researchers have used mathematical programming in similar cases. Therefore, in this study, mathematical programming will be used. The characteristics of the mathematical model in this research can be considered as follows:

- Development of mathematical model for fashion product planning.
- Simultaneous optimization of cost, time and satisfaction in the distribution function (using multi-objective function).
- Consider the mathematical model with probable demand.
- Consider the returned defective goods.
- Consider the auction item.
- Consider missing sales.

For the development of the mathematical model, the assumptions will be considered as follows:

- (1) The demand for each market is probable and is defined by the normal distribution function.
- (2) Each wholesaler has a specific storage capacity.
- (3) Each retailer has a specific storage capacity.
- (4) At the end of each period, non-sales goods will be auctioned on the customer's market.
- (5) The initial stock of the warehouse is considered zero. The inventory of the end of the last period is considered zero.
- (6) If the offer during the period be less than the demand, there is a lost sale at the end of each period, and if the amount of offer be higher than the demand, the sale of the not sold products is first auctioned and then returned to the producer.
- (7) Transportation costs from the manufacturer to wholesalers and from wholesalers to retailers is determined by any means of vehicle.
- (8) The time of transportation from the manufacturer to the wholesalers and wholesalers to the retailers is determined by any means of vehicle.
- (9) A certain percentage of the goods are considered as defective goods, which are determined by the retailers after distribution. These goods are returned to the wholesalers and then to the manufacturer.
- (10) Each means of transport has a certain capacity.
- (11) The number of vehicles is already known.

3.2. Indexes

The range of variables and parameters of the model is defined as follows:

- i : Number of available markets counter.
- j : Vehicle Type counter.
- T : Programming period counter.
- s : Wholesaler counter.
- k : Retail counter.
- ω : Target functions counter.

3.2.1. Parameters

- $D(i, t)$: The market i demand during the time t $D(i, t) \sim N(\mu_{i,t}, \sigma_{i,t}^2)$.
 $Q(i)$: Number of retailers in the market i .
 $A(s)$: Wholesaler s warehouse capacity.

 $B(ik)$: The retailer k capacity in the market i .
 $C(j)$: Vehicle type j capacity.
 $TV(sj)$: The time of transport of each unit product from the manufacturer to the wholesaler s by vehicle j .
 $CV(sj)$: The cost of carrying of each unit product from the manufacturer to the wholesaler s by vehicle j .
 $\phi(ti)$: Percentage of defective goods in each period t in market i .
 FC : Factory production effective capacity.
 $Tm(skj)$: The time of carrying each unit of product from wholesaler s to retailer k by vehicle j .
 $Cm(skj)$: The cost of carrying each unit of the product from the wholesaler s to the retailer k by vehicle j .
 $SC(it)$: Sales price per unit of product in market i during period t .
 $OC(kt)$: Auction price per unit of product by retailer k at the end of period t .
 $CS(it)$: The customer dissatisfaction of market i at the end of period t due to each lost sales.

3.2.2. Decision variables

In this mathematical model, seven variables are defined as:

- $X(st)$: The number of goods delivered to the wholesaler s in the period t (integer).
 $Y(kt)$: The number of goods delivered to the retailer k in the period t (integer).
 $U(kt)$: The number of returned goods given by the retailer k in the period t (integer).
 $V(st)$: The number of returned goods given by the wholesaler s in the period t (integer).
 $W(kt)$: The number of auctioned items by the retailer k during the time period t (integer).
 $Z(kt)$: The number of goods sold by the retailer k in the period t (integer).
 $L(it)$: The number of lost sales in the market i during the period t (integer).

3.2.3. Mathematical model

The mathematical model presented in this study is a Nonlinear Multi-objective Integer Programming model. This is due to the use of metaheuristic algorithms. On the other hand, the results of the literature review show that about 80% of research in this field have used metaheuristic algorithms for similar models.

$$\begin{aligned}
 \text{Max } \omega 1 : \alpha_1. \sum_t^T \sum_k^K SC(it).Z(kt) + OC(kt).W(kt) - \sum_t^T \sum_s^S CV(sj).[X(st) + V(st)] \\
 - \sum_t^T \sum_s^S \sum_k^K \sum_j^J Cm(skj).[Y(kt) + U(kt)]
 \end{aligned} \quad (3.1)$$

$$\text{Min } \omega 2 : \alpha_2. \sum_t^T \sum_s^S TV(sj).[X(st) + V(st)] + \sum_t^T \sum_s^S \sum_k^K \sum_j^J Tm(skj).[Y(kt) + U(kt)] \quad (3.2)$$

$$\text{Min } \omega 3 : \alpha_3. \sum_t^T \sum_i^I CS(it).L(it) \quad (3.3)$$

S.T :

$$\sum_k^K Y_{kt} = X_{st} \quad \forall t \& s \quad (3.4)$$

$$\sum_k^K Z_{kt} + \sum_k^K W_{kt} + \sum_k^K U_{kt} = \sum_k^K Y_{kt} \quad \forall t \& i \quad (3.5)$$

$$\sum_i^I Z_{kt} \leq D(i, t) \quad \forall t \& i \rightarrow D \sim N(\mu_t, \sigma_t^2) \quad (3.6)$$

$$\sum_k^K U_{kt} \leq \sum_k^K \phi_t \cdot Z_{kt} \quad \forall t \quad (3.7)$$

$$\sum_k^K U_{kt} \leq V_{st} \quad \forall s, t \quad (3.8)$$

$$X_{st} \leq A_s \quad \forall t, s \quad (3.9)$$

$$Y_{kt} \leq B_{i,k} \quad \forall i, t, k \quad (3.10)$$

$$X_{st} \leq \sum_j^J C_j \quad \forall t \quad (3.11)$$

$$\sum_s^S X_{st} \leq \sum_j^J C_j \quad \forall t \quad (3.12)$$

$$\sum_s^S X_{st} \leq FS \quad \forall t \quad (3.13)$$

$$L_{it} = D_{it} - \left[\sum_k^k (Z_{kt} + W_{kt} + U_{kt}) \right] \quad \forall i, t \quad (3.14)$$

$$\sum_{r=1}^3 \alpha_r = 1 \quad (3.15)$$

$$X_{st}; Y_{kt}; U_{kt}; V_{st}; W_{kt}; Z_{kt}; L_{it} \quad \text{are integer.} \quad (3.16)$$

The first objective function of this model is to maximize the profit of the organization, which has been calculated from products sells after deducting the cost of the model, including carrying from the manufacturer to the wholesalers in different markets, from wholesalers to retailers, the sales price per unit and the auction price per unit. The second objective function of this model is designed to minimize the time needed to deliver products to different markets. The final objective function of the model is to minimize customer dissatisfaction resulting from the sale of lost products.

The first constraint indicates that the amount of goods delivered to retailers in each market should be equal to the amount of delivery from the related market wholesaler. The second constraint shows the relationship between the products sold in the normal state, the auction and the return with the total deliveries to each market. The third constraint shows that the product cannot be sold in any period more than the forecasted demand of a market. In fact, the cause of the loss of sales in the real world of the industry is this subject because many companies in the fashion world produce based on market demand estimates and if this estimation be lower than the actual demand (which becomes known later and during the period), the organization will face the loss of sales. The fourth series of the constraints shows the number of defective products in each period. The fifth constraint indicates that the total defective products of all retailers over a period must be equal to the amount of returned products received by the relevant wholesaler. The sixth constraint implies that the amount

TABLE 2. Review table of the characteristics of the developed mathematical model.

Objective type	Multi-objective
Objectives	Total Cost/Completion Time/Customer Satisfaction
Demand	Uncertain
Programming type	Non-linear multi-objective integer programming
Product	Fashion
Market	Multi market
Scheduling type	Multi-period

of goods delivered to a wholesaler should be less than the wholesaler's capacity. The seventh line of constraints is that the quantity of goods delivered to each retailer should be less than the retailer's capacity. The eighth constraint shows that the amount of goods carried to wholesaler S should be less than the fleet capacity. The ninth constraint implies that the amount of goods transported to all wholesalers should be less than (or equal to) the total fleet capacity. The tenth constraint shows that the amount of merchandise offered to wholesalers should be smaller than (or equal to) the capacity of the factory production. The eleventh constraint shows that the amount of lost goods in each period can be calculated from the difference between the goods sold and the auctioned goods and the returned goods given in the demand for each period. The next constraint indicates the extent of the coefficients of the target functions, which, the weighting method will be used, the sum of these coefficients is considered as one. The final constraints also represent the range of variations of the eight variables of the developed mathematical model.

Lost sale in the model

- (1) If the demand for the period exceeds the amount delivered to wholesalers (and consequently retailers)
- (2) If the amount of demand predicted in the period be less than the supply of goods in the market (that is, if the capacity of the producer be less than the market demand).

Customer dissatisfaction

- (1) There is a certain amount of dissatisfaction with customers when there is lost sales in a period for each sales unit.

3.3. Contributions and novelties of the model

In this section, the developed mathematical model is studied in terms of modelling (Tab. 2).

Table 3 shows the contribution and novelties of this research comparing to some of the similar research in literature.

The studies carried out in the second part show that many of the mathematical models developed in the field of sales planning are hard non-polynomial. This leads to the fact that solving these algorithms by optimization algorithms in the conditions of increasing the dimensions of the problem is difficult and sometimes impossible.

According to the Table 4, the genetic algorithm is selected as an effective algorithm for solving the mathematical model. According to the developed mathematical model which is of the multi-objective decision making (MODM) type, the NSGAI algorithm will be used for solving such problems which is a genetic-based, efficient algorithm. However, due to the power of the simulated cold algorithm, in escape from the local optimal points, the hybrid of these two algorithms is used. So that the NSGAI algorithm is considered as the basic algorithm and then the running engine from the optimal local points, a simulated annealing algorithm will be used to increase the power of this algorithm.

What follows from the study of existing articles and dissertations shows that the type of processor system has a significant effect on the speed and performance of the algorithm. Therefore, many researchers have announced the type of processor.

TABLE 3. Contribution and novelties of this research.

Reference	Idea	Objectives	Model type	Product demand	Planning period	Solving algorithm	Novelties
This research	Distributing transferring sale	Minimizing Cost Minimizing Time Minimizing Customer dissatisfaction	NL-IP	Stochastic	Multi-Period	Hybrid NSGAI-SA	Fashion Goods/ Multi-market/ Multi-product/Sale/ Product Return/
Peidro <i>et al.</i> [40]	Production Planning	Minimizing system cost	FLP	Stochastic	Multi-Period	Fuzzy Programming	Utilizing Resource Usage
Delgoshaei <i>et al.</i> [8]	Production Planning	Minimizing system cost	MIP	Stochastic	Multi-Period	Genetic Algorithm	Minimizing work-load Variation
Liang <i>et al.</i> [22]	Production Planning	Minimizing system cost	FIP	Deterministic	Multi-Period	Fuzzy Programming	Inventory/ Labor Levels/ Machine Capacity/ Warehouse Space/ Available Budget

Notes. NL-IP: Non-linear integer programing; FLP: Fuzzy linear programing; MIP: Mixed integer programing; FIP: Fuzzy Integer Programing.

TABLE 4. Review table of functional characteristics of the metaheuristic algorithms.

Algorithm	Abbr.	Local escape	Memory	Learning	Speed	Single point	Multi point	Multi operator
Simulated annealing	SA	+			F		+	
Tabu search	TS		+		S		+	
Genetic algorithm	GA	+	+		F		+	+
Memtic algorithm	MA	+	+		F		+	+
Ant colony	ACO	+			M		+	+
Bacterial forging	BEA	+			M		+	+
Particle swarm method	PSO				M		+	+
Artificial neural networks	ANN		+	+	F	+		

In this study, a personal Laptop with Intel® Core™ i7 system, which has 2.50 GH CPU and 8GB of RAM, is a good system for doing this research.

4. A HYBRID NSGAI AND SIMULATED ANNEALING ALGORITHMS

Each of the metaheuristic algorithms has unique characteristics and features that speed up the search for the solution space. In this research, a hybrid NSGAI and simulated annealing algorithms is proposed. The reasons for this selection are as follows:

- (1) Genetic Algorithm and derived algorithms are used in similar models.
- (2) The NSGAI algorithm has the ability to solve MODM problems.
- (3) This algorithm is able to escape from local optima using the simulated annealing local escaping rate (LER).
- (4) This algorithm can provide a suitable convergence by using the cross-over operator.

The figure below shows the steps of the NSGAI-SA (Fig. 4).

In this section, all the data, including parameters and input matrices, will be entered into the model. The full list of these data is provided in the third section.

4.1. Number of generations

The number of generations indicates the repetition number of the algorithm. Genetic algorithms are a group of evolutionary ameliorative algorithms which can move to the optimum point by the directional selection of acceptable and unacceptable corner points. The number of generations in the algorithm is an input parameter and it will be determined according to the size of the problem through the design of the experiments.

4.2. Population size

In each generation, a number of points will be considered as members. The number of community members is also an input parameter and will be determined by the experimental design method for different parameters. An important point in this section is how choosing members will have a very significant effect on the next-generation production process or the Mating bath.

The better the quality of the members in each generation, the better the choice of members for the reproduction process.

4.3. Selecting operator

Step 1: This operator initially estimates the demand for each market that is determined by the normal distribution function as follows:

$$D(i, t) \sim N(\mu_{i,t}, \sigma_{i,t}^2). \quad (4.1)$$

Step 2: In the following, it will choose an answer based on the probability function, so that the best answer is more likely to be chosen, and based on that, it will be considered for genetic variation.

It should be noted that if the best solution is always chosen, it may lead to early convergence (which is a defect) and prevent the algorithm from moving to the optimal point and stop the search immediately. Here, the answer is the same as the amount allocated to wholesalers (Fig. 5).

Given the fact that the number of wholesalers is different and each covers a few cities, the amount allocated to wholesalers according to the amount of sales demand for each city results in different answers. The goal is to select the best allocation to wholesalers and then retailers, depending on the production size of the factory.

4.4. Cross-over operator

This operator is actually the main operator of the Mating Bath. The goal is to allocate and choose the best genes available among parents so that the next generation can be found to be a better generation (genetically) than its parents. In this operator, firstly, the products delivered to the wholesalers will be divided according to the priority of market demand and will be referred to retailers. Then they will be distributed in different markets and will be sold. Additional products are auctioned and then returned.

Another point to note here is that in the virtual world, the genetic algorithm does not necessarily have to be as the real world of the two parents to produce a begotten; in this virtual world, each parent alone or even more than two parents can lead to the emergence of a born. But the interesting point is that this creature should contain the superior genetic traits of its parent (s). In this algorithm, the multiplicity of candidates (multiple retailers with capacity to sell) as the parent is considered. Finally, among them the best parent based on genetic

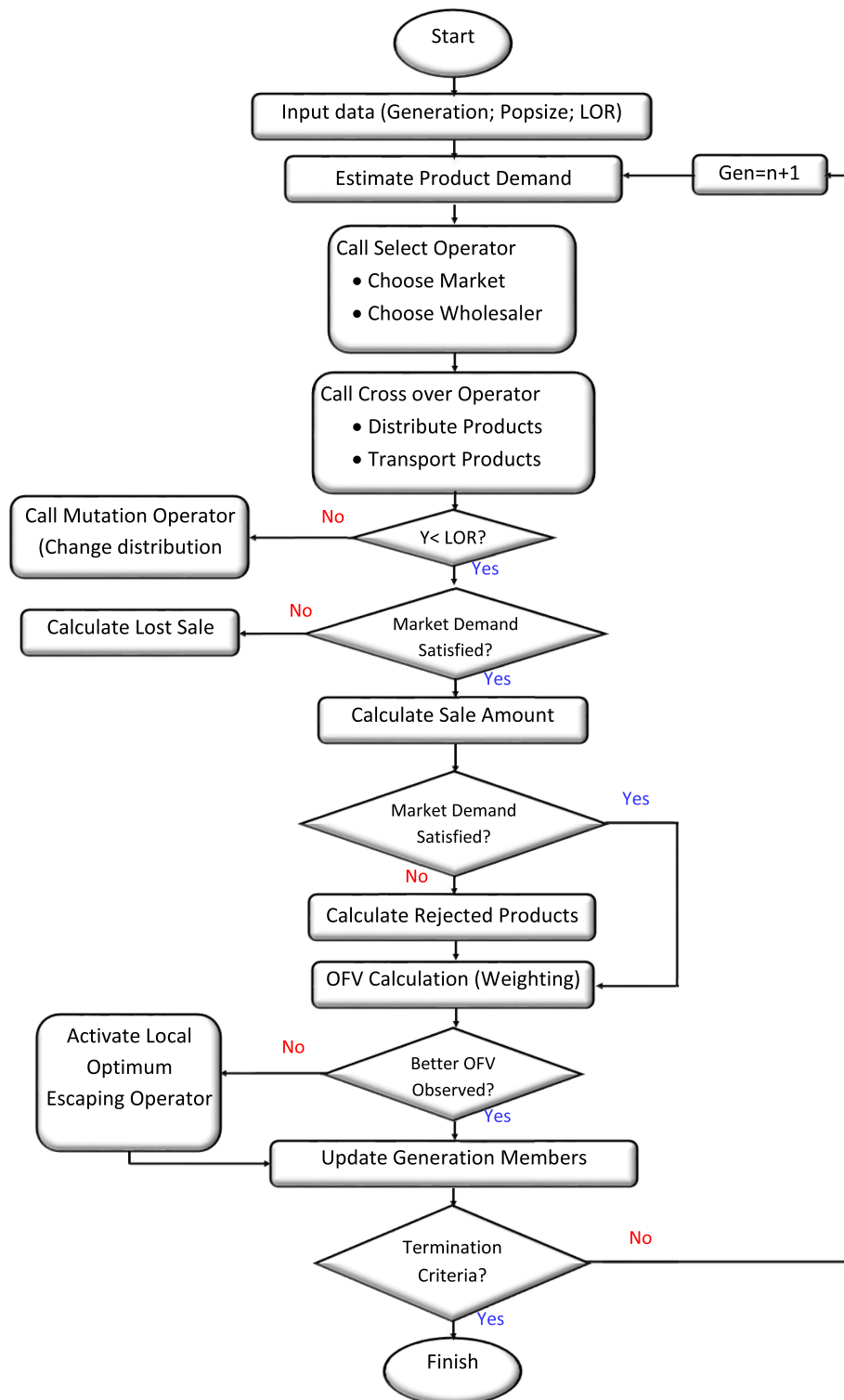


FIGURE 4. Flowchart of the NSGAII algorithm.

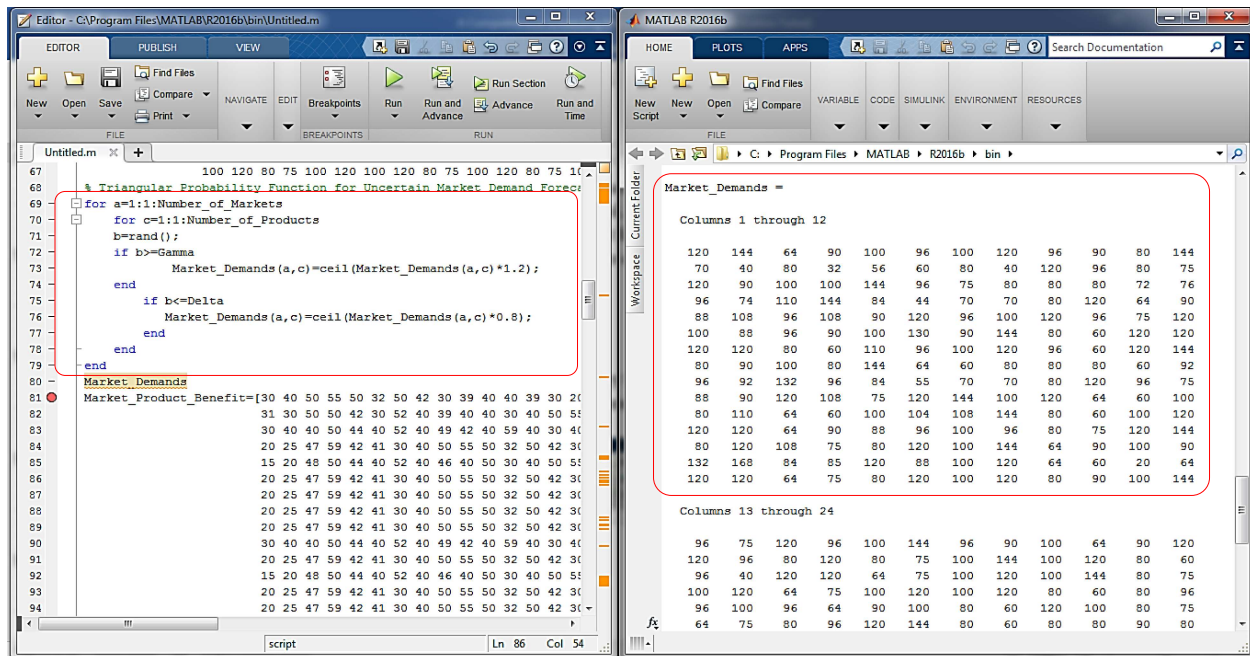


FIGURE 5. Using normal distribution function to estimate market demand values.

traits (residual capacity, real demand requested by the customer) will be chosen. Therefore, the number of members in all generations (up to the end of the algorithm search) will be constant (Fig. 6).

- (1) Identify retailers with capacity.
- (2) For each retailer, calculate the remaining capacity.
- (3) Choose the best retailer for the remaining capacity (this will allow the largest amount of goods to be transferred to the retailer and increase the chances of selling in the future).

4.5. Fitness function

After assignment, the algorithm examines the extent of the target function to determine whether this allocation has improved the model or not. In other words, does the algorithm have a tendency to accept a new answer or not. In the NSGAII algorithm, the amount of target function is determined by the MODM target functions. For this purpose, weighting method is used, which helps the decision maker to determine the priorities of the target functions (for example, the objective function coefficient would be considered 2 times greater than other functions to indicate that this target function is 2 times more important to the decision maker than others). If there were no prioritization between target functions, all weights would be considered equal.

If after assigning different products to retailers and then target markets, the response from the target functions is not improved, the response will not be immediately discarded, because on the part of the model answers may not be appropriate for some reason, but they will become better later. Therefore, prompt discarding of inappropriate answers and avoid searching for that area from the solution space does not seem to be appropriate (Fig. 7).

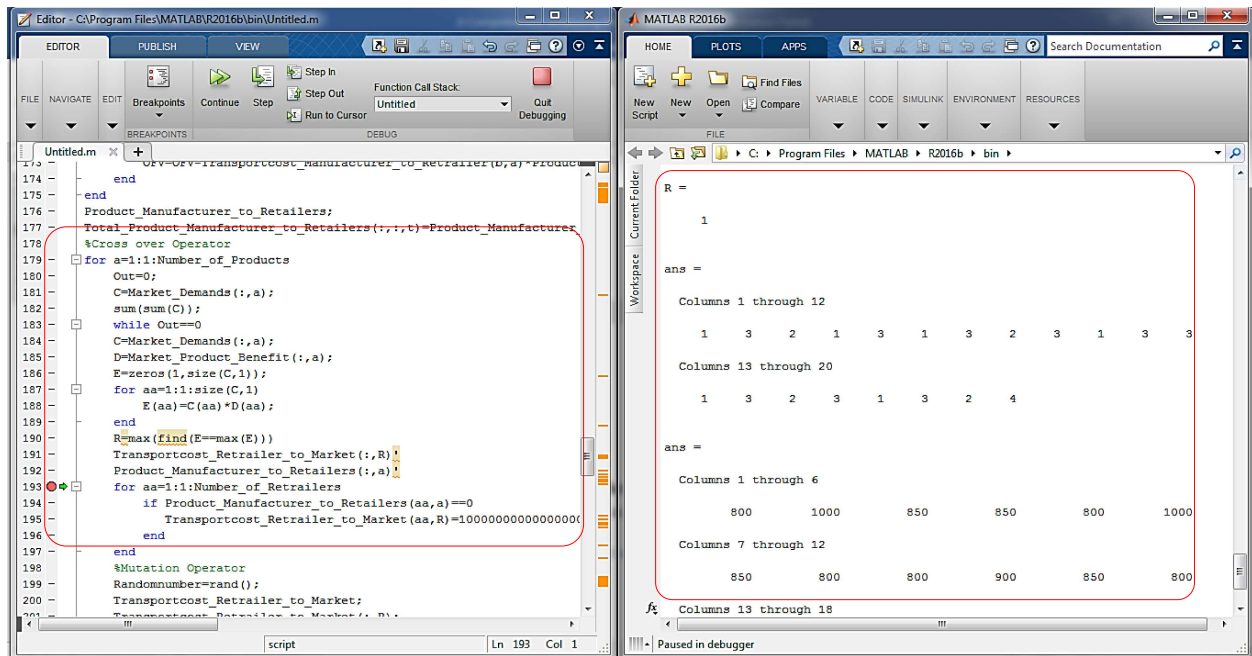


FIGURE 6. Cross-over operator performance.

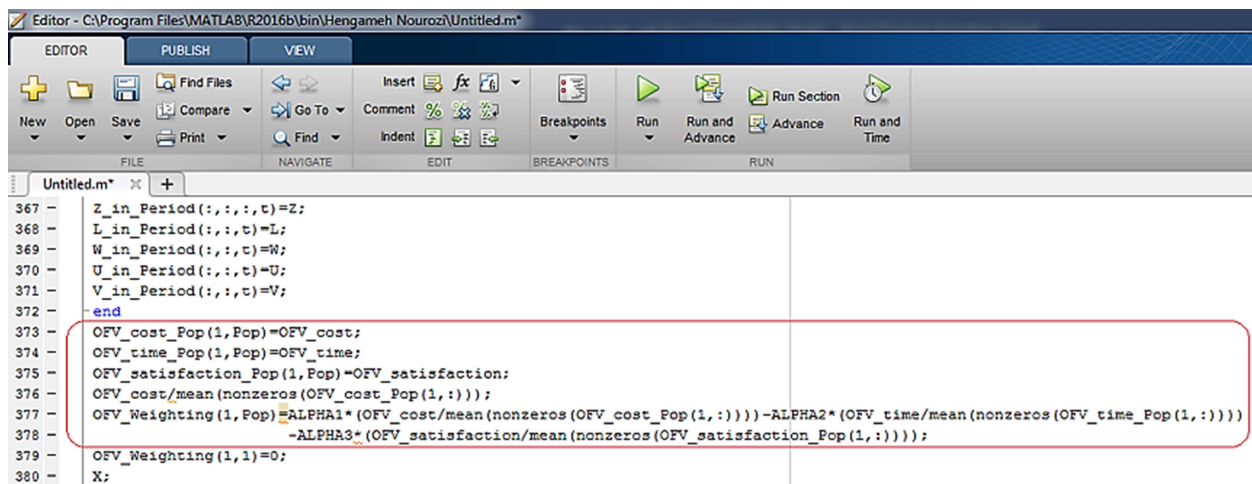


FIGURE 7. Calculation of the multi-objective fit function by weights method in solving algorithm.

4.6. Mutation operator

Which does this for a quick alteration of the search area, just like soccer players who have changed the playing field with a long pass and, for example, lead the ball from the left to the right of the ground (where space of movement is more suitable) (Fig. 8).

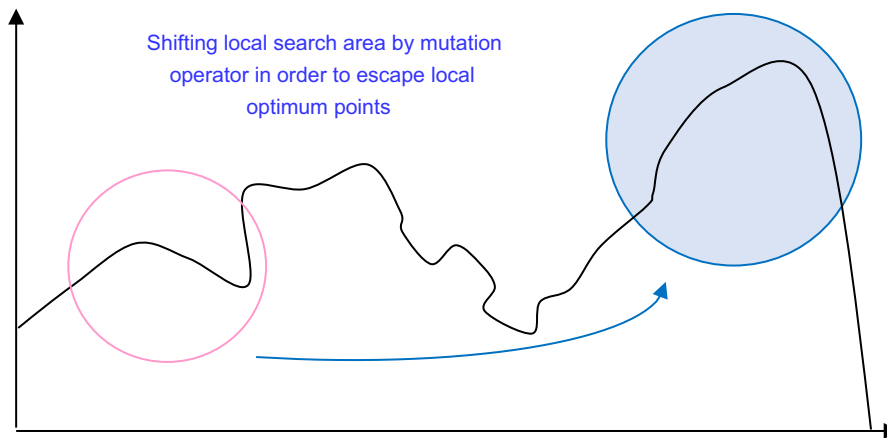


FIGURE 8. Use of the mutation operator and the exchange of the search area.

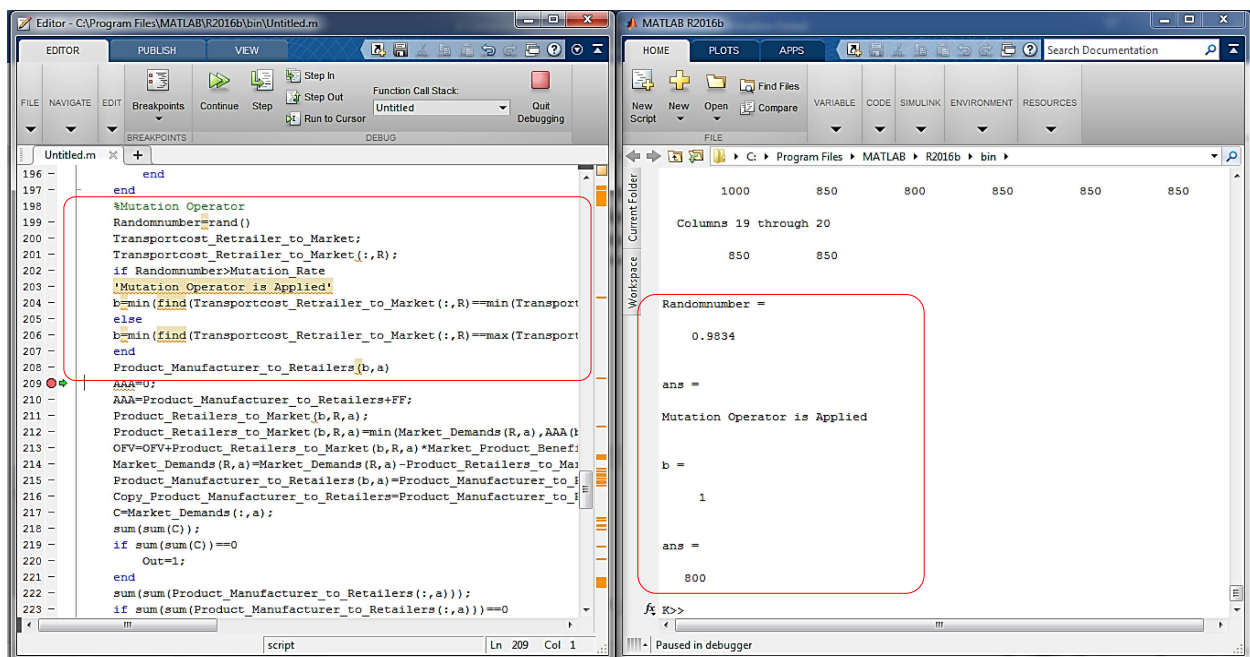


FIGURE 9. Use of the mutation operator in the NSGAII algorithm to increase the chance of more solution space search.

- (1) Consider a number as the mutation rate (Fig. 9).
- (2) Calculate the fitting function for a new generated member and compare it to the best value obtained from objective function.
- (3) If the amount of fitting function calculated for a newly generated member is less than the objective function, then accept the answer with the probability of a mutation rate.
- (4) Otherwise, reject it.

4.7. Local escaping operator

As shown in diagram 9.4, the search algorithms may be captured at optimal local points when the solution space becomes a bit complex. These points are points that are not optimal, but because their value is less than neighbourhood points (in terms of minimization issues), the algorithms incorrectly identify them as optimal points.

The Local Escaping Rate (LER), which is inspired from simulated annealing algorithm, can help the algorithm to escape from local optimum points. The mechanism of this operator is to accept worse solutions with a very small chance. In fact, the Simulated Annealing algorithms do not run directly from the optimal point but, by accepting somewhat poorly answers, deviate the search path from the local optimal point, so they can hope that they will not face the local optimal point in the search. If no such property is observed in the algorithm, algorithms always search specific areas of the solution space and deal with local optimization points.

But the amount of this probability must be a small number; otherwise, the algorithm will accept each and every answer and will search completely without purpose in the solving space. The LER rate from the local optimal point will also be determined by the design of the experiments.

4.8. Termination criteria

These following stopping criteria are considered in the algorithm:

- (1) Reaching the number of predetermined generations.
- (2) Failure to improve the response to more than half of the generations.

At this point, the NSGAI algorithm examines the exit conditions of the search process, and if these conditions are met, the algorithm stops and the best answer is displayed.

4.9. Solution representation

In this section, algorithm solution outputs are explained by MATLAB software. The first output of the algorithm is the reduction amount graph of the multiple objective function. An example of this diagram is given in Figure 10.

As shown in the diagram above, the slope of the graph shows the process of minimizing the multiple objective functions developed by the mathematical model. In the places where failure occurs, the likelihood of the algorithm getting to the optimal local points increases greatly, and the algorithm passes through it with two mutations and LER operators and continues to search. The second output of the algorithm is the matrices associated with the variables X , Y , L , Z , W , U and V .

In the third section, for each of these variables and their dimensions, explanations are required. An example of the output of the NSGAI algorithm for each of these variables is presented below and a description will be provided.

The first matrix indicates the variable X or the number delivered from the factory to each of the wholesalers:

```
Best_X_in_Pop(:, :, 1) =
110  20
38   69
63   61
Best_X_in_Pop(:, :, 2) =
105  37
46   82
72   63
```

The first matrix indicates the distribution to wholesalers in the first period and the second matrix represents the same values in the second period (assuming that the solved example in this section is two planning periods).

The columns of this matrix indicate the quantity of goods offered to the first and second wholesalers and the values of the rows represent the type of product. For example, 38 in the second row of the first column of the

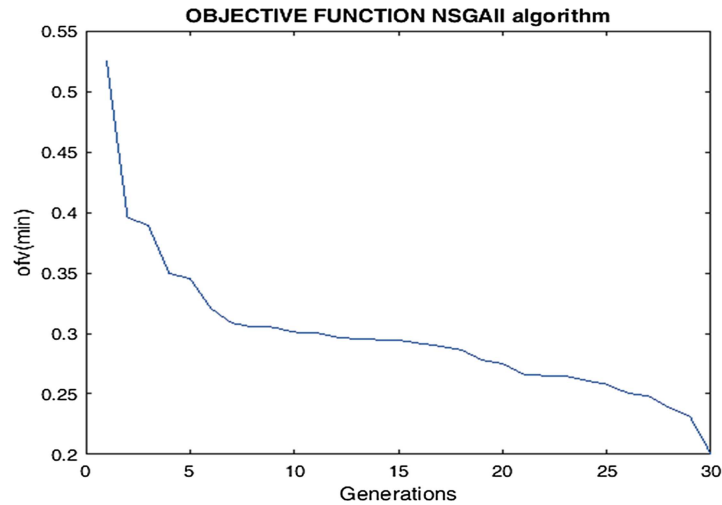


FIGURE 10. Improvement process of the Weighting Function of the NSGAI Algorithm.

first matrix shows that 38 units of product number 2 were delivered to the first wholesaler in the first period. The second matrix is the matrix Y , which represents the quantity of goods distributed to retailers. This matrix is determined from the matrix X .

```
Best_Y_in_Pop(:, :, 1) =
0   0   0   0
49   0   0   0
0   0  23   0
Best_Y_in_Pop(:, :, 2) =
0   0   0   0
66   0   0   0
0   0  45   0
```

The columns of this matrix represent retailers, and the matrix rows represent the products. For example, the number 23 in the first row of the third column indicates the quantity of 23 products of type I to retailer No. 3. The next matrix is the Matrix Z , which represents the amount of products sold by retailers in their underlying markets. The number of these matrices represents the number of markets. For example, the 5 Z matrices below show that there are 5 markets for this example. The columns of this matrix represent retailers and matrix rows express the products. For example, the number 12 in the first row of the fourth column of matrix 2 indicates the sale of 12 units of the first-type product by the fourth retailer in the second market.

```
Best_Z_in_Pop(:, :, 1, 1) =
17   0   0   0
0   15  80   0
23   0  10   0
Best_Z_in_Pop(:, :, 2, 1) =
0   0   0   0
12   0   0   0
0   0   0   0
Best_Z_in_Pop(:, :, 3, 1) =
0   0   0   0
0   0   0   0
0   0  90   0
```

TABLE 5. Taguchi design parameters and levels.

Parameter	Abbr.	Large size			Medium size			Small size		
		L1	L2	L3	L1	L2	L3	L1	L2	L3
Generations	G	10	20	30	20	30	50	50	80	100
Population size	Pop	10	20	30	20	30	50	50	80	10
Mutation rate	Mu	0.1	0.2	0.3	0.1	0.2	0.3	0.1	0.2	0.3
Selecting rate	S.R	0.7	0.8	0.9	0.7	0.8	0.9	0.7	0.8	0.9
Local optimum escaping rate	L.E.R	0.1	0.2	0.3	0.1	0.2	0.3	0.1	0.2	0.3

Note that every retailer cannot sell in any market, and this issue will be determined by the Retailers.in.market matrix in the algorithm. If the predicted demand is different from the actual market demand, the difference in demand is considered as a lost product (according to model assumptions). This is illustrated by the matrix L .

```
Best_L_in_Pop(:, :, 1) =
0   93  101
118  0   121
0   69   77
0    0   97
0    0   60
Best_L_in_Pop(:, :, 2) =
0   97  98
123  0  120
0   72  79
0    0  100
0    0   71
```

Next matrices are W , U , V that represent the number of products put up for auction, the number of returns returned to the wholesaler and then the manufacturer.

```
Best_W_in_Pop(:, :, 1) =
0  0  0  0
0  0  0  54
0  31  0  0
Best_W_in_Pop(:, :, 2) =
0  0  0  0
0  0  0  55
0  35  0  0

Best_V_in_Pop(:, :, 1) =
0  0  0  0
0  0  0  127
0  73  0  0
Best_V_in_Pop(:, :, 2) =
0  0  0  0
0  0  0  131
0  83  0  0
```

4.10. Design of experiments

As mentioned earlier, the design of the experiments should be used to determine the proper parameters of the algorithm. In this research, considering that all parameters are discrete, the Taguchi design method will be used. In the Taguchi design method, each factor (L) can have multiple levels (n). To do the design, consider each of the parameters in three levels: small, medium and large, and consider each one as a default. The choice of default values of parameters is completely optional and has no effect on the responses. Table 5 shows the parameters and the number of levels and values considered in each level.

Figure 11 shows that the Selecting-Rate, Mutation, population size (Pop), LER, and number of generations (Gen) parameters respectively play the most important roles in finding the solutions of the designed model.

Accordingly, for a small size problem, the best values for the number of generations will be 20, the population of the community will be 30, rate of mutation will be 0.2 and LER rate from the solutions with the optimal

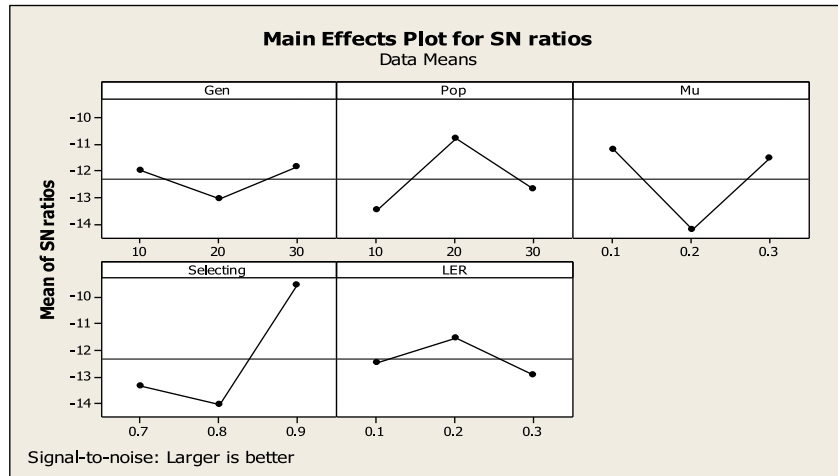


FIGURE 11. Chart of changes in the weighting target function relative to the considered levels of parameters.

TABLE 6. The values determined by Taguchi design for the NSGAI algorithm.

Size	Gen	Pop	Mu	SR	LER
Small	30	20	0.1	0.9	0.1
Medium	50	30	0.1	0.9	0.2
Large	80	50	0.3	0.8	0.3

local probability will be 0.3. Considering that the objective weight function is of the maximal type (considering the positive sign for the first objective function, the negative coefficients for the second and third objective functions), the largest values in the different parts of the graph above indicate the desired level. For example, with regard to the Pop parameter the maximum value of the graph is obtained when the value of 20 is considered for Pop. Other parameters are also quantified in the same way. Table 6 shows the proper values of the parameters that are designed for each problem:

4.11. Solving case studies from the literature (validation of the algorithm)

In this section, a small experiment is solved and illustrated in depth to determine the performance of the solving algorithm. The algorithm should be able to solve this mathematical model easily and obtain the best answer. In the second step, some numerical examples obtained from the literature review are solved and the results are analysed. The examples are designed in such a way to meet all the conditions considered in the mathematical model. In addition, examples are designed in three small, medium and large sizes. Examples range from 5 products, 5 retailers and 5 target markets to 100 products, 30 retailers and 30 target markets. Each of the above issues has been solved 10 times by Matlab software. Tables 7 and 8 show the inputs for each numerical example and the results.

Columns of Mutation rate; Selecting rate; LER were assigned from the experimental design section.

In this section, the results obtained from solving various problems in the above are examined from the viewpoint of performance and efficiency and solving time in order to ensure the applicability of the algorithm.

- (1) The analysis of the solved problems in this research shows that the developed algorithm NSGAI can solve all designed problems in different dimensions in a simple and reasonable time interval (Fig. 12).

TABLE 7. Numerical examples inputs.

No.	Product	Wholesaler	Retailer	Market	Planning period	Generation	Pop. size	Mutation Rate	Selecting rate	LER
1	3	2	4	5	2	30	20	0.1	0.9	0.1
2	3	3	4	5	3	30	20	0.1	0.9	0.1
3	10	2	6	5	2	30	20	0.1	0.9	0.1
4	10	4	6	5	2	30	20	0.1	0.9	0.1
5	15	4	10	5	3	30	20	0.1	0.9	0.2
6	20	4	10	10	3	50	30	0.1	0.9	0.2
7	20	6	10	10	4	50	30	0.1	0.9	0.2
8	30	5	20	10	3	50	30	0.1	0.9	0.2
9	50	5	25	20	4	80	50	0.3	0.8	0.3

TABLE 8. Results of solving numerical examples by NSGAII algorithm.

No.	Initial OFV	Best observed OFV	% improvement	CPU time
1	0.4488	0.1687	62.411	0.224
2	0.4138	0.1548	62.591	0.437
3	0.3596	0.2785	22.553	0.524
4	0.3437	0.2757	19.785	0.888
5	0.3441	0.2484	27.812	1.724
6	0.3502	0.3142	10.280	5.599
7	0.3363	0.5086	33.877	9.293
8	0.3762	0.3097	17.677	10.811
9	0.3385	0.3038	10.251	121.911

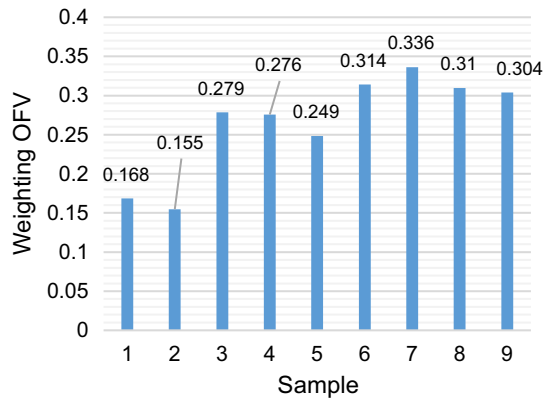


FIGURE 12. The amount of observed fit function for numerical examples solved by genetic algorithm.

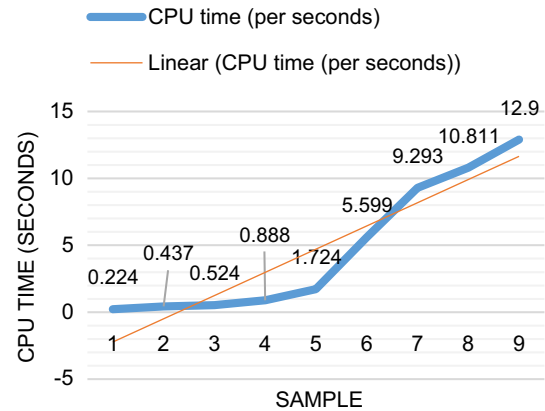


FIGURE 13. Solution timing of numerical examples by genetic algorithm.

- (2) The results presented in the diagram below show that the proposed NSGAII algorithm is capable of solving the problems of this research in small size in less than 5 s, medium problems in about 11 s, and large-scale issues in 121 s. Therefore, the algorithm can solve the industrial problems in the real world in a relatively reasonable time period (Fig. 13).

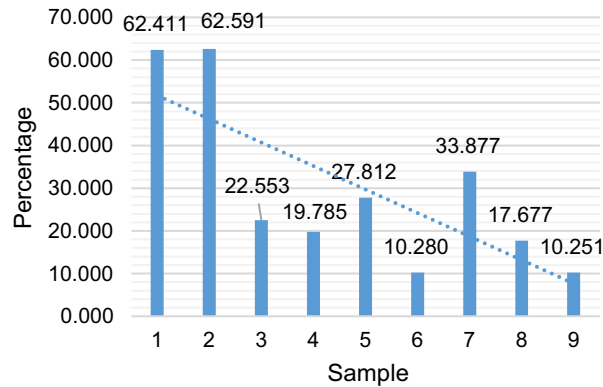


FIGURE 14. Improvement of the objective function from first to last generation.

TABLE 9. Estimating practical example demand.

Period		Period 1			Period 2			Period 3	
Market	Product 1	Product 2	Product 3	Product 1	Product 2	Product 3	Product 1	Product 2	Product 3
Market 1	5052	5036	5027	4943	4843	5094	4866	5019	4952
Market 2	2106	2085	2077	2095	2115	2085	2117	2081	2062
Market 3	1846	1936	1618	1981	1781	1711	1836	1963	1901
Market 4	6239	6265	6197	6244	6211	6252	6110	6295	6262
Market 5	3963	3850	4007	3988	3976	4157	4021	3989	4069

- (3) The outcomes show that the results can improve issues at a small level at 60%, medium-sized issues in the range of 11–34%, and high-level issues by about 11%. This suggests that the algorithm can be used with good performance in the industry. Decreasing the improvement slope by increasing the dimensions of the problem is due to the fact that as the dimensions of the problem increase, the number of corners of the problem increases, which adds to the complexity of the problem, which makes the amount of improvement harder (Fig. 14).
4. The results of comparing the genetic algorithm with the forward-looking random check programming method show that the developed genetic algorithm is capable of providing a very good improvement, indicating that the performance of the mutation and cross-over operators was appropriate.

4.12. Verification of the proposed algorithm by a real case study

In this section, in order to determine the performance and efficiency of the algorithm in the real world, a garment manufacturer will be considered. The wholesaler company sells its products in 5 provinces and is distributed by 4 major distributors. There are a number of retailers in each province, as shown in the table below. The products are distributed by two types of heavy vehicles, Fuso 5 tons and Isuzu 6 tons. Table 9 shows the demand for products in the markets, which are estimated by the normal distribution function in the planning period (3 periods). Also, the retailers' capacity is as follows (Tab. 10).

The parameters of the NSGAI algorithm are also considered in the following.

Generations=50

Pop.size=80

Mu=0.3

TABLE 10. Retailers' capacity table for numerical example.

Kuala Lumpur	Retailer's capacity						
Selangor	400	220	530	600	500	400	220
Penang	530	600	400	500	400	–	–
Johor	220	530	600	–	–	–	–
Langkawi	400	280	700	450	–	–	–
Kuala Lumpur	700	400	700	900	700	–	–

TABLE 11. Results from solving verification problem.

Transported products	57 543	57 476	57 304
Returned goods to manufacturer	5754	1724	1146
Lost sale	0	0	0
Sold in seasonal sale	16 365	17 351	17 156

Selecting rate=0.80

LER=0.3

The algorithm is able to solve the above mathematical model in 8.5 s.

Elapsed time is 8.576104 s.

The weighting target function achieved in the model is 0.1065, which improves the first round of search (first generation) by 67.815%. Other outputs of the algorithm are as follows (Tab. 11).

5. CONCLUSIONS AND RECOMMENDATIONS

In this research, a multi-objective model of transport and sales decision-making is presented. To this end, a MODM multi-objective programming model was developed. The above model can consider transportation costs, auction and return of goods, transportation time and customer dissatisfaction (the first goal of the research). The existence of multi-objective decision functions make the model difficult to solve using optimizing algorithms. Therefore, for solving the algorithm, a hybrid NSGAII and simulated annealing algorithms was considered. Then in order to determine the appropriate values of the parameters of the developed algorithm, a Taguchi design was used. In continue the algorithm was used to solve the problems of the literature history. The outcomes indicated that the NSGAII-SA algorithm can solve the issues easily and for an acceptable short period of time. This algorithm is capable of solving small issues (with 5 markets, 4 wholesalers and 10 retailers) within 6 s, medium issues (with 10 markets, 6 wholesalers and 20 retailers) within 11 s, and big issues (with 20 markets, 5 wholesalers and 25 retailers) within 2 min. In addition, results showed that, comparing to the Random Search algorithm, the above algorithm was able to further improve issues in the range of 10–62% over solved problems.

The findings also demonstrated that when the demand is probable, by increasing uncertainty in market demand of products, the complexity and solving time will increase by 21%. Therefore, in markets that are not stable, the use of the algorithm is of vital importance.

It is concluded that optimizing system costs, transporting time and customer satisfaction simultaneously causes finding logistic decisions that are completely different than considering each of the mentioned objectives solely. Thus using the proposed algorithm in this research is highly recommended for the SCM factories with similar objectives. Future expansions of the proposed method by considering rival's strategies on sailing of a dynamic supply chain is suggested. It is also recommended to consider the impact of market demand uncertainty as an objective for pricing of fashion goods.

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REFERENCES

- [1] C. Abecassis-Moedas, Integrating design and retail in the clothing value chain: an empirical study of the organisation of design. *Int. J. Oper. Prod. Manage.* **26** (2006) 412–428.
- [2] P. Basu and S.K. Nair, A decision support system for mean-variance analysis in multi-period inventory control. *Decis. Support Syst.* **57** (2014) 285–295.
- [3] P.Q. Brito, C. Soares, S. Almeida, A. Monte and M. Byvoet, Customer segmentation in a large database of an online customized fashion business. *Rob. Comput.-Integr. Manuf.* **36** (2015) 93–100.
- [4] F. Caniato, M. Caridi, A. Moretto, A. Sianesi and G. Spina, Integrating international fashion retail into new product development. *Int. J. Prod. Econ.* **147** (2014) 294–306.
- [5] C.M. Castelli and A. Brun, Alignment of retail channels in the fashion supply chain: an empirical study of Italian fashion retailers. *Int. J. Retail Distrib. Manage* **38** (2010) 24–44.
- [6] J.-M. Chen and C.-I. Chang, Dynamic pricing for new and remanufactured products in a closed-loop supply chain. *Int. J. Prod. Econ.* **146** (2013) 153–160.
- [7] M.J.B.L. Delgado and M.H.F. Albuquerque, The contribution of regional costume in fashion. *Proc. Manuf.* **3** (2015) 6380–6387.
- [8] A. Delgoshaei, A. Ali, M.K.A. Ariffin and C. Gomes, A multi-period scheduling of dynamic cellular manufacturing systems in the presence of cost uncertainty. *Comput. Ind. Eng.* **100** (2016) 110–132.
- [9] A. Delgoshaei, M.K.A.M. Ariffin, Z. Leman, B.H.T.B. Baharudin and C. Gomes, Review of evolution of cellular manufacturing system's approaches: material transferring models. *Int. J. Precis. Eng. Manuf.* **17** (2016) 131–149.
- [10] A. Delgoshaei, M.K.A. Ariffin and A. Ali, A multi-period scheduling method for trading-off between skilled-workers allocation and outsource service usage in dynamic CMS. *Int. J. Prod. Res.* **55** (2017) 997–1039.
- [11] C.-Y. Dye and T.-P. Hsieh, An optimal replenishment policy for deteriorating items with effective investment in preservation technology. *Eur. J. Oper. Res.* **218** (2012) 106–112.
- [12] M.A. El-Baz, Fuzzy performance measurement of a supply chain in manufacturing companies. *Expert Syst. App.* **38** (2011) 6681–6688.
- [13] R. Fornasiero, L. Macchion and A. Vinelli, Supply chain configuration towards customization: a comparison between small and large series production. *IFAC-PapersOnLine* **48** (2015) 1428–1433.
- [14] Y. He, S.-Y. Wang and K.K. Lai, An optimal production-inventory model for deteriorating items with multiple-market demand. *Eur. J. Oper. Res.* **203** (2010) 593–600.
- [15] P. Hsu, H. Wee and H. Teng, Preservation technology investment for deteriorating inventory. *Int. J. Prod. Econ.* **124** (2010) 388–394.
- [16] R. Iannone, G. Martino, S. Miranda and S. Riemma, Modeling fashion retail supply chain through causal loop diagram. *IFAC-PapersOnLine* **48** (2015) 1290–1295.
- [17] G. Jia and M. Bai, An approach for manufacturing strategy development based on fuzzy-QFD. *Comput. Ind. Eng.* **60** (2011) 445–454.
- [18] E. Levner, Risk/Cost analysis of sustainable management of wastewater for irrigation: supply chain approach. In: *Wastewater Reuse–Risk Assessment, Decision-Making and Environmental Security*. Springer (2007) 33–42.
- [19] E. Levner and J.-M. Proth, Strategic management of ecological systems: a supply chain perspective. In: *Strategic Management of Marine Ecosystems*. Springer (2005) 95–107.
- [20] E. Levner, D. Alcaide Lopez de Pablo and J. Ganoulis, Risk management of transboundary water resources using the green supply chain approach. *Int. J. Risk Assess. Manage.* **10** (2008) 357–372.
- [21] Y. Li, C. Wei and X. Cai, Optimal pricing and order policies with B2B product returns for fashion products. *Int. J. Prod. Econ.* **135** (2012) 637–646.
- [22] T.-F. Liang, H.-W. Cheng, P.-Y. Chen and K.-H. Shen, Application of fuzzy sets to aggregate production planning with multiproducts and multitime periods. *IEEE Trans. Fuzzy Syst.* **19** (2011) 465–477.
- [23] A. Lion, L. Macchion, P. Danese and A. Vinelli, Sustainability approaches within the fashion industry: the supplier perspective. *Supply Chain Forum: An International Journal* **17** (2016) 95–108.
- [24] C.K. Lo, A.C. Yeung and T. Cheng, The impact of environmental management systems on financial performance in fashion and textiles industries. *Int. J. Prod. Econ.* **135** (2012) 561–567.
- [25] B.L. MacCarthy and P. Jayarathne, Supply network structures in the international clothing industry: differences across retailer types. *Int. J. Oper. Prod. Manage.* **33** (2013) 858–886.
- [26] L. Macchion, A. Moretto, F. Caniato, M. Caridi, P. Danese and A. Vinelli, Production and supply network strategies within the fashion industry. *Int. J. Prod. Econ.* **163** (2015) 173–188.
- [27] L. Macchion, A.M. Moretto, F. Caniato, M. Caridi, P. Danese and A. Vinelli, International e-commerce for fashion products: what is the relationship with performance? *Int. J. Retail Distrib. Manage.* **45** (2017) 1011–1031.
- [28] L. Macchion, A. Moretto, F. Caniato, M. Caridi, P. Danese, G. Spina and A. Vinelli, Improving innovation performance through environmental practices in the fashion industry: the moderating effect of internationalisation and the influence of collaboration. *Prod. Plan. Control* **28** (2017) 190–201.

- [29] L. Macchion, A. Da Giau, F. Caniato, M. Caridi, P. Danese, R. Rinaldi and A. Vinelli, Strategic approaches to sustainability in fashion supply chain management. *Prod. Plan. Control* **29** (2018) 9–28.
- [30] M. Mehrjoo and Z.J. Pasek, Impact of product variety on supply chain in fast fashion apparel industry. *Proc. CIRP* **17** (2014) 296–301.
- [31] V.K. Mishra, L.S. Singh and R. Kumar, An inventory model for deteriorating items with time-dependent demand and time-varying holding cost under partial backlogging. *J. Ind. Eng. Int.* **9** (2013) 4.
- [32] G. Montagna, Multi-dimensional consumers: fashion and human factors. *Proc. Manuf.* **3** (2015) 6550–6556.
- [33] A. Moretto, L. Macchion, A. Lion, F. Caniato, P. Danese and A. Vinelli, Designing a roadmap towards a sustainable supply chain: a focus on the fashion industry. *J. Cleaner Prod.* **193** (2018) 169–184.
- [34] J. Mula, D. Peidro and R. Poler, The effectiveness of a fuzzy mathematical programming approach for supply chain production planning with fuzzy demand. *Int. J. Prod. Econ.* **128** (2010) 136–143.
- [35] A. Musa and B. Sani, Inventory ordering policies of delayed deteriorating items under permissible delay in payments. *Int. J. Prod. Econ.* **136** (2012) 75–83.
- [36] A. Nagurney and M. Yu, Sustainable fashion supply chain management under oligopolistic competition and brand differentiation. *Int. J. Prod. Econ.* **135** (2012) 532–540.
- [37] Y. Ni and F. Fan, A two-stage dynamic sales forecasting model for the fashion retail. *Expert Syst. App.* **38** (2011) 1529–1536.
- [38] E.U. Olugu and K.Y. Wong, An expert fuzzy rule-based system for closed-loop supply chain performance assessment in the automotive industry. *Expert Syst. App.* **39** (2012) 375–384.
- [39] L.-Y. Ouyang, K.-S. Wu and C.-T. Yang, A study on an inventory model for non-instantaneous deteriorating items with permissible delay in payments. *Comput. Ind. Eng.* **51** (2006) 637–651.
- [40] D. Peidro, J. Mula, M. Jiménez and M. del Mar Botella, A fuzzy linear programming based approach for tactical supply chain planning in an uncertainty environment. *Eur. J. Oper. Res.* **205** (2010) 65–80.
- [41] M.S. Pishvae, F. Jolai and J. Razmi, A stochastic optimization model for integrated forward/reverse logistics network design. *J. Manuf. Syst.* **28** (2009) 107–114.
- [42] Y. Qin, H. Tang and C. Guo, On an inventory model for deteriorating items of price-sensitive demand and quantity discounts [J]. *Oper. Res. Manage. Sci.* **15** (2006) 22–26.
- [43] Z. Qin, M. Bai and D. Ralescu, A fuzzy control system with application to production planning problems. *Inf. Sci.* **181** (2011) 1018–1027.
- [44] D.G. Regulwar and J.B. Gurav, Irrigation planning under uncertainty – a multi objective fuzzy linear programming approach. *Water Resour. Manage.* **25** (2011) 1387–1416.
- [45] A. Şen, The US fashion industry: a supply chain review. *Int. J. Prod. Econ.* **114** (2008) 571–593.
- [46] J. Sicilia, M. González-De-la-Rosa, J. Febles-Acosta and D. Alcaide-López-de-Pablo, An inventory model for deteriorating items with shortages and time-varying demand. *Int. J. Prod. Econ.* **155** (2014) 155–162.
- [47] S. Tong, C. Liu and Y. Li, Fuzzy-adaptive decentralized output-feedback control for large-scale nonlinear systems with dynamical uncertainties. *IEEE Trans. Fuzzy Syst.* **18** (2010) 845–861.
- [48] S.-P. Wang, W. Lee and C.-Y. Chang, Modeling the consignment inventory for a deteriorating item while the buyer has warehouse capacity constraint. *Int. J. Prod. Econ.* **138** (2012) 284–292.
- [49] G.A. Widyadana and H.M. Wee, Optimal deteriorating items production inventory models with random machine breakdown and stochastic repair time. *Appl. Math. Modell.* **35** (2011) 3495–3508.
- [50] L. Yang and C.T. Ng, Flexible capacity strategy with multiple market periods under demand uncertainty and investment constraint. *Eur. J. Oper. Res.* **236** (2014) 511–521.
- [51] F. Zhao, Y. Hong, D. Yu, Y. Yang and Q. Zhang, A hybrid particle swarm optimisation algorithm and fuzzy logic for process planning and production scheduling integration in holonic manufacturing systems. *Int. J. Comput. Integr. Manuf.* **23** (2010) 20–39.
- [52] E. Zhou, J. Zhang, Q. Gou and L. Liang, A two period pricing model for new fashion style launching strategy. *Int. J. Prod. Econ.* **160** (2015) 144–156.