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RESEARCH ARTICLE **Open Access**

Multi-Objective Mathematical Model for Locating Flow Optimization Facilities in Supply Chain of Deteriorating Products

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Abstract

Managing supply chain operations in a reliable manner is a significant concern for decision-makers in competitive industries. In recent years consumers and legislation have been pushing companies to design their activities in such a way as to reduce negative environmental impacts more and more. It is therefore important to examine the optimization of total supply chain costs and environmental impacts together. However, because of the recycling of deteriorated products, the environmental impacts of deteriorating items are more significant than those of non-deteriorating ones. The subject of supply chain of deteriorating products, simultaneously considering costs and environment has gained attention in the academia and from the industry. Particularly for deteriorating and seasonal products, such as fresh produce, the issues of timely supply and disposal of the deteriorated products are of high concerns. The objective of this paper is to develop multi objective mathematical model and to propose a new replenishment policy in a centralized supply chain for deteriorating products. In this model, the manufacturer produces a new product and delivers it to a distant market, and then the distributor buys the product and sells it to the end consumers. This study presents a new mathematical model of the location-routing problem (LRP) of facilities in supply chain network (SCN) for deteriorating products through taking environmental considerations, cost, delivery time and customer satisfaction into account across the entire network and customer satisfaction. In order to solve the model, the combination of the two red deer algorithm (RDA) and annealing simulation (AS) was proposed. We then perform the network optimization in SCN and provide some managerial insights. Finally, more promising directions are suggested for future research.

Key words: Location-Routing, Supply Chain, Deteriorating Products, Metaheuristic

Introduction

Decrease in raw materials, increment in pollutants and the degree of pollution brought about by them have been significant issues for associations in recent years. Moreover, inability to notice moral duties will lead to increased expanded and in this manner reduced benefits (Dai et al., 2018). There is a relation between the location of the facilities and the vehicle's routing. The supply chain network (SCN) for deteriorating products includes products with a durable shelf life and limited production, the management of which requires making right decisions (Katsaliaki et al., 2014). Since there were a few contemplations identified with creation and the environment, and on the other hand, the effect of the utilization of fabricated products, consideration was paid to the transformative pattern of these progressions and associations in recent years (De Keizer et al., 2017). Distribution of deteriorating products is not quite from other products. This issue derives wholesalers to move with lower volumes. On the other hand, one of the instruments that pull

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in purchasers to buy products is rebate; however a bigger measure of request has a lower cost for one product has a higher risk of deterioration (Mohammadi et al., 2020). The arrangement and distribution issues of products have now become a concern for specialty units, and it attracted attention to environmental issues and worldwide interest in the assembling unit's field to fulfill their needs notwithstanding meet client prerequisites. In the current circumstance, a straightforward design of SC to move products from production to consumption was changed into a chain. The administration of such chains at both the full scale and miniature levels is a test that assembling units should experience with them, and this interaction requires productive administration from an essential perspective and need a powerful plan for this organization from an operational point of view (Zhang et al., 2016). The economic concern, environmental mindfulness related enactments, and potential reusing benefits are the principle intentions that have changed the component of SC with ecologically effective transportation and piece assortment system. This arrangements with a coordinated advancement system for taking care of the green transportation and inventory issue in the principal echelon, and the capacitated multi station (distribution /collection center) heterogeneous green vehicle routing issue with concurrent pickup and delivery in the subsequent echelon (Sheri et al.,2021). Many scholars focused on SCN subject. SCN is a set of techniques used to adequately coordinate suppliers, producers, distributers, and retailers to minimize costs, deliver and distribute merchandise in legitimate numbers at the opportune spot, time and address client demands (Kovacic & Bogataj, 2015). Disintegrating, all around, may be considered because of various effects on the stock, some of which are hurt, waste, obsolete nature, decay, lessening comfort, and more. For example, in producing organizations like modifications, drugs, food products, radioactive substances, the thing disintegrates over a period. Although quality has gotten a huge consideration in the producing enterprises and its economic advantages are without question, parcel of inquiries emerge, for example, the amount to contribute and arrange, when to recharge and deliver, and in what premise the businesses keep up maintainable upper hand. A model is advanced here to direct a firm/industry is tending to these inquiries. The firm/industry delivers a solitary product and works in an oligopolistic rivalry (Oh &Jeong,2019).Numerous explores were performed about the SC of deteriorating products, and keeping in mind that it is quite possibly the most useful assets for assessing and assigning numerical programming assets, a lot of this exploration was performed utilizing logical program. In these investigations, explicit objectives and requirements were analyzed, and the greater part of them thought about a couple of objectives (basically expanding consumer loyalty and reducing costs). An important issue in SCN is the establishment of appropriate performance measures to determine efficiency and/or effectiveness of the current system in comparison with alternative systems. Traditionally, the focus of SCN problems is usually on a single objective, namely minimizing the cost or maximizing the profit. Time assumes a huge part in the entire chain of crumbling items, and if there is a deferral in the chain cycle, there will be a lot of financial misfortune to the items and destruction for the climate. To address this gap, concentrates in this challenge endeavor to cover objectives that incorporate the decrease of cost and acquisition time and the upgrade of consumer loyalty for mathematical programming by joining multiple manufactures, various suppliers, and multiple distributions. It is conceivable to gather and reuse items just as destroy items for capacity. With the incorporation of the three referenced objectives with the SC in this paper, profitability was fundamentally expanded. The purpose of this paper is to design a multi objective mathematical model that will perform the best facilities location for SCN about cost optimization, procurement time, and customer satisfaction. In the SCN of this paper, the manufacturer produces a new product and delivers it to a distant market, and then the distributor buys the product and sells it to the end consumers. Since the item is deteriorating, the two its quantity and quality might be diminished during the transportation interaction. Additionally, end-clients are delicate both to the retail cost and to item newness; market interest, thusly, has arbitrary nature and is reliant on these two variables. As per the variable transportation times, the choices of the three gatherings in SCN are exceptionally perplexing and may cause misfortunes with inappropriate execution. The main role of this exploration is to build up a model to recognize the ideal choices that every segment should make to invigorate the individuals from the chain to be more planned. In this manner they all profit by the improved exhibition of the system. The key contributions of this study are on two dimensions. Firstly, a compromise between green issues, and profitably in the design process of a SCN is considered simultaneously. Secondly, a hybrid multi-objective metaheuristic algorithm is proposed to handle the computational intractability and multiple objectives of the problem that obtain Pareto-optimal solutions. The proposed algorithm is different from the previous studies by incorporating modified neighborhood search structures and improving the neighborhood selection process by the fitness landscape technique. To cope with the described problem, the main contributions of this paper can be outlined as follows:

- Developing a tri-level programming model for the location-allocation design problem in SCN;
- Proposing a new nested approach, tri-level metaheuristic for the developed tri-level model;
- Comparing the metaheuristic methods (RDA & SA) by different criteria;
- Validation of the proposed methodology through a real case study in Iran

This study is structured as follows: in the second part, the literature on the subject is examined. In the third section, the multi objective mathematical model of optimization of in supply chain of deteriorating products is introduced; also, parameters, objective functions, and related constraints are described. In Section 4, the multi-objective optimization algorithms RDA & SA implemented, and in Section 5, the conclusions and suggestions for future research are presented.

Literature Review

A supply chain refers to the flow of physical goods and associated information from the source to the consumer. Key supply-chain activities include production planning, purchasing, materials management, distribution, customer service, and sales forecasting. These processes are critical to the success manufacturers, wholesalers, or service providers alike. In the traditional supply-chain model, raw material suppliers define one end of the supply chain. They were connected to manufacturers and distributors, which, in turn, were connected to a retailer and the end customer. Although the customer is the source of the profits, they were only part of the equation in this "push" model. The order and promotion process, which involves customers, retailers, distributors, and manufacturers, occurred through time-consuming paperwork. By the time customers' needs were filtered through the agendas of all the members of the supply chain, the production cycle ended up serving suppliers every bit as much as customers. Driven by e-commerce's capabilities to empower clients, most companies have moved from the traditional "push" business model, where manufacturers, suppliers, distributors, and marketers have most of the power, to a customer-driven "pull" model. This new business model is less product-centric and more directly focused on the individual consumer. As a result, the new model also indicates a shift in the balance of power from suppliers to customers. Whereas in the old "push" model, many members of the supply chain remained relatively isolated from end users, the new "pull" model has each participant scrambling to establish direct electronic connections to the end customer. The result is that electronic supply-chain connectivity gives end customers the opportunity to become better informed through the ability to research and give direction to suppliers. The net result is that customers now have a direct voice in the functioning of the supply chain, and companies can better serve customer needs, carry fewer inventories, and send products to market more quickly.

Xiao et al. (2008) focused on the optimization and coordination of a fresh product of SCN under the CIF (Cost, Insurance and Freight) plan of action with an uncertainty/ ambiguity distance transportation. The accompanying framework is thought of: A producer ships a specific measure of fresh items to a removed discount market, at which he offers them to a wholesaler. In view of the questionable transportation delays, he faces the risk that the product may rot or break down during the transportation process. The distributor obtains the items at the discount market and offers them to a consumer market that is delicate to both the cost and the freshness level of the item. The optimal introductory quantity, the optimal discount cost, and the retailing cost are concentrated under the assumption that both the leaders are risk. Single objective (SO) improvement for open loop (OL) network in SC research was performed by Abdallah et al. (2010) and Zhang and Liu (2013) in which financial indicators are selected as an optimization target. Despite the fact that financial indicators have been selected by these researchers, Abdallah et al. (2010) had additionally included the negative environmental effect in the plan of carbon exchanging by changing over the measure of overabundance carbon into a penalty cost. The optimization targets were formulated as a SO function in the form of total cost (Nurjann et al., 2017). Rafei Majd et al. (2018) provided a three-level SC including suppliers, distribution centers, and retailers (customers) in which products are delivered to customers within a limited time horizon. Retailer demand is random and follows the normal distribution with a mean and standard deviation. In this paper, the Lagrangian relaxation method is used to solve the model and determine the lower bound. A heuristic algorithm is also used to optimize the results of the Lagrangian relaxation algorithm and determine the upper bound. Rasi (2018) was presented a reverse logistics network (RLN) and MILP was developed to optimize the two objectives i.e. cost and time by a new fuzzy approach in returned products. Mogal et al. (2018) presented new multi-period, and purpose time-resolved mathematical model to support the Indian government decision-making (DM) process. The two objectives of minimizing cross-chain SC cost and total lead time were implemented using two Pareto models based on multi-objective algorithms with calibration parameters. Various factors, such as initial setup, transportation and inventory cost; residence and transfer time are included in the model. According to Boronoos et al. (2019), a bi-objective mixed-integer linear optimization model for CLSCND is developed. The proposed model included both the forward and reverse directions and different types of facilities, namely, manufacturing/ remanufacturing centers, warehouses, and disassembly centers. The first objective function tried to minimize the total cost of the SC, while the second one was aimed at maximizing the responsiveness of the network in both forward and reverse directions, simultaneously.

Zhang et al. (2019) studied the derivations of the optimal decisions of the order quantity and the freshness-keeping effort in both the pull and push models, which are common in practice but have not been studied in the literature. The analytical models lead to the result that, all other settings being the same, the distributor always puts a greater effort into preserving the product quality in the pull model than in the push model. A pull strategy is related to the just-in-time school of inventory management that minimizes stock on hand, focusing on last-second deliveries. Under these strategies, products enter the supply chain when customer demand justifies it. One example of an industry that operates under this strategy is a direct computer seller that waits until it receives an order to actually build a custom computer for the consumer. With a pull strategy, companies avoid the cost of carrying inventory that may not sell. The risk is that they might not have enough inventories to meet demand if they cannot ramp up production quickly enough (Ebner et al, 2019). Sun & Wang (2019) investigated RL production routing model by choosing a control policy for greenhouse gas emission. The purpose of this study was to select the optimal greenhouse gas control policy to follow the optimal production values, inventory, and delivery under the selected greenhouse gas control policy. In another study, Wu et al. (2019) studied RL network optimization under fuzzy demand. The goal of recycling was to prevent the rapid depletion of natural resources. Another purpose was the conversion of waste to value for the economy. Babazadeh et al. (2019) proposed a possibilistic programming model to provide a second-generation biodiesel SCN under epistemic uncertainty of input information. The extended model minimizes the total cost of SC from supply centers to the biodiesel and glycerin customer centers. Waste cooking oil and Jatropha plants, as non-edible feedstocks, was considered for biodiesel production. An accelerated Benders decomposition algorithm (BDA) using efficient acceleration mechanism was devised to deal with the computational complexity of solving the proposed model in an efficient manner. The performance of the proposed possibilistic programming model and the efficiency of the developed accelerated BDA were validated by performing a computational analysis using a real case study in Iran. Gitinavard et al. (2019) studied choosing the most reasonable optimal point among the Pareto optimal focuses could assist the specialists with settling on a suitable choice in a questionable and complex circumstance. In this paper, an assessing and evaluating methodology is proposed dependent on reluctant fuzzy set to evaluate the acquired Pareto optimal focuses from the proposed bi-objective multi-echelon SCN model with finding appropriation focuses. In this regard, the proposed model has explained for perishable products based on fuzzy customers' demand. To address the issue, the possibilistic chance constraint programming approach has controlled dependent on the trapezoidal fuzzy membership function. In addition, the proposed reluctant fuzzy positioning methodology is built dependent on collective choice investigation and the last aggregation approach. Vakili et al. (2020) considered a green open location-routing issue with concurrent pickup and delivery (GOLRPSPD) to limit the total costs. Notwithstanding cost minimization, the objective function is given the ecological competencies in regards to the costs of CO2 emissions and fuel consumption. Then, in complex circumstance, considering the exact data could lead the outcomes to untrustworthy wherein considering the uncertainty theories could lead the results. Khezerlou et al. (2020) proposed a bi-objective optimization model to design a reliable biomass-biofuel SC, in which loading and unloading hubs and bio refineries can be encountered with disruption. For this purpose, the first objective function minimized the total costs, and the second one minimizes the total times of recovery of disrupted facilities. Ghaderi et al. (2020) proposed a system dynamics model to study interactions between the variables of bioethanol and biodiesel SCs. This model was used constructing scenarios to consider appropriate policy options and their possible future effects on the market share of bioethanol and biodiesel in the USA. Policy implications related to increasing biofuel production in the USA were also provided. Shirazi (2020) his study examined the ability of contracts as one of the supply chain coordination mechanisms under competitive conditions. In this study, a two-tier supply chain model with two manufacturers and two retailers was considered to develop a competitive structure when demands are uncertain. The supply chain demand is random and depends on the price of the products. Moreover, the products manufactured by market manufacturers are replaceable. Therefore, the main competitive factor was the order decisions, and due to the nature of the demand, deciding on pricing and ordering is necessary. Each retailer is faced with the issue of determining the prices of goods from two manufacturers, which consequently forms a competitive ground between retailers.

Morad et al. (2021) presented a special type of qualitative research tradition called data theory. In this study, they showed that the management and implementation of the electricity emergency system (121) at the national level and the positive and effective points of the existence of 121electricity emergency centers as a suitable center to respond to the requests of electricity subscribers, especially in the rapid elimination of blackouts and the importance of this system in improving and upgrading effective and efficient monitoring.

Tarverdizadeh et al. (2021) presented with the aim of designing and validating a model for green quality management in the food industry. The presented study was an exploratory combination that through qualitative strategies with library study methods and grounded theory, a conceptual model was obtained and then through a quantitative strategy of structural equations with Smart PLS approach. In the qualitative section, after extensive study in the theoretical literature on the subject and taking notes, as well as through theoretical and purposeful sampling with a selection of 24 experts and officials, a semi-structured interview was conducted. In the quantitative part. Green management innovation was selected as a strategy and also green supply chain as a consequence of green quality management model.

Azami & Mehrabad (2021) provided a new multi-period production-distribution planning (PDP) for perishable products with a fixed lifetime in a seller-buyer system. The objective was to maximize the seller's profit conditional on the optimality of the buyer in a three-level SC, including the factories, distribution centers, and retailers. The factories and distribution centers act cooperatively at the leader level and, as the seller, make the location, production, inventory, and distribution decisions. While the retailers operate as the follower; therefore, a vertical competition is held in this SC. In addition to price, freshness owing to the perishability of the product is considered as an important competitive factor. Also, to encourage the retailers, three strategies in the development of a new demand function, including the return, discount policies, and credit period, were employed. Since the problem was NP-hard, a hierarchical heuristic approach based on enders Decomposition Algorithm (BDA) and Genetic Algorithm (GA) is proposed. Finally, to demonstrate the applicability and efficiency of the developed model, it was applied to a real industrial case. The computational results of the problems in different sizes confirmed the efficient performance of the proposed model and solution method. Much research has been done on SC of perishable goods, and since mathematical programming is a powerful tool for evaluating and allocating resources, many have used mathematical programming with finite numbers. Each of these papers examines specific goals and constraints, but in most studies, one or two goals (reducing costs and increasing satisfaction) are proposed. However, since time plays an important role in SC of perishable goods and delays in any process in the chain for any reason can lead to product corruption and financial and environmental losses, this study has tried to close this study gap with consider the goals of reducing procurement costs and time and increasing customer satisfaction for fuzzy (rather than definitive) mathematical scheduling by combining multiple suppliers, multiple manufacturers, three 3PLs, two distributors, two retailers, and one market where It is possible to collect and recycle the product or destroy it to be covered. Taking into account, these three goals helps to combine SC of this research to achieve the highest level of productivity.

Problem Statement and Mathematical Formulation

Supply chain management covers a wide range of topics. Customer orientation, marketing, distribution, production planning, and procurement in organizations are working independently and in parallel in the SCM. Although each of these organizations has its own goals and often these goals are in contradiction with another, so there needs to be a way to align these different goals. SCM is a method that can create this coordination (Rasi& Sohanian, 2020). SCM is a set of methods used to effectively integrate and enable suppliers, manufacturers, distributors, and retailers to minimize system costs, produce and distribute goods in exact numbers at the right time and place and meet customer needs. On the other hand, SC is a network of organizations that engage in processes and activities with an upstream-downstream relation and create value as products and services delivered to the end customer (Dai et al., 2018). The purpose of the SC is to increase competitiveness, or customer services from the end customer's point of view, an enterprise alone is not responsible for the competitiveness of its products or services and the SC considers all the involved organizations; these cases illustrate the impact of cost and time on customer satisfaction (Kovacic & Bogataj 2013). The goal of the experimental work presented here was to investigate the applicability and the performance frontier of suitable pull-type production control strategies to CLSC systems in the presence of both customer demand and return rate variability. The results of the experimental work were analyzed to propose, develop and test a production control strategy for CLSC that would enhance the benefits achievable from the best performing production control strategies. The purpose of this paper would be as following:

Table 1. Review of related literature

Research	delivery	Network flow		Network design						Mathematical characterizes			Objective Function		
	Time	returned	Forward	Collection and distribution	Transportation	Facilities	Repair and recovery	Recycle	limited capacity	Multi-period	Multi product	uncertainty	Choice of supplier	Maximize quality	Minimize costs
Salema et al(2007)		*			*			*			*	*		*	*
Pishavee et al(2008)		*	*									*		*	*
Chian-Son Yu et al(2010)			*		*					*					*
Pishvaee & Razmi(2012)			*							*		*		*	*
Boukherroub (2015)			*					*		*				*	*
Musavi et al (2017)		*				*					*		*	*	*
Mugal et al(2018)		*							*		*		*	*	*
Dulan etal (2018)		*				*					*		*	*	*
Sun & Wang (2019)	*		*							*	*			*	*
Wu et al. (2019)	*	*						*		*	*				*
Vakili et al. (2020)	*	*	*				*	*	*		*	*			*
Khezerlou et al. (2020)	*	*		*	*		*	*		*	*	*		*	*
Ghaderi et al. (2020)		*	*	*	*		*	*		*	*			*	*

Research	delivery	Network flow		Network design						Mathematical characterizes			Objective Function		
	Time	returned	Forward	Collection and distribution	Transportation	Facilities	Repair and recovery	Recycle	limited capacity	Multi-period	Multi product	uncertainty	Choice of supplier	Maximize quality	Minimize costs
Azami & Mehrabad (2021)	*	*					*	*		*	*			*	*
This paper	*	*	*	*	*			*		*	*	*		*	*

o Location of three-way logistics companies, retailers and distributors;
o Coordination of chain levels to reduce cost and procurement time;
o Create a balance between cost reduction and procurement time and increase customer satisfaction.

Let consider a SC as Figure (1), which is a SCN. It has a four-level supply chain with one supplier (I), one manufacturer (j), one distributor (K), and costumers (L). In this research, we intend to locate them to optimize cost, delivery time and meet customer satisfaction. Accordingly, the manufacturer provides the required raw materials by the triple part logistics companies of the supplier following their needs. After that, the manufacturer delivers the final product to the logistics companies during the manufacturing process, and the final product should be transferred to the market at the short time. The multi-objective optimization method was used to solve this model by GAMS software (CPLEX software solver) and the integrated Bender's decomposition algorithm and Lagrangian coefficient methods. Figure (1) illustrates that the SCN has four levels, several suppliers, several manufacturers, distributors, and several retailers. In this research explored their suitable location to optimize the logistics time, cost and meet customer satisfaction.

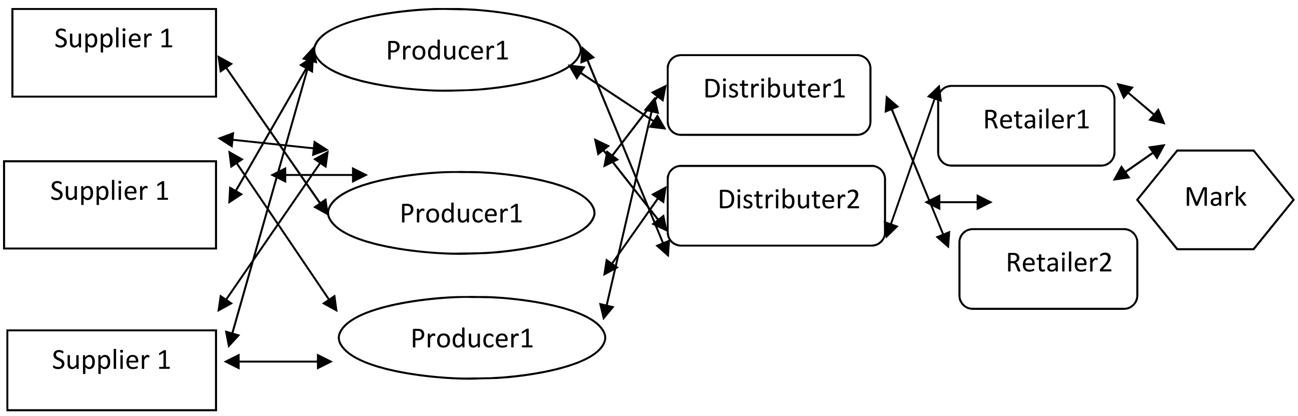

Fig.1. the frameork of supply chain in this paper

Accordingly, the manufacturer supplies its raw materials to suppliers. Afterwards, the manufacturer transfers its manufactured product to the distributor (s) in a short time. Distributors should deliver the products to several retailers after which may result in damage and demolition of product. According to the mentioned discussion in the problem statement, four objective logistics were identified for the paper problem. Different cost scenarios were addressed in various researches on cost reduction. Even in some studies, it was replaced by maximizing the profits from the difference between income and cost. The costs for this issue include the cost of establishing a location for production (Peterson & Sgersted, 2013; Pellegrino et al., 2019), a place for distribution (Pellegrino et al., 2019), a location for retailing (Li et al., 2018) , transportation costs (Saif-Eddine et al., 2019; Oh and Jeong, 2019; Pellegrino et al., 2019; Morto et al., 2019); Raw material procurement costs (Cole & Aitken, 2019), ordering costs (Wang et al., 2018; Pellegrino et al., 2019), production costs (Peterson & Sgersted, 2013; Wang et al., 2018; Ooh and Jeong, 2019; Cole & Aitken, 2019; Reiman et al., 2019; Asim et al., 2019; Sun & Wang, 2019; Orjuela Castro et al., 2018; delay penalties (Asim et al., 2019), missing order costs (Wang et al., 2018), cost of inventory storage (Saif-Edin et al., 2019; Cole & Aitken, 2019), cost of returned and deteriorating items (Raeiman et al., 2019), transfer cost of returned items (Asim et al., 2019), environmental costs (Wu et al., 2019; Mohammadi et al.2020). In recent studies, the required time for procurement was constant. For this reason, the logical relationship that was specified to avoid the sophisticated modeling between the time supplying and the transportation cost was ignored. In the proposed fourth model, there is a reverse relationship between transportation cost and logistics time. The further objective is the timing of the procurement, which is related to product quality, and the sensitivity of the deteriorating products. The timing of supply depends on variety of factors, regardless of the deterioration of durable products. Each vehicle has a certain capacity that is effective in the delivery schedule with a specified load, the type of transport route will be influenced by whether it is flat at the delivery time (Dey & Saha, 2018; Kaur et al., 2018; Kaur & Singh, 2018).The delivery time in this model is based on the period parameter index and includes the supplier's index, the manufacturing site, and the delivery vehicle. In the proposed model, it is possible to choose a vehicle. If the selected vehicles are expensive, the procurement time will be reduced. The preparation time has a reverse relationship with the amount of greenhouse gas emissions that is specified in the standard tables. On the other hand, the related costs to the emission of greenhouse gas in the supplier selection, manufacturer's construction, distributor's construction, transportation from supplier to manufacturer, transportation from manufacturer to distributor and final product transportation are considered. The quality of the product is very important and in order to minimize preparation time to compile the minimum function at the preparation time, the conditions for to maintain the quality and product freshness must be considered. As the shorter preparation time leads to higher customer satisfaction, another function is designed for customer satisfaction. As an excellent promising design method for dealing with the inevitable uncertainty factors, reliability-based design optimization (RBDO) is capable of offering reliable and robust results and minimizing the cost under the prescribed uncertainty level, which can provide a trade-off between economy and safety. As described in Chica et al. (2020), simheuristics are specifically designed to deal with scenarios, in which the non-deterministic behavior can be modeled as a set of random variables following certain probability distributions (stochastic uncertainty). When dealing with other types of uncertainty scenarios, fuzzy systems can become an excellent option. Lagrangian relaxation (LR) based algorithms were one of the topics we include in this special issue. In the paper "An Improved Lagrangian Relaxation Algorithm for the Robust Generation Self-Scheduling Problem". Chica et al.(2018) addressed the robust generation self-scheduling problem under electricity price uncertainty which is reformulated as a MINLP problem. Authors combine an LR approach and linear programming algorithms to approximately solve this problem. In this case, authors combine the generalized augmented Lagrangian approach and Benders. The proposed approach is applied to a set of optimization problems from mathematics and mechanical engineering. In this research, mathematical modeling is used to locate the SC of perishable goods in order to optimize time and cost and increase customer satisfaction. Also, despite the inherent uncertainty in the SC of perishable goods and the importance of this field, fuzzy logic will be used instead of definitive data to achieve more reliable results. Library data - articles, books and available documents - have been used to collect the information required for this research. To complete the required information circle, you can benefit from the advice of academic and especially operational experts. In this section, at first, the proposed model is discussed. After that, uncertain aspects of the problem are described and related mathematical programming model is formulated.

A. Research assumption

The assumptions of mathematical model would be as following:

- Products are transported through a range of distributors to retailers or customers. Distributors perform direct delivery to retailers;
- The same vehicle is not used for transportation;
- The time period is one week;
- There are not pre-determined vehicles for suppliers and retailers;
- Manufacturers and distribution centers have limited capacity;
- Variety of products is considered;
- The delivered item has a specific time and transportation cost;
- Each unit has a specific travel cost and distance;
- Fixed cost (FCT) equipment must be considered for the cost of intra-network transportation;
- The desired SCN is related to the multi-product model;
- The supply chain is of the pull-type;

B. Nomenclature

In this part, indices, parameters and decision variables applied in the proposed mathematical model are presented. The required indices are demonstrated in as following:

Indices:

I: set of suppliers $i \in \{1,2,...,I\}$

J: set of production centers $j \in \{1,2,...,J\}$

K: set of distribution centers $k \in \{1,2,...,K\}$

L: set of customers $l \in \{1,2,...,L\}$

P: set of products $p \in \{1,2,...,P\}$

τ : set of raw materials $\tau \in \{1,2,...,\tau\}$

M: set of transportation facilities $m \in \{1,2,...,M\}$

T: time period $t \in \{1,2,...,T\}$

G: group of products $g \in \{1,2,...,G\}$

A: Supplier capacity a $a \in \{1,2,...,A\}$

B: Manufacturer capacity b $b \in \{1,2,...,B\}$

C: Distributer capacity c $c \in \{1,2,...,C\}$

Parameters

$\widetilde{\theta}_{lt}^{p}$: Customer demand I for product p over time period t

$\omega_{\tau pt}$: Consumption of raw materials τ in the production of p product over time period t

ϕ_{pgt} : Product group g from p product over time period t

$\widetilde{S}_{i\tau}^{at}$: Maximum supply capacity, supplier i with capacity a level for raw materials τover time period t.

$\widetilde{M}_{jp}^{bt}$: Maximum production capacity by manufacturer j with capacity level b for product p in time period t

$\widetilde{D}_{kg}^{ct}$: Maximum distribution capacity, k distributor with capacity c level for p product group in time period t

$\widehat{A}_{it}$: Minimum number of selected suppliers i in time period t

$\widehat{B}_{jt}$: Minimum number of selected manufacturer j in time period t

$\widehat{C}_{kt}$: Minimum number of selected distributer k in time period t

$\widetilde{F}_{ij}$: Spatial distance between supplier I and manufacturer j

$\widetilde{W}_{jk}$: Spatial distance between manufacturer j to distributer k

$\widetilde{H}_{kl}$: Spatial distance between distributer k to customer I

σ_{τ} : Raw material unit τ

V_{p} : Product unit p

E_{it}^{a} : Fixed and operational costs of selecting supplier i with capacity a at time t

Q_{jt}^{b} : Fixed and operational cost of providing a manufacturer j with a capacity level b over time period t

N_{kt}^{c} : Fixed and operational cost of providing a distributer k with a capacity level c over time period t

R_{m} : The cost of each unit of transport of raw materials based on the distance between the levels according to the type of transport facility m

U_{m} : The cost of each unit of transport of the product based on the distance between the levels according to the type of means of transport m

$\in_{it}^{a}$: The cost of emitting greenhouse gases is the choice of supplier i with capacity a in the time period t

η_{jt}^{b} : The cost of emitting greenhouse gases is the choice of manufacturer j with capacity b in the time period t

v_{kt}^{c} : The cost of emitting greenhouse gases the construction of a distributor k with a capacity level c over time t

$\widetilde{\lambda}_{m}$: Greenhouse gas emission coefficient of each raw material transport unit based on the distance between levels according to the type of vehicle m

$\widetilde{\mu}_{m}$: Greenhouse gas emission coefficient of each raw material transport unit based on the distance between levels according to the type of vehicle m

Decision variables

Integer variables:

$\alpha_{it}^{a} = \begin{cases} 1 \\ 0 \end{cases}$: The binary variable, if the supplier i is selected with a capacity level a in time period t, is equal to 1, otherwise it is equal to zero.

$\beta_{jt}^{b} = \begin{cases} 1 \\ 0 \end{cases}$: The binary variable, if the manufacturer j is constructed with capacity b at time t, is equal to 1, otherwise it is equal to zero.

$\gamma_{kt}^{c} = \begin{cases} 1 \\ 0 \end{cases}$: The binary variable, if the distributer k is constructed with capacity c at time t, is equal to 1, otherwise it is equal to zero.

Non negative variables:

$\widetilde{X}_{ij}^{\tau t m}$: The amount of raw materials transferred t from the supplier i to the manufacturer j in the time period t according to the type of means of transport m

$\widetilde{Y}_{jk}^{ptm}$: The amount of product p transferred from manufacturer j to distributor k over time t according to the type of vehicle carrying m

$\widetilde{Z}_{kl}^{ptm}$: The amount of transferred product p from the distributer k to customer l in the time period t according to the type transportation facility m. The formulation of multi objective programming model for supply chain problem is as following:

$$
\begin{aligned}
Min \quad F_{Eco} &= \sum_i \sum_a \sum_t E_{it}^a . \alpha_{it}^a + \sum_j \sum_b \sum_t Q_{jt}^b . \beta_{jt}^b + \sum_k \sum_c \sum_t N_{kt}^c . \gamma_{kt}^c \\
&+ \sum_i \sum_j \sum_\tau \sum_t \sum_m \widetilde{F}_{ijt} . R_m . \sigma_\tau . \widetilde{X}_{ij}^{\tau tm} + \sum_j \sum_k \sum_p \sum_t \sum_m G_{jkt} . U_m . V_p . \widetilde{Y}_{jk}^{ptm} \\
&+ \sum_k \sum_l \sum_p \sum_t \sum_m \widetilde{H}_{kl} . U_m . V_p . \widetilde{Z}_{kl}^{ptm}
\end{aligned} \tag{1}
$$

$$
\begin{aligned}
Min \quad F_{Env} &= \sum_i \sum_a \sum_t \in_{it}^a \alpha_{it}^a + \sum_j \sum_b \sum_t \eta_{jt}^b . \beta_{jt}^b + \sum_k \sum_c \sum_t v_{kt}^c . \gamma_{kt}^c \\
&+ \sum_i \sum_j \sum_\tau \sum_t \sum_m \widetilde{F}_{ijt} \lambda_m . \sigma_\tau . \widetilde{X}_{ij}^{\tau tm} + \sum_j \sum_k \sum_p \sum_t \sum_m G_{jkt} . \mu_m . V_p . \widetilde{Y}_{jk}^{ptm} \\
&+ \sum_k \sum_l \sum_p \sum_t \sum_m \widetilde{H}_{kl} . \mu_m . V_p . \widetilde{Z}_{kl}^{ptm}
\end{aligned} \tag{2}
$$

$$
Min \quad F_{delivery-time} = \sum_i \sum_m \sum_j \sum_k \sum_t \left(\frac{\widetilde{\theta}_{lt}^{\,p}}{R_m + U_m} \right) \widetilde{Y}_{jk}^{ptm} \tag{3}
$$

$$
Min \quad F_{Backorder-level} = \sum_t Max \sum_p \sum_k \widetilde{Z}_{kl}^{ptm} \tag{4}
$$

$$
\sum_j \widetilde{X}_{ij}^{\tau t} \leq \sum_a \widetilde{S}_{i\tau}^{at} . \alpha_{it}^a \quad \forall i, \tau, t \tag{5}
$$

$$
\sum_k \widetilde{Y}_{jk}^{pt} \leq \sum_b \widetilde{M}_{jp}^{bt} . \beta_{jt}^b \quad \forall j, p, t \tag{6}
$$

$$
\sum_l \sum_p V_p \widetilde{Z}_{kl}^{pt} . \phi_{pgt} \leq \sum_c \widetilde{D}_{kg}^{ct} . \gamma_{kt}^c \quad \forall k, g, t \tag{7}
$$

$$
\sum_j X_{ij}^\tau \geq \sum_k \sum_p \widetilde{Y}_{jk}^p \omega_{\tau pt} \quad \forall j, \tau, t \tag{8}
$$

$$
\sum_j \widetilde{Y}_{jk}^{pt} \geq \sum_l \widetilde{Z}_{kl}^{pt} . \alpha_{it}^a \quad \forall k, p, t \tag{9}
$$

$$
\sum_k \widetilde{Z}_{kl}^{pt} \geq \widetilde{\theta}_{lt}^p \quad \forall l, p, t \tag{10}
$$

$$
\sum_a \alpha_{it}^a \leq 1 \quad \forall i, t \tag{11}
$$

$$
\sum_b \beta_{jt}^b \leq 1 \quad \forall j, t \tag{12}
$$

$$
\sum_c \gamma_{kt}^c \leq 1 \quad \forall k, t \tag{13}
$$

$$
\sum_i \sum_a \sum_t \alpha_{it}^a \leq \hat{A}_{it} \tag{14}
$$

$$
\sum_j \sum_b \sum_t \beta_{jt}^b \leq \hat{B}_{jt} \tag{15}
$$

$$
\sum_k \sum_c \sum_t \gamma_{kt}^c \leq \hat{C}_{kt} \tag{16}
$$

$$
\widetilde{X}_{ij}^{\tau t}, \widetilde{Y}_{jk}^{pt}, \widetilde{Z}_{kl}^{pt} \geq 0 \tag{17}
$$

$$
\alpha_{it}^a, \beta_{jt}^b, \gamma_{kt}^c = 0,1 \tag{18}
$$

The first objective function minimizes costs, including the fixed and operating cost of supplier selection; the fixed and operational cost of manufacturer construction; the cost of transporting raw materials based on the distance; the transportation cost of the product from the manufacturer to distributor, and costs of each product from the manufacturer to the customer. The second objective function minimizes environmental pollution so that the first part is the cost of greenhouse gas emissions; the second part is the cost of greenhouse gas emissions, the third part is the cost of greenhouse gas emissions. The fourth part is the cost of greenhouse gas emission due to raw material transportation from supplier to manufacturer, the fifth part is the cost of greenhouse gas emissions due to the transportation of the product from the manufacturer to distributor, and the sixth part is the cost of greenhouse gas emissions, due to the product delivery from distributor to customer. The third and fourth objective minimized transportation delivery time and lost sales levels to improve customer satisfaction. Constraint (5) ensures that the amount of transferred raw material from supplier to manufacturer does not exceed the maximum supply capacity of the supplier. Constraint (6) indicates that the amount of transferred products from the manufacturer to the distributor should not exceed the maximum capacity of the manufacturer. Constraint (7) indicates that the maximum distribution capacity, the distributor k with the capacity level for the product group g in the period should not exceed the defined capacity level. Constraint (8) indicates that the amount of transferred raw material from the supplier to the manufacturer must be at least equal to the amount of raw material required to produce all the planned products so that we do not suffer from a shortage of the required raw material. Based on the constraint (9), the amount of product transferred from the manufacturer to the distributor must be at least equal to the amount of product transferred from the distributor to the customer so that we do not suffer from shortages. Constraint (10) ensures that the amount of product transferred from the distributor to the customer is at least equal to the customer's demand. This will prevent lost sales. Constraint (11) indicates that a maximum of one supplier should be selected in each time period. Constraint (12) also keeps the amount of manufacturers at a maximum of one. Constraint (13) illustrates the amount of distributors in each period to be at most 1. Constraints (14 -16) show that the minimum amount of suppliers must be equal to the selected suppliers. Constraints (17 - 18) are also logical constraints of the problem.

Model Solution with Metaheuristic Method

Most real world optimization issues have a place with the class of NP-hard issues. Habitually, precise techniques cannot tackle this class of issues in typical and sensible time (Rasi & Sohanian, 2018; Nurjann et al., 2017). This class of meta-heuristic is reasonable devices. Frequently, exact methods cannot solve this class of problems in normal and reasonable time. To optimize this class of meta- heuristic algorithms are suitable tools. For experimentation, this section presents the application of the proposed model along with the proposed RDA on some random test problems. Some sets of small, medium and large sized instances are considered to evaluate the performance of the solution approach. In addition, since no benchmark is available in the literature to verify and validate the results obtained by RDA, another popular MOEA called SA is suggested to solve the problem as well (Wang et al., 2020). To do this, some preliminary concepts and principles of RDA and SA are first reviewed. The purpose of employing the second algorithm (SA) is to verify the results obtained by RDA. It is noticed that since most real world cases are large scale and NP- hard, it justifies the use of meta-heuristics; however, they do not guarantee to achieve optimal solutions and usually obtain near optimal solutions.The SCM in this research goes under the rubric of NP-hard category, which cannot be solved by applying exact methods. To solve such problems, heuristic and meta-heuristic methods based on optimization of hybrid problems were applied. In this study, for validation, valid mathematical models presented by leading researchers in mathematical modeling of SCMPs have been used as the basis of the model design. In order to solve the MO-SCMP mathematical model, the meta-heuristic RDA and SA algorithms are utilized, which has been one of the most widely used multi-objective optimization methods in recent years. At the end, the efficiency of these two algorithms is compared and the superior algorithm introduced according to Rasi et al. (2020) research. In this section, according to the main solution method indicated in the problem statement section, which is the combined method of RDA and SA, we express the setting parameters before solution. Then the results of model solution will be illustrated. The proposed model is a mixed nonlinear multi-objective integer problem under uncertainty. According to (Bridge, 2011), first the decision-making binary variables for supply chain configuration are identified and then the correct and continuous variables related to product volume and displacements are shown. And the input data for each parameter is based on the random distribution function. A Kaleh dairy product (KDP) is an Iranian dairy company based in Amol, Mazandaran. This company, which is the largest company of Soliko Holding Group, was established in 1990 by Gholam Ali Soleimani in Amol. The company produces dairy products such as milk with its supplements, butter, cheeses, yogurt, buttermilk and desserts. Kaleh with 16 production groups, has a large volume of the Iranian dairy market to some extent. It is considered to be the largest producer of dairy products in the country and the largest exporter of dairy products in Iran. Kaleh factory of 14000 meters is one of the largest factories in all industries of the country. Kaleh company in 1374 as a sample unit of food industry in Iran.

Hybrid Methahuristic Algorithm (RDA & SA)

The results of metaheuristic algorithms depend on the values of its input parameters, so we now describe how to set the values of the proposed parameters. In addition, the stop condition is twenty iterations. Experimental design methods are widely used in many systems. It is very important tool for process performance and correction. Parameter tuning methods include: Citation to former studies; Trial and error method; complete tests method; Taguchi method; Response surface methodology; Adaptive neural network and fuzzy neural network; Meta-heuristic algorithms. In this dissertation, in this paper used the Taguchi method. Dr. Genichi Taguchi developed the range of experimental design knowledge. Parameter design method provided an engineering method for product or process design whose purpose was to minimize changes and the sensitivity of disturbance factors. In an efficient parameter design, the first goal is to identify and adjust the factors that minimize variable responses, and the next goal is to identify controllable and uncontrollable factors. Taguchi addressed the concept of the loss function. The function combines loss, cost, objective, and variation, achieves a measurement criterion, and prioritizes the specifications constraints. In addition, he provided the concept of robustness. The ultimate goal of this method is to find the optimal composition of the controllable factors amounts. The foundation of Taguchi philosophy is a robust and stable design. To use this method, we enter the window (DOE) using Minitab 16 software and select the Taguchi method. Here, it is necessary to determine the number of factors needed to determine the number and combination method of test levels and the amount of levels.

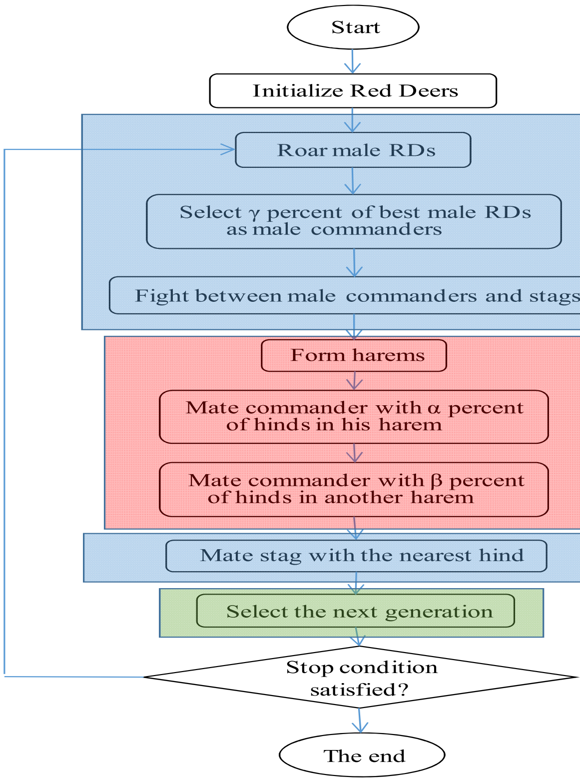

Fig 2. Flowchart of RDA

Hybrid algorithms are frequently used in real-world optimization. In this case, an algorithm is used for the general approach, but in the return operation, it is converted to another algorithm with more efficiency on small data. In this research, a combination of SA and RDA is applied as a new hybrid algorithm, and its parameters are adjusted for one of the intended dimensions. In this algorithm, RDA and SA serve as the main ring and as a tool for local search, respectively. The two phases of roaring and fighting, which are related to the focus phase, are eliminated from the RDA. To this end, the SA algorithm is used as the search tool instead of these two steps. This algorithm generally uses the SA as the focus phase and the RDA as the diverse phase. In each generation, every male brocket is a basic answer to SA. A hybrid optimization algorithm will be used for the problem of this study, which combines the SA and RDA, abbreviated as H-RS. The RDA is a population-based algorithm consisting of multiple stages. This combination was designed to decline computation time and exclude some stages by substituting SA rules. All algorithms are coded by using MATLAB R20179a on an Intel® Core™ i5 CPU @ GHz with 8 GB RAM, 64 Bit operating system. For each factor, the optimal surface value is that the standard value (S / N) is higher; therefore, according to Figure (2) for all four factors, the results of parameter adjustment are as follows. During the process development. Two of the applications in which the concept of S/N ratio is useful are the improvement of quality through variability reduction and the improvement of measurement. The S/N ratio characteristics can be divided into three categories given by nominal is the best characteristic; smaller is the best characteristic and larger the better characteristic. From the table, we affirm that the conclusions from Main effects Plots, that Pu was obtained for L=300mm, D=48.3, T= 3.2 mm but the S/n ratio plots are shown in figs (3-4).

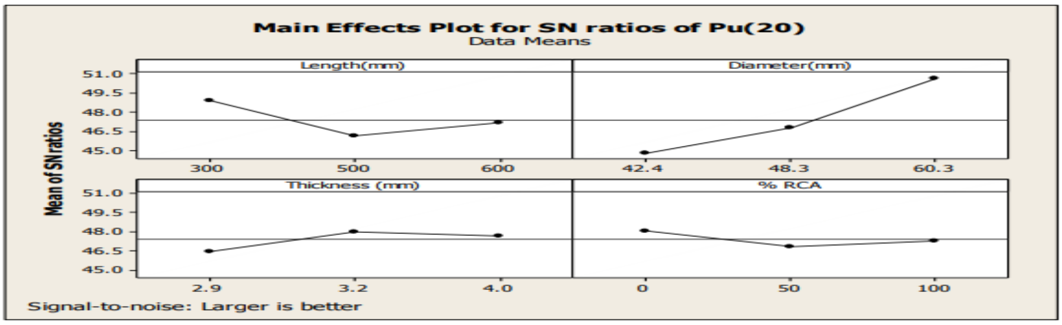

Fig 3. Main effects plot of mean of S/N ratio for Pu (20)

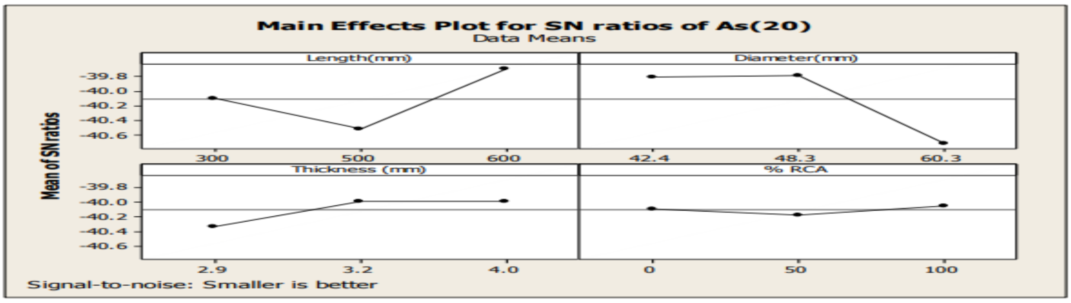

Fig 4. Main effects plot of mean of S/N ratio for as (20)

The proposed metaheuristic algorithm is implemented for each Taguchi test, and then the mean ratio (S / N) for each level of the algorithm-related factors and the optimal levels of the input parameters of this algorithm is presented in Table (II). The results of meta-heuristic algorithms depend on the values of its input parameters, so now we explain how to adjust the values of the proposed parameters. In addition, the condition of stopping to reach the repetition of 20 is considered. Experimental design methods are widely used in many systems according to Keshteli & Fard (2018). This is an extremely important tool for process performance and refinement. Parameter setting methods include: References to past studies; Trial and error method; How to perform complete tests; Taguchi method; Response level method; Adaptive neural network and fuzzy neural network and use of meta-heuristic algorithms (before or during execution).Table (III) illustrate Factors and Candidate Levels in the RDA and SA in six parameters in three levels as following:

Table 2.
Factors and Candidate Levels in the RDA and SA

Level values			Parameter
Level 3	Level 2	Level 1	
200	150	100	**Maximum iteration**
300	100	100	**Population size**
50	35	20	**Number of males**
0.8	0.6	0.5	**Percentage of commanders**
0.7	0.6	0.4	**Percentage of inside the harems**
0.5	0.5	0.3	**Percentage of outside the harems**

Table (3) shows experimental array in 9 running sequence with 6 algorithm parameters i.e. outside, inside, commanders, males, population and iteration. MID shows responsible value.

Table 3.
Experimental Array

Running sequence	Algorithm parameters						Responsible values
	outside	inside	commanders	males	Population	iteration	MID
1	1	1	1	1	1	1	6.9517
2	1	2	2	1	2	2	37.162
3	1	3	3	1	3	3	3.0812
4	2	1	2	2	1	2	9.465
5	2	2	3	2	2	3	5.6565
6	2	3	1	2	3	1	9.5747
7	1	1	1	3	1	3	16.3752
8	1	2	2	3	2	1	14.2128
9	1	3	3	3	3	2	7.9231

The amount of solved objective function of multi objective mathematical in 12 periods in table (4) presented as following:

Table 4.
Optimal results of each objective function in each period

period												Objective function
12	11	10	9	8	7	6	5	4	3	2	1	
146.78	164.52	144.99	166.34	160.66	169.78	151.77	167.86	157.71	156.91	157.92	159.5	**1**
261.46	225.04	260.03	262.31	253.63	256.31	234.80	245.64	236.69	238.45	276.77	263.94	**2**
58.57	63.18	67.21	78.50	72.75	73.03	59.64	76.66	75.49	72.82	74.17	74.57	**3**
50.29	50.31	50.35	50.32	50.32	50.28	50.26	5.31	50.28	5.31	50.34	50.30	**4**

Figure (5) shows the variation trend in the four functions of the research model based on the twelve periods with hybrid RDA and SA.

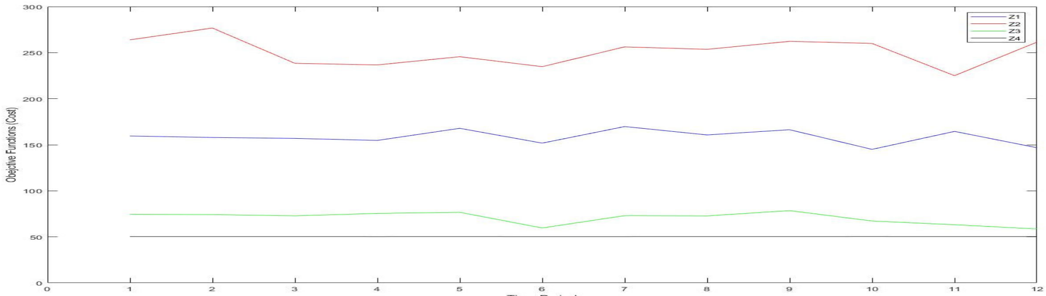

Figure 5. The trend of variations in objective functions over different time periods

Figure (6) shows that the present research problem has four raw materials, five suppliers, five manufacturers, four distributors, and three customers. The values shown in the diagram above indicate the number of transferred products from one level to another. For example, the manufacturer 4 sends 89 units of the product produced in this unit from 100 produced item to the distributor 4 and 11 units of the remaining product to the distributor of 3. This diagram shows that the network optimization is such that attempts were taken to provide the required values for each level of the nearest unit from the previous level.

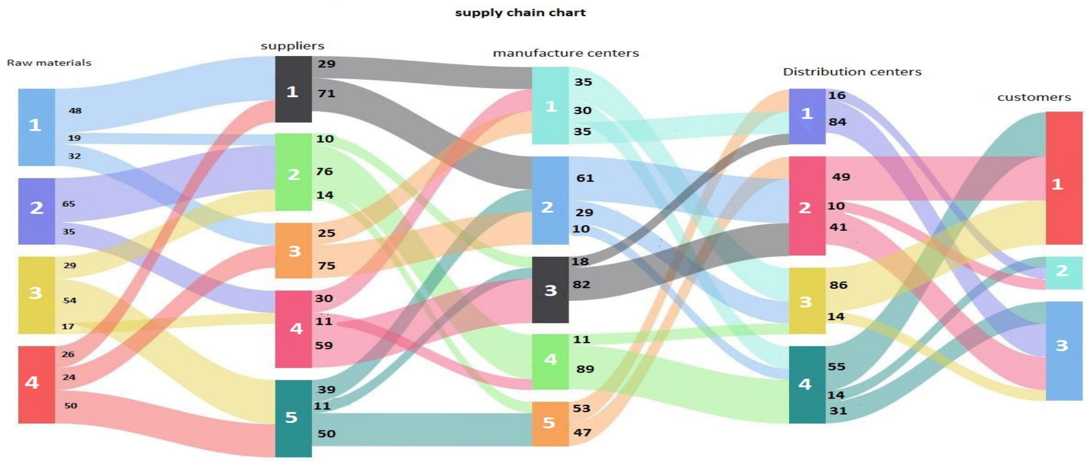

Figure 6. Flow transfer values between different levels of the research problem

Managerial Insights

This section provides some insights which managers need to check in their minds while evaluating the findings of the study. The proposed research provides multi objective mathematical model, which can be applied to SCN within the concept of deteriorating products by applying small revisions. Since both deterministic and stochastic model are developed, managers are free to apply any of the two whether having uncertain parameters or not. Obviously, based on the results, one can discuss that this SCN is not profitable under the current circumstances. However, we note that the SCN within the concept of deteriorating products in Kaleh Company is optimized (see Figure. 6). Thus, there is still space for cost improvement if more stability of the received responses enters into the SC and minimizes delivery time and the number of motions between stations of collecting centers. Another major issue affecting the profitability of the SCN is the total development levels are compared in Kaleh Company with respect to the devised development scheme in table (II). The results reveal that the model is capable to improve the development level SCM of deteriorating products can provide more useful managerial insights.

Conclusion and Future Research

This study presented a closed-loop SCND problem. The characteristics of model were investigated clearly. The model considered different assumptions which were new in comparison of the previous studies. For instance, the transportation cost was considered on a closed-loop SCN for the first time. To solve our model, first of all, we utilized the multi-objective programming for the two recent and interesting meta-heuristics were utilized. In this regard the advantages and disadvantages of all algorithms, we probed. All of the parameters of algorithms were tuned by response surface method (RSM) and also MODM based on Pareto optimal solution. In this paper, random programming models are presented for production planning in the SCN. Approaches that include centralized integration of general planning decisions and SCP comprise two necessary steps: In the first step, major pre-production decisions are made, such as the amount and how to supply the raw materials from suppliers, logistics planning and related transportation, production rate determination and human resource management in manufacturing plants. In the second step, when decision are performed about the first step, a decision is made about the value and the storage method of inventories, the value and distribution method of products to customers along with its logistical planning. Decisions about the first step are based on the value prediction values of parameters, and decisions about the second step are based on the actual values parameters. The presented model in this study includes four objective functions. The evaluation of the efficiency and usability of the model was conducted in the form of a case study, and then various sensitivities were analyzed to validate the model. The computational results from a set of real-time data showed that the model could consider integrated concepts such as customer satisfaction as tactical production decisions. With the concept of labor productivity, the model integrates human resource management decisions and makes the overall production plan more flexible with uncertainties in demand. The model also showed how international rules and regulations, such as environmental regulations, greenhouse gas emissions, and industrial waste, can influence overall program structures, as well as consider real nonlinear functions for discounts and shortages. It creates more realistic models and provides a clearer picture of what will happen in the future as the result of different scenarios.

For future works, more comprehensive analysis on our proposed model may be required to be explored. In addition, to expand the mathematical model and the suggestions for new works, the model can be added by more real-life constraints such as: cross-docking operations and vehicle routing practicing which can be diminished the trans- portation total cost by utilizing same facility in forward and reverse logistics and can also be abated the capacity of vehicles which is unused. In this research, the cost and emission of carbon were considered as two independent factors; in future research, the cost factor can be considered as time dependent. Finally, we suggest other researchers to use new algorithm and apply random dataset generation to overcome the problems arising from violations of the inclusion of observations axiom in DEA settings with ordinal or internal data. And further above modeling the problem by considering other objectives such as minimizing change in the level of manpower, minimizing greenhouse gas emissions.

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