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A New Wooden Supply Chain Model for Inventory Management Considering Environmental Pollution: A Genetic algorithm

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Abstract. Nowadays, companies need to take responsibility for addressing growing markets and the growing expectations of their customers to survive in a highly competitive context that is progressing on a daily basis. Rapid economic changes and increasing competitive pressure in global markets have led companies to pay special attention to their supply chains. As a result, in this research, a mathematical model is proposed to minimize closed loop supply chain costs taking into account environmental effects. Thus, suppliers first send wood as raw materials from forests to factories. After processing the wood and turning it into products, the factories send the wood to retailers. The retailers then send the products to the customers. Finally, customers send returned products to recovery centers. After processing the products, the recovery centers send their products to the factories. The considered innovations include: designing a supply chain of wood products regarding environmental effects, customizing the genetic solution approach to solve the proposed model 3- Considering the flow of wood products and determining the amount of raw materials and products sent and received.

Keywords: Supply chain, Environmental effects, Inventory control Meta-heuristic algorithm.

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1. Introduction

Today, despite the competitive markets and the increasing demands of customers, it is essential that industries seek to achieve competitive advantage [1]. Accordingly, activities such as material procurement, production, and product distribution, which were previously performed in the company, have now been transferred to the supply chain level. One of these industries is the wood industry, which can have high income, employment, and added value [2]. Investigating the costs associated with the supply of products shows that approximately 30% of the prime cost of each product is related to logistics and distribution activities [3]. This indicates the potential for significant improvement in the competitive capabilities of any company [4]. If we add the effect of improvements in logistics and distribution processes on other competitive areas such as agility, flexibility, service level, and etc. to this issue, the importance of paying attention to the development and improvement of logistics process optimization doubles [5, 6]. Considering the changing realities of business regarding globalization, the issue of supply chain has been promoted to the list of top executives' priorities [7, 8, 9]. However, in many cases, managers only pay attention when they are trying to reduce costs or solve a problem [10, 11]. Perhaps it can be said that the biggest problem of production and service organizations, after customer relationship management, is the proper management of the supply chain and the supply of production and service requirements [12, 13]. The belief that supply chain management can make organizations more responsive to customers and therefore more profitable has led managers to place more emphasis on improving the supply chain process. Many organizations and companies have realized to some extent the role and place of supply chain management in the success of their business [14, 15, 16]. In many cases, managers of organizations have attempted to carry out study projects to improve their supply chain management, both in terms of using information technology and in terms of using optimization techniques, such as inventory management and control, using the concepts of closed chain supply chain and etc [17, 18]. Increasing barriers to international trade, lack of economic freedom, globalization, and lawlessness have caused numerous challenges for organizations and developing countries, such as Iran. Organizations have shifted to expanding supply chain management systems in order to respond more quickly and effectively to changes in the environment, customer needs, and increase competitiveness [19, 20].

Therefore, in this research, a multilevel mathematical model for wood supply chain management is proposed. Thus, suppliers first send wood as raw materials from forests to factories. After processing the wood and turning it into products, the factories send the wood to retailers. The retailers then send the products to the customers. Finally, customers send returned products to recovery centers. After processing the products, the recovery centers send their products to the factories. The main objective of this research is to minimize supply chain costs taking into account environmental effects. The optimal amount of products sent to customers and raw materials sent to factories are also calculated. Figure 1 shows the proposed supply chain structure.

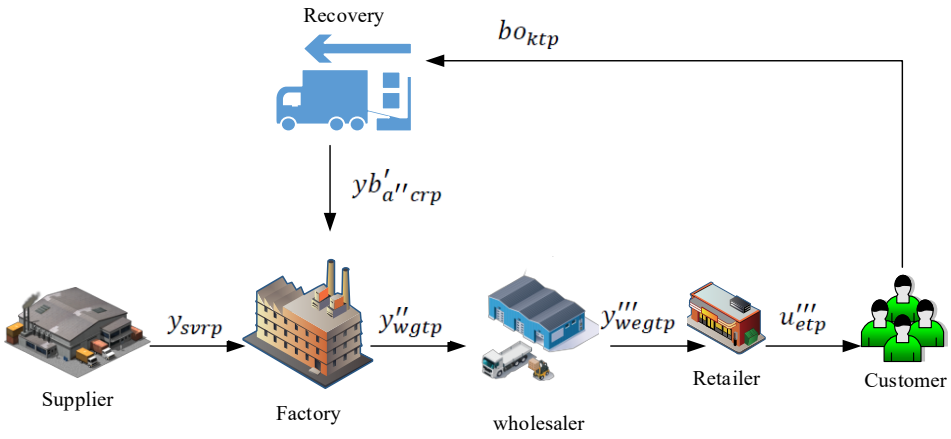


Figure 1. Supply Chain Structure

This research is presented in 6 sections. In the second section, literature review is discussed and in the third section, mathematical model is presented. In the fourth and fifth sections, the algorithm is solved and the calculation results are presented. Finally, in the sixth section, the conclusion is presented.

2. Literature Review

Salehi-Amiri et al. [21], designed a two-stage waste management system. In this research, two sub-models are used that developed the vehicle routing problem concept. In the two sub-models, they determined an effective and innovative collection route and waste separation and transferring them into the recovery value center. They used a new meta-heuristic algorithm to probe the problem's accuracy. Finally, the model parameters were investigated by sensitivity analysis. Besides, by defining and analyzing two indices, the best efficiency in using the transport fleet, the optimal amount of traveled distance, and the amount of collected waste can be achieved by setting the threshold waste level (TWL) between 70 and 75%. Salehi-Amiri et al. [22], designed a closed-loop supply chain considering social factors. They used a two-objective model developed in the intended industry. They designed their model based on the costs of the industry and the social factor. Their objective was to minimize costs and maximize job employment in the industry. They validated a real case in Mexico to validate the model they proposed using the Gomez software and its CPLEX solver. Finally, they concluded that demand has the most effect on this network in which a 25 percent decrease in demand can increase the total cost (the first objective) up to 40 percent and improve employment efficiency (the second objective) up to around 30 percent, simultaneously. Daneshdoost et al. [23], used hybrid meta-heuristic approaches based on tabu search for cable manufacturing systems. This study has modeled the scheduling problem in cable industries and minimized the total cost of production. They combined the hybrid meta-heuristic algorithm with the tabu search algorithm. They

obtained an initial solution for optimizing the algorithm. They also used computational experiments to show superiority of the combination of tabu search and simulated annealing comparing to the other proposed hybrid and classical meta-heuristics. Chouhan et al. [24], proposed a sustainable decision-making planning model considering environmental issues in sugarcane mills. They developed a mixed-integer linear programming model, which is considered a Non-Polynomial hard (NP-hard) problem. They used three meta-heuristic genetic algorithms (GA), Simulated Annealing (SA) and Social Engineering Optimizer (SEO). The meta-heuristic parameters were tuned using the Taguchi approach. Finally, they elucidate the performance of their proposed algorithm using Analysis of variance (ANOVA). Mondal and Roy [25], presented a new multi-objective mathematical modeling for assembling suppliers keeping in mind the sustainability aspects. Considering Markowitz portfolio theory was the one of the contributions of their paper. The main purpose of their research was suppliers' evaluation and order allocation phases.

Mondal et al. [20], presented a multi objective and multi-item model under an intuitionistic fuzzy environment. Considering economic aspects, customers' satisfaction and social aspects was the one of the contributions of their paper. The intuitionistic fuzzy game-theoretic method was used to solved the model. Midya et al. [26], presented a multiple objective fractional fixed-charge transportation problem. The parameters of the designed model are considered to be fuzzy. They solved the proposed model using fuzzy chance-constrained rough approximation (FCRA) technique. Taleizadeh et al. [27], addressed the pricing strategy in a two-channel supply chain. They investigated a two-level dual channel green supply chain consisting of a retailer and a manufacturer with a separate sales channel for the manufacturer. The manufacturer in this model is obliged to comply with existing regulations. Using game theory, they compared cases where members decide to compete or cooperate with each other in terms of pricing and production. They also investigated the amount of carbon emissions produced. Finally, they provided recommendations to prevent market and investment failure. Barman et al. [28], investigated optimal pricing and strategy in a competitive green supply chain considering government policies. In this paper, they propose a green supply chain in which the manufacturer produces green and non-green items separately through a retailer. Using a centralized and decentralized model, two cases of government interference and no government interference are analyzed. This study focuses on exploring the pricing strategy to maximize the overall profitability. Finally, they addressed numerical results and sensitivity analysis and provided valuable results on optimum choices with government interference and without government interference that lead to manufactured eco-friendly items. Rana et al. [29], investigated the growing items inventory model for carbon emission in the poultry industry, which are responsible for emitting greenhouse gases. Accordingly, retailers also affect their inventory behavior due to carbon emissions. Therefore, the effect of carbon emissions from the poultry industry is investigated here. The study has been carried out to investigate the optimum breeding period and optimum livestock inventory. Finally, a numerical example and illustrations validate the analytical results. Lastly, a sensitivity analysis has been provided concerning some key parameters. Sana [30], proposed a structural mathematical model on the supply chain system. This paper investigated two situations in two models. In Model 1, it analyzed the profit functions of the producer and retailer based on the computational method. Model 2 introduced a price competition for two alternative products in which end-user demand depends on the price and quality of the green product. In this model, the profit functions of companies 1 and 2 were formulated separately, taking into

account revenues from sales items, green quality costs and shares for social responsibility activities. The main objective of this paper is to find the optimum price and quality of green in order to maximize profit functions. The developed models were mathematically analyzed using the proposed models. Finally, numerical examples were provided to justify the feasibility study of the model in reality.

Salehi-Amiri et al. [31], designed a new Close Loop Supply Chain (CLSC) network for the walnut industry as a part of agricultural crop by conducting a complete review of the past studies. Therefore, they used a new Mixed Integer Linear Programming (MILP) for the proposed network to minimize the overall costs of the walnut industry. Their model has created a response to the demand of different markets and the preparation of returned products. They used metaheuristics and hybrid metaheuristics to solve the problem. The initial answers were assessed using the Taguchi method. Their results showed excellent consistency between the proposed networks and the algorithm used in the paper. Chouhan et al. [32], designed and addressed the closed-loop supply chain network in the sugarcane industry using meta-heuristic approaches, which helps reduce the overall cost of the model. They used meta-heuristic techniques that are very useful for NP-hard problems. They used three hybrid meta-heuristic algorithms: 1-H-GASA, a combination of genetic algorithm with simulated annealing 2. H-KASA a combination of Keshtel algorithm with simulated annealing, 3.H-RDASA a combination of red deer algorithm with simulated simulation. For the performance of the algorithms, they used Taguchi experiments to create the most complete parameters. Their results showed that H-KASA performs better in small-sized problems, while H-RDASA performs better in medium and large-sized problem samples.

Mosallanezhad et al. [33], investigated the design of the shrimp closed-loop supply chain network. This paper considers SSC as a collection of wholesalers, shrimp processing factories, distribution centers, markets. A mathematical model is proposed to minimize the total cost through. They used three well-known metaheuristics. They also used a real-world application with 15 test problems to validate the model. Their results showed that the model and solution methods lead to cost savings. Hamdi-Asl et al. [34], investigated the supply chain network in the date industry. This study first investigated the characteristics of dates as the richest fruits and supply chain design. They used old and new meta-heuristic algorithms to achieve better diversity. They used the Taguchi method to obtain appropriate parameters. For solution quality, relative percentage deviation (RPD), CPU time and weighted LP-metric methods were used. Finally, their results showed that the multi-objective Keshtel algorithm (MOKA) method is more efficient and more effective than other algorithms. Fasihi et al. [35], investigated the optimization of fish closed-loop supply chain network design by three multi-objective meta-heuristic algorithms. They first proposed a new two-objective and multi-period mathematical model of the fish closed-loop supply chain. They used the Taguchi method to obtain superior performance. Their results showed that the exact method could not solve large-sized problems. According to the results, it was found that the developed model can be applied to the proposed solution approach. Mosallanezhad et al. [36], investigated the supply chain of disasters during the corona virus pandemic. Considering the prevalence of Covid-19, they investigated a multi-objective, multi-product, multi-period model that aims to optimize total cost and shortage simultaneously. They used the Taguchi method to tune the parameters of the algorithm. In this paper, fifteen experimental samples were designed to prove the supply chain model and the applicability of the algorithms. Finally, the meta-heuristic algorithm was evaluated through various statistical analyses. The results showed an efficient and valuable method.

Mousavi et al. [37], designed a bi-objective and sustainable supply chain network for blood decomposition using social and environmental factors. They also considered aspects of uncertainty. In the first objective function, they sought to minimize the total cost by considering bi-objective programming in the developed network, balancing the flow of all utilized vehicles, the penalty coefficient of non-visited centers, and achieved it, in the second objective function, they investigated the maximization of the social factor of blood decomposition performed by the second objective function. They also used stochastic programming and sensitivity analysis to better understand the problem in different situations. Their findings show that more social factors transfer more costs. Zahedi et al. [38], designed a new closed-loop supply chain network with sales agencies and customers. Their model was designed according to the previous constraints and new constraints. In the objective function, they considered maximizing profit. They created the structure of the model by mixed-integer linear programming complex linear integers. The proposed model was designed through a case study of the manufacturing industry. They used a set of meta-heuristic and hybrid algorithms in various test problems along with data from a real-world case study to confirm the model's efficiency. Finally, they came to the conclusion that sales agencies and customers increase total revenue and the number of the collected returned products

Mahapatra et al. [39], investigated the problem of food and medicine supply to hospitals. They used a stochastic programming model containing the parameters that follow the logistic distribution and used binary variables in the objective function coefficients. They also benefited from auxiliary constraints. Finally, they presented a numerical example to illustrate the whole idea. Sana [40], addressed the competition between green and non-green products and compared green and non-green markets in which the government implements subsidies and taxes and analyzes them. It also created price competition between the green producer and the non-green producer. Assuming the cost and profit parameters, an expected profit function of the systems is formulated and maximized analytically. Finally, numerical examples are illustrated to justify the proposed model.

1: Lack of attention to environmental factors in Wood supply chain. Considering environmental costs is in a way that the objective function considers penalty costs for cutting the trees. Since the objective function is for cost reduction, this penalty leads to the increase of objective function. Therefore, the model tries to consider lower wood weight for producing the products.

2: Lack of attention to multi-echelon, multi-period and multi-product wood supply chain in closed loop supply chain. In this research, several suppliers, wholesalers, and retailers w used in four-level supply chain that were not used in previous studies

3: Lack of attention to customized and efficient algorithm to solve the closed-loop supply chain in large scale

Therefore, according to the literature review, the research innovations are as following: The first innovation is considering the environmental factors in wood supply chain. The second innovation is considering four-level wood supply chain in closed loop supply chain. Finally, the third innovation is solving closed loop logistics problem in large scale using Genetic Algorithm

3. Mathematical model

In this research, three major suppliers, five major distributors, five major customers and five collection centers are investigated. Three products and three wooden raw materials are investigated in this 5-level supply chain. Research assumptions are as follows:
1-The supply chain is considered to include five echelons: supplier, factory, retailer, customer and recovery.
2-The products have different types and have capacity limitations at the factory.
3-The shortage in the supply chain is allowed
4-There are two types of vehicles, including departure or non-departure of vehicle.

3.1. Indices and Sets

c	Collection center index ($c \in C$)
p	Planning period index $p \in P$
h_c	The retailers who take service from collection center *c*
s	Supplier index $s \in S$
w	Wholesaler index $w \in W$
e	Customer index $e \in E$
e_w	The retailers who take service from wholesaler $e_w \subset E$
v	Vehicle supplier index $v \in V$
V_s	The set of all available vehicles in supplier *s* $V_s \subset V$
f	Factory vehicles index $f \in F$
g	Wholesaler vehicle index $g \in G$
a	Index of available vehicles in collection centers that carry wooden waste from retailers to collection centers $a \in A$
a_c	The set of all available vehicles in collection center *c* that carry wooden waste from customer to collection center *c*
a'	The set of all available vehicles in collection center for servicing the producer
a''	Index of available vehicles in collection center for servicing the producer($a'' \in a'$)
a'_c	The set of all available vehicles in collection center *c* that carry wooden waste to the factory
G_w	The set of all available vehicles in wholesaler *w* $G_w \subset G$
t	Factory products index $t \in T$
r	Raw materials index, including lumber $r \in R$
$\mathrm{Ba_{tr}}$	The set of all r that transform to t

3.2. Parameters

$\mathrm{T_s}$	The approximate time of going back and forth from supplier s to the factory
$\mathrm{T'_w}$	The approximate time of going back and forth from the factory to wholesaler w

T''_{we}	The approximate time of going back and forth from wholesaler w to retailer e
ct_t	The production cost of each unit of product *t* in the factory
cs_{wf}	The fixed cost of sending vehicle *f* from the factory to wholesaler *w*
cf_{wt}	The transportation cost of unit of product *t* from the factory to wholesaler *w*
cr_{weg}	The fixed cost of sending vehicle *g* from wholesaler w to customer *e*
cd_{wet}	The transportation cost of unit of product *t* from wholesaler *w* center to retailer *e*
cp	Capacity of factory storage for wooden raw materials
cp'	Capacity of factory storage for products
cp''_w	Storage capacity of retailer *w*
dem_{etp}	Demand of customer *e* from product *t* on day *p*
α_{rt}	The consumption coefficient of material *r* in product *t*
I_r	The volume of each unit of wooden raw material *r*
I'_t	The volume of each product *t*
ch_{rp}	The maintenance cost of each wooden raw material *r* in the factory wooden raw material storage on day *p*
P_{etp}	The penalty of shortage of product *t* for retailer *e* of on day *p*
$cinv$	The cost of environment destruction for the reduction of each unit of natural resources (tree)
Ts_{ec}	The approximate time of going back and forth from customer *e* to collection center *c*
Ts'_c	The approximate time of going back and forth from collection center *c* to the factory
M	A very large number
Hd	Work hours in a day
ck_{et}	The cost of purchasing each unit of wooden waste *t* from retailer *e*
f_{eac}	The fixed transportation cost of vehicle *a* from customer *e* to collection center *c*
cz_{ect}	The transportation cost of each unit of wooden waste *e* from collection center *c* to factory *t*
$f'_{a'c}$	Fixed costs of sending vehicle $a'$from collection center *c* to the factory
cz'_{cr}	The transportation cost of each unit of wooden waste *r* from collection center *c* to the factory
Sp_a	Capacity of vehicle *a*
ch'_{tp}	The maintenance cost of each unit of product *t* in the factory products storage on day *p*
ch''_{wtp}	The maintenance cost of each unit of product *t* for wholesaler *w* on p day
ch'''_{etp}	The maintenance cost of each unit of product *t* for retailer *e* on day *p*
$Sp'_{a''}$	Capacity of vehicle a''
cab_c	Storage capacity of collection center *c*
BR_{te}	The percentage of product t that returns from retailer *e*
$Cinv'$	The benefit of environment enhancement for each unit of natural resources (tree)
c_{rs}	The cost of purchasing each unit of wooden raw material *r* from supplier *s* to the factory
c'_{sv}	The fixed cost of sending vehicle *v* from supplier *s* to the factory
c''_{rs}	The transportation cost of each unit of wooden raw material *r* from supplier *s* to

	the factory
vol_v	Capacity of vehicle *v*
vol'_f	Capacity of vehicle *f*
vol''_g	Capacity of vehicle *g*

3.3. Variables

w_{svp}	The frequency of movement of vehicle *v* from supplier *s* to factory on day *p*
w'_{wfp}	The frequency of movement of vehicle f from factory to wholesaler *w* on day *p*
w''_{wegp}	The frequency of movement of vehicle g from wholesaler *w* to retailer *e* on day *p*
y'''_{wegtp}	The number of product *t* transported by vehicle *g* from wholesaler *w* to retailer *e* on day *p*
bo_{ktp}	The amount of postponed orders of customer k from product t on day p
u'_{rp}	Storage inventory (weight) of wooden raw material *r* in the factory on day *p*
u'_{tp}	Storage inventory (weight) of product t in the factory on day *p*
u''_{wtp}	Storage inventory of wholesaler *w* from product *t* on day *p*
u'''_{etp}	Storage inventory of customer *e* from product *t* on day *p*
wb_{eacp}	The frequency of movement of vehicle *a* from retailer e to collection center *c* on day *p*
w_{svp}	The frequency of movement of vehicle *v* from supplier *s* to factory on day *p*
w'_{wfp}	The frequency of movement of vehicle *f* from factory to wholesaler *w* on day *p*
w''_{wegp}	The frequency of movement of vehicle *g* from wholesaler *w* to retailer e on day *p*
$wb'_{a''cp}$	The frequency of movement of vehicle *a ″* from collection center *c* to the factory on day *p*
x_{svp}	Binary variable representing the departure or non-departure of vehicle *v* from supplier s to the factory on day *p*
x'_{wfp}	Binary variable representing the departure or non-departure of vehicle *f* from factory to wholesaler *w* on day *p*
x'''_{wegp}	Binary variable representing the departure or non-departure of vehicle *g* from wholesaler *w* to retailer *e* on day *p*
yb_{eactp}	The amount of product *t* sent from retailer e to collection center *a* by vehicle *c* on day *p*
$yb'_{a''crp}$	The amount of material *r* sent from collection center *c* to the factory by vehicle *a″* on day *p*
y_{svrp}	The amount of wooden raw material *r* sent by vehicle *v* from supplier *s* to the factory on day *p*
y'_{tp}	The number of manufactured products *t* by the factory on day *p*

y''_{wgtp} The number of products t sent by vehicle g from the factory to wholesaler w on day p

xb_{eacp} Binary variable representing the departure or non-departure of vehicle a from retailer e to collection center c on day p

$xb'_{a''cp}$ Binary variable representing the departure or non-departure of vehicle a'' from collection center c to the factory on day p

$wb'_{a''cp}$ The frequency of movement of vehicle a'' from collection center c to the factory on day p

3.4. Objective Function

$$\text{Minimize } Z = \left(\sum_{s\in S}\sum_{v\in V_s}\sum_{r\in R}\sum_{p\in P}\left(c_{rs}y_{svrp}\right)\right)$$

$$+\left(\sum_{s\in S}\sum_{v\in V_s}\sum_{p\in P}c'_{sv}x_{svp}+\sum_{s\in S}\sum_{v\in V_s}\sum_{r\in R}\sum_{p\in P}c''_{sr}y_{svrp}\right)+\left(\sum_{t\in T}\sum_{p\in P}\left(ct_t y'_{tp}\right)\right)$$

$$+\left(\sum_{w\in W}\sum_{f\in F}\sum_{p\in P}cs_{wf}x'_{wfp}+\sum_{w\in W}\sum_{g\in G}\sum_{t\in T}\sum_{p\in P}cf_{wt}y''_{wgtp}\right)$$

$$+\left(\sum_{w\in W}\sum_{e\in E_w}\sum_{g\in G_w}\sum_{p\in P}cr_{weg}\,x''_{wegp}+\sum_{w\in W}\sum_{e\in E_w}\sum_{g\in G_w}\sum_{t\in T}\sum_{p\in P}cd_{wet}y'''_{wegtp}\right)$$

$$+\left(\sum_{r\in R}\sum_{p\in P}\boldsymbol{ch_{rp}u_{rp}}+\sum_{t\in T}\sum_{p\in P}\boldsymbol{ch'_{tp}u'_{tp}}+\sum_{w\in W}\sum_{t\in T}\sum_{p\in P}\boldsymbol{ch''_{wtp}u''_{wtp}}\right.$$

$$\left.+\sum_{e\in E}\sum_{t\in T}\sum_{p\in P}\boldsymbol{ch'''_{etp}u'''_{etp}}\right)+\sum_{e\in E}\sum_{t\in T}\sum_{p\in P}\boldsymbol{P_{etp}bo_{etp}}+\left(\boldsymbol{Cinv}\sum_{s\in S}\sum_{v\in V}\sum_{r\in R}\sum_{p\in P}\boldsymbol{y_{svrp}}\right)$$

$$+\left(\sum_{e\in h_c}\sum_{a\in a_c}\sum_{c\in C}\sum_{t\in T}\sum_{p\in P}\boldsymbol{ck_{et}yb_{eactp}}\right)+\left(\sum_{e\in h_c}\sum_{c\in C}\sum_{a\in a_c}\sum_{p\in P}\boldsymbol{f_{eac}\,xb_{eacp}}\right.$$

$$\left.+\sum_{e\in h_c}\sum_{c\in C}\sum_{a\in A_C}\sum_{t\in T}\sum_{p\in P}\boldsymbol{cz_{ect}yb_{eactp}}\right)+\left(\sum_{c\in C}\sum_{a\in a'_c}\sum_{p\in P}\boldsymbol{f'_{a''c}\,xb'_{a'cp}}\right.$$

$$\left.+\sum_{c\in C}\sum_{a'\in a'_c}\sum_{r\in R}\sum_{p\in P}\boldsymbol{cz'_{cr}yb'_{a'crp}}\right)-\left(\boldsymbol{Cinv'}\sum_{c\in C}\sum_{a'\in a'}\sum_{r\in R}\sum_{p\in P}\boldsymbol{yb'_{a'crp}}\right)$$

The objective function includes 12 parts. The first part minimizes the cost of purchasing the second part minimize the fixed and transportation cost of sending vehicle from supplier to the factory. The Third and fourth parts minimize the production cost and the fixed and transportation cost of sending vehicle from the factory to wholesaler. The fifth and sixth parts minimize the fixed and transportation cost of sending vehicle from wholesaler to customer and the maintenance cost. The seventh and eighth parts minimize the penalty of shortage and the cost of environment destruction. The ninth and tenth parts minimize the cost of purchasing wooden waste and the fixed and transportation cost of vehicle from customer to collection center. The eleventh and twelfth minimize fixed costs of sending vehicle from collection center and the benefit of environment enhancement.

3.5. Model Constraints

Constraints (1) and (2) ensure the balance of retailers' inventory

$$\left(\sum_{w\in W}\sum_{g\in G_w} y'''_{wegtp} + u'''_{et(p-1)} - u'''_{etp}\right)BR_{te} = \sum_{c\in C}\sum_{a\in a'_c} yb_{eactp} \quad (1)$$
$$\forall e\in E,\ t\in T,\ p\in P$$

$$\sum_{e\in h_c}\sum_{a\in a'_c}\sum_{t\in Ba_{tr}} \alpha_{rt} yb_{eactp} = \sum_{a''\in a'_c} yb'_{a''crp} \qquad \forall r\in R,\ c\in C,\ p\in P \quad (2)$$

Constraint (3) is the raw material storage capacity of the factory.

$$\sum_{r\in R} I_r u'_{rp} \le cp \qquad \forall p \in P \quad (3)$$

Constraint (4) is the final product storage capacity in a factory.

$$\sum_{t\in T} I'_t u'_{tp} \le cp' \qquad \forall p \in P \quad (4)$$

Constraint (5) is the wholesaler storage capacity.

$$\sum_{t\in T} I'_t u'_{wtp} \le cp''_w \qquad \forall w\in W,\ p\in P \quad (5)$$

Constraint (6) is the balance of raw material inventory in a factory.

$$\sum_{s\in S}\sum_{v\in V_s} y_{svrp} + u_{r(p-1)} = \sum_{t\in T} \alpha_{rt} y'_{tp} + u_{rp} \qquad \forall p\in P,\ r\in R \quad (6)$$

Constraints (7), (8), (9), (10) and (11) are related to the time of vehicles.

$$w_{svp} * T_s \le Hd * x_{svp} \qquad \forall s\in S,\ v\in V_s,\ p\in P \quad (7)$$

$$\sum_{w\in W} w'_{wfp} * T'_w \le hd \qquad \forall f\in F,\ p\in P \quad (8)$$

$$\sum_{e\in E} w''_{wegp} * T''_{we} \le hd \qquad \forall w\in W,\ g\in G_w,\ p\in P \quad (9)$$

$$w'_{wfp} \le M.x'_{wfp} \qquad \forall w\in W,\ f\in F,\ p\in P \quad (10)$$

$$w''_{wegp} \le BigM * x''_{wegp} \qquad \forall w\in W,\ e\in E_w,\ g\in G_w,\ p\in P \quad (11)$$

Constraint (12) represents the balance of products inventory in a factory.

$$y'_{tp} + u'_{t(p-1)} = \sum_{w\in W}\sum_{g\in G} y''_{wgtp} + u'_{tp} \qquad \forall t\in T,\ p\in P \quad (12)$$

Constraint (13) represents the balance of wholesaler's inventory.

$$\sum_{g\in G} y''_{wgtp} + u''_{wt(p-1)} = \sum_{e\in E_w}\sum_{g\in G_w} y'''_{wegtp} + u''_{wtp} \qquad \forall w\in W,\ t\in T,\ p\in P \quad (13)$$

Constraint (14) represents the inventory requirements in retail centers.

$$\sum_{w\in W}\sum_{g\in G_w} y'''_{wegtp} + u'''_{et(p-1)} + bo_{etp} = dem_{etp} + u'''_{etp} \qquad \forall e\in E,\ t\in T, p\in P \tag{14}$$

Constraint (15) is the vehicles capacity that moves between retailers and collection centers.

$$\sum_{t\in T} I'_t yb_{eactp} \le Sp_a . wb_{eacp} \qquad \forall\, e \in E_c,\ a\in a'_c,\ c\in C,\ p\in P \tag{15}$$

Constraint (16) is the vehicles capacity that moves between factory and collection centers.

$$\sum_{r\in R} I_r yb'_{a''crp} \le Sp'_{a''} wb'_{a''cp} \qquad \forall\ a''\in a'_c,\ c\in C,\ p\in P \tag{16}$$

Constraints (17), (18) and (19) are time constraints of vehicles.

$$\sum_{e\in h_c} wb_{eacp} * Ts_{ec} \le Hd \qquad \forall\ \ a\in a'_c,\ c\in C,\ p\in P \tag{17}$$

$$wb'_{a''cp} * Ts'_c \le Hd * xb'_{a''cp} \qquad \forall\, a''\in a'_c,\ c\in C,\ p\in P \tag{18}$$

$$wb_{eacp} \le M * xb_{eacp} \qquad \forall c\in C,\ a\in a'_c,\ e\in h_c,\ p\in P \tag{19}$$

Constraint (20) is the balance of raw material inventory in the factory.

$$\sum_{s\in S}\sum_{v\in V_s} y_{svrp} + \sum_{c\in C}\sum_{a''\in a'_c} yb'_{a''crp} + u_{r(p-1)} = \sum_{t\in T} \alpha_{rt} y'_{tp} + u_{rp} \qquad \forall p\in P,\ r\in R \tag{20}$$

Constraint (21) is the capacity of available vehicles for a supplier.

$$\sum_{r\in R} I_r y_{svrp} \le Vol_v . w_{svp} \qquad \forall s\in S,\ v\in V_s,\ p\in P \tag{21}$$

Constraint (22) is the vehicle capacity that transports the product from the factory to wholesaling centers.

$$\sum_{t\in T} I'_t y''_{wgtp} \le vol'_f w'_{wfp} \qquad \forall\, w\in W,\ f\in F,\ g\in G_w,\ p\in P \tag{22}$$

Constraint (23) is the vehicles capacity that moves between wholesaling centers and retailing centers.

$$\sum_{t\in T} I'_t y'''_{wegtp} \le vol''_g w''_{wegp} \qquad \forall\, w\in W,\ e\in e_w,\ g\in G_w,\ p\in P \tag{23}$$

4. Genetic algorithm (GA)

4.1. General structure of genetic algorithms

The general structure of a genetic algorithm can be thought of as follows. First of all, a mechanism needs to be defined to convert each solution to a chromosome. Then, a set of chromosomes, which are actually a set of solutions, are prepared as an initial population. This set, which is arbitrary in size and is user-defined, is often created randomly. After this stage, new chromosomes called offspring must be created using genetic operations. These operations are divided into two main types of crossover and mutation. Also, the two

concepts of crossover rate and mutation rate are widely used to select the chromosomes that need to play the role of parents, which are also determined by the user before the start of the algorithm. The Genetic algorithm uses only the values of the objective function to perform the optimization process and does not require any additional information such as the derivative of the function. Also, due to the simplicity of the search process, this algorithm works very fast and efficiently. In addition, Genetics is very flexible and works with any kind of objective function and constraints in the search space [41].

4.2. Production of the initial population

The first stage after determining the technique used to convert each solution to a chromosome is to create an initial population of chromosomes. In this stage, the initial solution is usually generated randomly.

4.3. Calculation of the fitting function

It is obvious that there must be an index to evaluate the chromosomes to identify more suitable chromosomes. Regarding function optimization problems, this index is usually the value of the objective function of the problem, i.e. each chromosome becomes the corresponding solution and is placed in the target function, then the value of the objective function for any solution that is better, the chromosome corresponding to that solution will be more suitable.

4.4. Production of new generation

To produce a new generation, we must first determine the percentage of reproduction (pr). Of course, this value is optional and is determined by trial and error. For example, if the percentage of reproduction is 15%, it means that15% of the initial generation that has the best fitting function can be passed on to the next generation. Therefore, the number of chromosomes that enter directly into the next generation is equal to:

$$Npr = pr \times popsize \tag{24}$$

Popsize: The number of chromosomes in each generation

4.5. Applying the genetic

Genetic operations imitate the process of inherited gene transfer to create new offspring in each generation. An important part of the genetic algorithm is the creation of new chromosomes called offspring through some old chromosomes called parents. In general, this operation is performed by two main operators. Mutation operator and crossover operator.

4.6. Crossover operators and mutation

These operators select one or more points from two or more solutions and exchange their values. These operators consider a solution and exchange positions of the solution with other solutions to create new solutions. These types of operators are called crossover operators. In fact, crossover is performed on the remaining chromosomes of the initial population. The number of possible crossovers is equal to:

$$Npc = popsize - Npr \tag{25}$$

Now we have to select chromosomes as the parent from the remaining chromosomes to perform the crossover operation. The main task is to select the direction of the algorithm to the promising areas of the solution space. There are several ways to select parent chromosomes from the initial population:

- Random selection

Regardless of the degree of optimality (fitting function), we select two chromosomes randomly.

- Competitive selection

Each time we select several chromosomes randomly and from them we select two chromosomes with better fitting function.

- Selection based on roulette wheel

The selection of roulette wheel, first proposed by Holland (1975), has been one of the most suitable random selections. The probability of selection corresponding to each chromosome is calculated based on its fitting, so that if f_k is the fitting value of the kth chromosome, the probability of survival corresponding to that chromosome is:

$$P_k = {f_k}\Big/{\sum_{i=1}^{n} f_i} \qquad (n = pop - size) \tag{26}$$

Now we arrange the chromosomes according to p_k and q_k, which is the cumulative value of p_k, is obtained as follows:

$$q_k = \sum_i^k P_i \tag{27}$$

In the roulette wheel selection method, in order to select each chromosome, first a random number between one and zero is generated and then any interval at which the mentioned number is placed, the corresponding chromosome is selected. However, the method of implementing the roulette wheel is that a circle is considered and divided by the number of chromosomes so that each part corresponds to the fitting value of the chromosome. Now the wheel is spun, and we look at the wheel index wherever the wheel

stops, the chromosome related to that part is selected. We need two parents to perform the crossover operation in each stage.

In various papers, crossover operation has been performed in several different forms, such as single-point crossover, two-point crossover, weighted mapping crossover (WMX), and sorted match crossover. However, only one-point crossover is used in our solution approach. Here we mention its performance:

- Single-point crossover

1. Select a random point along the chromosome (both in discrete and continuous modes) and divide the parents into two parts from this point.

2. Each offspring is created by choosing the first piece from one parent and the second piece from the other parent.

In the following example, a random number of 4 is assumed. Therefore, each offspring takes the first 4 genes from one parent and the next 3 genes from the other parent.

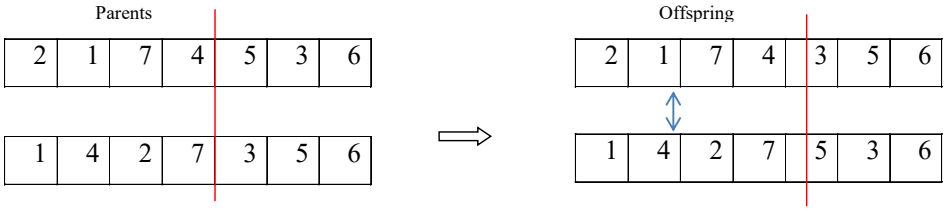


Figure 2. Crossover operator

These operators select one or more genes from a chromosome and change their values. In these operators, one or more places of a character string with a certain length are considered and the values of the characters in those places change. In this type of operator, the information of one solution is used and another solution is generated. This change may be more or less the same amount of information is used more or less. In other words, the greater the changes, the more random the result will be, and this randomness will be beneficial for new genetic material to enter the population. When the population converges towards a particular solution, the probability of mutation has to increase to prevent this, and vice versa, when the population has dissimilar solutions, the probability of mutation has to decrease.

According to the above explanations, we must first determine the percentage of mutation (pm) arbitrarily and then randomly select a gene using a uniform distribution and change its value. In the papers, mutations such as big swap, insert, inversion, swap, and scramble, all of which are suitable for both continuous and discrete display modes, have been used and also the classic method has been used only for continuous display mode. In

our solution approach, the big swap type is used in the discrete display mode and the classic type is used for the continuous display mode that its performance is described below.

In big swap method, we select two genes randomly and swap them together. The characters between the two selected genes remain unchanged.

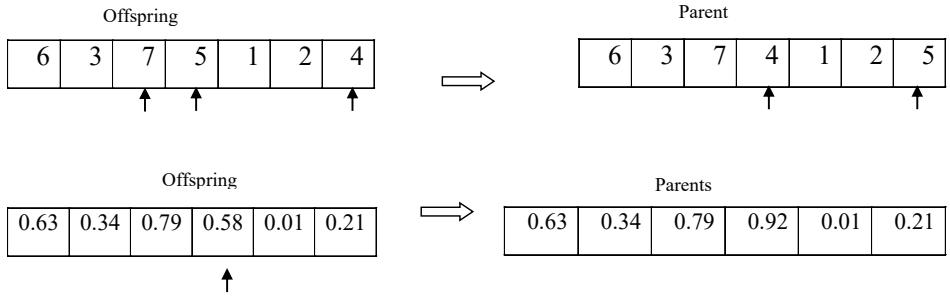


Figure 3. Mutation operator

In this method, which is used only in continuous display mode, one gene is selected randomly and another random number replaces the current number.

4.7. Stopping criterion

After the birth of offspring and the production of a new generation and the calculation of its fitting function, there is a need for a criterion for completing the algorithm, some of the most common of which are mentioned.

- The program is often run for a predetermined number of generations. For example, at the very beginning of the program, the number of generations is considered for 50 iterations.
- Computation time is sometimes considered as a criterion to stop the algorithm.
- Sometimes this criterion is based on the extent of gene dispersion within the population.

In the problem-solving approach, in some algorithms, time is used and in others, the maximum number of generations is used.

4.8. Taguchi method

The provided levels with the factors are reported in Table 1, which for algorithm's factors, three levels are provided. It should be noted that the Taguchi approach reduces the total number of tests by presenting a set of orthogonal arrays to control the proposed algorithms in a reasonable time (See table 1).

Table 1. The orthogonal array for Genetic Algorithm

	A	B	C	D
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	

Therefore, the output of the S/N ratio should be analyzed by Minitab Software to detect the best levels for each algorithm. Where the S/N index has reached its minimum, the levels can be selected as the optimal levels (See figure 4).

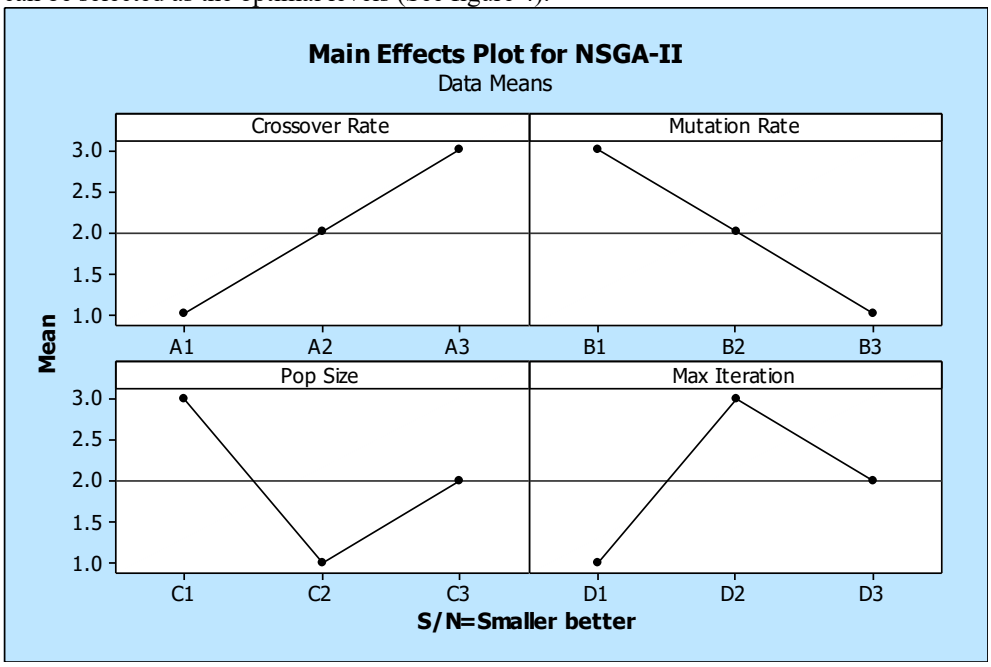


Figure 4. The Taguchi method of the Genetic algorithm

5. Computational results of GA algorithm

The approximate time of going back and forth from wholesaler w to retailer e is as follows:

Table 2. The Comparison of GAMS and GA

T''_{we} (min)	w_1	w_2	w_3	w_4	w_5	w_6
e_1	30	156	71	176	197	90
e_2	117	151	135	50	122	131
e_3	61	152	188	43	82	110
e_4	154	95	168	154	36	79
e_5	41	50	172	167	118	138

Table 3 defines the dimensions of the problems.

Table 3. Dimensions of the problems

No	Collection center	Period	Supplier	Wholesaler	Customer	Products	Raw material
1	1	1	2	2	2	1	1
2	2	2	2	2	2	2	2
3	3	2	2	3	3	2	3
4	3	3	3	3	3	3	3
5	4	4	3	5	5	4	3
6	5	5	5	5	5	5	5
7	5	6	6	5	5	6	5
8	6	7	6	6	6	6	6
9	7	7	7	7	7	7	7
10	8	8	8	8	8	8	8

Since the proposed algorithm is random in nature, it is possible to encounter different results in every implementation. We implemented the algorithm for each sample. The results are presented in the following Table 3.

Table 4. Comparison of Exact and genetic Algorithm

N	GAMS		GA					
		t(s)	1	2	3	4	5	T (s)
1	664.2	1	662.2	662.2	663.2	661.2	675.2	1
2	666.1	1	668.1	667.2	668.1	666.3	677.2	2
3	669.1	2	669.1	669.1	670.4	672.1	680.3	3
4	669.8	3	670.9	673.8	672.9	675	682.8	3
5	675.8	5	675.8	675.9	685.0	677.8	685.9	4
6	1731.5	8	1743.2	1745.5	1744.1	1735.6	1741.5	5
7	1752.4	123	1754.6	1763.5	1747.9	1757.2	1753.5	6
8	1759.6	413	1759.5	1767.7	1768.5	1762.8	1767.8	8
9	1781.5	706	1783.2	1781.5	1784.7	1781.4	1788.5	9
10	1788.8	3019	1789.6	1792.8	1794.2	1784.3	1794.9	10

The first and second columns of Table 4 show the results of the model objective function using GAMS software and the model solution time. The third to seventh columns show the results of solving 5 numerical samples by Genetic approach. Finally, the last column shows the solution time of the model with the Genetic approach. Since it is impossible to test all the possible types, here we investigated only some of them. As it can be seen, when the problem's scale increases, its objective functions (model costs) increases, too. The first five types are related to small scale and the next five types are in medium scale. The results revealed that because of the slight difference of GA with exact algorithm, we can rely on exact algorithm in solving large scale problems. Also, due to the high CPU time of exact solution approach, we have to use the Genetic algorithm.

Here are the solution results for problem number 5. Table 5-6 shows the parameters of the fifth problem. Table 5 shows the storage capacity of retailers. Table 6 shows demand of customers from products on each day. Table 7 shows the cost of purchasing each unit of wooden waste from retailer

Table 5. Storage capacity of retailers (m^3)

Retailer	1	2	3	4	5
Storage capacity	3000	4000	3000	3000	4000

Table 6. Demand of customer from product on day (Kg)

t.p/e	e_1	e_2	e_3	e_4	e_5
t1.p1	700	740	807	271	217
t1.p2	997	139	807	410	423
t1.p3	796	141	262	510	774
t1.p4	650	382	746	329	428
t2.p1	921	998	707	591	248
t2.p2	532	464	151	616	910
t2.p3	595	990	145	298	544
t2.p4	818	121	515	489	962
t3.p1	695	248	866	509	298
t3.p2	646	389	336	644	368
t3.p3	166	272	432	877	991
t3.p4	806	373	797	840	661
t4.p1	147	864	812	957	350
t4.p2	571	445	466	590	830
t4.p3	608	459	107	632	841
t4.p4	841	133	208	468	869

Table 7. The cost of purchasing each unit of wooden waste from retailer ($)

t.e	e_1	e_2	e_3	e_4	e_5
t_1	50	40	50	70	65
t_2	85	78	80	90	88
t_3	40	45	40	50	55
t_4	15	15	20	15	18

The variables that are initialized in algorithm are as the following:

Table 8, presents the unit amount of wooden raw material m that was transported by vehicle v from supplier a to the factory on day t. As an example, according to this table, the amount of the wooden raw material of type 2 that was transported by vehicle 2 from supplier 2 on the third day is 2560 units.

Table 8. Unit amount of wooden raw material y_{svrp}

Variable	Amount	Variable	Amount
$y_{s1,v3,r1,p1}$	2475	$y_{s1,v3,r1,p2}$	4512
$y_{s1,v3,r1,p3}$	3728	$y_{s1,v3,r1,p4}$	1121
$y_{s2,v2,r2,p1}$	3092	$y_{s2,v2,r2,p2}$	6738
$y_{s2,v2,r2,p3}$	2575	$y_{s2,v2,r2,p4}$	2515
$y_{s3,v5,r3,p1}$	3164	$y_{s3,v5,r3,p2}$	4218
$y_{s3,v5,r3,p3}$	1898	$y_{s3,v5,r3,p4}$	1631

Table 9 shows the frequency of movement of vehicle v from supplier a to the factory on day t. According to this table, the frequency of movement of the third type vehicle from the first supplier in the fourth period is 12 times.

Table 9. The frequency of movement of vehicle v from supplier a to the factory w_{svp}

Variable	Amount	Variable	Amount
$\boldsymbol{w_{s1,v3,p1}}$	14	$w_{s1,v3,p2}$	15
$\boldsymbol{w_{s1,v3,p3}}$	8	$w_{s1,v3,p4}$	16
$\boldsymbol{w_{s2,v2,p1}}$	18	$w_{s2,v2,p2}$	17
$\boldsymbol{w_{s2,v2,p3}}$	19	$w_{s2,v2,p1}$	14
$\boldsymbol{w_{s3,v5,p1}}$	9	$w_{s3,v5,p2}$	18
$\boldsymbol{w_{s3,v5,p3}}$	12	$w_{s3,v5,p4}$	13

Table 10 shows the binary variable representing the departure or non-departure of vehicle f from the factory to wholesaler b on day t. According to this table, the third vehicle did not depart to visit the third wholesaler in the first period but the second vehicle visited the first wholesaler in the third period.

Table 10. The variable representing the departure or non-departure of vehicle from the factory to distribution x'_{wfp}

Variable	Amount	Variable	Amount
$x'_{w1,f1,p1}$	1	$x'_{w1,f1,p2}$	1
$x'_{w1,f1,p3}$	1	$x'_{w1,f2,p1}$	1
$x'_{w1,f2,p2}$	1	$x'_{w1,f2,p3}$	1
$x'_{w1,f2,p4}$	1	$x'_{w3,f3,p1}$	0
$x'_{w4,f4,p1}$	0	$x'_{w4,f4,p3}$	1
$x'_{w4,f4,p4}$	1	$x'_{w5,f5,p1}$	1
$x'_{w5,f5,p1}$	1	-	-

Table 11 shows the output results of variable u'''_{ept}.

Table 11. Customers' demand for the products

	t_1	t_2	t_3	t_4
$e_1.p_1$	2400	2200	2200	1200
$e_1.p_2$	4300	2500	3400	1300
$e_2.p_3$	2800	3500	4100	2500
$e_3.p_1$	4200	1800	2700	2700
$e_4.p_2$	4300	2900	1800	3400
$e_5.p_1$	1800	3700	4900	1600
$e_5.p_3$	2100	2800	3300	2300

Table 12 discusses the sensitivity analysis considering the basic parameters of the model. In this table, X_1 is the sum of purchasing cost, X_2 is the sum of production cost, X_3 is the sum of shortage cost, X_4 is the sum of the transportation cost, X_5 is the sum of maintenance cost and X_6 is the sum of environmental cost. The results show that production costs have changed the most with increasing demand. Then the environmental cost has changed the most with the change in demand. Therefore, it is more important to pay attention to these two costs.

Table 12. The Results of Changes in Demand

	Primary data	**The secondary data With 10% increase**	**The secondary data With 20% increase**
x_1	35200000	38350000	41810000
x_2	90800000	99590000	11400000
x_3	12200000	13200000	14220000
x_4	65000000	68200000	74000000
x_5	11200000	11500000	12590000
x_6	55000000	33380000	36420000

6. Conclusion

A multilevel and multi product wood supply chain is proposed in this paper. The proposed supply chain consists of: suppliers, factories, retailers and customers. The main objective of this research is to minimize supply chain costs taking into account environmental effects. Therefore, the proposed model is solved by the genetic approach. The research results can be useful for environmental organizations, municipalities, chipboard and wood products factories. Also, minimizing environmental pollution can benefit all members of society. In addition, minimizing supply chain costs while minimizing the amount of postponed orders of the customer can satisfy factories and their customers. The results show that production costs have changed the most with increasing demand. Then the environmental cost has changed the most with the change in demand. Therefore, it is more important to pay attention to these two costs. The research innovations are as following:

1: Considering the Environmental Factors in Wood Supply Chain. Considering environmental costs is in a way that the objective function considers penalty costs for cutting the trees. Since the objective function is for cost reduction, this penalty leads to the

increase of objective function. Therefore, the model tries to consider lower wood weight for producing the products.

2: Considering four-level wood supply chain in closed loop supply chain. In this research, several suppliers, wholesalers, and retailers w used in four-level supply chain that were not used in previous studies

3: Solving closed loop logistics problem in large scale using Genetic Algorithm

The limitations of the paper are as follows: As there was no official database for some parts of cost elements, the driver's estimations were asked to help. The questions about the transportation costs for each route have been categorized and the estimated costs have been entered into the mathematical model. The proposed model for the Environment Organization applies to all jobs related to the production of wood products such as chipboard, tables and chairs, etc. It also benefits all members of society by reducing environmental pollution.

The further studies are suggested as follows:

- Considering the proposed model as a scenario and solving the proposed closed loop supply chain model using robust optimization
- Considering sustainability and resiliency in the proposed model
- Considering other objectives in the proposed model such as minimizing service-providing time and maximizing coverage level

References

[1] Auer, V., Rauch, P., Wood supply chain risks and risk mitigation strategies: *A systematic review focusing on the Northern hemisphere. Biomass and Bioenergy*, 148, 2021, 106001.

[2] Vitale, I., Dondo, R. G., González, M., Cóccola, M. E., Modelling and optimization of material flows in the wood pellet supply chain. *Applied Energy*, 313, 2022, 118776.

[3] Babaeinesami, A., Tohidi, H., Ghasemi, P., Goodarzian, F., Tirkolaee, E. B., A closed-loop supply chain configuration considering environmental impacts: a self-adaptive NSGA-II algorithm. *Applied Intelligence*, 2022, 1-19.

[4] Ghasemi, P., Goodarzian, F., Gunasekaran, A., Abraham, A., A bi-level mathematical model for logistic management considering the evolutionary game with environmental feedbacks. *The International Journal of Logistics Management*. 2021.

[5] Khanchehzarrin, S., Shahmizad, M., Mahdavi, I., Mahdavi-Amiri, N., Ghasemi, P., A model for the time dependent vehicle routing problem with time windows under traffic conditions with intelligent travel times. *RAIRO--Operations Research*, 2021.

[6] Demirel, N., Özceylan, E., Paksoy, T., Gökçen, H., A genetic algorithm approach for optimising a closed-loop supply chain network with crisp and fuzzy objectives. *International Journal of Production Research*, 52, 12, 2014, 3637-3664.

[7] Paksoy, T., Özceylan, E., Environmentally conscious optimization of supply chain networks. *Journal of the Operational Research Society*, 65, 6, 2014, 855-872.

[8] Abdolazimi, O., Shishebori, D., Goodarzian, F., Ghasemi, P., Appolloni, A., Designing a new mathematical model based on ABC analysis for inventory control

problem: A real case study. *RAIRO-Operations Research*, 55, 4, 2021, 2309-2335.

[9] Goli, A., Tirkolaee, E. B., Malmir, B., Bian, G. B., Sangaiah, A. K., A multi-objective invasive weed optimization algorithm for robust aggregate production planning under uncertain seasonal demand. *Computing*, 101, 6, 2019, 499-529.

[10] Shafipour-Omrani, B., Rashidi Komijan, A., Ghasemi, P., Ghasemzadeh, E., Babaeinesami, A., A simulation-optimization model for liquefied natural gas transportation considering product variety. *International Journal of Management Science and Engineering Management*, 16, 4, 2021, 279-289.

[11] Tirkolaee, E. B., Mardani, A., Dashtian, Z., Soltani, M., Weber, G. W., A novel hybrid method using fuzzy decision making and multi-objective programming for sustainable-reliable supplier selection in two-echelon supply chain design. *Journal of Cleaner Production*, 250, 2020, 119517.

[12] Ghasemi, P., Babaeinesami, A., Simulation of fire stations resources considering the downtime of machines: A case study. *Journal of Industrial Engineering and Management Studies*, 7, 1, 2020, 161-176.

[13] Tirkolaee, E. B., Goli, A., Weber, G.W., Fuzzy mathematical programming and self-adaptive artificial fish swarm algorithm for just-in-time energy-aware flow shop scheduling problem with outsourcing option. *IEEE transactions on fuzzy systems*, 28, 11, 2020, 2772-2783.

[14] Khalilzadeh, M., Ghasemi, P., Afrasiabi, A., Shakeri, H., Hybrid fuzzy MCDM and FMEA integrating with linear programming approach for the health and safety executive risks: a case study. *Journal of Modelling in Management*, 2021.

[15] Lotfi, R., Yadegari, Z., Hosseini, S. H., Khameneh, A. H., Tirkolaee, E. B., Weber, G.W., A robust time-cost-quality-energy-environment trade-off with resource-constrained in project management: A case study for a bridge construction project. *Journal of Industrial & Management Optimization*, 18, 1, 2022, 375.

[16] Mardanya, D., Maity, G., Kumar Roy, S., The multi-objective multi-item just-in-time transportation problem. *Optimization*, 2021, 1-32.

[17] Shafipour-omran, B., Khalili-Damghani, K., Ghasemi, P., Solving a supply chain problem using two approaches of fuzzy goal programming based on TOPSIS and fuzzy preference relations. *Journal of Industrial and Systems Engineering*, 13, 2, 2020, 27-48.

[18] Shaw, L., Das, S.K., Roy, S.K., Location-allocation problem for resource distribution under uncertainty in disaster relief operations. *Socio-Economic Planning Sciences,* 2022, 101232.

[19] Ghasemi, P., Khalili-Damghani, K., Hafezolkotob, A., Raissi, S., A decentralized supply chain planning model: a case study of hardboard industry. *The International Journal of Advanced Manufacturing Technology*, 93, 9, 2017, 3813-3836.

[20] Mondal, A., Roy, S. K., Midya, S., Intuitionistic fuzzy sustainable multi-objective multi-item multi-choice step fixed-charge solid transportation problem. *Journal of*

Ambient Intelligence and Humanized Computing, 2021, 1-25.

[21] Salehi-Amiri, A., Akbapour, N., Hajiaghaei-Keshteli, M., Gajpal, Y., Jabbarzadeh, A., Designing an effective two-stage, sustainable, and IoT based waste management system. *Renewable and Sustainable Energy Reviews*, 157, 2022, 112031.

[22] Salehi-Amiri, A., Zahedi, A., Gholian-Jouybari, F., Calvo, E. Z. R., Hajiaghaei-Keshteli, M., Designing a closed-loop supply chain network considering social factors; a case study on avocado industry. *Applied Mathematical Modelling*, 101, 2022, 600-631.

[23] Daneshdoost, F., Hajiaghaei-Keshteli, M., Sahin, R., Niroomand, S., Tabu Search Based Hybrid Meta-Heuristic Approaches for Schedule-Based Production Cost Minimization Problem for the Case of Cable Manufacturing Systems. *Informatica*, 2022, 1-24.

[24] Chouhan, V. K., Khan, S. H., Hajiaghaei-Keshteli, M., Sustainable planning and decision-making model for sugarcane mills considering environmental issues. *Journal of environmental management*, 303, 2022, 114252.

[25] Mondal, A., Roy, S.K., Multi-objective sustainable opened-and closed-loop supply chain under mixed uncertainty during COVID-19 pandemic situation. *Computers & Industrial Engineering*, 159, 2021, 107453.

[26] Midya, S., Kumar Roy, S., Wilhelm Weber, G., Fuzzy multiple objective fractional optimization in rough approximation and its aptness to the fixed-charge transportation problem. *RAIRO--Operations Research*, 2021, 55(3).

[27] Taleizadeh, A. A., Shahriari, M., Sana, S.S., Pricing and Coordination Strategies in a Dual Channel Supply Chain with Green Production under Cap and Trade Regulation. *Sustainability*, 13, 21, 2021, 12232.

[28] Barman, A., Das, R., De, P. K., Sana, S.S. Optimal pricing and greening strategy in a competitive green supply chain: Impact of government subsidy and tax policy. *Sustainability*, 13, 16, 2021, 9178.

[29] Rana, K., Singh, S. R., Saxena, N., Sana, S.S., Growing items inventory model for carbon emission under the permissible delay in payment with partially backlogging. *Green Finance*, 3, 2, 2021, 153-174.

[30] Sana, S. S., A structural mathematical model on two echelon supply chain system. *Annals of Operations Research*, 2021, 1-29.

[31] Salehi-Amiri, A., Zahedi, A., Akbapour, N., Hajiaghaei-Keshteli, M., Designing a sustainable closed-loop supply chain network for walnut industry. *Renewable and Sustainable Energy Reviews*, 141, 2021, 110821.

[32] Chouhan, V. K., Khan, S. H., Hajiaghaei-Keshteli, M., Metaheuristic approaches to design and address multi-echelon sugarcane closed-loop supply chain network. *Soft Computing*, 25, 16, 2021, 11377-11404.

[33] Mosallanezhad, B., Hajiaghaei-Keshteli, M., Triki, C., Shrimp closed-loop supply chain network design. *Soft Computing*, 25, 11, 2021, 7399-7422.

[34] Hamdi-Asl, A., Amoozad-Khalili, H., Tavakkoli-Moghaddam, R., Hajiaghaei-Keshteli, M., Toward sustainability in designing agricultural supply chain network: A case study on palm date. *Scientia Iranica*, 2021.

[35] Fasihi, M., Tavakkoli-Moghaddam, R., Najafi, S. E., Hajiaghaei, M., Optimizing a bi-objective multi-period fish closed-loop supply chain network design by three multi-objective meta-heuristic algorithms. *Scientia Iranica*, 2021.

[36] Mosallanezhad, B., Chouhan, V. K., Paydar, M. M., Hajiaghaei-Keshteli, M., Disaster relief supply chain design for personal protection equipment during the COVID-19 pandemic. *Applied Soft Computing*, 112, 2021, 107809.

[37] Mousavi, R., Salehi-Amiri, A., Zahedi, A., Hajiaghaei-Keshteli, M., Designing a supply chain network for blood decomposition by utilizing social and environmental factor. *Computers & Industrial Engineering*, 160, 2021, 107501.

[38] Zahedi, A., Salehi-Amiri, A., Hajiaghaei-Keshteli, M., Diabat, A., Designing a closed-loop supply chain network considering multi-task sales agencies and multi-mode transportation. *Soft Computing*, 25, 8, 2021, 6203-6235.

[39] Mahapatra, D. R., Panda, S., Sana, S.S., Multi-choice and stochastic programming for transportation problem involved in supply of foods and medicines to hospitals with consideration of logistic distribution. *RAIRO-Operations Research*, 54, 4, 2020, 1119-1132.

[40] Sana, S.S., Price competition between green and non green products under corporate social responsible firm. *Journal of Retailing and Consumer Services*, 55, 2020, 102118.

[41] Mirjalili, S., Genetic algorithm. In Evolutionary algorithms and neural networks , 2019, 43-55.

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