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# Genetic Algorithm-Based Optimization of Mass Customization Using Hyperledger Fabric Blockchain

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**Abstract:** With the developing technology, the production model, which is structured in line with user requests, has become a very popular topic. This production model, which expresses individualization, has become increasingly common. For this reason, it attracts the attention of many researchers and company executives. At this point, studies are concentrated on the concept of mass customization, which expresses personalized production. Considering the related studies, various difficulties are encountered in this production model on issues such as cooperation, trust, and optimization. In this proposed method, a blockchain-based platform is designed to solve the problems of cooperation and trust, one of the most important problems of mass customization. In addition, in this study, the problem of optimization of the production and supply chain process in the manufacturing sector has been examined. This process includes reaching from the producer to the consumer and many parameters. Therefore, the optimization of this process is a very difficult problem. A two-stage system has been proposed to find a solution to this problem. In the first stage, a reliable platform was created by bringing together service providers and buyers in the manufacturing sector with blockchain. In the second stage, the most suitable parties were selected by a genetic algorithm.

**Key words:** Blockchain, Smart Contract, Genetic Algorithm, Mass Customization.

## Hyperledger Fabric Blok Zincirini Kullanarak Kitlesel Özelleştirmenin Genetik Algoritma Tabanlı Optimizasyonu

**Öz:** Gelişen teknoloji ile birlikte kullanıcı istekleri doğrultusunda yapılandırılan üretim modeli oldukça popüler bir konu haline gelmiştir. Bireyselleşmeyi ifade eden bu üretim modeli giderek yaygınlaşmaktadır. Bu nedenle birçok araştırmacının ve şirket yöneticisinin ilgisini çekmektedir. Bu noktada, kişiselleştirilmiş üretimi ifade eden kitlesel özelleştirme kavramı üzerinde çalışmalar yoğunlaşmaktadır. İlgili çalışmalara bakıldığında bu üretim modelinde işbirliği, güven, optimizasyon gibi konularda çeşitli zorluklarla karşılaşılmaktadır. Önerilen bu yöntem de kitlesel özelleştirmenin en önemli sorunlarından işbirliği ve güven problemlerini çözmek için blok zincir tabanlı bir platform tasarlanmıştır. Ayrıca bu çalışmada imalat sektöründe üretim ve tedarik zinciri sürecinin optimizasyonu problem incelenmiştir. Bu süreç üreticiden tüketiciye ulaşmayı ve birçok parametreyi içermektedir. Bu nedenle, bu sürecin optimizasyonu çok zor bir problemdir. Bu soruna çözüm bulmak için iki aşamalı bir sistem önerilmiştir. İlk aşamada blockchain ile imalat sektöründe hizmet verenler ve alıcılar bir araya getirilerek güvenilir bir platform oluşturulmuştur. Daha sonra ikinci aşamada, genetik algoritma ile en uygun taraflar seçilmiştir.

**Anahtar kelimeler:** Blockchain, Akıllı Sözleşme, Genetik Algoritma, Kitlesel Özelleştirme.

## 1. Introduction

With the developing technology, it is seen that traditional production models have been replaced by sectors that act in line with consumer demands and expectations [1–4]. Meeting consumer demands in optimum conditions and thus ensuring consumer satisfaction is the key to the success of the company. In customer-oriented production models, intersectoral studies provide higher efficiency. Therefore, there is a need for a cross-sectoral collaborative platform in today's customization paradigm. It is seen that the manufacturing sector is experiencing a transition from centralized production to decentralized production on a global scale [5]. In collaborative production models in the industry, it means that stakeholders are/will carry out dynamic interactions and transactions. However, many difficulties are encountered in the transition of the stakeholders serving in the sector to the collaborative customization production model (for example, price fluctuation, product diversity, consumer participation,

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production flexibility, etc.) [6,7]. With mass customization (MC), increasing demand, costs, and lead-time complexities increase. Consistent approaches are required when designing the product to ensure consumer demands, minimize cost and shorten lead time [8–10].

Blockchain, which has been very popular recently, offers a transparent, cryptographic, and reliable platform where consensus independent from authority is ensured with its decentralized structure [11–13]. It also enables shareholders to make decisions and set rules together in a commercial environment where trust is extremely important. It is anticipated that this new system will serve the market in many ways, with its feature that increases competition and provides a consensus protocol [14–16]. In traditional centralized customizations, the available resources of the producers are defined and the consumers choose them in line with their needs [17–19]. In this case, optimum consumer-producer matching does not occur. The proposed method is aimed to ensure that the stakeholder materials defined on a decentralized platform are matched to the user requirements at the optimum level. Another disadvantage of traditional methods is that consumer needs are obtained through surveys. With this proposed study, it is ensured that those who serve on a platform where consumer needs are met with blockchain can make inferences about the demands.

This study, it is aimed to carry out the optimum ordering process. There are various studies on supply chain scheduling optimization in MC in the literature. In the proposed models, it is seen that one or more objective functions are usually specified. It is aimed to minimize cost and maximize service level [20–22]. However, as far as we know, there is no study in the literature on the optimization of both the supply process and the production process. The problem we should be most concerned with here is the planning optimization from the production process to the supply chain in MC. Unlike the supply chain scheduling process, the scheduling process in MC contains complex parameters. In this research, a two-stage distribution network including multiple suppliers, manufacturers, retailers, and distributors is designed. It is aimed to provide optimum timing and service. The first stage is aimed to find the optimum manufacturer, supplier, retailer, and distributor. In the second stage, it is investigated whether these stakeholders will meet the requirements of the product created by the consumer. At this stage, it is ensured that optimum stakeholders work together on a common platform through the blockchain. The resulting multi-objective integer programming cannot be solved by exact methods [23]. Therefore, a multi-objective genetic algorithm is used to solve this problem.

The contribution of this research is the proposal of a consortium blockchain-based system in which the cooperation of mass customization actors in the manufacturing sector is ensured. A platform where all actors and consumers in the supply chain are registered is used in the system. It is aimed to ensure the optimum selection of service (supplier, producer, distributor…) and service-receiving (consumer) actors with genetic algorithms and to bring collaborators together. In this study, in which the consumer-oriented production model is adopted, optimization and blockchain integration is aimed. The remainder of the article is organized as follows. In Section 2, the theoretical background is given about the topics used in the proposed study. The proposed method is presented in Section 3. In Section 4, the results of the proposed method are given.

## 2. Theoretical Background

### 1.1. Genetic algorithm

The genetic algorithm (GA), first introduced by Holland in 1975, is a group computational process model. With this algorithm, an optimal solution to a particular problem is sought, inspired by the survival principle of chromosomes. Figure 1 shows the steps of the GA. In this method, a random population consisting of sequences of numbers is first created. This population consists of individuals, individuals from chromosomes, and chromosomes from genes. Then, the population is subjected to the determined fitness function, and fitness results close to the optimal solution are determined. It consists of three stages: selection, crossover, and mutation. In the selection process, the parent individual is selected according to the fitness values of the individuals in the population. In the crossover process, certain parts of the parent individuals obtained by the selection process are replaced. In this way, individuals with new characteristics that are not in the population are obtained. In the mutation process, any gene of the newly formed individual is subjected to the process of changing [23–25].

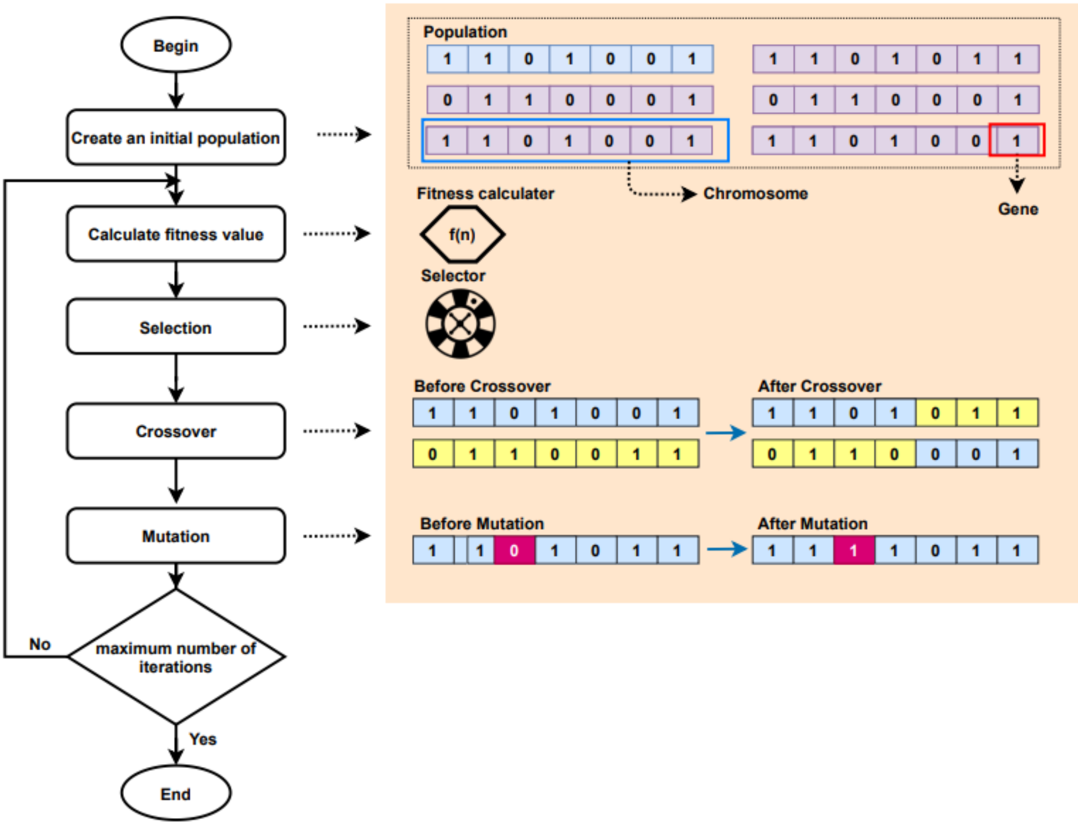


**Figure 1.** Genetic algorithm

### 1.2. Genetic algorithm in the manufacturing industry

With the widespread use of the MC-based production model, global production has shifted from traditional offline platforms to online platforms [26]. While product production is carried out from a single point in traditional platforms, it is carried out from independent points in service-oriented production models. By creating an online platform, service providers can work together under a single roof. With new generation technologies, the online participation of customers in the production process can be ensured [27] . In addition, models of product production can be developed collaboratively by service providers and customers. Consumer demands are at the forefront when producing personalized products. Meeting various customized product requirements complicates production processes. The process, which is complicated in an online production model, can be optimized with a GA and suitable solutions can be obtained.

MC in the manufacturing industry is a typical NP-Hard problem. The solution set created by the join process grows exponentially. Therefore, high-performance production models that meet customer demands are a challenging problem for academic and industry researchers [28]. In addition, timing problems in the production process reveal a very complex structure. GA is widely used in task scheduling strategies research. In a study in the literature, optimization was presented in terms of determining task completion and transmission times as a timing strategy. The simulation results proved the efficiency of the algorithm [29]. There are two objective functions in a proposed study. The first is aimed at optimizing transportation, holding, and purchasing costs. Transport costs increase in direct proportion as the distance increases. In this function, the aim is to solve the minimum cost with minimum distance. The other objective function, is to ensure that the products are produced with minimum cost. For this purpose, the optimum solution will be found at the shortest distance and in the case of the minimum bid. During planning, a mathematical model was created to determine the amount of product that needs to be shipped between two locations [23].

## 3. Blockchain Application Proposed for Mass Customization

In general, the manufacturing sector is divided into two categories: service recipients and service providers. Service recipients can be users, while a manufacturer who can request raw materials can also be service recipients. Service providers are actors such as manufacturers, suppliers, and retailers in general. The production and supply process has a very important place in the manufacturing sector. Therefore, the optimization of these processes is critical in terms of efficiency. In this study, a proposal has been made to realize an optimum process. For this purpose, as seen in Figure 2, information such as raw material, retail support, and distribution support are recorded on the platform. In addition, customer requests are received over the blockchain. In line with this information, it is aimed to produce an optimum process by using GA. Then, the service providers registered in the blockchain are selected with the help of this optimum solution process result.

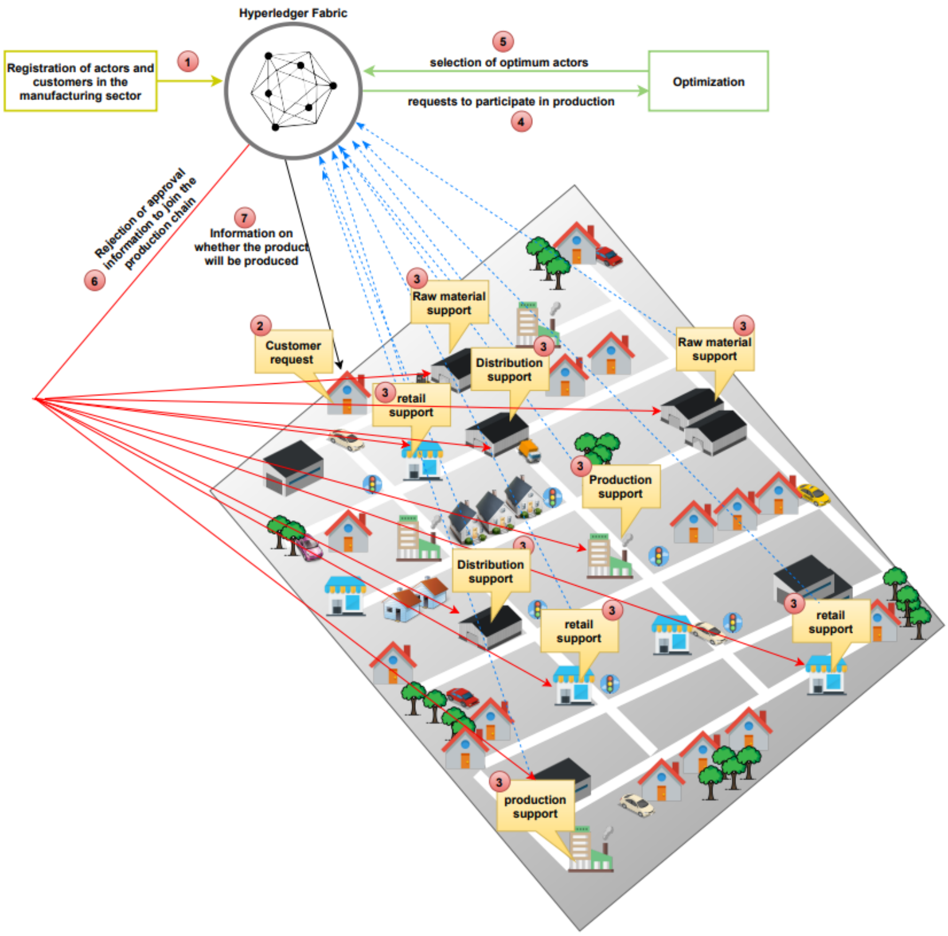


**Figure 2**. Proposed method

It is seen that companies with similar policies tend to do more business with each other. In addition, there are various difficulties in communication to ensure cooperation. This means that there is a need for an environment that will bring actors together to do a common business and implement the same policy. For this purpose, blockchain technology, which offers a traceable and reliable common environment, is proposed in this study. With the smart contract feature, a platform is offered where actors can create common rules where they can unite on a common denominator.

### 3.1. Multihost deployment

The proposed method accommodates multiple users. Therefore, as shown in Figure 3, a 4-organization network design is first simulated on a virtual machine. The connection between the channel in the created system and these organizations is provided. With this channel, the business logic in the smart contract will be distributed. Raft algorithm was used as the consensus algorithm and 3 orderers were defined. The structure of the organizations is the same, and a single peer is suggested as both anchor and committing peers. It has the couch database, which is a peer status database, and smart contracts. A certificate authority is defined for each organization and orderer service. The Docker Swarm network will enable organizations in the virtual machine to communicate effectively with each other. As seen in the registry, smart contracts, and certificates are defined on each machine. Organizations can perform workflows, queries, and transactions defined in smart contracts with the help of the channel.

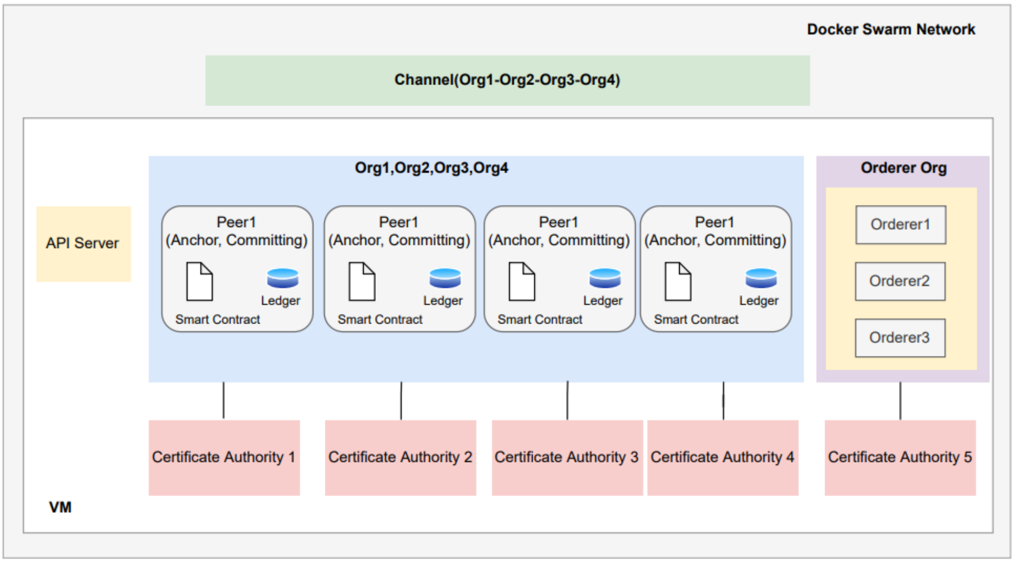


**Figure 3.** Virtual machine and network settings

As can be seen in Figure 4, crypto materials must be created for all participants. Certificate authority services should be run for all organizations. In Hyperledger Fabric, each organization is represented by a Membership Service Provider. MSP is the Hyperledger Fabric component that defines the membership processes of the participants.

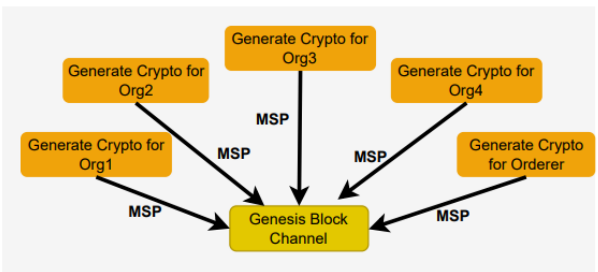


**Figure 4.** Creation of Crypto materials for organizations

Verification of each organization's identity and signature is required for MSP configuration. For this purpose, the authentication process and the boot of the network must be performed.

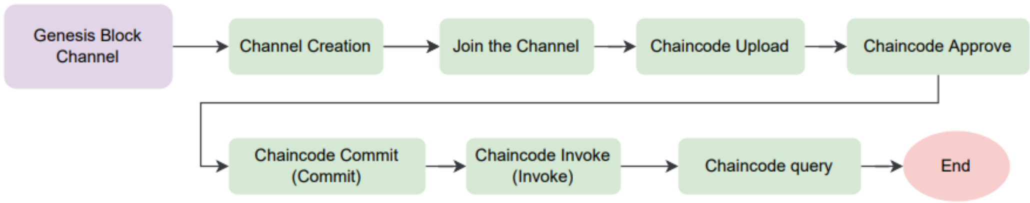


**Figure 5.** Channel creation and chaincode operations

As can be seen in Figure 5, the genesis block must be created first. Afterward, the channel is created and the participation of the participants is ensured. Participants must have the same organization. Thus, unauthorized access from outside is prevented. After the channel is created and the participants are defined to the channel, the chain code is uploaded to each participant. The uploaded chain code is submitted for the approval of the participants. Each participant must approve and commit. Then the chain is activated by calling the code. Finally, a query is made on the chain code, and the transactions in this section are terminated.

### 3.2. Mathematical model and optimization of supply chain

In the production sector, where the competitive environment is developing, producing in line with user requests provides an important advantage. In addition, it is an important factor that suppliers deliver the product in the right quantity, at the right time, and to the right place [30]. Products are temporarily stored before being delivered to warehouses. Considering the capacity constraints of warehouses, it is of great importance to have a system where they can buy the required amount of goods on time. The warehouses of suppliers and retailers have limitations on capacity, holding, and delivery capacities [11,31–34].

After the product enters the production process, it is included in the procurement process shown in Figure 6. First, the supplier provides the raw material guarantee for the product. It then manufactures the product for the manufacturer. The product produced is bought by the retailer. The received product is sent to the distributor for distribution. Finally, the distributor delivers the product to the customer.

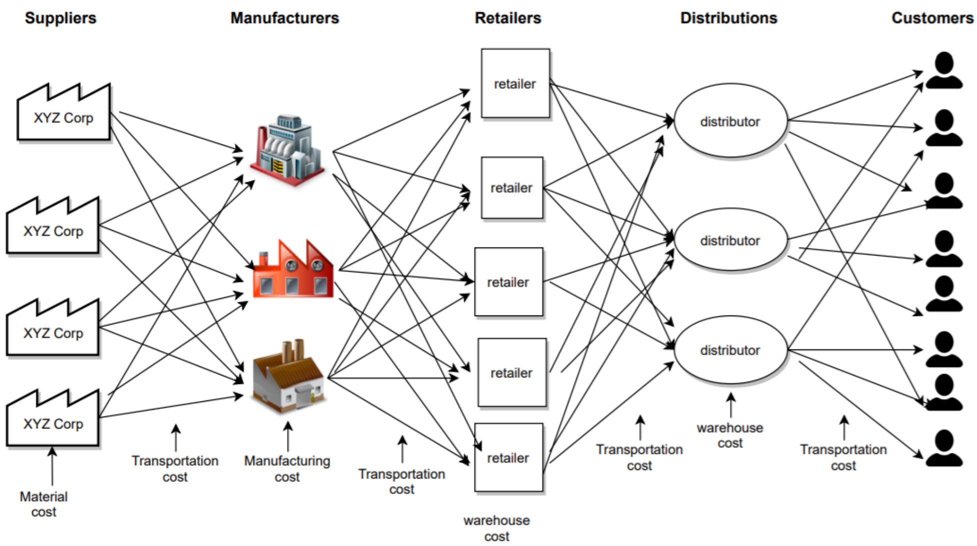


**Figure 6.** Product supply chain

As seen in Table 1, costs are encountered during the product supply and production process. This proposed study, it is aimed to minimize these costs. This table contains explanations of the equation parameters to be used in the optimization process. The parties, product, and number of parties in MCare defined. In addition, transportation, holding, supply, and production costs are specified.

**Table 1.** Explanations of model assumption, indexes, and parameters

| Parameters | Explanations | |
|---|---|---|
| $z$ | The customer index | z=1,2……..Z |
| $i$ | The supplier index | $i$=1,2,……I |
| $j$ | The producer index | j=1,2,……J |
| $k$ | The retailer index | k=1,2,……….K |
| $l$ | The distributer index | l=1,2,………..L |
| p | The product index | p=1,2,……P |
| t | The period index | t=1,2,……T |
| w | The raw materiels index | w=1,2…..W |
| Z | Total number of customers | |
| I | Total number of suppliers | |
| J | Total number of producers | |
| K | Total number of retails | |
| L | Total number of distributors | |
| P | Total number of products | |
| T | Total number of periods | |
| W | Total number of raw materials | |
| $a_{ijp}$ | Cost of transporting product p from supplier i to producer j | Approach 1 |
| $b_{jkp}$ | Cost of transporting product p from producer j to retailer k | |
| $c_{klp}$ | Cost of transporting product p from retailer k to distributor l | |
| $x_{kzp}$ | Cost of transporting product p from distributor l to customer z | |
| $s_{ipw}$ | Cost of raw material procurement w of product p of supplier i | Approach 2 |
| $f_{jp}$ | Cost of producer j to produce product p | |
| $g_{kpt}$ | The cost of k retailers to hold product p in period t | Approach 3 |
| $q_{lpt}$ | The cost of distributor l of hold product p in period t | |
| $d_{ijpt}$ | Time to move product p from supplier i to producer j | Approach 4 |
| $e_{jkpt}$ | Time to move product p from producer j to retail k | |
| $f_{klpt}$ | Time to move product p from retailer k to distributor l | |
| $o_{lzpt}$ | Time to move product p from distributor l to customer z | |
| $y_{pijt}$ | The amount of product p transported from supplier i to producer j in period t | Approach 5 |
| $u_{pjkt}$ | The amount of product p transported from producer j to retailer k in period t | |
| $h_{pklt}$ | The amount of product p transported from retailer k to distributor l in period t | |

In this proposed method, the values of $F_1, F_2, F_{3,}$ and $F_4$ in equations (1), (2), (3), and (4) represent transportation cost, supply cost, holding cost, and production time. That is, they are fitness functions to find service providers that will meet the minimum level. $F_1, F_2, F_{3,}$ and $F_4$ values are calculated with the fitness function offered by the GA and it is aimed to find the optimum values. Since the value of $F_5$ in equation (5) expresses the amount of product transport, the maximum transport situation will make the system more efficient.

**Approach 1**

The values of $F_1$, in equation (1) represent transportation costs. This equation, it is aimed to find the minimum shipping cost. It covers the transportation process from the procurement process to the customer. For this purpose, optimum 4 transportation costs are calculated.

$$\text{Min } F_1 = a_{ijp} + b_{jkp} + c_{klp} + x_{kzp} \quad (1)$$

**Approach 2**

The values of $F_2$, in equation (2) represent the supply cost. The aim is to adjust the raw material and production cost of the product to be produced to a minimum.

$$\text{Min } F_2 = s_{ipw} + f_{jp} \quad (2)$$

**Approach 3**

The values of $F_3$, in equation (3) represent the holding cost. The aim is to ensure that the holding cost of the product is minimal. Therefore, it is aimed to choose optimum parties with low holding costs.

$$\text{Min } F_3 = g_{kpt} + q_{lpt} \quad (3)$$

**Approach 4**

The values of $F_4$, in equation (4) represent the production time. The aim is to keep the shipping time of the product to a minimum. For this reason, parties that will provide quick access are selected.

$$\text{Min } F_4 = d_{ijpt} + e_{jkpt} + f_{klpt} + o_{lzpt} \quad (4)$$

**Approach 5**

The values of $F_5$, in equation (5) represent the amount of product. In this equation, the aim is to select the optimum sides that will ensure maximum product transport.

$$\text{Max } F_5 = y_{pijt} + u_{pjkt} + h_{pklt} \quad (5)$$

This proposed study, it is aimed to bring together the parties in a collaborative working group under optimum conditions. The optimization methodology of the GA was examined and its compatibility with the blockchain was reviewed. In addition, this study, it is aimed to minimize the costs and time with the optimum solution provided by the GA. It refers to a large-scale problem such as the supply chain. Therefore, the combination of blockchain and supply chain is designed with a multi-objective GA.

## 4. Conclusion

In this proposed study, the problems encountered in the production and supply chain process in the manufacturing sector are examined and a solution-oriented approach to these problems is presented. In addition, the shortcomings of MC in the literature were investigated. When the studies in the literature are examined, it is understood that one of the biggest obstacles to the realization of MC is cooperation and trust. At this point, blockchain will bring the parties together, cooperate and provide security with its cryptological structure. For this purpose, the Hyperledger Fabric blockchain used in business networks was used. Thus, it was aimed to create a platform with common policies. Another problem with MC is optimization in the purchasing process. For this purpose, it is aimed to select the most optimal parties among the parties brought together with the blockchain. In this study, in which a GA, which is one of the optimization methods, was used, more than one objective function was defined and a solution was sought for a difficult problem such as the supply chain. As far as we know, there is no study in the literature covering the production process and supply process. With this method we recommend, that the process of a product from raw material supply to its delivery to the customer has been defined and optimum results have been tried to be found. This work is a recommendation and has some shortcomings in the case of a real-time application. For example, the parameters in the supply chain are very diverse and this study is based on basic parameters. The feasibility of MC is not impossible, but it is difficult and involves many parameters. In addition, companies are cautious as blockchain is a new technology. Future works, it is aimed to design the necessary layers, smart contracts, and network models for a Hyperledger-based application.

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