LogForum

> Scientific Journal of Logistics <

2023, 19 (4), 515-533

http://doi.org/10.17270/J.LOG.2023.930

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

CIRCULAR SUPPLY CHAIN MANAGEMENT WITH BLOCKCHAIN INTEGRATION

Bui Minh Hau[1], Sam-Sang You[2], Gyu-Sung Cho[3], Jeong-Hum Yeon[4], Hwan-Seong Kim[1]

1. Department of Logistics, Korea Maritime and Ocean University, Yeongdo-gu, Busan, **Republic of Korea**
2. Northeast-Asia Shipping and Port Logistics Research Center, Korea Maritime and Ocean University, Yeongdo-gu, Busan, **Republic of Korea**
3. Department of Port Logistics System, Tongmyong University, Nam-gu, Busan, **Republic of Korea**
4. R&D Department, Busan Port Authority, Daegyo-ro, Jung-gu, Busan, **Republic of Korea**

ABSTRACT. Background: Circular supply chain management encourages manufacturers to take advantage of used materials and industrial wastes, ensuring social and economic benefits of enhanced environmental sustainability in production. With the development of digital technologies, transactions can be recorded within distributed or decentralized ledger technology. To improve the reliability of digital transactions on the internet, manufacturers need to apply security software such as blockchain technology across a network. Blockchain technology in the supply chains brings transparency, traceability, and security to online transactions, increasing customer attractiveness to the used product and recycling process. Secure transactions might bring significant benefits to the future of the retail industry. The manufacturer exploits the retailer as an online store. Consumers access an online store for purchase, return, and comment on the manufacturer's products.

Methods: This research presents a novel meta-heuristic algorithm, specifically, adaptive particle swarm optimization (adaptive PSO), to determine the optimal policy for product price and quantity of materials imported from suppliers for maximizing total profits with sustainability. The adaptive PSO algorithm evaluates the fitness function involving discrete random variables. The supply chain model captures realistic conditions by considering the inherent uncertainties of customer demand. Two scenarios in business settings have been tested on the same customer demand. The proposed framework is intended to yield a more sustainable, resilient, and regenerative system, securing the data of the shared community.

Results: The swarm intelligence algorithm implements profit optimization to determine the unit price of the product and the number of materials to be imported. The numerical experiments are conducted to demonstrate the efficacy of the optimal strategy and to evaluate the effect of the number of used products returned to the recycling center. An effective circular supply chain management is realized based on a secure database shared across a network of participants. Key findings significantly contribute to the intelligent decision support system for optimizing inventory management under various stochastic scenarios.

Conclusions: Sharing, reusing, repairing, and remanufacturing help companies transition to a circular economy, minimize waste, diversify sources of supply, and maintain production continuity. Transactions on the blockchain framework become transparent and traceable. Based on the circular economy and blockchain platform, this study deals with an adaptive particle swarm optimization algorithm (APSO) to determine the optimal policy for product unit price and quantity of materials imported from suppliers to maximize total profits. The presented methodology can provide better supply chain visibility and traceability under highly realistic stochastic environments.

Keywords: Supply chain management, circular economy, blockchain technology, inventory management, particle swarm optimization

INTRODUCTION

Supply chain management has long been an important business activity in controlling the source of raw materials, the production rate, the inventory level, and the unit price of products. One of the ways to optimize profits is to manage consumer demand, which is typically unpredictable or volatile in a fluctuating market. Lin et al. [2021] evaluated the optimal number of buyers based on the Markov chain demand. In

Citation: *Hau B.M., You S., Cho G., Yeon J., Kim H., 2023. Circular supply chain management with blockchain integration. LogForum 19 (4), 515-533,* http://doi.org/10.17270/J.LOG.2023.930

Received: 06.10.2023, Accepted: 05.11.2023, on-line: 10.12.2023

addition, adjusting product prices can also significantly impact profits. Kumar Jena et al. [2023] presented the pricing decision for optimizing competitive, sustainable processes in the digital supply chain. Asghari et al. [2022] proposed a closed-loop supply chain based on the pricing strategy. There is a growing awareness of environmental care in supply chains. The circular supply chain system is a dynamic model in a transition towards a sustainable economy, ensuring a more restorative and regenerative economy. This will help the supply chains to leverage the used materials to improve resource efficiency. The issues of growing importance include improving resource productivity, reducing waste, and maintaining sustainable practices. In supply chain management, environmental issues typically occur along with the production cycle, manufacturing practices, raw material handling, waste treatment, etc.

Scarcity and supplies of resources are now becoming the industry's biggest problem, especially after the COVID-19 pandemic and wars. Transportation delays have become more common due to centralized bans or blockade policies imposed by nations. To avoid interruptions in the production line, manufacturers must diversify sources of raw materials and methods of trading products. One of the ways to give manufacturers an additional source of raw materials and attract more customers is to adopt a recycling policy to collect used products or materials from customers and recycle them into usable raw materials. Waste can be transformed into high-quality secondary raw materials for making new products. The continual reuse of recycled materials in manufacturing is a part of the circular economy and is considered a vital strategy for supply chain innovation. Ghoushchi et al. [2021] proposed optimizing a multi-stage-multi-product closed-loop supply chain (CLSC) from a circular economy perspective. Sarkar et al. [2022] presented the nullification of food waste produced in the circular economy-driven two-stage supply chain model. The utilization of used products is the foundation for sustainable development. Between 2010 and 2020, approximately 131 articles were published on inventory management in the context of supply chain sustainability [Salas-Navarro et al. 2022]. With future trends in the shipping industry and the popularity of e-commerce platforms, customers can buy products online without visiting a physical store. Customers can easily search for products and check reviews or distribution information online. Digital online shopping boomed during the COVID-19 crisis. Maritime transport has played an essential role in response to the coronavirus pandemic and significantly contributed to world economic growth. Import and export ports worldwide are gradually developing in the direction of automation and port digitalization through IoT systems and management software. However, cyber-attacks are more widespread than ever before. An online transaction always comes with fraud risks due to inherent security susceptibility. Some malicious actors might steal transaction information.

Blockchain technology can help participants protect digital information from unauthorized access to ensure efficient supply chain management. This technique allows secure data transmission, based on a highly complex encryption system, which is similar to a company's accounting ledger, where banking information is closely monitored and recorded in all transactions on the peer-to-peer network. Blockchain technology is based on two main components: block and chain. The block is the place where data is entered into the system. The chain is a link that connects data blocks and has two heads. One is associated with a previous block by one hash code, and the other fuses with a current block by the same hash code. Data stored on the blockchain is digitally distributed to every node linked in the system, and the blockchain also works on the decentralized consensus mechanism. The shared information makes the data in the blockchain impossible to alter because it is also recorded in many different databases. When a database changes, the system will compare it with other databases to detect that change. With the emergence of cryptocurrencies, blockchain technology has been applied to many fields. Chinnaraj and Antonidoss [2022] proposed a methodology to develop intelligent secured inventory management, using blockchain technology. The applications and challenges of using blockchain technology in the maritime supply chain are presented by Liu et al. [2021]. In the circular economy-driven supply chain management by Ma and Hu [2022], the blockchain platform can solve some bottleneck problems that strictly affect the recycling of waste products. In addition to security issues, blockchain can impact the operating costs of a specific sector. Ho and Hsu [2020] analyzed the importance of critical factors in shipping companies with the effect of blockchain technology. These factors can impact the costs and level of risks. Park and Li [2021] proved that blockchain technology might bring supply chain sustainability.

This article employs blockchain technology to ensure supply chain transparency and traceability through a digitally distributed ledger. A new platform can potentially increase the customer's interest in products. In addition, the information in the blockchain supply chain, such as the shipping processes, the origin of raw materials, how to handle used products, customer contributions when returning used products, and manufacturer's policies, are shared with customers when customers make a purchase or return products that are no longer needed after use to the manufacturer. The customer will receive a discount voucher for each returned used product for the next purchase. Some scholars also mentioned the relationship between incentives and used product returns in the logistics and supply chain management (SCM) research field. Asghari et al. [2014] studied the relationship between incentive and product return in the reverse logistics network. Aras and Aksen [2008] proposed a nonlinear mixed-integer programming model for optimizing the facility allocation problem and the inventive values for each type of product return. However, previous studies only dealt with the relationship between incentives and product re-turns without considering factors such as recycling used products or the effect of the number of materials or products imported from outside.

The measure of profit the manufacturer can achieve comes from the difference between revenue and incurred costs. The economic Order Quantity (EOQ) model assesses supply chain costs through the number of raw materials imported from the supplier and the amount of inventory held by the manufacturer. Typical costs in the EOQ model are carrying (holding) costs and ordering costs. It is a measurement used in operations, logistics, and supply management. However, this paper will consider an additional recycling cost to represent the waste from recycling used products in the circular economy framework. Ouyang et al. [2005] used the EOQ model to evaluate the costs in the deteriorating inventory model under trade credits. Li et al. [2015] combined the Hamilton-Jacobi-Bellman equation and the EOQ cost policy to optimize the profit in the stochastic inventory model.

This paper does not consider a specific product but focuses on building a circular supply chain model for generic items under the influence of blockchain technology. Online stores could replace retailers, and at the same time, every transaction would be made within a blockchain framework. From information stored and shared by blockchain technology, customers can trace the origin of raw materials, production lines, discount information, and the purpose of recycling used products.

This paper aims to realize the optimal strategy for product price and the number of raw materials ordered from the supplier in the circular economy and the blockchain framework. The methodology used in this paper is the particle swarm optimization algorithm (PSO), a popular meta-heuristic strategy used for higher-level optimization problems. This swarm intelligence is applied to determine the optimal reorder point of a stochastic supply chain [2013]. The algorithm is also employed to optimize inventory total costs [2020]. Sometimes, this algorithm might get stuck at the local optimal point and take time to converge at the global optimal point. The adaptive PSO algorithm is an advanced version with adjusting parameters to achieve better optimal results and faster convergence. Zhan et al. [2009] introduced the APSO algorithm, adjusting inertia weights and control strategy for the acceleration coefficients to improve search efficiency. Most businesses are keen to put the theories into practice using the circular economy and blockchain framework. In this study, the novel decision-making strategy can offer new insights into effectively managing digital supply chain networks against market volatility. The key contributions of this paper are described as follows:

- Based on transaction information shared through blockchain technology, this work considers the customer demand or

the raw material price affected by activities in the supply chains.
- The inventory model considers economic factors of production and consumption for eliminating waste and pollution, circulating products and materials, and regenerating nature.
- Circular supply chain dynamics are formulated under decentralized ledger technology.
- The swarm intelligence algorithm implements profit optimization to determine the unit price of the product and the number of materials to be imported.
- Numerical experiments are presented to validate the circular supply chain management, considering changes in the number of used products returned to the recycling center.

More importantly, the presented algorithms are robust and effective, linking a firm's *supply chain* strategy to its overall business strategy in a volatile market.

This paper is organized as follows. Section 2 discusses a literature review of relevant studies. Section 3 presents the circular supply chain model from a blockchain perspective. Section 4 introduces the APSO algorithm to find the optimal unit price and the number of materials needed to order from the supplier to maximize the total profit. Section 5 shows the numerical experiment to demonstrate the efficiency of the proposed approach. Section 6 presents the discussion with managerial insights. Finally, the conclusion is given in Section 7.

LITERATURE REVIEW OF RELEVANT RESEARCH

The circular supply chain system is a dynamic model that uses excess materials, waste, and used products as raw materials in production processes [Ghoushchi et al. 2021; Sarkar et al. 2022]. In the context of raw materials or resources becoming increasingly scarce and more expensive, the transition to circularity in the supply chain is essential, benefiting from high material and component recovery rates. It saves the environment and helps the company save money, providing a source of raw materials for production. Especially after the COVID-19 pandemic and recent wars, many enterprises are focused on a circular economy or sharing economy. During the pandemic, some countries issued blockade orders, the global supply chain became stagnant, and some factories couldn't get raw materials or workers for production. Atabaki et al. [2020] presented an optimal approach for a circular supply chain considering the costs associated with emissions, energy, and recovery facilities. Suhandi and Chen [2023] studied inventory optimization problems in the circular supply chain for the pharmaceutical market.

Along with the importance of the circular economy, digital technology is constantly evolving. Online payments via the internet have become popular along with decentralized and distributed databases—typically blockchain technology. The application of blockchain can bring many incredible benefits to supply chain networks, such as security, transparency, and traceability in digital transactions [Liu et al. 2021; Park and Li 2021]. Blockchain technology can further improve supply chain sustainability [Park and Li 2021]. Saurabh and Dey [2021] studied blockchain technology in the wine supply chain, such as implementing costs and ensuring product reliability and traceability. Blockchain technology is integrated into an e-commerce business, advancing digital transformation [Ma and Hu 2022]. Pakseresht et al. [2022] specified four significant areas of applying blockchain technology to the circular food supply chain system. Giovanni [2022] analyzed the critical benefits of blockchain technology in application to the circular supply chain model.

There are many ways to optimize supply chain networks. Manufacturers can use the Internet of Things (IoTs) and high-tech devices to optimize the supply chain [Saurabh and Dey 2021]. Govindan et al. [2023] analyzed routes for circular economy supply chains under the constraints of carbon tax policy. In addition, manufacturers can proactively consider effective inventory management to establish the desired profit [Asghari et al. 2022; Sarkar et al. 2022]. The firm's goal is to maximize profits by minimizing costs in inventory management. The EOQ model is commonly used to determine the most economical number of items a business should order to reduce costs [Ouyang et al. 2005; Li et al. 2015].

Recently, many papers have presented a supply chain model with blockchain technology or circular economy framework. Table 1 describes the similarities and differences of the developed model with other publications on similar topics. Motivated by the research gap from the literature review, this paper focuses on building a circular economy supply chain model under the influence of blockchain technology and optimizing manufacturers' profits.

Table 1. Recent studies of circular supply chain model with blockchain technology

Article	Circular Economy	Blockchain Technology	Inventory Model	Customer Factors	Solution Method	Key Findings
Chinnaraj and Antonidoss [2021]	No	Yes	Yes	No	Average fitness-based colliding bodies optimization	Optimal inventory management in a secure manner under the cloud sector
Liu et al. [2021]	No	Yes	No	No	Systematic literature analysis	Construction of a blockchain-based maritime supply chain system
Ma and Hu [2022]	Yes	Yes	No	No	Algebraic procedure	Integration of blockchain and sales format in an internet-based platform
Park and Li [2021]	No	Yes	Yes	No	Systematic literature analysis	Application of blockchain technology in sustainable supply chain
Ghoushchi et al. [2021]	Yes	No	Yes	No	Epsilon-constrained method	Strategies of economic order to the suppliers and third-party companies
Sarkar et al. [2022]	Yes	No	Yes	No	Algebraic procedure	Reducing carbon emissions and total costs
Atabaki et al. [2020]	Yes	No	Yes	No	Possibilistic programming approach	Strategic, tactical, and operational decisions in the supply chain network
Suhandi and Chen [2023]	Yes	No	Yes	Yes	A generalized reduced gradient algorithm	Feasibility of the drug recycling program
Saurabh and Dey [2021]	No	Yes	No	No	Conjoint value analysis	Adoption factors for the wine supply chain
Pakseresht et al. [2022]	Yes	Yes	Yes	No	Statistical analysis	Key factors for blockchain-based food supply chain model
Giovanni [2022]	Yes	Yes	Yes	Yes	Structural equation modeling and least squares-path modeling	Blockchain makes supply chains transparent and traceable
Govindan et al. [2023]	Yes	No	No	No	Epsilon-constrained method	Reducing transport emissions and vehicle waiting time
Our work	Yes	Yes	Yes	Yes	Adaptive particle swarm optimization	An optimal strategy for product price and the number of raw materials ordered from the supplier in the circular supply chains under the blockchain framework

PROBLEM FORMULATIONS AND DYNAMIC MODELING

The circular economy research field and a sustainable business strategy are evolving rapidly. Since all companies have finite resources, the reuse and recycling of materials help companies make their production line always have resources available for production, ensuring sustainability. The manufacturer might use an online store to trade products with the shipping company. The online store lets customers contact the manufacturer's customer service directly and quickly. Customers only need to notify the exchange on the online store, and the manufacturer will plan and implement the exchange as soon as possible. Shipping information will also be available online through a partnership between the carrier and the manufacturer. Apart from the production line, the manufacturer might also open a recycling center to receive the used products of customers and conduct product analysis to retrieve reusable parts for the next production. The manufacturer can get materials for production from the supplier and the recycling center. Figure 1 describes the circular supply chain model for reserving resources by reducing, reusing, and recycling.

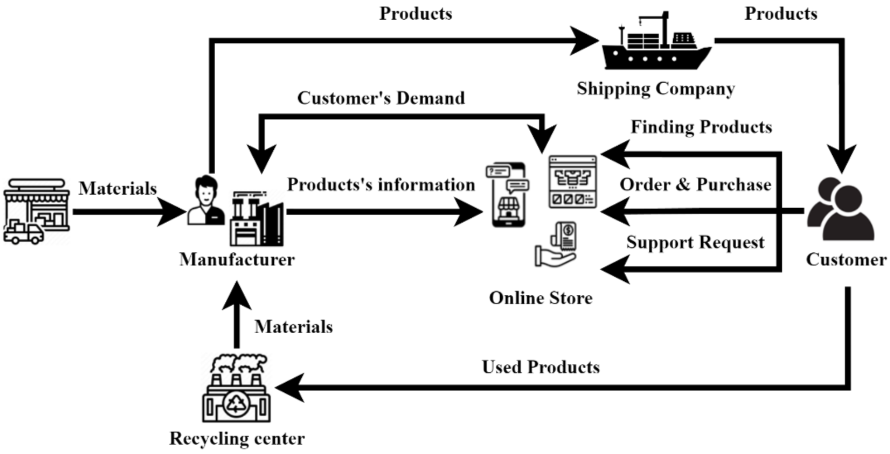


Fig. 1. Circular economy adoption in supply chain management

In addition, the supply chain model employs blockchain technology to ensure the safety and visibility of online transactions. Transactions on the blockchain framework become transparent and traceable as transaction data is stored and distributed across supply chain network participants. The implementation of blockchain technology will give customers a sense of security. Besides that, the origin of the materials that make up the products can also be easy to check. Also, the transparency in the blockchain supply chains helps manufacturers, suppliers, or carriers to check the estimated shipping times. As described in Figure 2, promising blockchain technology can offer possible applications related to operations and supply chain management.

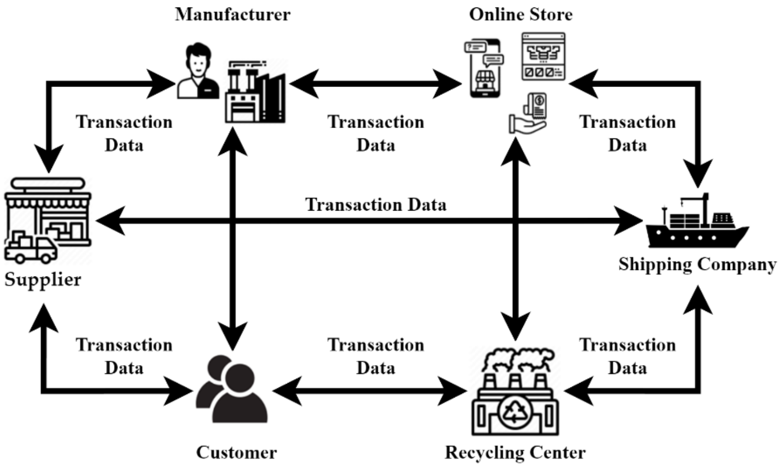


Fig. 2. Generic diagram of blockchain supply chain model

This paper aims to find the product costs and materials order strategy that optimizes the total profit of supply chain management in blockchain and circular economy practices. The traditional supply chain model will be shifted to a more circular economy with a blockchain concept, ensuring waste elimination, keeping materials in use for longer, avoiding the consumption of finite resources, and keeping transaction data safe. The mathematical notation and symbols are summarized in Table 2.

Table 2. Notations and descriptions for the supply chain model

Symbol	Definition	Unit
$D(t)$	Customer demand at a time t	Item
$u(t)$	Production rate at a time t	Item/time
$I(t)$	Inventory level at a time t	Item
$p(t)$	Product unit price at a time t	USD
$m_s(t)$	Number of materials ordered from the supplier at a time t	Item
$m_r(t)$	Number of materials recycled at a time t	Item
X	Random variable affecting customer demand	None
Y	Random rate of the defective product's appearance	None
$N_u(t)$	Number of used products	Item
H	Holding cost	USD
O	Ordering cost	USD
R	Recycling cost	USD
DC	Discount cost	USD
TP	Total profit	USD
h	Holding cost per unit of the product	USD
o	Ordering per unit of the product	USD
r	Recycling cost per unit of the product	USD
v	Discount price per unit of the product	USD
η	Discount rate	None
T	Cycle time of the inventory model	Month

Before presenting the mathematical model, the assumptions will be given below:

1. Customer demand is a random variable.
2. In production, there is a rate of damaged and substandard products.
3. Raw materials are converted into products at a specific rate.
4. Used products would be recycled into raw materials at a specified rate.
5. The cost of ordering materials can be influenced by customer demand.
6. There is no shortage in the inventory.

The transaction data is distributed across the participants in the supply chain network. Customers can quickly check information on the source of materials for the production cycle to collect used products, production standards, and customer service. Thus, these factors can directly or indirectly affect customer demand $D(t)$. In addition, customer demand decreases over time and is inversely proportional to the product unit price $p(t)$. Many unknown factors, such as political conflicts, war, and pandemics, disturb global supply chains. This paper describes the demand uncertainty by a random variable X distributed normally with mean μ_X and standard deviation σ, or $X \sim N(\mu_X, \sigma^2)$. Modern supply chain operations might involve stochastic demand fluctuations under unpredictable markets. The random demand $D(t)$ can be described as follows:

$$D(t) = \lambda(D(0) + Ae^{-(qt+gp)}) + X \qquad (1)$$

where A, q, g, and λ are the coefficients. $D(0)$ is the value of customer demand at $t = 0$ (time period). The coefficient impacting customers λ is the value that shows the customer's interest in the manufacturer's product. As illustrated in Figure 2, the information about the transaction data is shared with each component in the supply chain network, ensuring transparency and security. Then the customer can quickly check the information about the materials' origin, the recycling center's operation, and the benefit of returning the used products. The value of λ is derived from surveying a large number of different customers based on the events making them interested in the manufacturer's supply chain,

$$\lambda = K_1 + K_2 + K_3 + K_4 + K_5 = 1{,}0 \leq K_1, K_2, K_3, K_4, K_5 \leq 1 \qquad (2)$$

where the coefficients (K_1, K_2, K_3, K_4, and K_5) indicate the attraction of the source of the materials, the production standards, the purpose of using used products, the environment's contribution, and the customer support policies, respectively. After serving the customer request, the inventory level in the manufacturer refers to the number of goods or raw materials held by the premises of a business. In the production process, sometimes there are damaged products or products of poor quality to serve customers. A random variable Y expresses the rate of occurrence of defective products in the production process and can be described by a normal distribution with mean μ_Y and standard deviation σ. Based on the production rate and customer demand, the inventory level is characterized by,

$$I(t) = I(t-1) + (1-Y)u(t) - D(t) \qquad (3)$$

In this formulation, the defective rate Y is so volatile that decision-makers can hardly handle it in general. The production rate is the number of products that can be produced at a time t, and the production rate $u(t)$ is described as follows:

$$u(t) = \gamma(m_s(t) + m_r(t)) \qquad (4)$$

where the coefficient γ represents the conversion rate from materials to products. The materials from the recycling center depend on the number of the used products returned from customers, and one used product can be recycled into α materials,

$$m_r(t) = \alpha N_u(t) \qquad (5)$$

The number of used products returned from customers is affected by the manufacturer's purpose of collecting the used products, the environmental contribution, and the customer support policies. The coefficient β is introduced to describe the influence of customers on the decision to exchange used products. It is expressed as a combination of the coefficients (K_3, K_4, and K_5) to form complex scenarios. Then, the number of used products is given by

$$N_u(t) = \beta D(t) = (K_3 + K_4 + K_5)D(t) \qquad (6)$$

Policymakers must pay attention to the costs incurred during the operations to manage the supply chain network. One popular way to optimize inventory management is to use the economic order quantity (EOQ) model, which might determine the optimal order quantity to minimize costs and maximize profits. As a metric used in logistics and supply chain management, this model can be employed to determine the unit volume and order frequency needed to satisfy a specific level of demand. Three main factors are crucial in formulating the EOQ model when the market fluctuates: holding cost, ordering cost, and shortage cost. A comprehensive pathway for the transition to a more sustainable system focuses on eliminating waste and the continual use of resources. The inventory-related costs include holding, ordering, recycling, and discount costs. A firm's holding cost is the expenditures used for storing the products in the warehouse, costs for equipment maintenance, warehouse fees, and labor costs. The holding cost can be represented as follows:

$$H = \sum_{t=1}^{T} hI(t) \tag{7}$$

The ordering costs are the expenses used to order raw materials from suppliers, including purchasing materials, transportation, etc. The supplier can also track the manufacturer's product consumption through the transaction information shared by the blockchain network; therefore, the cost of ordering materials can also be affected, depending on the customer demand of the manufacturer. ψ is the coefficient indicating the change in customer demand for the ordering cost. The ordering costs are described by,

$$O = \sum_{t=1}^{T} oe^{\psi D(t)} m_s(t) \tag{8}$$

The recycling policy promotes reutilizing materials and reducing waste for production. For recycled materials or reusing materials to manufacture their products, the recycling cost includes transportation costs to get the used products from customers, operation costs, labor charges, etc.,

$$R = \sum_{t=1}^{T} r\beta D(t) \tag{9}$$

The discount cost is the loss due to pricing adjustments designed to increase sales,

$$DC = \sum_{t=1}^{T} v\alpha\beta D(t) = \sum_{t=1}^{T} \eta p(t)\beta D(t) \tag{10}$$

By considering various cost parameters, the objective function or fitness function is to maximize the total profit in the overall supply chain,

$$\begin{aligned} TP &= \max_{p,m_s} \left\{ \sum_{t=1}^{T} \left(p(t)D(t) - (H + O + R + DC) \right) \right\} \\ &= \max_{p,m_s} \left\{ \sum_{t=1}^{T} \left(p(t)D(t) - \left(hI(t) + om_s(t) + r\beta D(t) + \eta p(t)\beta D(t) \right) \right) \right\} \end{aligned} \tag{11}$$

In this optimization problem, some parameters are described as random variables. The supply chain system is simplified by assuming that the inventory quantity is always positive and there are no shortages. The dynamic inventory model focuses on determining the unit price or the number of raw materials needed from suppliers to optimize profits rather than calculating factors to maintain a positive inventory. The heuristic algorithm is presented to deal with the optimization problem.

HEURISTIC OPTIMIZATION APPROACH

As described, the customer demand $D(t)$ and the inventory level $I(t)$ represent mixtures of randomness and uncertainty depending on the random variables X and Y, respectively. The objective function in Equation 11 has an inherent uncertainty that relies on a set of random variables. In this paper, a metaheuristic algorithm must be generic and practical such that it is used to solve fitness functions containing random variables. The adaptive particle swarm optimization (APSO) algorithm is the heuristic search technique tuned by trial and error to solve function optimization problems. The heuristic algorithm starts with initializing a swarm with a specified number of particles at different positions in the search space. Each particle will give one solution for the fitness function. This paper aims to optimize the total profit of the supply chain model under uncertainty. The adaptive PSO algorithm is executed in a predefined number of iterations for an efficient optimization problem solution. In the first iteration, each solution given by one particle will compare with the others and find the largest value of the objective function. Then the solution and the particle will be saved for reference in the next iteration. The best solution in one iteration is called the local best value. The best solution on all iterations is called the global best value. The final search result will be the global best value and the corresponding particle's position at all other feasible points. At the beginning of each iteration, the position of each particle will change its direction with the rate as the formula is given below,

$$V_i^{j+1} = wV_i^j + c_1 b_1 \left(L_{localbest}^j - L_i^j \right) + c_2 b_2 \left(L_{globalbest} - L_i^j \right) \quad (12)$$

$$L_i^{j+1} = L_i^j + V_i^{j+1} \quad (13)$$

where V_i^j is the velocity of the particle i at iteration j; L_i^j is the position of the particle i at iteration j; w is the inertia weight, $w > 0$; c_1 and c_2 are the learning rates, $c_1, c_2 > 0$; b_1 and b_2 are the random constants, $b_1, b_2 \in [0,1]$; $L_{localbest}^j$ is the best solution in one iteration; $L_{globalbest}^j$ is the best solution on all iterations. Equation (12) represents the velocity, which makes the particles change their position in each iteration. Equation (13) determines the next position of the particle L_i^{j+1}. The inertia weight w is the positive constant, affecting the speed and direction. The learning rates (c_1 and c_2) make the particle move towards the direction with the best solution. The parameters b_1 and b_2 are distributed with the $[0, 1]$ range, maintaining their normal-like shapes. In iterative search, each particle gives one solution for the fitness function. The result is more likely to be trapped in a local optimum position in the standard PSO algorithm, especially in high-dimensional problems. The adaptive PSO algorithm has been presented to overcome this problem to improve search efficacy and convergence speed. In this strategy, the inertia weight w, the local learning rate c_1, and the global learning rate c_2 will be changed in each iteration to help the algorithm find the optimal point faster and avoid convergence to the local optimal point,

$$w^{j+1} = w_0 \left(1 - \frac{L_{localbest}^j}{L_{globalbest}^j} \right)^2, c_1^{j+1} = c_{1,0} \left(1 + \frac{L_{localbest}^j}{L_{globalbest}^j} \right)^2, c_2^{j+1} = c_{2,0} \left(1 + \frac{L_{localbest}^j}{L_{globalbest}^j} \right)^2 \quad (14)$$

where the parameters w_0, $c_{1,0}$ and $c_{2,0}$ are the initial values of w, c_1 and c_2, respectively. The algorithm will update the parameter values (w, c_1, and c_2) based on the difference between the local optimal value $L_{localbest}^j$ and the global optimal value $L_{globalbest}^j$. When the local optimal value is near the global optimal one for a specific search space region, the weight value w will be decreased to focus on the search region that contains the global optimal value and make little adjustments to find it faster. Conversely, the values of c_1 and c_2 will increase as the local optimal value is closer to the global optimal value. Increasing the values of c_1 and c_2 will help the algorithm speed up the search for the optimal value at all other feasible points. Specifically, the optimization problem in this paper is to determine the unit price of the product and the number of materials that need to be imported from outside suppliers to optimize the total profit. Two separate sets of particles need to be initialized at the start of the optimization process. One is the set of particles representing the product's unit price, and the other is the set of particles representing the number of materials to be imported. The algorithm and pseudocode are presented in Table 3.

Table 3. Pseudocode algorithm for adaptive PSO strategy

```
Pseudo code for the adaptive PSO algorithm
Initialize particles 1 ( p );
Initialize particles 2 ( m_s );
Initialize the local best solution ( BestLocal );
Initialize the global best solution ( BestGlobal );
for j = 1: maximum iteration
    for i = 1: maximum population size
        BestProfit = TP( L^j_{i,p}, L^j_{i,m_s} );
        if BestProfit ≥ BestLocal
            BestLocal = BestProfit ;
            BestPrice = L^j_{i,p} ;
            BestMaterials = L^j_{i,m_s} ;
        End
        V^{j+1}_{i,m_s} = wV^j_{i,m_s} + c_1 b_1 ( L^j_{localbest,m_s} − L^j_{i,m_s} ) + c_2 b_2 ( L^j_{globalbest,m_s} − L^j_{i,m_s} ) ;
        L^{j+1}_{i,m_s} = L^j_{i,m_s} + V^{j+1}_{i,m_s} ;
        V^{j+1}_{i,p} = wV^j_{i,p} + c_1 b_1 ( L^j_{localbest,p} − L^j_{i,p} ) + c_2 b_2 ( L^j_{globalbest,p} − L^j_{i,p} ) ;
        L^{j+1}_{i,p} = L^j_{i,p} + V^{j+1}_{i,p} ;
        w^{j+1} = w_0 ( 1 − L^j_{localbest} / L^j_{globalbest} )^2 ;
        c_1^{j+1} = c_{1,0} ( 1 + L^j_{localbest} / L^j_{globalbest} )^2 ;
        c_2^{j+1} = c_{2,0} ( 1 + L^j_{localbest} / L^j_{globalbest} )^2 ;
    end
    if BestLocal ≥ BestGlobal
        BestGlobal = BestLocal ;
        BestPrice = L^j_{i,p} ;
        BestMaterials = L^j_{i,m_s} ;
    end
end
```

NUMERICAL EXPERIMENTS

The proposed framework is intended to yield a more sustainable, resilient, and regenerative system, securing the data of the shared community. Numerical experiments are conducted to verify the effectiveness of inventory optimization schemes. The numerical simulations are performed using MATLAB environment on Windows 10 Pro 64-bit computer, 16GB RAM, and AMD Ryzen 5 5600G processor with Radeon Graphics. The adaptive swarm optimization method evaluates the fitness function involving discrete random variables. Supply chain management captures the realistic conditions by considering the inherent uncertainties of customer demand. The influence of the number of used products on the optimal strategy is analyzed to maximize the total profit in the cycle T. The experimental settings and conditions are described below in detail. The online store receives the customer demand, $D(1)=1000$ items and sends them back to the manufacturer. The random variable X represents the uncertain event that affected customer demand. It has the value from $[-200, 200]$ items, with the normal distribution, $X \sim N(0,1^2)$. The manufacturer plans to import raw materials and produce the product for a period of 12 months, or $T=12$ (months). The recycling center accepts requests to return the used products to manufacturers through the online store. For each returned used product, the customer can receive a discount rate on the unit price of the product, $v(t) = 0.1p(t)$. In the production process, the random variable Y represents the rate of occurrence of defective products. It has the value from $[0, 0.2]$ and follows the normal distribution, $X \sim N(0.1, 1^2)$. In the production line, it is assumed that one product is made from five materials, $\gamma = 1/5$. In the recycling center, one used product can be recycled into two materials used for production, $\alpha = 2$. The holding cost for one product is given in $h = 20$ (USD). The ordering cost for one material is $o = 30$ (USD). Using blockchain transaction information, the manufacturer can adjust the ordering cost according to customer needs with the influence of the coefficient $\psi = 0.0001$. The recycling cost for one used product is $r = 15$ (USD). The numerical experiment considers two scenarios to assess the impacts of returned used products on the supply chain network. In Scenario 1, the coefficient (λ) impacting customers has the following components: 35% the number of customers interested in the origin of raw materials, or $K_1 = 0.35$, 25% number of customers for the production's standard, or $K_2 = 0.25$, 20% number of customers for the collecting used products, or $K_3 = 0.2$, 10% number of customers for the environment's contributions, or $K_4 = 0.1$, and 10% number of customers for the customer services, or $K_5 = 0.1$. The coefficient indicates the influence of customers on the decision to exchange used products in Scenario 1, or $\beta = K_3 + K_4 + K_5 = 0.4$. In Scenario 2, the coefficients are similarly selected as follows: $K_1 = 0.1, K_2 = 0.1, K_3 = 0.3$, $K_4 = 0.2$, and $K_5 = 0.3$, or $\beta = K_3 + K_4 + K_5 = 0.8$. The number of returned used products in Scenario 2 is greater than in Scenario 1. In summary, the key parameters, along with the numerical scenarios used in this test, are listed in Table 4.

Table 4. Summary of the experimental settings

Parameter	Scenario 1	Scenario 2	Parameter	Scenario 1	Scenario 2
$D(0)$	1000 items	1000 items	K_2	0.25	0.1
$I(0)$	1100 items	1100 items	K_3	0.2	0.3
A	-75	-75	K_4	0.1	0.2
q	0.3	0.3	K_5	0.1	0.3
g	0.2	0.2	β	0.4	0.8
γ	0.2	0.2	w	1	1
α	2	2	c_1	0.001	0.001
h	20 (USD)	20 (USD)	c_2	0.001	0.001
o	30 (USD)	30 (USD)	w_0	1	1
r	15 (USD)	15 (USD)	$c_{1,0}$	0.1	0.1
η	0.1	0.1	$c_{2,0}$	0.1	0.1
ψ	0.0001	0.0001	Number of population	25	25
T	12 (months)	12 (months)	Maximum iteration	250	250
K_1	0.35	0.1			

Now, the proposed optimization problems can be solved by an adaptive PSO algorithm. As shown in Figure 3, the maximum total profits that the manufacturer can achieve after 12 months in Scenario 1 and Scenario 2 are 1867383 (USD) and 1287409 (USD), respectively.

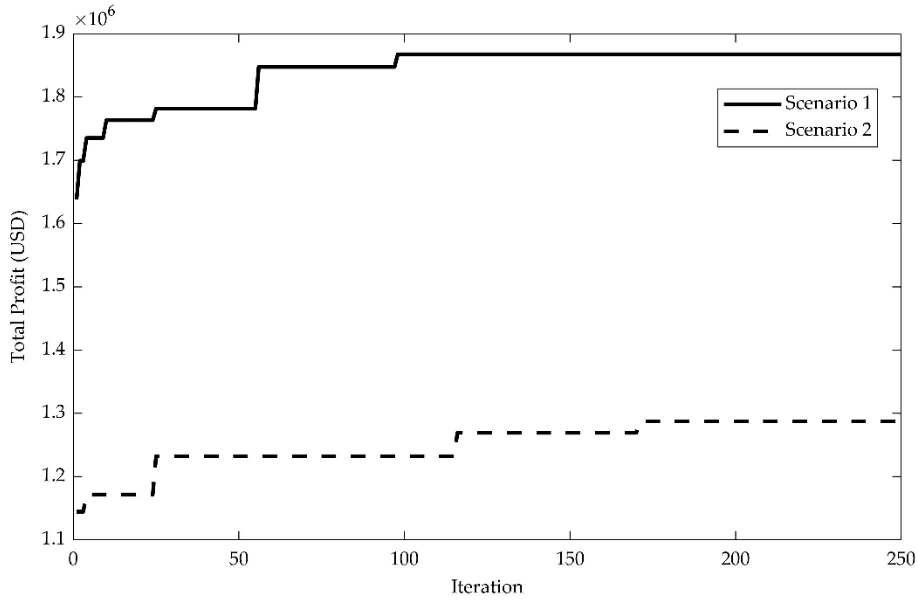


Fig. 3. Total profits achieved under heuristic algorithm.

Two scenarios in business settings have been tested on the same customer demand. However, the number of used goods returned in Scenario 2 is more than in Scenario 1, resulting in more inventory than in Scenario 1. This study assumes that there is no shortage in the inventory. The negative value implies that the inventory value will be set to zero. The inventory level of Scenario 2 is always greater or equal to that of Scenario 1. Holding a lot of inventory at one time will likely impose high carrying costs, leading to reduced profits in Scenario 2. The inventory levels and profits are illustrated in Figure 4.

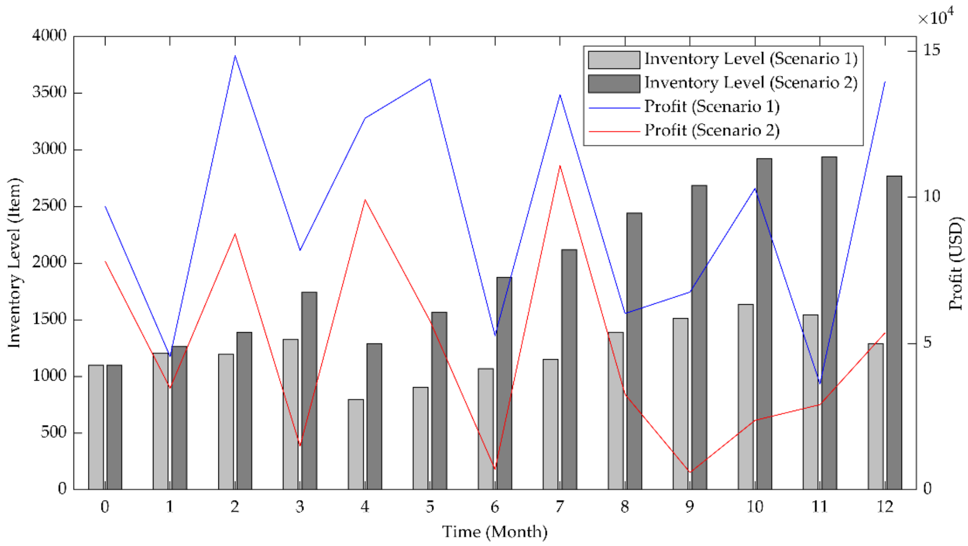
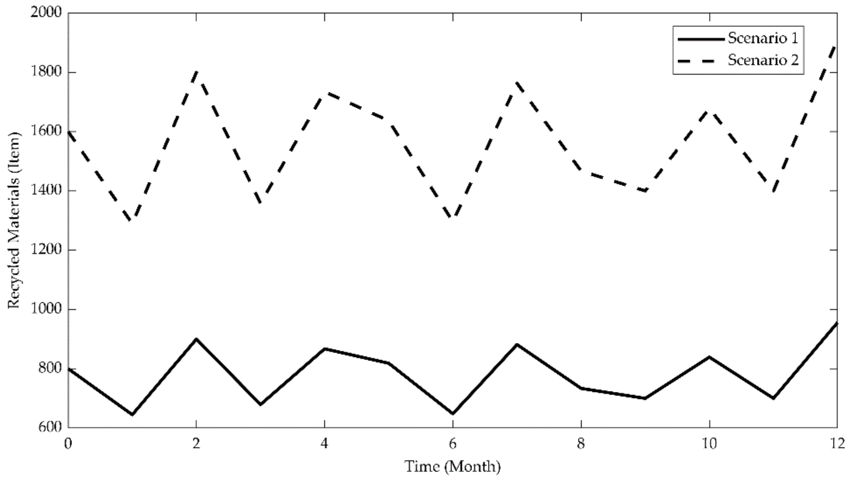
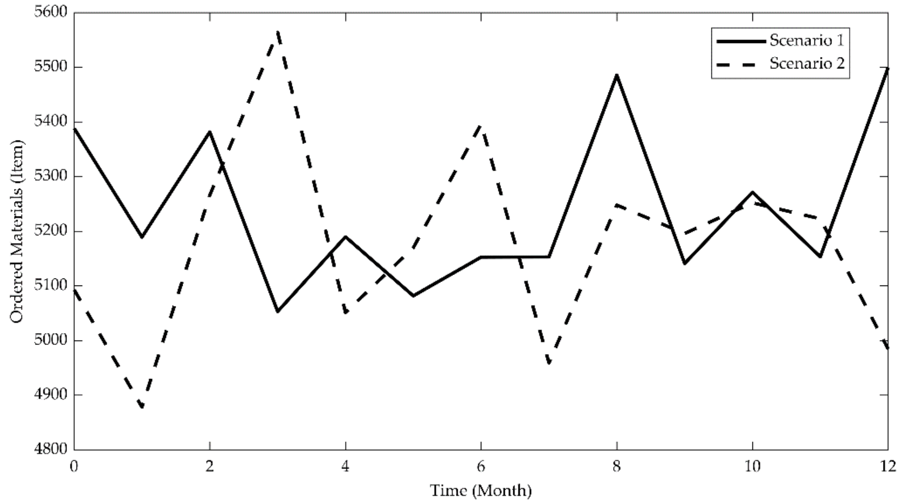


Fig. 4. Time history of inventory levels and profits

Figure 5(a) shows the number of recycled materials in two scenarios. Since the number of used products returned in Scenario 2 is greater than in Scenario 1, the number of recycled materials in Scenario 2 is also greater than in Scenario 1. As illustrated in Figure 5(b) and Table 5, the optimal numbers of ordered materials in both methods are not so different. There is no statistically significant variation.



(a)



(b)

Fig. 5. Time history of ordered and recycled materials in two scenarios: (a) number of recycled materials, (b) an optimal number of ordered materials.

Table 5. The optimal number of ordered materials

Scenario 1	Month	0	1	2	3	4	5	6
	Number of ordered materials (item)	5389	5190	5382	5053	5190	5082	5153
	Month	7	8	9	10	11	12	
	Number of ordered materials (item)	5153	5486	5142	5272	5154	5500	
Scenario 2	Month	0	1	2	3	4	5	6
	Number of ordered materials (item)	5094	4879	5267	5565	5052	5170	5397
	Month	7	8	9	10	11	12	
	Number of ordered materials (item)	4960	5249	5197	5253	5223	4985	

The optimal price strategy in both scenarios is shown in Figure 6, and the detailed values are shown in Table 6. The optimal number of ordered materials and the optimal product price are two decision variables that will lead to the best total profit of the supply chain model.

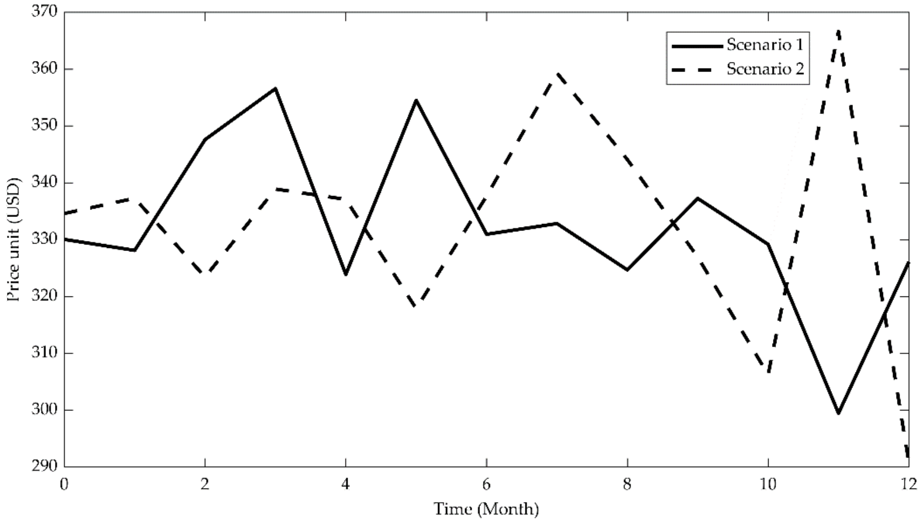


Fig. 6. Optimal product price

Table 6. Value of the optimal product unit in each month

Scenario 1	Month	0	1	2	3	4	5	6
	Price unit (USD)	330.05	328.12	347.59	356.56	323.90	354.51	330.95
	Month	7	8	9	10	11	12	
	Price unit (USD)	332.83	324.68	337.25	329.18	299.47	326.09	
Scenario 2	Month	0	1	2	3	4	5	6
	Price unit (USD)	334.60	337.28	323.42	338.90	337.09	317.87	337.66
	Month	7	8	9	10	11	12	
	Price unit (USD)	359.33	344.09	326.95	306.25	366.61	290.82	

With the given customer demand, the total profit in Scenario 1 is higher than in Scenario 2 (Figure 3). In Scenario 2, the number of used products returned is more significant than in Scenario 1. The average number of used products in Scenario 1 has nearly doubled in Scenario 2 due to the value of β in each scenario, leading to increased recycling costs and fees for publishing discount vouchers to customers. However, the increase in the number of used products returned makes manufacturers hold an abundant source of materials for production. The increase in the number of used products returning to the recycling center might result in fewer ordered materials for Scenario 2 than for Scenario 1. Because of holding more inventories (Figure 4) and recycling more used products (Figure 5a) than Scenario 1, the unit price of Scenario 2 is higher than Scenario 1. The unit price in Scenario 1 equals nearly 98.64 percent of the unit price in Scenario 2. Increasing the number of raw materials by recycling used products might not bring advantages in terms of profits. However, it can diversify the source of raw materials for production, avoiding resource shortages. The extensive numerical results demonstrate that the presented strategy can offer more robust supply chain management under uncertainty where the quality or quantity is subject to frequent, rapid, and significant changes.

DISCUSSION AND MANAGERIAL INSIGHTS

Critical issues for the *development* of an effective *SCM strategy* are discussed as follows. The numerical experiments have provided numbers and charts illustrating the impact of circular supply chain management with blockchain integration, demonstrating an essential building block for sustainability targets. The manufacturers utilized used products for recycling into raw materials for the next production stage through the recycling center. Sharing, reusing, repairing, and remanufacturing help companies transition to a circular economy, minimize waste, diversify sources of supply, and maintain production continuity. Previous studies only deal with the relationship between incentives and product returns without considering factors such as recycling used products or the effect of the number of materials or products imported from outside.

There are many ways to motivate customers to return used products to the manufacturers, such as issuing discount vouchers, positively contributing to environmental protection, and creating convenience for users when they want to return products through online customer services. The information between parts of the supply chains is connected by blockchain technology, enabling customers to identify the origin of the materials, the purpose of collecting secondary materials of the manufacturer by names, and information of departments that receive and process transactions. In this circular economy supply chain model, the customer's perspective can influence demand and determine the number of used products a recycling center can receive. The more used products the recycling center receives, the more secondary materials can be recycled. In the numerical experiments, the difference between the two scenarios is the coefficient beta, which describes the influence of customers on the decisions to exchange used products. In Scenario 1, the beta (β) is 0.4, corresponding to the number of used products returned to the recycling center, equaling 40 percent of the sold products. The beta in Scenario 2 is 0.8. The difference between the coefficient beta in the two scenarios presents the variance in the number of recycled materials described in Figure 5a. Acquiring more recycled materials might reduce the quantity of materials imported from suppliers. It is noted that the ordered materials for Scenario 2 are 5.48 percent less than Scenario 1. Diversifying the sources of raw materials helps manufacturers always have materials to maintain their production activities, lowering costs, increasing productivity, improving sustainability, and enhancing innovation. However, the manufacturers should have to bear other costs. To attract customers to return used products, they need to give a discount voucher of 10 percent for the next purchase for each used product returned by customers. To optimize the profit that the manufacturer can achieve, the product unit price of Scenario 2 is 1.37 percent higher than Scenario 1 due to a higher recycling fee and discount fee. If the customer demand in Scenario 2 is the same as Scenario 1, the total profit of Scenario 1 is higher than Scenario 2 (Figure 3).

Typically, no single model *suitably fits all* businesses under *every circumstance* for the decision support system in the managerial field. Therefore, a flexible selection from a generic strategy is crucial for decision-makers. This paper does not consider a specific product but focuses on building a circular supply chain model for generic items under the influence of blockchain technology. Based on the above analysis, a circular supply chain model can help manufacturers use secondary materials to reduce costs when ordering materials from outside suppliers. However, manufacturers must offer promotions or gifts based on the number of returned products to attract customers to return used products. The proposed approach usually works best but *has some* obvious *limitations* that should be improved in future research. The manufacturer must control the number of used products to achieve the desired total profit. Furthermore, having an additional source of raw materials from the recycling center will help manufacturers diversify their supply, enhancing their ability to maintain production even in the event of a shortage of raw materials in the market.

CONCLUSION

The circular economy might provide a systematic path to ensuring supply chain sustainability and reducing environmental harm. The recycled materials will be alternative sources of raw materials for producing or manufacturing goods. In the context of increasing digital technology, online stores as retailers can simplify product selection procedures and customer payments. Recently, transparency in transactions and the security of decentralized systems have been focused on in the field of information security, providing the potential to reduce inventory management risk. Applying blockchain technology to supply chain transactions can help the participants better trace transaction data and create trust for customers. Based on the circular economy and blockchain platform, this study deals with an adaptive particle swarm optimization algorithm (APSO) to determine the optimal strategy for product unit price and quantity of materials imported from suppliers to maximize total profits. The supply chain model incorporates realistic market conditions by considering the inherent uncertainties of customer demand. In the stochastic optimization problem, some parameters are described as random processes. This paper aims to examine the secure and decentralized business strategy of product pricing and the number of ordered materials for the circular supply chains to bring the optimal profit for the manufacturer and analyze the effect of the number of returned used products on total profits. The numerical test results are presented to verify the efficacy of a novel decision-making policy offering exceptional performance and reliability. Based on comparison with experimental data, it is shown that the amount of recycled used products affects the producer's profitability. Recycling too many used products has increased recycling costs and holding costs. However, it can reduce the manufacturer's dependence on external material suppliers, diversify the sourcing of raw materials, and hedge against material scarcity issues. Furthermore, all validation tests *ensure that* the proposed decision support system can aid policymakers in managing stochastic supply chain systems with minimal effort and adopting novel *strategies* to ensure resilience and customer satisfaction. Finally, the key findings significantly contribute to the intelligent decision support system for optimizing inventory management under various stochastic scenarios.

ACKNOWLEDGMENT

Conceptualization, B.M.H., S.S.Y.; Data curation, B.M.H., H.S.K., J.H.Y.; Investigation, G.S.C., H.S.K.; Software, B.M.H., G.S.C., J.H.Y.; Writing—original draft, B.M.H., H.S.K.; Methodology, G.S.C., J.H.Y., S.S.Y.; Writing—review and editing, B.M.H., H.S.K.; Supervision, H.S.K., S.S.Y.; Visualization, B.M.H., G.S.C., J.H.Y.; Funding acquisition: H.S.K., S.S.Y. All authors have read and agreed to the published version of the manuscript.

This research was supported by "Regional Innovation Strategy (RIS)" through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (MOE) (2023RIS-007)

REFERENCES

Alejo-Reyes A., Olivares-Benitez E., Mendoza A., Rodriguez A., 2020, Inventory Replenishment Decision Model for the Supplier Selection Problem Using Metaheuristic Algorithms, Mathematical Biosciences and Engineering, 17 (3), 2016–2036, https://doi.org/10.3934/mbe.2020107

Aras N., Aksen D., 2008, Locating collection centers for distance- and incentive-dependent returns, International Journal of Production Economics, 111 (2), https://doi.org/10.1016/j.ijpe.2007.01.015

Asghari M., Afshari H., Mirzapour A.S.M.J., Fathollahi-Fard A.M., Dulebenets M.A., 2022, Pricing and Advertising Decisions in a Direct-Sales Closed-Loop Supply Chain, Computers & Industrial Engineering, 171, 108439, https://doi.org/10.1016/j.cie.2022.108439

Asghari M., Abrishami S.J., Mahdavi F., 2014, Reverse Logistics Network Design with Incentive-Dependent Return, Industrial Egineering and Management Systems, 13 (4), https://doi.org/10.7232/iems.2014.13.4.383

Atabaki M.S., Mohammadi M., Naderi B., 2020, New robust optimization models for closed-loop supply chain of durable products: Towards a circular economy, Computers & Industrial Engineering, 146, 106520. https://doi.org/10.1016/j.cie.2020.106520

Chinnaraj G., Antonidoss A., 2022, A New Methodology for Secured Inventory Management by Average Fitness-Based Colliding Bodies Optimization Integrated with Block Chain under Cloud, Concurrency Computat Pract Exper, 34 (1), https:/doi.org/10.1002/cpe.6540

Ghoushchi S.J., Hushyar I., Sabri-Laghaie K., 2021, Multi-Objective Robust Optimization for Multi-Stage-Multi-Product Agile Closed-Loop Supply Chain under Uncertainty in the Context of Circular Economy, Journal of Enterprise Information Management, https://doi.org/10.1108/JEIM-12-2020-0514

Giovanni P.D., 2022, Leveraging the circular economy with a closed-loop supply chain and a reverse omnichannel using blockchain technology and incentives, International Journal of Operations and Production Management, 42 (7), 959-994, https://doi.org/10.1108/IJOPM-07-2021-0445

Govindan K., Salehian F., Kian H., Hosseini S.T., Mina H., 2023, A location-inventory-routing problem to design a circular closed-loop supply chain network with carbon tax policy for achieving circular economy: An augmented epsilon-constraint approach, International Journal of Production Economics, 257, 108771. https://doi.org/10.1016/j.ijpe.2023.108771

Ho T.C., Hsu C.L., 2020, An Analysis of Key Factors Influencing Integration of Blockchain into Shipping Companies in Taiwan, Journal of Marine Science and Technology (Taiwan), 28 (4), https://doi.org/10.6119/JMST.202008_28(4).0001

Kumar J.S., Singhal D., 2023, Optimizing the Competitive Sustainable Process and Pricing Decision of Digital Supply Chain: A Power-Balance Perspective, Computers & Industrial Engineering, 177, 109054, https://doi.org/10.1016/j.cie.2023.109054

Li S., Zhang J., Tang W., 2015, Joint Dynamic Pricing and Inventory Control Policy for a Stochastic Inventory System with Perishable Products, International Journal of Production Research, 53 (10), 2937–2950, https://doi.org/10.1080/00207543.2014.961206

Lin Z.P., Ho S.P., 2021, Supply Chain Inventory Model with Markov Chain Demand, Journal of Marine Science and Technology (Taiwan), 29 (4), https://doi.org/10.51400/2709-6998.1585

Ma D., Hu J., 2022, The Optimal Combination between Blockchain and Sales Format in an Internet Platform-Based Closed-Loop Supply Chain, International Journal of Production Economics, 254, 108633, https://doi.org/10.1016/j.ijpe.2022.108633

Ouyang L.Y., Chang C.T., Teng J.T., 2005, An EOQ Model for Deteriorating Items under Trade Credits, Journal of the Operational Research Society, 56 (6), 719–726, https://doi.org/10.1057/palgrave.jors.2601881

Pakseresht A., Kaiji S.A., Xhakollari V., 2022, How Blockchain Facilitates the Transition toward Circular Economy in the Food Chain?, Sustainability, 14 (18), 11754. https://doi.org/10.3390/su141811754

Park A., Li H., 2021, The Effect of Blockchain technology on Supply Chain Sustainability Performances, Sustainability, 13 (4), 1726, https://doi.org/10.3390/su13041726

Salas-Navarro K., Serrano-Pájaro P., Ospina-Mateus H., Zamora-Musa R., 2022, Inventory Models in a Sustainable Supply Chain: A Bibliometric Analysis, Sustainability, 14 (10). https://doi.org/10.3390/su14106003

Sarkar B., Debnath A., Chiu A.S.F., Ahmed W., 2022, Circular Economy-Driven Two-Stage Supply Chain Management for Nullifying Waste, Journal of Cleaner Production, 339, 130513. https://doi.org/10.1016/j.jclepro.2022.130513

Saurabh S., Dey K., 2021, Blockchain technology adoption, architecture and sustainable agri-food supply chains, Journal of Cleaner Production, 284, 124731. https://doi.org/10.1016/j.jclepro.2020.124731

Suhandi V., Chen P.S., 2023, Closed-loop supply chain inventory model in the pharmaceutical industry toward a circular economy, Journal of Cleaner Production, 383, 135474. https://doi.org/10.1016/j.jclepro.2022.135474

Varga T., Király A., Abonyi J., 2013, 19 - Improvement of PSO Algorithm by Memory-Based Gradient Search—Application in Inventory Management, Swarm Intelligence and Bio-Inspired Computation, 403–422, https://doi.org/10.1016/B978-0-12-405163-8.00019-3

Zhan Z.H., Zhang J., Li Y., Chung H.S.H., 2009, Adaptive Particle Swarm Optimization, IEEE Transactions on Systems, Man, and Cybernetics, Part B (Cybernetics), 39 (6), 1362–1381. https://doi.org/10.1109/TSMCB.2009.2015956

Bui Minh Hau   ORCID ID: https://orcid.org/0000-0001-7153-0613
Department of Logistics,
Korea Maritime and Ocean University, Yeongdo-gu, Busan, **Republic of Korea**
e-mail: bmh99116@g.kmou.ac.kr

Sam-Sang You   ORCID ID: https://orcid.org/0000-0003-2660-4630
Northeast-Asia Shipping and Port Logistics Research Center,
Korea Maritime and Ocean University, Yeongdo-gu, Busan, **Republic of Korea**
e-mail: ssyou@kmou.ac.kr

Gyu-Sung Cho   ORCID ID: https://orcid.org/0000-0002-1289-4908
Department of Port Logistics System,
Tongmyong University, Nam-gu, Busan, **Republic of Korea**
e-mail: gscho@tu.ac.kr

Jeong-Hum Yeon   ORCID ID: https://orcid.org/0000-0002-5872-0727
R&D Department,
Busan Port Authority, Daegyo-ro, Jung-gu, Busan, **Republic of Korea**
e-mail: jhyeon@busanpa.com

Professor Hwan-Seong Kim   ORCID ID: https://orcid.org/0009-0003-6167-5167
Department of Logistics,
Korea Maritime and Ocean University, Republic of Korea, Yeongdo-gu, Busan, **Republic of Korea**
e-mail: kimhsyskmou@gmail.com
Corresponding Author (H.S. Kim)