

Research Article

Truck Scheduling for Cross-Docking of Fresh Produce with Repeated Loading

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Due to mismanagement of supply chain operations, fresh produce, which deteriorates highly depending on time and operating environment (including temperature and humidity), will suffer huge losses in transit, resulting in substantial monetary losses. Cross-docking, as an efficient logistics operation strategy, has been widely used in fresh produce distribution in the cold supply chain, whereas it has not received adequate attention in the scientific literature. In order to improve the efficiency of fresh produce distribution, this study formulates a novel mixed-integer mathematical formulation model that allows repeated loading of outbound trucks to minimize the total deterioration (TD) of all the fresh produce in the cross-docking center. To solve this problem, an advanced genetic algorithm is proposed based on a constructional mixed chromosome with two parts and three levels. The numerical analyses are conducted on 10 typical instances under different combinations of parameters. Results show that our proposed model based on the repeated loading mode can effectively decrease the total deterioration compared with the traditional nonrepeated loading mode. And this superiority becomes more significant, as the value of truck changeover time and lot loading quantity (called lot size in the text) decrease. In particular, when the truck changeover time equals 0, the total deterioration obtained under repeated loading mode will be more than 31.8% on average smaller than that under nonrepeated loading mode.

1. Introduction

Fresh produce, including fruits, vegetables, meat, and seafood, damage greatly during supply chain operations, which leads to great losses of revenues in fresh produce supply chains [1–3]. In Europe, the deterioration of fresh fruits and vegetables accounted for nearly 20% of losses in the retail and foodservice industry [4]. In China, the average deterioration of fruit and vegetable products reached up to 25%–30% in circulation, causing more than \$17 billion of losses per year [5]. In the United States alone, more than 30% of perishable products (fresh produce accounts for the majority), worth almost \$50 billion, are thrown away every year [6]. Such a significant waste of products occurs due to the mismanagement of supply chain operations, and efficient logistics operations can significantly decrease this damage [7, 8]. Thus, how to effectively improve operations to decrease these losses has been a great challenge in research and practice.

Cross-docking, as an efficient logistics operation strategy, has been proved to shorten the circulation cycle, increase the delivery efficiency, and reduce losses in practice for fresh produce truck scheduling problems [9–11]. In a cross-docking center (CDC), products are unloaded from inbound trucks, transferred either automatically (on conveyor belts) or manually (by operators), sorted out based on customer demands, and finally loaded into outbound trucks with as small inventory quantity as possible [12]. Figure 1 shows the flow of products in a typical CDC. When the inbound trucks arrive at the receiving dock, the products are unloaded. Then, they are sorted and consolidated for reshipment at the shipping dock. If the products are not immediately uploaded on the outbound truck(s), they are stored in temporary storage until the scheduled truck arrives at the shipping dock. Real-life practice of cross-docking implementation, such as Walmart [13], UPS [14], and Toyota [15], shows its competitive importance.

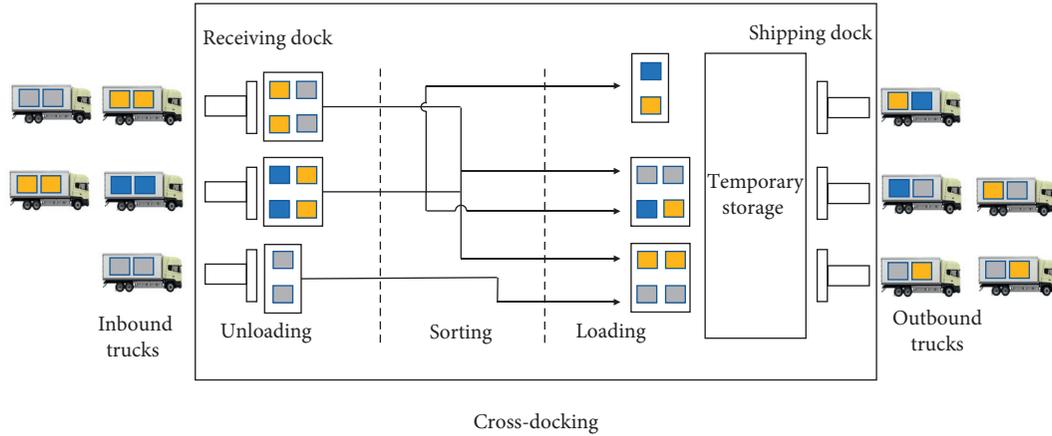


FIGURE 1: Flow of products in a typical CDC.

Therefore, cross-docking can be effectively applied in the transition of fresh produce to reduce their deterioration [16]. Previous literature has attempted to use cross-docking mode to reduce deterioration for fresh produce from different perspectives. However, these studies are largely based on the perspective of just-in-time strategy, cold-chain transportation strategy, multidocks strategy, etc. In fact, according to Yu's [17] work on the classification of cross-docking research issues, there are two holding patterns for inbound/outbound trucks, namely, nonrepeat and repeat truck holding patterns at the receiving/shipping dock. In this paper, we only focus on the repeat truck holding pattern for outbound trucks. Since the outbound truck is required to complete the loading task, this paper abbreviates this pattern as repeated loading. In this case, the outbound trucks can enter and leave the shipping docks intermittently. Therefore, it is possible that an outbound truck "A" loads some of its products, leaves the shipping dock for another outbound truck "B," and waits until outbound truck "B" completes the formulated loading task, and then outbound truck "A" goes into the shipping dock again to load all or part of its remaining products. Cross-docking with repeated loading can be regarded as a more flexible type of operation, and it has been proved that the optimal solution in this pattern is, at least, as good as or better than the optimal solution obtained in the nonrepeated loading pattern from the viewpoint of makespan [18]. Therefore, applying the repeated loading strategy to cross-docking scheduling for fresh produce can reduce deterioration effectively.

This paper formulates a novel mixed-integer mathematical formulation model and proposes a solution framework based on the genetic algorithm (GA) with repeated loading of outbound trucks to minimize the total deterioration (TD) of all the fresh produce in the cross-docking center. According to the concept of repeated loading, we design the loading rule to stipulate the quantity of each loading process, and based on this, a constructional mixed chromosome with two parts and three levels for the genetic algorithm is proposed. Correspondingly, crossover and mutation operations are carried out based on the constructional mixed chromosome. The numerical analyses

are conducted on 10 typical instances under different combinations of parameters. Comparing with the traditional nonrepeated loading rule, results show that our proposed model presents a strong economic incentive and benefit in decreasing the total deterioration. The parametric sensitivity analyses are also performed to draw some significant managerial implications to the supply chain stakeholder.

The remainder of this paper is organized as follows. In Section 2, we review the literature related to cross-docking scheduling in general and cross-docking scheduling for fresh produce in particular. In Section 3, we describe the loading rules and develop a mixed-integer mathematical formulation model. The advanced genetic algorithm applied to solve this model is proposed in Section 4. In Section 5, we summarize our computational results from numerical experiments. Finally, the conclusion and future research are represented in Section 6.

2. Literature Review

The literature related to our work mainly includes the following streams: truck scheduling problems in a cross-docking center and truck scheduling for fresh produce in a cross-docking center. Then, Section 2.3 summarizes the state-of-the-art and contributions of our work.

2.1. Truck Scheduling in a Cross-Docking Center. Boysen and Flidner [15] summarized three structures of the truck scheduling problems in a cross-docking center: door environments, operational characteristics, and objective functions. The door environment mainly refers to the number of dock doors. Molavi et al. [19] extended the cases of a single receiving dock and a single shipping dock into a multiple-door problem and determined the schedules for inbound and outbound trucks at a cross-docking center with fixed due dates for the outbound trucks. Guemri et al. [20] researched the cross-docking assignment problem (CDAP), in which the goal is to assign the inbound/outbound trucks to receiving/shipping dock doors to minimize the material

handling cost with respecting the capacity and assignment constraints. Wisittipanich et al. [21] paid attention to the integration problem between multiple cross-dockings. They addressed the novel problem in a cross-docking network and synchronized all inbound/outbound trucks throughout the network to minimize total operational time.

Operational characteristics influence the structure of truck scheduling, which is mainly as constraints for truck scheduling problems. A classic cross-docking model with infinite temporary storage capacity was constructed by Yu and Egbelu [22]; they also proposed nine heuristic algorithms for determining the optimal truck schedules for inbound and outbound trucks to minimize the total operation time. Furthermore, Boysen et al. [23] introduced a more generalized model for scheduling trucks at a cross-docking center, in which the time horizon was divided into discrete time slots, and the individual handling times of products were merged into the service slots to which the trucks were assigned. Baniamerian et al. [24] integrated the truck routing problem with the scheduling problem at cross-docking centers to minimize the total transportation cost and deviation cost of customer dissatisfaction. Tadumadze et al. [25] modified the assumption that unloading/loading times of trucks are fixed and proposed mixed-integer models integrating workforce planning and truck scheduling in the distribution center and cross-docking context. Similar work can also be found in Corsten et al. [26]; they assumed that the workforce consists of permanent and temporary workers, and the number of permanent workers is fixed, while temporary workers can be requested daily from an external personnel service provider. A linear programming model, which integrates the truck and workforce scheduling, is proposed with the goal of minimizing costs for engaging temporary workers.

With respect to the objective function of truck scheduling, Ladier and Alpan [9] summarized the possible objective function for cross-docking, including inventory level, travel distance, congestion, total product stay time, total loading or unloading time, and schedule length or makespan. Both Boloori Arabani et al. [27] and Madani-Isfahani et al. [28] took the makespan, which is the most common consideration in truck scheduling problems, as the objective to establish model. Rijal et al. [29] proposed an integrated problem with the truck-to-door assignment to minimize the transportation cost, temporary storage cost, and tardiness cost of outbound trucks. Besides, an adaptive large neighborhood search algorithm was proposed to solve the integrated problem. Dulebenets [30] constructed a novel diploid evolutionary algorithm to solve the truck scheduling problem of minimizing the total truck service cost. Numerical experiments demonstrate the developed algorithm effective in the aspect of total truck handling time, total truck waiting time, and total truck delayed departure time. Furthermore, Dulebenets [31] then took the total weighted truck service cost as the objective function to establish a mixed-integer programming model with the truck service priority and service order restrictions. Ladier and Alpan [32] regarded the total number of pallets put in storage on the planning horizon as the objective function.

2.2. Cross-Docking Scheduling for Fresh Produce. Several studies analyzed different topics related to truck scheduling for fresh or perishable products. Boysen [33] focused on a special truck scheduling problem arising at a cross-docking, where products subject to deterioration were not allowed to be stored at the cross-docking and were instead required to be immediately loaded onto refrigerated outbound trucks. Various objectives (minimization of the flow time, the processing time, and the tardiness of the outbound trucks) were investigated, and suitable algorithms were proposed to solve this problem. Agustina et al. [34] introduced a cost minimization model to study truck scheduling and routing problems for fresh produce at cross-docking centers. This integrated model accounted for both product consolidation and delivery time windows. To reduce the size of the solution space, customer zones and hard time windows were considered to solve larger instances. Compared to Agustina et al. [34], Rahbari et al. [7] paid more attention to truck scheduling and routing problems for fresh produce at cross-dockings subject to uncertainty. They aimed to analyze the effects of uncertainty in travel time and uncertainty in freshness life on the optimal schedule. Accordingly, a bi-objective mixed-integer linear programming model was proposed to solve this problem, where the upper objective was to minimize the total cost, and the lower objective was to maximize the total weighted freshness of the delivered fresh produce. Bilgen and Celebi [35] addressed the production scheduling and distribution planning problems in the yogurt production lines of multiproduct dairy plants. The model obtained the optimal production plan for each product type on each production line in each period, as well as the delivery plan. Pan et al. [36] considered that the perishable products deterioration rate may vary due to the unstable logistic environment and proposed a mixed-integer programming model with minimizing the total deterioration rate variation within the cross-docking service platform.

2.3. Literature Summary and Contributions. Although much literature has discussed the truck scheduling problem for cross-docking, only a few researchers have concentrated on more flexible truck operations, in which repeated loading or unloading could be allowed. Mohtashami [18] considered two scenarios of operations for outbound trucks at a cross-docking center: operations with repeated loading allowed and operations with repeated loading prohibited. He proposed a genetic algorithm for scheduling inbound and outbound trucks to minimize the total operation time at a cross-docking, where repeated loading was allowed. To illustrate the performance of truck scheduling with repeated loading, several numerical experiments were presented, and the results were compared with the minimum total operation times obtained with repeated loading prohibited. Similarly, Alpan et al. [37] and Fazel Zarandi et al. [38] also focused on the truck scheduling problem for a cross-docking with repeated loading. Different from that of Mohtashami [18], the objective function of Alpan et al. [37] was designed to minimize inventory holding and truck changeover costs, whereas Fazel Zarandi et al. [38] aimed to determine the

optimal schedule to minimize the total costs of earliness and tardiness and the number of preemption for outbound trucks. Alpan et al. [39] presented a cross-docking environment with multiple receiving and shipping doors, where the objective function was formulated to determine the optimal flexible schedule for inbound and outbound trucks that could minimize the total operational cost. Shahmardan and Sajadieh [40] studied a truck-scheduling problem in a cross-docking center, where compound trucks, which refer to the inbound trucks that can also be served as outbound trucks, can be partially unloaded. They proposed a new heuristic algorithm, and several reinforcement learning-based simulated annealing algorithms to solve the NP-Hard integrated model. Theophilus et al. [41] believed that future truck scheduling studies for cross-docking should focus on the modeling of cross-docking, where repeated loading or unloading is allowed.

All of the above studies were aimed at determining the optimal truck schedules at cross-dockings for fresh produce to minimize either the total operation time or total operation cost. However, different fresh produce have different deterioration rates. If two types of fresh produce are to be scheduled at the same time, the fresh produce with a higher deterioration rate should be scheduled first. Consequently, scheduling by minimizing the total operation time or total operation cost may not be suitable for fresh produce. Therefore, we propose a cross-docking scheduling model for fresh produce with repeated loading. The objective is to determine the optimal schedule for inbound and outbound trucks that minimizes the Total Deterioration (TD) of all fresh produce.

3. Mathematical Model

3.1. Assumptions and Notations. Consider a cross-docking center that has a receiving dock that is designated to serve a set R of inbound trucks and a shipping dock that is designated to serve a set S of outbound trucks. Each inbound truck $i \in R$ is loaded with different types $k \in N$ of fresh produce. The quantity of fresh produce type k initially loaded on inbound truck i is denoted by r_{ik} . After arriving at the receiving dock, the inbound truck i needs to unload all of its fresh produce before leaving. Once unloaded, these products must be sent to the shipping dock and either loaded directly onto outbound trucks or stored in temporary storage with no capacity restrictions for a short wait. At the shipping dock, each outbound truck $j \in S$ needs to be loaded with a predetermined quantity s_{jk} of product type k . Unlike inbound trucks, repeated loading is allowed for outbound trucks. In other words, it is possible that an outbound truck may be loaded with some of its products, leave the shipping dock to make room for another truck, and wait and later return to the shipping dock to be loaded with all or part of its remaining fresh produce.

In addition to the operational conditions stated above, the following assumptions are applicable to our model:

- (1) All inbound and outbound trucks are available at time zero

- (2) The loading and unloading times are the same for all fresh produce types, and either loading or unloading takes one unit of time for one unit of product.
- (3) It also takes one unit of time to unload one unit of fresh produce from a conveyor to the temporary storage or to load one unit of fresh produce from the temporary storage onto an outbound truck.
- (4) Only one unit of a given type of fresh produce can be loaded onto an outbound truck at a time. Therefore, loading fresh produce simultaneously from the conveyor and the temporary storage onto an outbound truck is prohibited.
- (5) The truck changeover time is the same for all inbound and outbound trucks.
- (6) The time required to move fresh produce from the receiving dock to the shipping dock is certain and deterministic.
- (7) The deterioration rate of the fresh produce when exposed to the cross-docking center is different from the of the deterioration rate on the inbound/outbound trucks.

In the study of cross-docking scheduling problem with one exclusive receiving dock and one exclusive shipping dock, assumptions (1)–(6) are generally adopted for many researchers, such as Yu and Egbelu [22], Keshtzari et al. [42], and Golshahi-Roudbaneh et al. [43]. According to the research of Grunow and Piramuthu [44] on refrigerated truck scheduling, assumption (7) is also adopted in their research.

The parameters and decision variables are defined as follows:

Parameters

R : set of inbound trucks, $i \in R$

S : set of outbound trucks, $j \in S$

N : set of fresh produce types, $k \in N$

P : set of slots in the docking sequence for outbound trucks, $p \in P$

r_{ik} : quantity of fresh produce type k loaded in the inbound truck i

s_{jk} : quantity of fresh produce type k needed for the outbound truck j

U : lot size

α_{jk} : number of slots required for the outbound truck j to load a quantity of fresh produce type k

n_{jkp} : quantity of products for the outbound truck j loading fresh produce type k for each loading operation, $p = 1, 2, \dots, \alpha_{jk}$

D : truck changeover time

V : time required to move fresh produce from the receiving dock to the shipping dock

λ_k^{IO} : deterioration rate of fresh produce type k in inbound/outbound trucks

λ_k^{CD} : deterioration rate of fresh produce type k during handling and storage at the cross-docking

q_k : the initial freshness of fresh produce type k

M : large number

Decision variables

C_i : time at which inbound truck i enters the receiving dock

F_i : time at which inbound truck i leaves the receiving dock

E_{jkp} : time at which outbound truck j enters the shipping dock for loading the fresh produce type k in the p^{th} slot

L_{jkp} : time at which outbound truck j completes loading the fresh produce type k in the p^{th} slot and leaves the shipping dock

L_j : time at which outbound truck j leaves the shipping dock after loading all the products it needs

x_{ijk} : quantity of fresh produce type k to be transferred from inbound truck i to outbound truck j

$p_{ii'}$: a binary variable that is 1 if inbound truck i precedes inbound truck i' in the sequence, and 0 otherwise

y_{jkp} : a binary variable that is 1 if outbound truck j is assigned to the p^{th} slot in the docking sequence for fresh produce type k at the shipping dock, and 0 otherwise

v_{ijk} : a binary variable that is 1 if inbound truck i transfer fresh produce type k to outbound truck j , and 0 otherwise

3.2. Loading Rules. We extend the study of Mohtashami [18] to transform the outbound truck docking sequence for fresh produce at a cross-docking with repeated loading. The loading rules are designed based on the outbound trucks and the product types and quantities to be loaded onto them. Moreover, a lot size (U) is introduced to represent that whenever an outbound truck is at the shipping dock, it should be loaded with a fixed quantity of products for a specified fresh produce type k . Based on the lot size, we can compute the number of slots required for an outbound truck j to load a quantity of the k^{th} type fresh produce with

$$\alpha_{jk} = \max\left(\text{floor}\left(\frac{s_{jk}}{U}, 1\right)\right). \quad (1)$$

Here, the meaning of the ‘‘floor’’ representation is taking an integer down. If the total quantity of fresh produce type k required to be loaded on outbound truck j is less than the lot size, then the slot number is equal to 1 instead of 0. Based on the slot number, we set the number of products to be loaded on an outbound truck from each slot according to the following rules:

- (1) If $\alpha_{jk} = 1$, which means that $s_{jk} \leq U$, then the loading quantity for outbound truck j of fresh produce type k is equal to s_{jk} .
- (2) If $\alpha_{jk} \geq 2$, the outbound truck j needs to load the k^{th} type product several times. At slot 1 to $\alpha_{jk} - 1$, U

quantity products are loaded each time, and at the α_{jk}^{th} slot, all remaining quantities are loaded, i.e., $s_{jk} - (\alpha_{jk} - 1)U$.

In summary, depending on the value of s_{jk} and U , three values of the quantity of loads per slot exist, i.e., s_{jk} , U , and $s_{jk} - (\alpha_{jk} - 1)U$. For the convenience of modeling, we use n_{jkp} to represent this loading quantity uniformly.

$$n_{jkp} = \begin{cases} s_{jk} & \text{if } \alpha_{jk} = 1, \\ U & \text{if } \alpha_{jk} \geq 2 \text{ \& } p = 1, 2, \dots, \alpha_{jk} - 1, \\ s_{jk} - (\alpha_{jk} - 1)U & \text{if } \alpha_{jk} \geq 2 \text{ \& } p = \alpha_{jk}. \end{cases} \quad (2)$$

In order to better explain the above computation and equation (1) as well, we provide a simple numerical example with three outbound trucks and three types of perishable products with lot size $U = 10$. Detailed information can be expressed as matrix s :

$$s = \begin{bmatrix} 15 & 0 & 0 \\ 10 & 0 & 20 \\ 0 & 25 & 0 \end{bmatrix}. \quad (3)$$

We can obtain that outbound truck 3 should appear in the docking sequence 2 times for the loading of fresh produce type 2, and 10, 15 units of product are loaded from each slot. Besides, it occupies 1 slot for the first type product with a quantity of 15 and 3 slots for the first and third type product with a quantity of 10 products from each slot. Therefore, in total, outbound trucks should occupy 6 slots in the docking sequence to be loaded with all the fresh produce it needs. That is, the number of slots to be occupied by all the outbound trucks can be obtained by adding up all the product types of all outbound trucks with α_{jk} , which is formulated with the following equation:

$$|P| = \sum_{j \in S} \sum_{k \in N} \alpha_{jk}, \quad (4)$$

where $|P|$ represents the length of the set P .

In order to depict the loading information of outbound trucks at each slot, we then depict the shipping docking sequence for outbound trucks as a matrix with 3 rows and $|P|$ columns, which is shown in Table 1. The meaning of the three numbers in the second column of the table is that outbound truck 2 loads the first type of product with 10 units from slot 1. Besides, under the matrix s mentioned previously, we can only determine the slot number as 6, whereas the specific sequence of outbound trucks is undetermined. Table 1 also presents two possible sequences of outbound truck sequences. If the sequence is 2-1-3-2-2-3, considering that the fourth and fifth slots are both outbound truck 2, therefore, the number of outbound trucks repeatedly entering and leaving the shipping dock is 5; we mark the repeat number as 5. Similarly, we can compute the repeat number of the second possible sequence 2-2-1-2-3-3 is 4.

TABLE 1: Descriptions of the outbound truck docking sequences.

$ P = 6$	Possible sequence: 1						Possible sequence: 2					
Outbound truck	2	1	3	2	2	3	2	2	1	2	3	3
Fresh produce type	1	1	2	3	3	2	1	3	1	3	2	2
Loading quantity	10	15	10	10	10	15	10	10	15	10	10	15

3.3. Total Deterioration. In general, the total deterioration (TD) should be an increasing function of the operation time, deterioration rates, and quantities corresponding to the different types of fresh produce. Consider the fact that (1) the environment (such as temperature and humidity) on inbound/outbound truck area and cross-docking center area is different; (2) the environment on trucks (usually refrigerated trucks) is relatively stable, and the temperature is low, meaning that the deterioration rate on trucks remains at a low level; (3) the TD of all the fresh products is dependent on the batch quantity x_{ijk} , the deterioration time on inbound/outbound truck areas or cross-docking center area, and the deterioration rates ($\lambda_k^{IO}, \lambda_k^{CD}$) of products on these areas. Rahbari et al. [7] and Wang and Li [45] also used these three elements to calculate the deterioration of fresh produce.

Therefore, the deterioration process of a batch quantity x_{ijk} fresh produce within the cross-docking center can be divided into three stages: (1) the first stage is from time 0 to the time when the products start to be unloaded from inbound truck i (i.e., C_i); (2) the second stage is from C_i to the time when the products are loaded onto outbound truck j . Here, based on the loading rules, L_{jkp} only records the departure time of the loaded products, and only when

$v_{ijk} = 1$, it means that the products indeed come from the inbound truck i ; therefore, the duration time of the second stage is $(L_{jkp} - C_i)v_{ijk}$; (3) the third stage starts from the second stage to the time when outbound truck j has met all its demand and leaves the shipping dock.

We then formulate the total deterioration of all the fresh produce throughout the cross-docking processes. Wang and Li [45] described the deterioration changing that follows a linear to exponential decay, and the exponential form is the most common description for predicting the deterioration of fresh produce. As they stated, if the initial quality of a product is q_0 , after the deterioration time of t_1 and t_2 with respective deterioration rate λ_1, λ_2 , then the quality is equal to $q_0 e^{-(\lambda_1 t_1 + \lambda_2 t_2)}$. Therefore, the formula for calculating the total deterioration of one product is $q_0 - q_0 e^{-(\lambda_1 t_1 + \lambda_2 t_2)}$. Based on the calculation formula, we can derive the total deterioration (TD) of all the fresh produce in a cross-docking as follows:

$$TD = \sum_{i \in R} \sum_{j \in S} \sum_{k \in N} \sum_{p \in P} x_{ijk} \cdot \left[q_k - q_k e^{-(\lambda_k^{IO} (C_i + L_j - L_{jkp}) v_{ijk} + \lambda_k^{CD} (L_{jkp} - C_i) v_{ijk})} \right], \quad (5)$$

where $(C_i + L_j - L_{jkp})v_{ijk}$ represents the total duration time that a certain batch of products x_{ijk} stays on the inbound and outbound trucks and $(L_{jkp} - C_i)v_{ijk}$ represents the duration time of these batch products staying in the cross-docking area.

3.4. Model Formulation. The fresh produce truck scheduling problem in a cross-docking center with repeated loading can, therefore, be formulated as follows:

$$\text{Min TD} = \sum_{i \in R} \sum_{j \in S} \sum_{k \in N} \sum_{p \in P} x_{ijk} \cdot \left[q_k - q_k e^{-(\lambda_k^{IO} (C_i + L_j - L_{jkp}) v_{ijk} + \lambda_k^{CD} (L_{jkp} - C_i) v_{ijk})} \right], \quad (6)$$

subject to

$$\sum_{j \in S} x_{ijk} = r_{ik}, \quad \forall i \in R, k \in N, \quad (7)$$

$$\sum_{i \in R} x_{ijk} = s_{jk}, \quad \forall j \in S, k \in N, \quad (8)$$

$$x_{ijk} \leq M v_{ijk}, \quad \forall i \in R, j \in S, k \in N, \quad (9)$$

$$F_i \geq C_i + \sum_{k \in N} r_{ik}, \quad \forall i \in R, \quad (10)$$

$$C_{i'} \geq F_i + D - M(1 - p_{ii'}), \quad \forall i, i' \in R, i \neq i', \quad (11)$$

$$C_i \geq F_{i'} + D - M p_{ii'}, \quad \forall i, i' \in R, i \neq i', \quad (12)$$

$$p_{ii} = 0, \quad \forall i \in R, \quad (13)$$

$$\alpha_{jk} = \max\left(\text{floor}\left(\frac{s_{jk}}{U}, 1\right)\right), \quad (14)$$

$$n_{jkp} = \begin{cases} s_{jk}, & \text{if } \alpha_{jk} = 1, \\ U, & \text{if } \alpha_{jk} \geq 2 \text{ \& } p = 1, 2, \dots, \alpha_{jk} - 1, \\ s_{jk} - (\alpha_{jk} - 1)U, & \text{if } \alpha_{jk} \geq 2 \text{ \& } p = \alpha_{jk}, \end{cases} \quad (15)$$

$$\sum_{p \in P} y_{jkp} = \alpha_{jk}, \quad \forall j \in S, k \in N, \quad (16)$$

$$\sum_{j \in S} \sum_{k \in N} y_{jkp} = 1, \quad \forall p \in P, \quad (17)$$

$$E_{j'k', p+1} \geq L_{jkp} + D - M(1 - y_{jkp}), \quad \forall j, j' \in S, k, k' \in N, \quad (18)$$

$$L_{jkp} \geq E_{jkp} + n_{jkp}, \quad \forall j \in S, k \in N, p \in P, \quad (19)$$

$$E_{ikp} \geq C_i + V - M(1 - v_{ijk}), \quad \forall i \in R, j \in S, k \in N, \quad (20)$$

$$L_j \geq L_{jkp}, \quad \forall j \in S, k \in N, p \in P, \quad (21)$$

$$E_{jkp} \geq V, \quad \forall j \in S, k \in N, p \in P, \quad (22)$$

$$\text{Variables} \geq 0. \quad (23)$$

The objective function, equation (6), minimizes the TD of all the fresh produce. Constraints (7) and (8) represent the balance of the quantity of fresh produce (i.e., the total quantity of fresh produce of type k received on inbound trucks must be equal to the total quantity of fresh produce sent out on outbound trucks). Constraint (9) enforces the correct relationship between the x_{ijk} variables and the v_{ijk} variables. The inbound constraints are described by equations (10)–(13). Constraint (10) indicates that the departure time of each inbound truck is equal to the sum of its arrival time and the time required to unload all products. Constraints (11) and (12) construct an effective sequence of arrival and departure times for the inbound trucks based on their order. Constraint (13) ensures that no inbound truck can precede itself in the receiving dock sequence. The outbound constraints are described by equations (14)–(22), and constraints (14)–(15) have been described previous. Constraint (16) represents the relationship between α_{jk} and y_{jkp} . Constraint (17) ensures that each slot in the docking sequence must be occupied by an outbound truck with loading products. Constraints (18)–(20) construct an effective sequence of arrival and departure times for the outbound trucks based on their slot sequence. Constraints (21)–(22) ensure the correct value of outbound trucks at the earliest and latest time.

4. Advanced Genetic Algorithm

Genetic algorithms are a well-known class of probabilistic search methods developed by Holland [46]. In a genetic algorithm, chromosomes are evolved from generation to generation through operations such as crossover and mutation and finally converge to the most suitable chromosome, representing either the optimal solution or a satisfactory solution to the problem. To accelerate the calculation of the objective function and find the optimal truck schedule for fresh produce at a cross-docking with repeated loading, an advanced genetic algorithm is proposed in this paper. The main steps are as follows.

4.1. Representation Scheme of Solutions. The mixed chromosome representation in this paper consists of two parts (Part I and Part O) and three levels (inbound/outbound truck, fresh produce type, and loading quantity). Part I and Part O represent the sequence and loading information about inbound and outbound trucks, respectively. It should be noted that the unloading process of the inbound trucks is different from the loading process of the outbound trucks. Once an inbound truck enters the receiving dock, all its

unloading activities must be completed before the truck leaves the dock. Therefore, we can only concentrate on the possible sequences of R inbound trucks concerning Part I . And the second level of inbound trucks can be labeled as O , while, for the third level (the loading quantity), we also just count the total quantity of products loading on the inbound trucks. The sorting rules of outbound trucks are the same as those in Table 1. The complete chromosome form containing the inbound and outbound truck sequences is shown in Table 2.

$$\begin{aligned} r &= \begin{bmatrix} 5 & 0 & 10 \\ 0 & 25 & 10 \\ 20 & 0 & 0 \end{bmatrix}, \\ s &= \begin{bmatrix} 15 & 0 & 0 \\ 10 & 0 & 20 \\ 0 & 25 & 0 \end{bmatrix}. \end{aligned} \quad (24)$$

In general, the initial solutions are a set of two-part, three-level mixed chromosomes, and the inbound part (Part I) and the outbound part (Part O) need to be crossed and mutated separately because of the different rule regarding with unloading and loading process. Besides, the corresponding genes on the three levels in the chromosome should be exchanged simultaneously.

4.2. Fitness Value Evaluation. The objective function is formulated to minimize the TD of all fresh produce, which is related to their operation times, quantities, and deterioration rates. The deterioration value of single fresh produce is multiplied by the deterioration rate and the operation time during the inbound/outbound trucks and cross-docking area. The deterioration value of all types of fresh produce is summed to obtain the TD corresponding to the current chromosome. In the genetic algorithm, a higher fitness value means a greater probability of being selected and inheriting a good gene to the next generation. In this paper, we adopt the inverse ratio form to compute the fitness values and the fitness value equals $1/\text{TD}$. And the calculation method and idea follow the model in Section 3.4.

4.3. Selection Operation. Based on the constructional rule of mixed chromosomes with two-part and three-level, we can generate the initial population. And the individuals need to be selected from the population with a certain probability. The probability of an individual being selected is related to the fitness value. The greater the individual fitness value, the greater the probability of being selected. We adopt the traditional method of roulette to do the selection operation.

4.4. Crossover Operation. The crossover operator exchanges genes between two chromosomes, which allows the genetic algorithm to explore new solutions while still retaining some structured parts of previously discovered solutions.

TABLE 2: A chromosome representation of inbound and outbound trucks.

	Part I				Part O				
Inbound/outbound truck	3	1	2	2	1	3	2	2	3
Fresh produce type	0	0	0	1	1	2	3	3	2
Unloading/Loading quantity	20	15	35	10	15	10	10	10	15

4.4.1. Crossover Operation for Inbound Trucks. With respect to the sequence of inbound trucks, each one must stay in the receiving dock until it finishes its unloading process once it comes into the receiving dock. In other words, each inbound truck enters the receiving dock only once; therefore, an inbound truck is located once in the sequence of inbound trucks. In order to retain this property, a modified random single-point crossover operator is proposed in Algorithm 1.

In Algorithm 1, P_c represents the crossover probability and $|R|$ represents the total number of inbound trucks. The word “legitimate genes” in Algorithm 1 means that we should delete the genes that are identical in the offspring and replace them sequentially with genes that are not present in the offspring in sequence. Figure 2 illustrates a legitimate crossover operation for inbound and outbound trucks with the example in Table 2.

4.4.2. Crossover Operation for Outbound Trucks. Although the outbound trucks can repeatedly enter and leave the shipping dock for multiple loading operations, once the sequence is determined, the crossover operation is similar to Algorithm 1. And the process of generating the outbound truck sequence has already been described in Section 3.2. Detailed crossover operations are illustrated in Figure 2 with regard to the example in Table 2.

4.5. Mutation Operation. Both the mutation operation of inbound and outbound trucks are adopted the interchange method in this paper. In this case, two genes that are not adjacent are selected randomly and then change their positions. We just take the mutation operation of inbound trucks as an example to represent the interchange method, and a detailed algorithm is performed in Algorithm 2:

4.6. Stopping Criteria. Two different criteria are used for termination: a maximum number of iterations and the convergence degree of the best solution. More specifically, the first is the common criterion of GAs, which is the specification of a maximum number of generations. The algorithm will terminate once the iteration number reaches the maximum number of generations. However, we may not need to run so many iterations. The second stopping criterion considers that when the same best solution has not been improved in a fixed number of iterations, the solution is considered to be the best solution, and thus, the GA can be terminated.

The default parameter values used in the advanced genetic algorithm are as follows: size of the initial population (N_p) is 1000, maximum number of iterations (N_i) is 500,

selection probability (P_s) is 0.9, crossover probability (P_c) is 0.8, and mutation probability (P_m) is 0.1.

The procedure of the proposed GA is presented in Figure 3.

5. Numerical Analyses

5.1. Data Generation. To compare the optimal truck schedules between the scenarios in which repeated loading is allowed and prohibited (abbreviated as repeated loading mode and nonrepeated loading mode) at the cross-docking for the scheduling of fresh produce, 10 sets of instances given in Yu and Egbelu [22] are adopted for numerical experiments. The scenario of nonrepeated loading mode means that once an inbound truck enters the receiving dock, it must stay there until all the products it required have been unloaded. The detailed 10 test instances are represented in Table 3. For each instance, the deterioration rates of all fresh produce in inbound/outbound trucks (λ_k^{IO}) are assumed to be approximately zero. Therefore, we mainly calculate the total deterioration of fresh produce in the cross-docking center with a deterioration rate of λ_k^{CD} . The initial freshness of all the fresh produce is set to 1. And, in all cases, the time required for transferring the fresh produce from the receiving dock to the shipping dock is assumed to be equal to 100 units time. The optimal schedules and minimum TDs for these 10 instances under the repeated loading mode and nonrepeated loading mode are recorded after 3 runs by the GA. The ranges of other parameters in the sensitivity analysis are given as follows.

- (i) Lot size U : $U \in \{10, 20, \dots, 100\}$.
- (ii) Truck changeover time D : $D \in \{0, 100, 200, \dots, 500\}$.
- (iii) Deterioration rates λ_k^{CD} : from Table 3, we can detect that instance 10 possesses the largest number of product types, which equals 9. Without loss of generality, we set the deterioration rate of the first quarter product type as 5×10^{-5} , and the remaining three quarters product type as 1×10^{-5} .

In the last two columns of Table 3, we calculate the total number of slots of outbound trucks in the shipping sequence under two lot size levels $U = 50$ and $U = 100$. Taking instance 1 as an example, which consists of 5 outbound trucks loading with 990 units of 4 types of fresh produce, through equation (1), it can be calculated that when $U = 50$, the first outbound truck needs 4 slots calculated by the loading matrix [151, 0, 0, 87], and the others are 3, 5, 3, 3 slots with loading matrix [0 106 33 0], [0 264 0 0], [61 132 0 0], [0 26 130 0], respectively. Therefore, instance 1 needs 18 slots in the shipping sequence. The calculation of slot number in the other instances is similar and is listed in the last two columns of Table 3.

5.2. Sensitivity Analysis of Lot Size U . We have already known from Table 3 that selecting a larger lot size U will make the slot number decrease, while the reduction degree of slot number is different for each increase in lot size U by a certain number. Figure 4 then detects the relationship

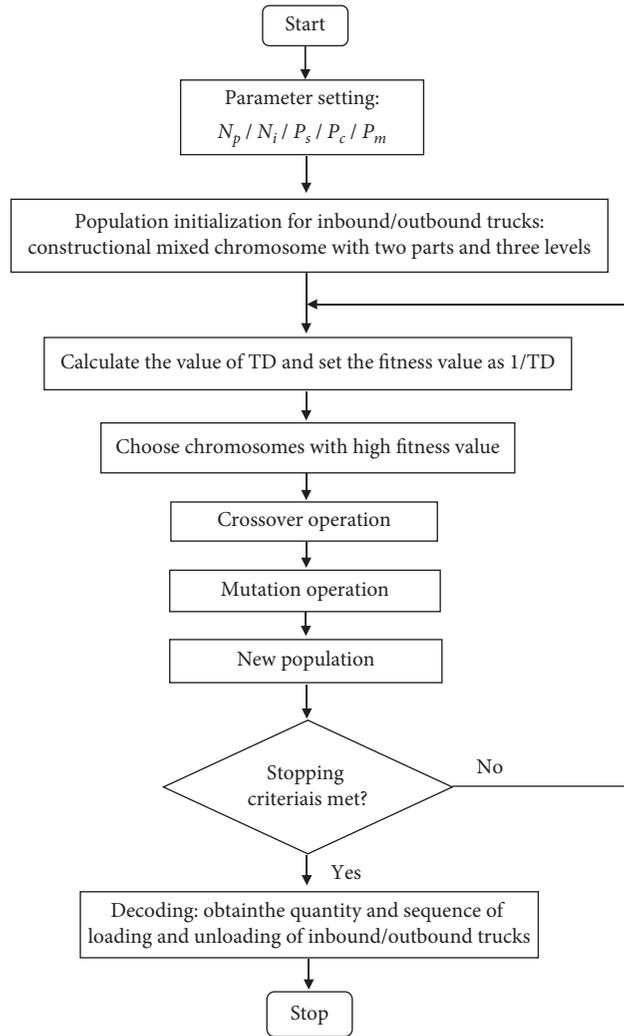


FIGURE 3: Procedure of the proposed genetic algorithm.

TABLE 3: Characteristics and values of the instances.

Instance	No. of inbound trucks	No. of outbound trucks	No. of fresh product types	Total quantity of fresh produce	No. of slots	
					$U = 50$	$U = 100$
1	4	5	4	990	18	10
2	5	4	6	1030	17	14
3	3	3	8	890	18	13
4	5	5	8	1000	25	23
5	5	3	8	960	20	15
6	4	4	5	1020	21	13
7	5	4	6	980	18	14
8	3	5	7	890	27	24
9	4	4	8	900	20	17
10	3	4	9	930	21	17

optimal solution. However, this is not absolutely the case, because smaller U can also greatly increase the solution space of the algorithm, making it easy to fall into the local optimum solution and difficult to find a better solution within a limited time or number of iterations. In the case of truck changeover time $D = 300$, by reducing the value of U from 100 to 10, the TD decreases from 22.5 to 16.59 with a

decrease of 26.3%. And the decreasing rates in the other two cases are 21.8% and 16.6%, respectively. (2) The slope of TD to U gradually increases. When U is small, increasing its value makes TD slightly increase. When U becomes larger, increasing its value makes TD significantly increase. This is mainly because when U is small, it is already extremely close to the optimal solution, and changing its value has less effect.

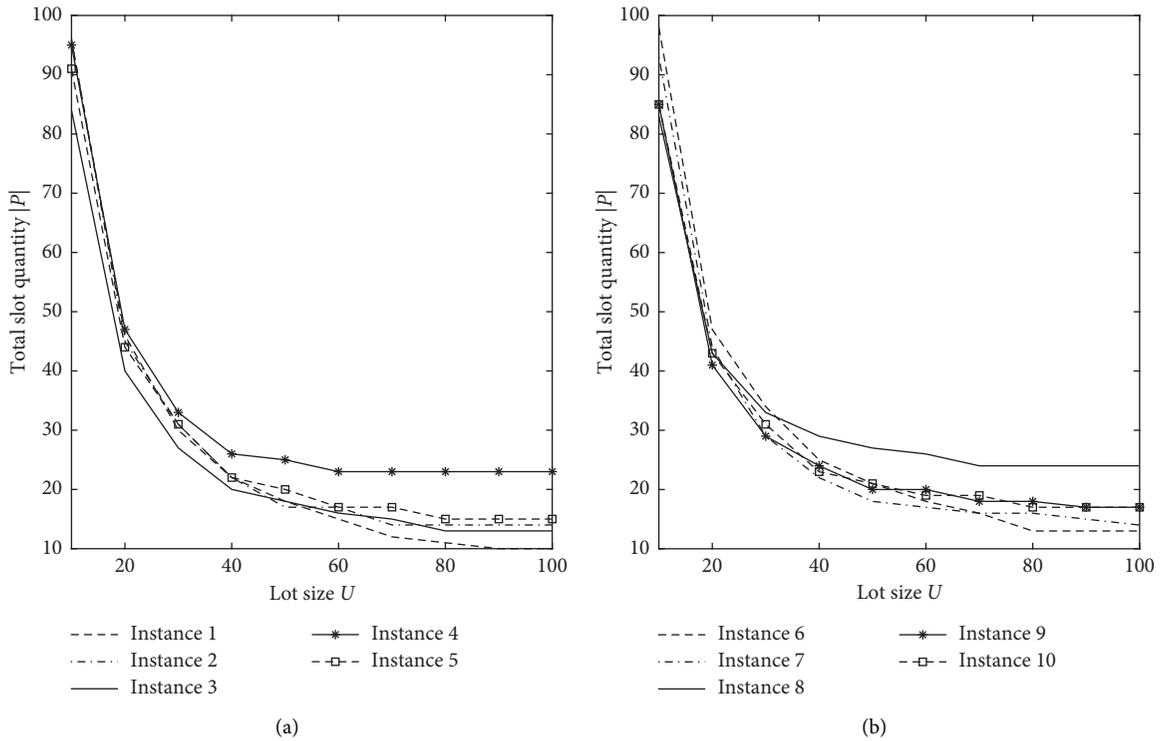


FIGURE 4: Total slot quantity of outbound trucks under different lot sizes.

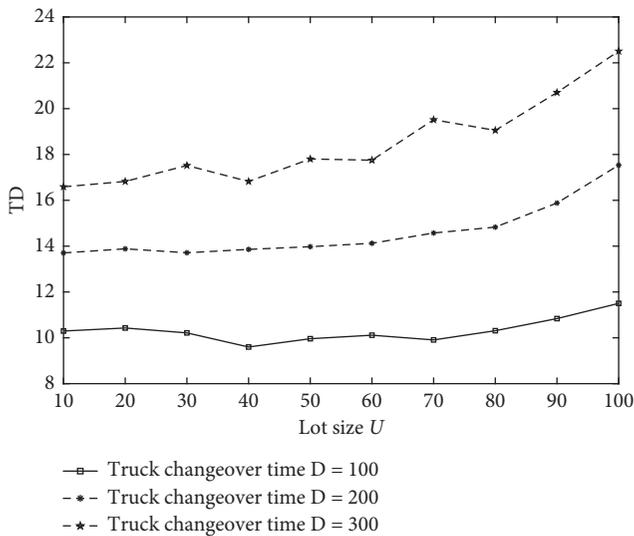


FIGURE 5: Variation of TD on lot size U under $D = 100$, $D = 200$, and $D = 300$.

(3) The value of TD increases as truck changeover time D increases, which is mainly due to larger D that will also significantly increase the completion time, thereby increasing the value of TD.

5.3. Sensitivity Analysis of Truck Changeover Time D . If the truck changeover time D is short, repeated entries and exits to the shipping dock allow the outbound truck to complete the loading process as flexibly as possible without

significantly increasing the completion time. At the extreme, if $D = 0$, then the products unloaded from inbound trucks can be loaded onto outbound trucks without interruption, thus significantly reducing the completion time. Therefore, it is also necessary to explore the effect of D on TD in this paper.

Figure 6 investigate the influence of D on TD under $U = 30$ and $U = 60$. Similar to the analysis in Section 5.2, we can come to the following conclusions: (1) there is a linear growth tendency for TD as the value of truck changeover time D increases and the average slopes in the two cases are 0.0318 and 0.0334, respectively, and (2) the increase of lot size U will increase the value of TD, but it does not significantly change the slope of TD to D .

5.4. Comparing the TDs under Repeat and Nonrepeat Modes.

Traditional cross-docking models study nonrepeat mode of the trucks, and scheduling truck sequences are the main purpose of their researches. While the repeat mode focuses on scheduling the loading and unloading tasks, therefore, it is more flexible. In this paper, we adopt Yu and Egbelu [22] instances to compare the TD values calculated by the two modes to show the advantages and disadvantages of the repeated loading mode.

Table 4 takes instance 1 as an example to compare the TDs under repeat and nonrepeat modes with different truck changeover time. As mentioned before, when $D = 0$, the loading process of outbound trucks under repeated mode is continuous, which leads to the loading efficiency greatly improved. Specifically, when $U = 30$, the percentage

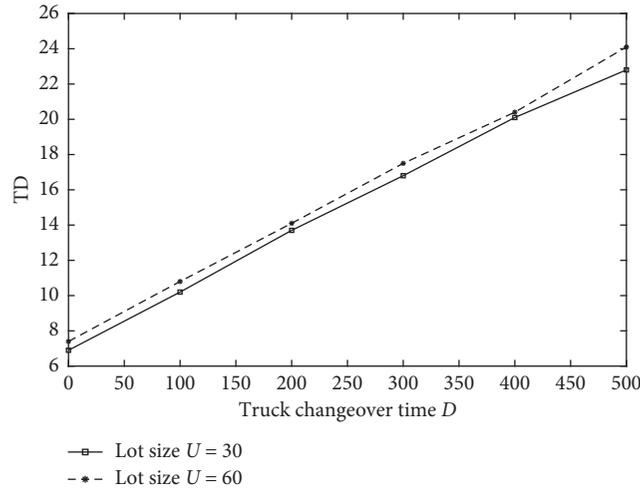


FIGURE 6: Variation of TD on truck changeover time D under $U = 30$ and $U = 60$.

TABLE 4: Instance 1: percentage deviations of TD between repeated and nonrepeated modes.

D	Min TD under $U = 30$		PD (%)	Min TD under $U = 60$		PD (%)
	Repeat	Nonrepeat		Repeat	Nonrepeat	
0	6.9	9.7	28.9	7.4	9.7	23.7
100	10.2	12.8	20.3	10.8	12.8	15.6
200	13.7	15.9	13.8	14.1	15.9	11.3
300	16.8	19.0	11.5	17.5	19.0	8.0
400	20.1	22.1	9.0	20.4	22.1	7.7
500	22.8	25.0	8.8	24.1	25.0	3.6
Average	—	—	15.4	—	—	11.7

TABLE 5: Percentage deviations of TD between repeated and nonrepeated mode under all instances.

Case	Instances	Min TD		PD (%)
		Repeat	Nonrepeat	
$D = 0, U = 30$	1	6.9	9.7	28.9
	2	8.5	12.3	30.9
	3	8.2	12.9	36.4
	4	9.3	13.3	30.1
	5	7.5	13.3	43.6
	6	5.5	7.6	27.6
	7	5.9	7.5	21.3
	8	5.6	8.9	37.1
	9	9.6	13.6	29.4
	10	6.8	10.1	32.7
Average	—	—	—	31.8
$D = 0, U = 60$	1	7.4	9.7	23.7
	2	9.1	12.3	26.0
	3	9.3	12.9	27.9
	4	9.8	13.3	26.3
	5	8.8	13.3	33.8
	6	6.1	7.6	19.7
	7	6.1	7.5	18.7
	8	5.8	8.9	34.8
	9	8.8	13.6	35.3
	10	7.3	10.1	27.7
Average	—	—	—	27.4

TABLE 5: Continued.

Case	Instances	Min TD		PD (%)
		Repeat	Nonrepeat	
<i>D</i> = 100, <i>U</i> = 30	1	10.2	12.8	20.3
	2	13.4	15.7	14.6
	3	10.5	15.6	32.7
	4	16.5	18.4	10.3
	5	11.7	18.5	36.8
	6	8.6	9.7	11.3
	7	9.0	10.0	10.0
	8	8.9	12.2	27.0
	9	14.7	17.7	16.9
	10	9.7	12.2	20.5
Average	—	—	—	20.1
<i>D</i> = 100, <i>U</i> = 60	1	10.8	12.8	15.6
	2	13.2	15.7	15.9
	3	12.8	15.6	17.9
	4	14.7	18.4	20.1
	5	12.8	18.5	30.8
	6	8.4	9.7	13.4
	7	9.1	10.0	9.0
	8	9.1	12.2	25.4
	9	15.1	17.7	14.7
	10	10.5	12.2	13.9
Average	—	—	—	17.7
<i>D</i> = 200, <i>U</i> = 30	1	13.7	15.9	13.8
	2	15.6	19.0	17.9
	3	14.8	18.3	19.1
	4	20.8	23.1	10.0
	5	16.7	23.6	29.2
	6	10.9	11.8	7.6
	7	11.6	12.5	7.2
	8	11.9	15.2	21.7
	9	18.7	21.9	14.6
	10	12.3	14.4	14.6
Average	—	—	—	15.3
<i>D</i> = 200, <i>U</i> = 60	1	14.1	15.9	11.3
	2	16.2	19.0	14.7
	3	15.1	18.3	17.5
	4	20.8	23.1	10.0
	5	17.7	23.6	25.0
	6	10.5	11.8	11.0
	7	11.7	12.5	6.4
	8	12.1	15.2	20.4
	9	19.0	21.9	13.2
	10	12.2	14.4	15.3
Average	—	—	—	14.5

deviation (calculated by equation (25)) of TD between repeated loading and nonrepeated loading reaches 28.9%. Besides, as *D* increases, the percentage deviation between the two modes becomes smaller. It can be predicted that when *D* is large enough, the repeated loading mode will converge infinitely to the nonrepeated loading mode. This is mainly because, in this case, additional entry and exit of the outbound truck will waste a lot of time, which tends to be the nonrepeated mode finally.

$$PD(\%) = \frac{\text{nonrepeat mode} - \text{repeat mode}}{\text{nonrepeat mode}} \times 100. \quad (25)$$

The results of other instances are shown in Table 5. Similarly, we divide the value of *D* into three levels: *D* = 0, *D* = 100, and *D* = 200; and the value of *U* into two levels: *U* = 30 and *U* = 60. By analyzing the results, several conclusions can be drawn:

- (1) Decreasing the value of *U* can obtain smaller TD value. At the extreme, if *U* = 1, we can obtain the global optimal solution of TD in the repeated loading mode, and this value would be smaller than all the TD values in the table. However, setting smaller *U* will greatly increase the computational complexity, which is almost impossible to obtain in a limited

time. Therefore, this section only takes U that is equal to 30 and 60.

- (2) Compared with the nonrepeat mode, repeated loading can result in a lower TD for fresh produce; specifically, when $D = 0$, there is more than 31.8% reduction on average among these instances. This phenomenon is particularly evident in instances 3, 5, and 8.
- (3) Increasing the value of D will increase the value of TD in both modes and reduce the superiority of repeated loading mode compared to the nonrepeat mode. As stated before, when D is large enough, the TD values obtained by the repeated mode will be close to those by the nonrepeat mode. This trend can also be seen from the changes in D from 0 to 100 and 100 to 200 in the table.

6. Conclusion and Future Research

We formulate a truck scheduling model for the cross-docking of fresh produce under repeated loading mode and present a definition of the total deterioration (TD) that considers the operation times, deterioration rates, and quantities corresponding to different types of fresh produce. Accordingly, the objective of this paper is to determine the optimal schedule for inbound and outbound trucks, such that the TD of all fresh produce is minimized. To solve this model, specific loading rules are presented to transform the outbound truck sequence into a slot docking sequence, and an advanced genetic algorithm is proposed to solve the problem. In the advanced genetic algorithm, a mixed chromosome representation consisting of two parts and three levels is utilized for each solution. In addition, the main steps of the algorithm (solution representation; crossover, mutation operation; fitness value evaluation, and stopping criteria) are introduced in this paper. To compare the optimal truck schedules and minimum TDs between the repeat mode and nonrepeat modes, 10 instances under different truck changeover time D and lot size U are solved using the genetic algorithm. Computational results show that the repeat mode can effectively decrease the TD value of fresh produce compared with nonrepeat mode, and this superiority decreases with the increase of D and U values. In particular, when the truck changeover time D equals 0, the value of TD obtained under repeated loading mode will be more than 31.8% on average smaller than that under nonrepeated loading mode.

This research contributes to enabling better truck scheduling problems for fresh produce at cross-docking centers. For further studies on this problem, the following extensions are also worthy to investigate: (1) considering repetitive dock patterns for both inbound and outbound trucks, and the performance between these patterns can be further evaluated; (2) we can not only regard the total deteriorated proposed in this paper as the cost function, but also consider incorporating other important components in cross-docking operations as the elements of cost function (e.g., waiting cost of trucks, service cost of trucks, and

delayed departure cost of trucks) and finally integrate these costs as the objective function for optimization; (3) we assumed that there are only one receiving dock and one shipping dock. Future researchers can consider more than one dock; (4) the parameters of the proposed genetic algorithm of this paper are determined by an experimental approach. Some other approaches, e.g., designing experiments to evaluate the possibility of obtaining better solutions, can also be adapted to determine the parameters.

Data Availability

The data supporting this META-ANALYSIS are from previously reported studies and datasets, which have been cited by Yu and Egbelu [22]. The processed data are available in the Supplementary Materials.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Supplementary Materials

The supplementary material lists the detailed dataset of “inbound/outbound truck and fresh product type,” which had been used in the section of numerical analyses in this paper. (*Supplementary Materials*)

References

- [1] X. Cai, J. Chen, Y. Xiao, and X. Xu, “Optimization and coordination of fresh product supply chains with freshness-keeping effort,” *Production and Operations Management*, vol. 19, no. 3, pp. 261–278, 2010.
- [2] Y.-H. Hsiao, M.-C. Chen, and C.-L. Chin, “Distribution planning for perishable foods in cold chains with quality concerns: formulation and solution procedure,” *Trends in Food Science & Technology*, vol. 61, pp. 80–93, 2017.
- [3] Q. Wu, Y. Mu, and Y. Feng, “Coordinating contracts for fresh product outsourcing logistics channels with power structures,” *International Journal of Production Economics*, vol. 160, pp. 94–105, 2015.
- [4] Y. Qin, J. Wang, and C. Wei, “Joint pricing and inventory control for fresh produce and foods with quality and physical quantity deteriorating simultaneously,” *International Journal of Production Economics*, vol. 152, pp. 42–48, 2014.
- [5] S.-h. Li and M. Zhu, “Research on the differential outsourcing risks for fresh cold-chain logistics,” in *Proceedings of 20th International Conference on Industrial Engineering and Engineering Management*, pp. 827–840, Springer, Berlin, Germany, January 2013.
- [6] O. Theophilus, M. A. Dulebenets, J. Pasha, Y.-Y. Lau, A. M. Fathollahi-Fard, and A. Mazaheri, “Truck scheduling optimization at a cold-chain cross-docking terminal with

- product perishability considerations,” *Computers & Industrial Engineering*, vol. 156, no. 1, Article ID 107240, 2021.
- [7] A. Rahbari, M. M. Nasiri, F. Werner, M. Musavi, and F. Jolai, “The vehicle routing and scheduling problem with cross-docking for perishable products under uncertainty: two robust bi-objective models,” *Applied Mathematical Modelling*, vol. 70, pp. 605–625, 2019.
- [8] M. Verbic, “Discussing the parameters of preservation of perishable goods in a cold logistic chain model,” *Applied Economics*, vol. 38, no. 2, pp. 137–147, 2006.
- [9] A.-L. Ladier and G. Alpan, “Cross-docking operations: current research versus industry practice,” *Omega*, vol. 62, pp. 145–162, 2016.
- [10] J. Van Belle, P. Valckenaers, and D. Cattrysse, “Cross-docking: state of the art,” *Omega*, vol. 40, no. 6, pp. 827–846, 2012.
- [11] M. A. Dulebenets, “A delayed start parallel evolutionary algorithm for just-in-time truck scheduling at a cross-docking facility,” *International Journal of Production Economics*, vol. 212, pp. 236–258, 2019.
- [12] C. Serrano, X. Delorme, and A. Dolgui, “Scheduling of truck arrivals, truck departures and shop-floor operation in a cross-dock platform, based on trucks loading plans,” *International Journal of Production Economics*, vol. 194, pp. 102–112, 2017.
- [13] S. Rahmazadeh Tootkaleh, S. M. T. Fatemi Ghomi, and M. Sheikh Sajadieh, “Cross dock scheduling with fixed outbound trucks departure times under substitution condition,” *Computers & Industrial Engineering*, vol. 92, pp. 50–56, 2016.
- [14] B. Vahdani, R. Soltani, and M. Zandieh, “Scheduling the truck holdover recurrent dock cross-dock problem using robust meta-heuristics,” *International Journal of Advanced Manufacturing Technology*, vol. 46, no. 5-8, pp. 769–783, 2010.
- [15] N. Boysen and M. Fliedner, “Cross dock scheduling: classification, literature review and research agenda,” *Omega*, vol. 38, no. 6, pp. 413–422, 2010.
- [16] D. Vasiljevic, M. Stepanovic, and O. Manojlovic, “Cross docking implementation in distribution of food products,” *Economics of Agriculture*, vol. 60, no. 1, pp. 91–101, 2013.
- [17] W. Yu, *Operational Strategies for Cross Docking Systems*, ProQuest, Ann Arbor, MI, USA, 2002.
- [18] A. Mohtashami, “Scheduling trucks in cross docking systems with temporary storage and repetitive pattern for shipping trucks,” *Applied Soft Computing*, vol. 36, pp. 468–486, 2015.
- [19] D. Molavi, A. Shahmardan, and M. S. Sajadieh, “Truck scheduling in a cross docking systems with fixed due dates and shipment sorting,” *Computers & Industrial Engineering*, vol. 117, pp. 29–40, 2018.
- [20] O. Guemri, P. Nduwayo, R. Todosijević, S. Hanafi, and F. Glover, “Probabilistic tabu search for the cross-docking assignment problem,” *European Journal of Operational Research*, vol. 277, no. 3, pp. 875–885, 2019.
- [21] W. Wisittipanich, T. Irohara, and P. Hengmeechai, “Truck scheduling problems in the cross docking network,” *International Journal of Logistics Systems and Management*, vol. 33, no. 3, pp. 420–439, 2019.
- [22] W. Yu and P. J. Egbelu, “Scheduling of inbound and outbound trucks in cross docking systems with temporary storage,” *European Journal of Operational Research*, vol. 184, no. 1, pp. 377–396, 2008.
- [23] N. Boysen, M. Fliedner, and A. Scholl, “Scheduling inbound and outbound trucks at cross docking terminals,” *OR Spectrum*, vol. 32, no. 1, pp. 135–161, 2010.
- [24] A. Baniamerian, M. Bashiri, and F. Zabihi, “Two phase genetic algorithm for vehicle routing and scheduling problem with cross-docking and time windows considering customer satisfaction,” *Journal of Industrial Engineering International*, vol. 14, no. 1, pp. 15–30, 2018.
- [25] G. Tadumadze, N. Boysen, S. Emde, and F. Weidinger, “Integrated truck and workforce scheduling to accelerate the unloading of trucks,” *European Journal of Operational Research*, vol. 278, no. 1, pp. 343–362, 2019.
- [26] H. Corsten, F. Becker, and H. Salewski, “Integrating truck and workforce scheduling in a cross-dock: analysis of different workforce coordination policies,” *Journal of Business Economics*, vol. 90, no. 2, pp. 207–237, 2020.
- [27] A. R. Boloori Arabani, S. M. T. Fatemi Ghomi, and M. Zandieh, “Meta-heuristics implementation for scheduling of trucks in a cross-docking system with temporary storage,” *Expert Systems with Applications*, vol. 38, no. 3, pp. 1964–1979, 2011.
- [28] M. Madani-Isfahani, R. Tavakkoli-Moghaddam, and B. Naderi, “Multiple cross-docks scheduling using two meta-heuristic algorithms,” *Computers & Industrial Engineering*, vol. 74, pp. 129–138, 2014.
- [29] A. Rijal, M. Bijvank, and R. de Koster, “Integrated scheduling and assignment of trucks at unit-load cross-dock terminals with mixed service mode dock doors,” *European Journal of Operational Research*, vol. 278, no. 3, pp. 752–771, 2019.
- [30] M. Dulebenets, “A diploid evolutionary algorithm for sustainable truck scheduling at a cross-docking facility,” *Sustainability*, vol. 10, no. 5, p. 1333, 2018.
- [31] M. A. Dulebenets, “A comprehensive evaluation of weak and strong mutation mechanisms in evolutionary algorithms for truck scheduling at cross-docking terminals,” *IEEE Access*, vol. 6, pp. 65635–65650, 2018.
- [32] A. L. Ladier and G. Alpan, “Crossdock truck scheduling with time windows: earliness, tardiness and storage policies,” *Journal of Intelligent Manufacturing*, vol. 29, no. 3, pp. 1–15, 2018.
- [33] N. Boysen, “Truck scheduling at zero-inventory cross docking terminals,” *Computers & Operations Research*, vol. 37, no. 1, pp. 32–41, 2010.
- [34] D. Agustina, C. K. M. Lee, and R. Piplani, “Vehicle scheduling and routing at a cross docking center for food supply chains,” *International Journal of Production Economics*, vol. 152, pp. 29–41, 2014.
- [35] B. Bilgen and Y. Çelebi, “Integrated production scheduling and distribution planning in dairy supply chain by hybrid modelling,” *Annals of Operations Research*, vol. 211, no. 1, pp. 55–82, 2013.
- [36] F. Pan, W. Zhou, T. Fan, S. Li, and C. Zhang, “Deterioration rate variation risk for sustainable cross-docking service operations,” *International Journal of Production Economics*, vol. 232, Article ID 107932, 2021.
- [37] G. Alpan, A.-L. Ladier, R. Larbi, and B. Penz, “Heuristic solutions for transshipment problems in a multiple door cross docking warehouse,” *Computers & Industrial Engineering*, vol. 61, no. 2, pp. 402–408, 2011.
- [38] M. H. Fazel Zarandi, H. Khorshidian, and M. Akbarpour Shirazi, “A constraint programming model for the scheduling of JIT cross-docking systems with preemption,” *Journal of Intelligent Manufacturing*, vol. 27, no. 2, pp. 297–313, 2016.
- [39] G. Alpan, R. Larbi, and B. Penz, “A bounded dynamic programming approach to schedule operations in a cross docking platform,” *Computers & Industrial Engineering*, vol. 60, no. 3, pp. 385–396, 2011.
- [40] A. Shahmardan and M. S. Sajadieh, “Truck scheduling in a multi-door cross-docking center with partial unloading -

- reinforcement learning-based simulated annealing approaches,” *Computers & Industrial Engineering*, vol. 139, Article ID 106134, 2020.
- [41] O. Theophilus, M. A. Dulebenets, J. Pasha, O. F. Abioye, and M. Kavousi, “Truck scheduling at cross-docking terminals: a follow-up state-of-the-art review,” *Sustainability*, vol. 11, no. 19, p. 5245, 2019.
- [42] M. Keshtzari, B. Naderi, and E. Mehdizadeh, “An improved mathematical model and a hybrid metaheuristic for truck scheduling in cross-dock problems,” *Computers & Industrial Engineering*, vol. 91, pp. 197–204, 2016.
- [43] A. Golshahi-Roudbaneh, M. Hajiaghahi-Keshteli, and M. M. Paydar, “Developing a lower bound and strong heuristics for a truck scheduling problem in a cross-docking center,” *Knowledge-Based Systems*, vol. 129, pp. 17–38, 2017.
- [44] M. Grunow and S. Piramuthu, “RFID in highly perishable food supply chains - remaining shelf life to supplant expiry date?” *International Journal of Production Economics*, vol. 146, no. 2, pp. 717–727, 2013.
- [45] X. Wang and D. Li, “A dynamic product quality evaluation based pricing model for perishable food supply chains,” *Omega*, vol. 40, no. 6, pp. 906–917, 2012.
- [46] J. H. Holland, *Adaptation in Natural and Artificial Systems: An Introductory Analysis with Applications to Biology, Control, and Artificial Intelligence*, MIT Press, Cambridge, MA, USA, 1992.