Hindawi
Journal of Advanced Transportation
Volume 2020, Article ID 6972123, 13 pages
https://doi.org/10.1155/2020/6972123

Research Article

Research on Loading and Unloading Resource Scheduling and Optimization of Rail–Road Transportation in Container Terminal Based on "Internet +"—for Ghana Container Port Development Planning

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Received 12 February 2019; Revised 12 August 2019; Accepted 5 September 2019; Published 9 January 2020

Academic Editor: Stefano de Luca

Based on the "Internet +" technology, this paper establishes a logistics information platform for the container terminal. Under the premise of the scheduled arrival time and quantity of the truck, this paper aims at minimizing the working time of the loading and unloading equipment and the stay time of the train and truck in the station, and develops a scheduling optimization of loading and unloading model combing equilibrium assignment and flexible scheduling to realize the seamless transfer between rail and road transportation in container terminal. In order to solve the model, a multi-layer coding genetic algorithm with chromosome feasibility is designed to obtain the optimal scheduled time for the truck, and the optimal operation sequence of the gantry crane. Referring to China's container station, this paper takes Takoradi container terminal of Ghana as a case to verify the accuracy and effectiveness of the model and algorithm and provides the medium or long term planning for Ghana's development.

1. Introduction

The globalization of economy and trade has improved the necessity of multimodal transport research and laid a good foundation for container transportation. Recently, the study of railway container transportation emphasises more on the wagon flow organization [1, 2], but with the development of the container transportation, the study of optimization of station layout [3, 4], resource allocation [5, 6] and optimization of resource scheduling [7, 8] is increasing. Domestic and foreign scholars have also conducted a lot of research on the scheduled arrival of trucks and the optimization of loading/unloading resources scheduling in the container central station. In terms of truck service, Lin et al. [9] aiming at the uncertainty of the arrival moment of trucks, establish central station fuzzy queuing system, and study the optimal service rate of the central station under the fuzzy environment. Huynh et al. [10] take the trucks turnaround time and the utilization rate of the dock yard into account at the same time, and the planning model and the simulation joint optimization method are used to calculate the maximum number of reserved trucks that can be accepted during the period. Guan et al. [11] describe the gate query system based on M/E(k)/c model and establish the reserved optimization model. Chen et al. [12] establish a two-stage model to optimize the arrival of trucks and the congestion cost according to transient queuing theory. Zeng et al. [13] describe the query process when trucks arrive at gate and stock yard by BCMP query network, and optimize the reservation share per time period based on genetic algorithm and point-by-point fixed fluid approximation algorithm (PSFFA). Xu et al. [14] use the nonstationary queuing theory and the backlog-stationary estimation method to formulate the truck reservation strategy. The multi-objective optimal truck reservation model of the gate-stock two-stage terminal is constructed, and the improved NSGA-II algorithm is designed to solve the model. The optimization of loading and unloading resources of container central station can greatly improve the efficiency of container operation, and thus improve the efficiency of highway-rail transportation. Boysen et al. [15, 16] study on scheduling plan and the equilibrium operation of gantry crane working in the fixed. Jeong et al. [17] study the scheduling of container transit operation in railway station by matching, and establish a two-cycle operation plan by matching the import and export containers to determine the parking position of trucks and the operation sequence of the gantry crane. Wang et al. [18] establish a scheduling planning model of the gantry crane with the shortest idle time in the process of performing the task (ie the moving time between the two container tasks), and the ant colony algorithm is designed. And use the actual case to verify the effectiveness of the model and algorithm in reducing the idle time of gantry crane. Fu et al. [19] study on scheduling model of the shore bridge in the flexible working with safe working distance constraint between the shore bridges is added to the model and ship priority constraints. Zhang et al. [20] built a quay crane scheduling model with the flexible working region with the minimum finish time of container ship as the target; Li [21] developed a resource allocation model and applied it to the scheduling optimization model of loading and unloading equipment both working in the fixed region and flexible region and designed double level GA to solve it. Songya [22] develop a flexible scheduling operation model of gantry crane as the train arrives on time, and a scheduling model combining operation of gantry crane and front loader as the train arrives on delay time. And the genetic and bee colony algorithm is designed to solve the model. Chen [23] analyse the related properties of the loading/unloading and moving process of the bridge crane based on the scheduling optimization problem of container terminal loading and unloading operation with noncrossing between the bridge cranes, safety distance constraints and deck opening and closing constraints, and propose a heuristic algorithm to reduce the moving distance of bridge cranes and equilibrate their loads.

In summary, these papers mentioned have their limits, some just analyse the scheduled arrival of trucks, or others just study the optimization of loading/unloading resources scheduling in the container central station. Although the papers studying the optimization of loading/unloading resources combing with scheduled arrival moment of trucks are abundant, the "Internet +" technology is not mentioned in these papers [24], This research study the optimization of loading/unloading resources and at the same time get the scheduled arrival time of trucks based on logistic information platform built by "Internet +" technology. According to the logistic information platform, the dispatcher of container central station can know the arrival and dispatch time of train exactly, the dispatcher assigns the optimal sequence of loading/unloading resources and gives information to truck drives based on logistic information platform, which enable truck drivers to arrive at container central station at the appropriate moment, so that the waiting time of truck, gantry crane and train can be reduced and the efficiency can be improved.

2. Synchronous Loading and Unloading Optimization Model of Gantry Crane Based on Equilibrium Assignment and Flexible Scheduling

2.1. Problem Statement. The railway container central station, as a crucial node for the connection between highway and railway, is the key to achieve the "last mile" of efficient operation of the entire logistics chain. At the container centre station, the key to achieve the seamless connection of highway-rail transportation is its volume connection and time connection. Nowadays, with the development of internet, "Internet +" represents a new economic form, which refers to the integration of the Internet and traditional industries based on Internet information technology to optimize production factors and update industries. Therefore, this paper proposes to use the "Internet +" technology to establish a logistics information platform for the railway container central station where the dispatcher of container central station and truck drivers can share information for each other. According to the arrival volume and time requirements of container train, the operation status of loading and unloading equipment, to reserve the truck's arrival time, which is not only guarantee the quantity of demand of the container for collection and distribution operation, but also effectively reduce the waiting time of trucks in the station, and realise the maximum efficiency of seamless link of highway-rail transportation. Under the premise of shared scheduled arrival time of the truck through logistic information platform.

This paper develops a optimization of synchronous loading and unloading model combing equilibrium assignment and flexible scheduling to realise the matching of the volume and time between the train on the loading/unloading line and the trucks and to solve the problem of resources scheduling of loading and unloading in railway container central station and realize the optimal efficiency of the highway-rail transportation based on the logistics information platform, and the information exchange on logistics information platform based on "Internet +" technology is as Figure 1 shows. Then, this paper designs multilevel coding genetic algorithm with feasibility judgment of chromosomes to solve the model, and receive the optimal scheduled arrival time of trucks and the optimal operation sequence of gantry crane in the central station.

2.2. Subject Definition. This research assumes that both the loading and unloading of container groups can be carried out simultaneously. The optimization scope includes operated containers, operation passageway of trucks and main container block, gantry cranes can influence each other during operation, and safety distance ensured with the provision of additional constraints, to enforce gantry cranes are flexible with multiple lines. And this thesis considers the following types of containers due to the complexity of connection problems at the container terminal.

(1) Dispatched containers stored in main container block waiting to be loaded on railway flatcars.

(2) Dispatched containers arrived with trucks ready for loading onto railway flatcars.

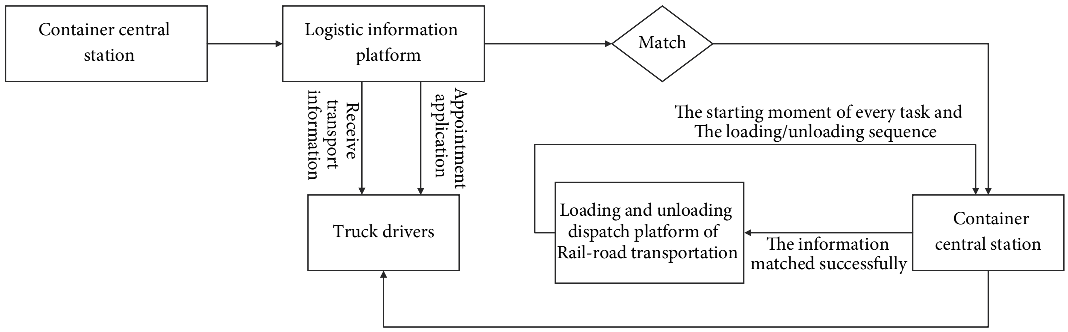

Figure 1: Schematic diagram of information exchange on logistics information platform based on "Internet +" technology.

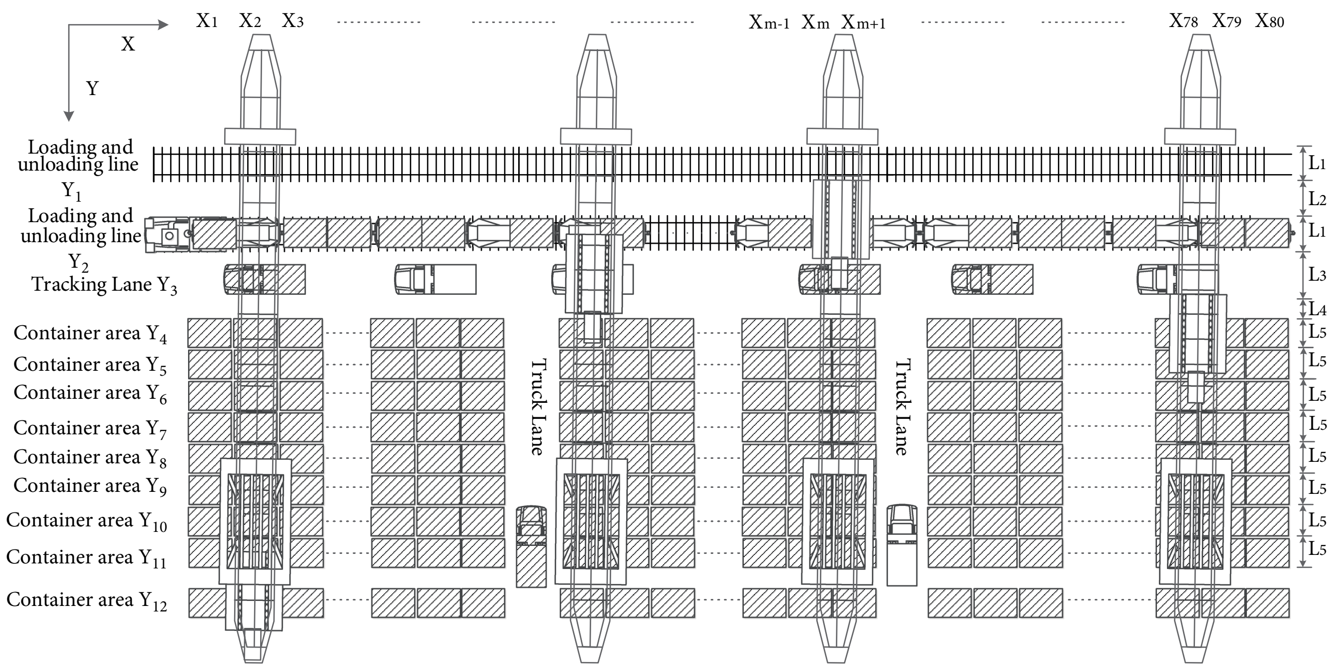

Figure 2: Graphical operational layout of gantry cranes in container terminal.

(3) Arrived containers with railway flatcars ready to be loaded onto trucks.

(4) Arrived containers with railway flatcars ready for unloading in main container stock.

In this paper, the loading and unloading line, the truck lanes and the slots of container are numbered (as shown in Figures 2 and 3), and assuming the container loading position on the railway flatcar are corresponded with the container slots in main container block along the Y-axis direction, so that the gantry operation process can be described as point-to-point movement for modelling.

The coding of loading/unloading lines, trucks operational lines, container slots in main container block to describe the gantry crane operation as movements between points using the following steps:

Step 1. The gantry crane moves along the X-axis; Columns of temporally stored containers are coded in an ascending order in the direction of the X-axis from the end of the line denoted as $x_1, x_2, \ldots, x_n$, as Figure 2 shows.

Step 2. The gantry crane trolley moves along Y-axis; The container terminal has two loading/unloading lines, Y_1 being the line further away from the main container block and the thesis mainly study the optimization of operation of Y_2 which is closer to the main container block; Y_3 is the trucks lane; Rows of the main container block are coded in an ascending order in the Y-axis direction from loading/unloading line denoted as $y_4, y_5, \ldots, y_n$ shown in Figure 2.

Step 3. Assume that the height of railway flatcar floor is coded as Z_1, the height of trailer car floor is coded as Z_2, and number of plies of temporally stored containers is $Z_i (i = 3, 4, 5)$, as shown in Figure 3.

For example, a loading task means a container is loaded from the container block (x_1, y_1, z_1) to the train (x_2, Y_2, Z_1) or from the trucks to the train (x_2, Y_2, Z_1), it is same with the unloading task. The operation process of gantry crane can be divided into 6 steps; (1) lifting sling downs without load; (2) lifting sling ascends up with container; (3) gantry crane moves along

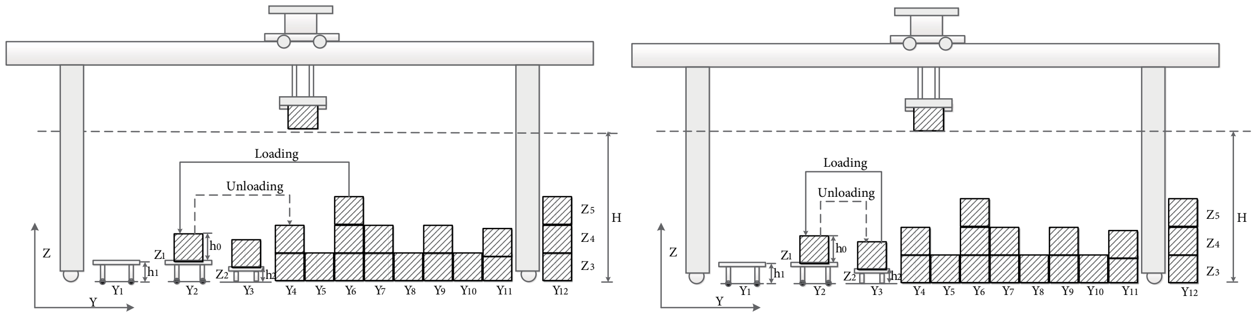

Figure 3: Diagram of loading/unloading operations of gantry crane.

X-axis; (4) gantry crane trolley moves along Y-axis; (5) lifting sling downs with container; (6) lifting sling ascends without load. It should be noted that not all of the 6 operation processes may occur in each loading and unloading operation, but each gantry crane is selected and completed according to its operation task arrangement.

2.3. Variables Definition. Tables 1 and 2 show the variables and decision variables definitions respectively in this thesis.

2.4. Mathematic Model. In order to simplify the model and improve the accuracy of its solution to fit in the actual operation in container terminal, the thesis transfers the stay time of the railway flatcar and the truck to the matched-degree between the scheduled time of trucks and the operation time of gantry crane, that is the time difference between the arrival moment of trucks for the operation and the beginning moment for the same operation or the finished moment for the former operation of the gantry crane. The smaller time difference is, the better matched-degree is and the shorter stay time of railway flatcar and trucks is.

Then the scheduling optimization of the loading and unloading resource model based on "Internet +" is as follows:

$$T = \begin{cases} \text{Min} \sum_{a=1}^{N_a} \left(T_{ac} - T_{ac}\right) \\ \min\left(\sqrt{\frac{1}{N_c}\sum_{a=1}^{N_c}\left(T_{ac} - \frac{1}{N_c}\sum_{a=1}^{N_c} T_{ac}\right)^2}\right) \end{cases} \quad (1)$$

$$\Delta t_i = \min\left(\underset{a\in N_c, i,j\in I}{\text{Max}}\left(\left|t_j^s - T_{a,i}^c\right|, \left|t_j^s - T_{a,j}^s\right|\right)\right) \quad i \neq j. \quad (2)$$

S.T.

$$\sum_{a=1}^{N_c} n_a = N \quad (3)$$

$$T_{ac} = T_{as} + \sum_{i\in R_a}\left[\left(ct_i^a - st_i^a\right) + t_{i,j}^a\right] \quad (4)$$

$$ct_i^a - st_i^a = \frac{d_{ix}}{V_x} + \frac{d_{iy}}{V_y} + \frac{d_{iz}}{V_z} + \frac{d_{iz}}{V_k} \quad (5)$$

$$t_{i,j}^a = \max\left(\frac{d_{i,jx}}{V_x}, \frac{d_{i,jy}}{V_y}\right) \quad (6)$$

$$d_{ix} = \left|x_i^c - x_i^s\right| \times l \quad (7)$$

$$d_{iy} = \begin{cases} \frac{b_c}{2} + \frac{b_l}{2} & (\textit{operation between train and truck}) \\ \frac{b_l}{2} + b_c + \left(y_i^s - y_4 + 0.5\right)b & \left(y_i^s \geq y_4, \textit{ loading between train and container stock}\right) \\ \frac{b_l}{2} + b_c + \left(y_i^c - y_4 + 0.5\right)b & \left(y_i^c \geq y_4, \textit{ unloading between train and container stock}\right) \end{cases} \quad (8)$$

$$d_{iz} = \begin{cases} 2H - 2h_0 - h_1 - h_2 \\ \quad (\textit{operation between train and truck}) \\ 2H - h_1 - z_i^c h_0 \\ \quad (\textit{operation between train and container stock}) \end{cases} \quad (9)$$

$$d_{i,jx} = d_{ix} \quad (10)$$

$$d_{i,jy} = \begin{cases} \left|y_j^s - y_i^c + 0.5\right|b \\ \quad (\textit{operation from unloading to loading}) \\ \left|y_j^s - y_4 + 0.5\right|b + \frac{b_l}{2} + b_c \\ \quad (\textit{operation from loading to unloading}) \end{cases} \quad (11)$$

$$ct_i^a + t_{i,j}^a - st_j^a \leq 0 \quad \forall a \in C, \forall i, j \in I, i \neq j. \quad (12)$$

$$X_1\left(ct_e^a + t_{e,f}^a - st_f^a\right) \leq 0 \; \forall e, f \in I. \quad (13)$$

$$X_2\left(ct_k^a + t_{k,q}^a - st_q^a\right) \leq 0 \;\; \forall k, q \in I. \quad (14)$$

$$\sum_{a=1}^{N_c}\sum_{j\in R_a} X_{i,j}^a = 1 \; \forall i \in R_a. \quad (15)$$

$$\sum_{i\in R_a} X_{i,j}^a \leq 1, \forall a \in C, \forall i, j \in R_a. \quad (16)$$

$$\sum_{j\in R_a} X_{i,j}^a \leq 1, \forall a \in C, \forall i, j \in R_a. \quad (17)$$

Table 1: Variables definition table.

Symbol	Definition	Symbol	Definition
I	Set of operations of loading or unloading containers, operation j is different from operation i. $i, j \in I$	M	Positive number that is large enough
N_c	Number of gantry cranes on a loading and unloading line	R_a	Set of operations of loading or unloading for gantry crane a. $R_a \subset I$
N	Total amount of loading and unloading operations	n_a	Total amount of loading and unloading operations for gantry crane a
x_i^s	Original X-coordinate of container i	x_i^c	Final X-coordinate of container i
y_i^s	Original Y-coordinate of container i	y_i^c	Final Y-coordinate of container i
z_i^s	Original Z-coordinate of container i	z_i^c	Final Z-coordinate of container i
e, f	Unloading operation e and loading operation f, which are carried out at the same place on the train $e, f \in I$	k, q	Unloading operation k and loading operation q, which are carried out at the same trailer $k, q \in I$
l	Length of container	b	Width of container
b_c	Width of trucks operation passageway	b_l	Width of loading/unloading line
H	The minimum height that the container bottom ascends when it was moved crosswise by lifting sling	h_0	Height of container
h_1	Height of railway flatcar floor	h_2	Height of truck floor
b_{safe}	Safe distance between two gantry cranes	$d_{i,j}$	Distance that gantry crane trolley moves from y_i^s to y_j^c from operation i to j
d_{ix}	The distance travelled by gantry crane when it completes the operation i	d_{iy}	The distance travelled by gantry crane trolley when it completes the operation i
d_{iz}	The distance travelled by lifting sling when it completes the operation i	v_x	Speed of gantry crane
v_z	Speed of lifting sling when it ascends or descends with container	v_y	Speed of gantry crane trolley
T_o	The permitting time for operation of railway flatcars	v_k	Speed of lifting sling when it ascends or descends idly
T_{as}	The moment when the loading or unloading operation of gantry crane a is started	T_{ac}	The moment when the loading or unloading operation of gantry crane a is finished
st_i^a	The moment when gantry crane a starts operation i	ct_i^a	The moment when gantry crane a completes operation i
t_i^s	The scheduled arrival moment of the truck for operation i	$t_{i,j}^a$	The time cost of that gantry crane a finishes operation of container i, and then moves to the start place of operation of container j

Table 2: Decision variables table.

Symbol	Definition	Symbol	Definition
X_1	0-1 variable, if loading operations i are finished at the same place (x_a, Y_2, Z_1) on train with the unloading operations j by the same gantry crane a, then it is 1, otherwise, it is 0	X_2	0-1 variable, if loading operation i and unloading operation j of the same truck are finished by the same gantry crane a, then it is 1, otherwise, it is 0
X_i^a	0-1 variable, if container operation i is finished by gantry crane a, then it is 1, otherwise, it is 0	$X_{i,j}^a$	0-1 variable, if gantry crane moves to the start place of operation after finishing the operation, then it is 1, otherwise, it is 0

$$\left|x_i^c X_i^a - x_j^s X_j^b\right| \geq b_{safe}\ \forall a,\ b \in C,\ \forall i \in R_a,\ \forall j \in R_b \quad (18)$$

$$\sum_{a=1}^{N_a} \left(T_{ac} - T_{as}\right) \leq T_o \quad (19)$$

The objective function (1) is a piecewise function, the first part minimizes the total operating time of gantry crane by summing the difference between the beginning moment and the completed moment for every gantry crane. The second part minimizes the variance of gantry crane operating time to measure the balance of working volume assigned to different gantry cranes for equilibrium assignment. Objective function (2), assuming task i is the former task for task j, the formula (2) minimizes the difference between the arrival moment of trucks for task i and the beginning moment of the gantry crane for task i or the completed moment for the former task, which means minimizing the waiting time between the gantry crane and its related trucks. Constraint (3) is the sum of operations of all gantry which is the total amount of operations of this scheduling. Constraint (4) is the finishing moment of gantry crane a for all operations. Constraint (5) explains that the

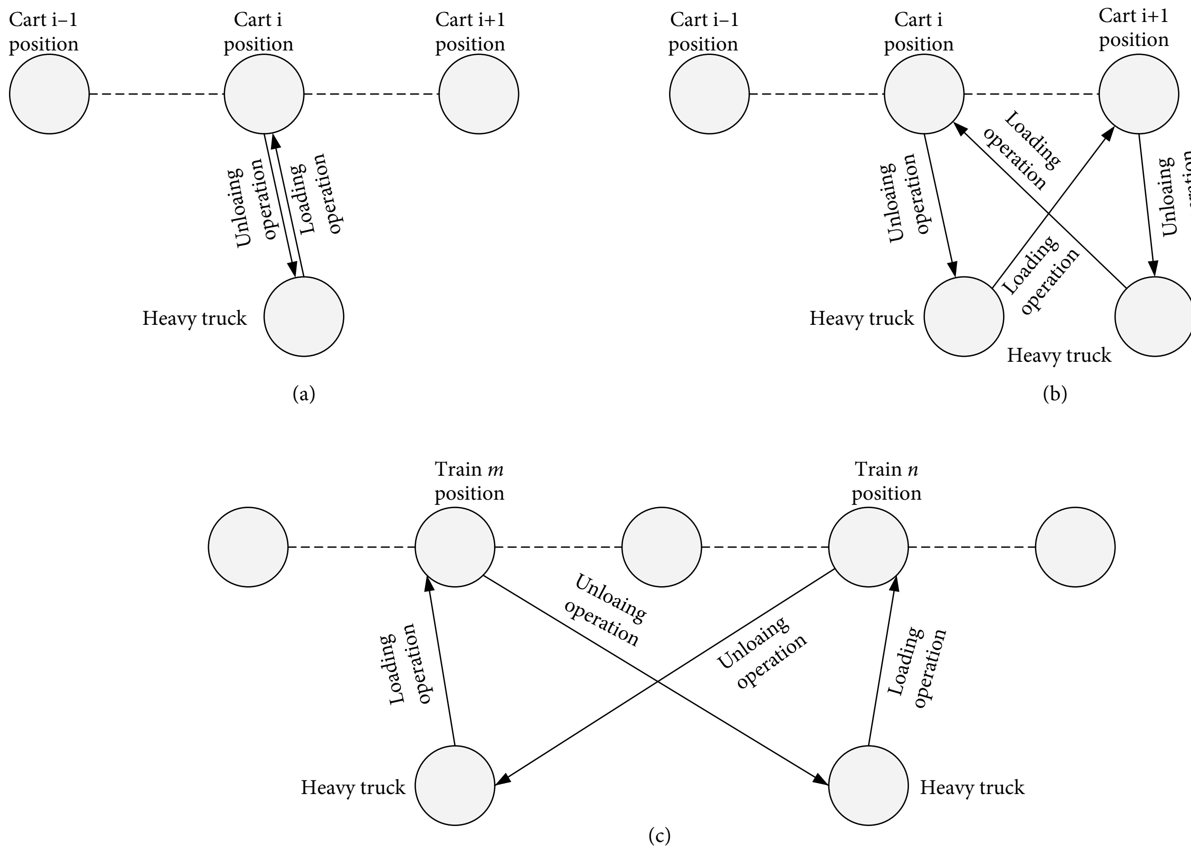

Figure 4: Schematic diagram of deadlock.

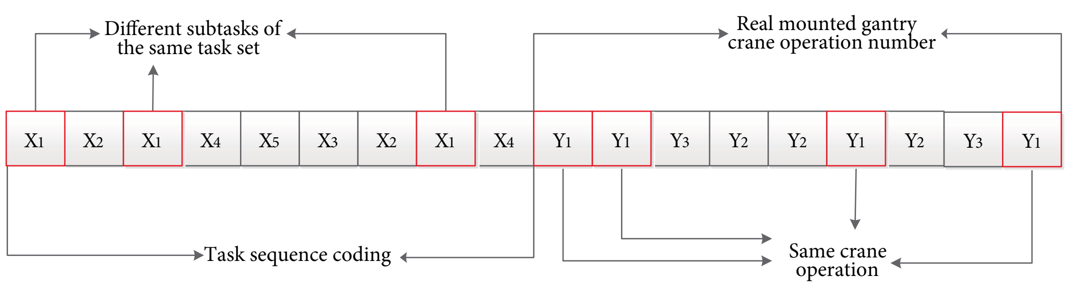

Figure 5: Schematic diagram of chromosome coding.

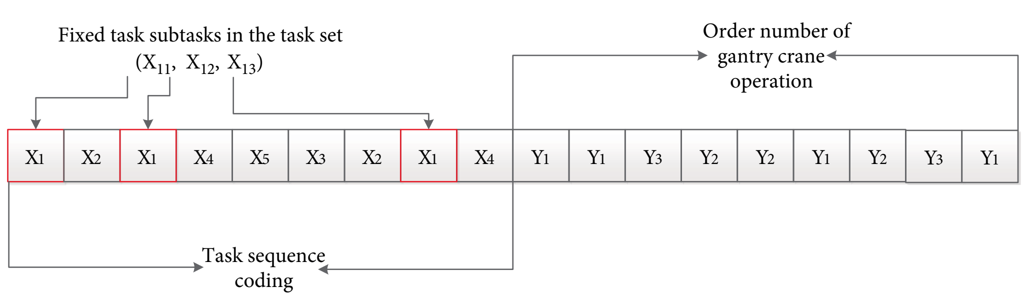

Figure 6: Schematic diagram of chromosome coding with fixed task sequence.

operation time of operation i, carried out by gantry crane a is equal to the moving time of gantry crane, plus moving time of gantry crane trolley, plus ascending and descending time of lifting sling. Constraint (6) ensures that the moving time of gantry crane a between finish time of operation i and start time of operation j is equal to the larger moving time of gantry crane or gantry crane trolley. Constraint (7) is the distance travelled by gantry crane from x_i^s to x_i^c for operation i. Constraint (8) is

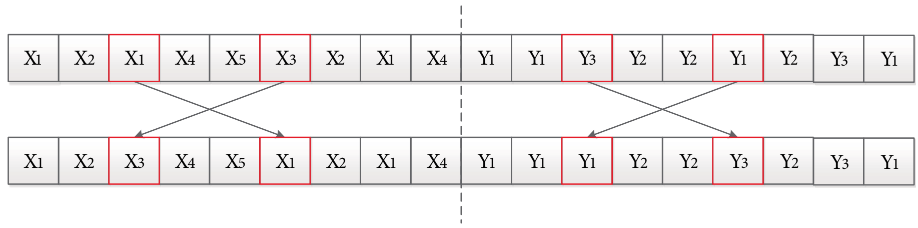

Figure 7: Chromosome variation schematic diagram.

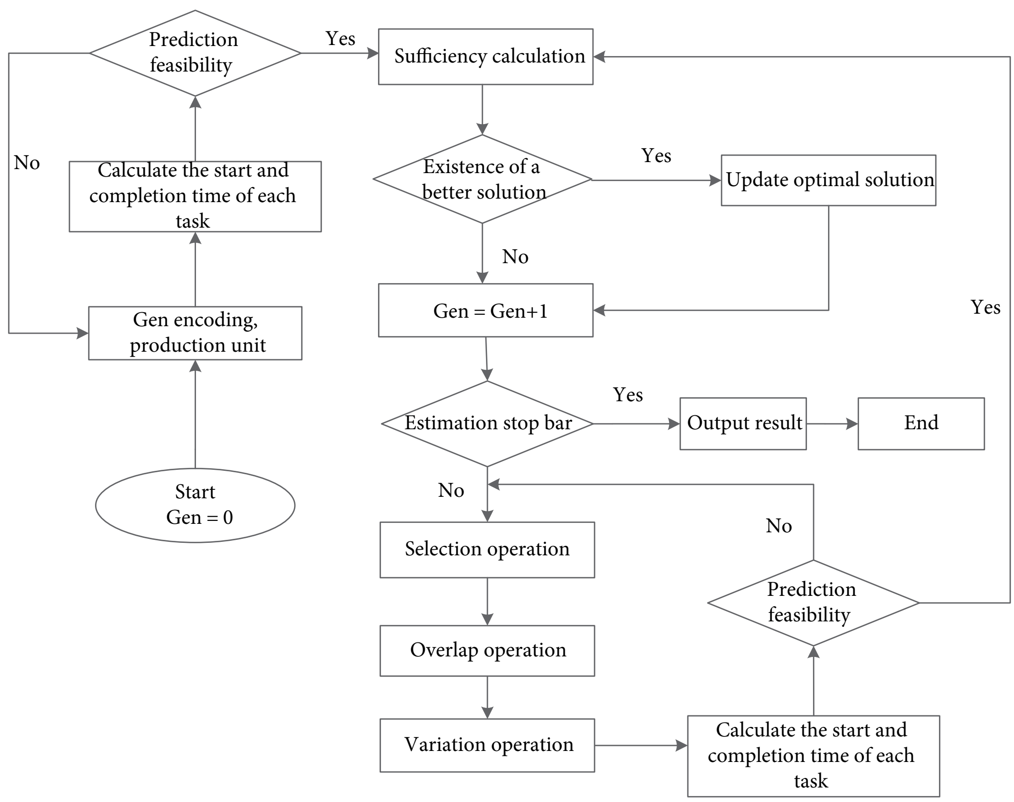

Figure 8: Genetic algorithm flow based on multi-layer coding.

the distance that gantry crane trolley moves from y_i^s to y_i^c for operations i. Constraint (9) is the distance that lifting slings descends or ascends from z_i^s to z_i^c for operation i. Constraint (10) and (11) is the distance travelled by gantry crane and gantry crane trolley between operation i and j respectively. Constraint (12) forces gantry cranes to finish two operations seamlessly i.e., the start moment of later operation is not earlier than the finish moment of former one plus the moving time of gantry crane between two operations. Constraint (13) guarantees that the finishing time for unloading operation e must be earlier than the start time of loading operation f, if the loading and unloading operations are carried out on the same place (x_a, Y_2, Z_1) of the train by the same gantry crane a. Constraint (14) explains the completion moment of unloading operation k, must be earlier than the start time of loading operation q, if the loading and unloading operations are carried out on the same truck by the same gantry crane a. Constraint (15), (16) and (17) enforces that each loading/unloading operation is carried out by one and only one gantry crane, each operation has one subsequent operation maximally and that each operation has a predecessor operation maximally respectively. Constraint (18) safeguards that, the distance between two gantry cranes is not smaller than the safety distance during the operation. Constraint (19) ensures that the total operation time of gantry crane is within the permitted operation time of the railway flatcars.

Table 3: Time table of trains.

Train number	Arrival time	Dispatch time	Remaining time	Allowed operation time
XXXX	8:00	14:40	200 minutes	180 minutes

Table 4: Relative parameters of gantry crane.

Relative parameters	N_c	$H\,(m)$	$V_x\,(m/s)$	$V_y\,(m/s)$	$V_z\,(m/s)$	$V_k\,(m/s)$	$b_{safe}\,(m)$
Parameters values	5	12	1.5	1	0.2	0.5	7

Table 5: Layout of loading/unloading operation region.

Operation region	Loading/unloading lines	Trucks operation passageway	Arrival loaded containers	Dispatched loaded containers
Y-axis value	1, 2	3	9, 10, 11, 12	4, 6, 7, 8

Table 6: Relative parameters of railway cars, trucks and container slots.

Relative parameters	$l\,(m)$	$b\,(m)$	$h_0\,(m)$	$h_1\,(m)$	$h_2\,(m)$
Parameters values	6.1	2.44	2.59	1.21	1.5

Table 7: Parameters of layout of container terminal.

Parameters of layout of container terminal	$b_l\,(m)$	$b_c\,(m)$
Parameters values	1.435	4

Table 8: Operations of trucks.

Trucks number	Loading operation	Unloading operation	Trucks number	Loading operation	Unloading operation
1	4	84	19	67	153
2	9	83	20	—	110
3	10	91	21	—	125
4	5	150	22	—	159
5	16	99	23	—	160
6	22	101	24	1	—
7	29	142	25	2	—
8	36	116	26	15	—
9	39	132	27	17	—
10	42	137	28	23	—
11	49	127	29	26	—
12	53	143	30	33	—
13	57	122	31	35	—
14	58	133	32	43	—
15	59	134	33	54	—
16	71	146	34	56	—
17	72	158	35	60	—
18	73	95	—	—	—

3. Synchronous Scheduling Optimization Algorithm for Gantry Crane

3.1. Feasibility Analysis of the Solution. If the loading and unloading tasks of the trucks match the loading and unloading tasks of the railway wagons at the same location on the loading line, as shown in Figure 4(a) (loading or unloading operations are relative to the railway flatcar), Or the loading and unloading tasks of multiple sets of trucks correspond to the same number of railway flatcar loading and unloading tasks corresponding to the X-axis position, such as Figures 4(b) and 4(c), because the logic contradiction between heavy truck and heavy railway flatcar loading and unloading operation sequence, may cause the transfer machine (gantry crane) to be unable to complete the operation and produce a deadlock, that is, there must be a circular chain of scheduling resources, such as the process p_0 in the $\{p_0, p_1, p_2, \ldots, p_n\}$ is waiting for p_1 being occupied, p_1 waiting for the resource p_2 being occupied ... p_n the resource p_0 that is waiting being occupied. This deadlock phenomenon occurs only in the process of the loading/unloading between trucks and the railway flatcar, regardless of the configuration of the gantry crane. In order to remove this deadlock and

Table 9: Extra scheduling operation.

No.	Unloading operation						No.	Extra scheduling Operation					
	Start block			Final block				Start block			Final block		
	X	Y	Z	X	Y	Z		X	Y	Z	X	Y	Z
4	4	2	1	4	10	4	161	4	10	4	4	3	2
36	36	2	1	36	10	5	162	36	10	5	36	3	2
42	42	2	1	42	11	5	163	42	11	5	42	3	2

Table 10: Comparison of operation time by multilayer GA.

Amount of gantry crane	Max (s)	Min (s)	Average (s)	Algorithm runtime (s)
3	14099	13029	13504	255
4	10839	10065	10350	269
5	8733	8143	8342	292

Table 11: Comparison of operation time by traditional GA.

Amount of gantry crane	Max (s)	Min (s)	Average (s)	Algorithm runtime (s)
3	15650	14202	14926	296
4	11706	11575	11640	317
5	9956	9202	9579	336

allow the loading and unloading cycle to proceed normally, an additional dispatch task is required. That is, the container on the railway flatcar is unloaded to the main container block, and then rail/truck transfer operation is restarted and kept going until the final unloading to the main container block of the first container to be unloaded to the last set of trucks, completed the operation of all the container loading and unloading operations.

3.2. Design of Multilayer Coded Genetic Algorithm with Chromosome Feasibility Judgment. Considering that the dispatch optimization of the container Centre station is an Np-hard problem, it is difficult to obtain the ideal solution result, but the basic genetic algorithm only performs genetic operations within a population, and is not suitable for the competition of multiple groups in the natural world. It is prone to precocity, and because it generally has a large population size, it needs a large number of genetic and evolutionary operations, making the evolutionary operation process slow and difficult to meet the calculation speed requirements. So in this thesis, a multilayer coded genetic algorithm with chromosome viability judgment is designed to solve the model. The algorithm design process is as follows;

(1) The coded chromosome encoding is encoded by an interactive integer encoding method. First, a fixed sequence of loading and unloading tasks are grouped as a set of tasks into the same genome, then each of the loading and unloading task is the subtask of the set of tasks, thus the chromosomes are divided into two parts. In the first part, each genome represents a set of loading and unloading tasks, in which the same genes in the genome represent different subtasks under the same set of tasks, and the sequence of genes indicates the sequence of loading and unloading tasks from left to right. The gene sequence is randomly produced but does not change the number of genes. In the second part, each gene represents a track gantry crane corresponding to the position of the first part, and its genetic value is randomly generated based on the number of cranes involved in the operation. The chromosome code is shown in Figure 5.

(2) Calculates the start and completion moment of each task. First, the subtasks in each task set are placed into the first part of the chromosome in a fixed order, as shown in Figure 6. Then, according to the second part of the chromosome calibration of the gantry crane serial number, calculate each task start time and job completion time.

(3) Feasibility judgment. The feasibility judgment of the design is divided into the operational sequence feasibility judgment and the operation location feasibility judgment. The steps of the algorithm are as follows:

Step 1. Define P for each set of tasks, indexed by i, $i = 1, 2, 3, \ldots, n$, and define each set of subtasks OP, indexed by j as $j = 1, 2, 3, \ldots, m$.

Step 2. Order $i = 1$, if $i \leq n$, then go to Step 2.1, otherwise, each operation is not belonged to the same set of task so that it is performed under an independent task, then there are no conflict between each operation, the operation sequence is feasible, proceed to Step 3.

Step 2.1. Order $j = 1$, if $j \leq m$, then go to Step 2.2, if $j > m$, it means the operation j is not belonged to the same subtask with other operation whose index is smaller than m, then order $i = i + 1$, proceed to Step 2.

Step 2.2. To judge the time relationship between each subtasks. Assume the finished moment of subtask j in the task i is ct_i^j and the start moment of adjacent task $j + 1$ is st_i^{j+1}, if $ct_i^j \geq st_i^{j+1}$, then order $j = j + 1$, move to step 2.1; Otherwise, for infeasible solutions, multiply by a maximum penalty value, and terminate the check.

Step 3. Select container task serial number $k = 1$ ($k = 1, 2, \ldots, s$).

Step 4. Check if there is overlap time between two-container operation tasks k and $k + 1$. Considering the adjacent container tasks $[st_k, ct_k]$ and $[st_{k+l}, ct_{k+l}]$, if $ct_k \leq st_{k+l}$, it shows that there is no overlap of time, move to Step 4.1; otherwise go to Step 5.

Step 4.1. If $k + 1 < s$, order $k = k + 1$, return to Step 4, otherwise move to Step 5.

Step 5. Judging whether the constraint (15) is satisfied can judge whether there is overlap time between two container tasks (st_k, ct_k) and (st_{k+1}, ct_{k+1}). If it is, move to Step 6, otherwise it means that the individual is an infeasible solution, multiplied by the maximum number of penalty values, and terminates the test.

Step 6. Judge the x coordinate of two adjacent container operating tasks (st_k, ct_k), (st_{k+1}, ct_{k+1}), whether the minimum value of their coordinate difference satisfies the safety distance constraint, judging whether $\min\{|x_k^c - x_{k+1}^s|, |x_{k+1}^c - x_k^s|\} < b_{safe}$ is satisfied, if it is, order $k = k + 1$ and return to Step 4.1, otherwise, the solution is not feasible, multiplied by the maximum number of penalty values, and terminates the test.

(4) Fitness calculation. In this thesis, the optimization model is a multi-objective mixed integer programming model. Therefore, the weighted coefficients are introduced by the Pareto optimal solution, and the multi-objective function is normalized to a single objective function to express the fitness function of the chromosome.

$$fitness = \omega_1 T + \omega_2 D_t. \tag{20}$$

Among $\omega_1 + \omega_2 = 1$, at the same time, in the selection operation, we choose the roulette wheel method.

(5) Overlapping operation. The population obtains new chromosomes through cross manipulation, thus promoting the whole population to evolve. In reference to the ordered intersectional method.

(6) Mutational operation. In this thesis, two elements are randomly selected exchanging their positions to determine chromosomal variation, as shown in Figure 7.

Table 12: Comparison between multilayer GA and traditional GA.

Amount of gantry crane	Multilayer GA		Traditional GA		Difference	
	Average (s)	Algorithm runtimes (s)	Average (s)	Algorithm runtime (s)	Average (s)	Algorithm runtimes (s)
3	13504	222	14926	296	1422	74
4	10350	247	11640	317	1290	70
5	8342	255	9579	336	1237	81

The genetic algorithm flow based on multi-layer coding is shown in Figure 8.

4. Case Study

The rapid development of China's container transportation in recent years, coupled with the continuous growth of Eurasian goods exchanges, has driven the development of international multimodal transport on the southeast coast of China and further promoted the development of China's container transport. So this paper studies the organization mode of container transportation in Takoradi Port of Ghana referring to the configuration and organization mode of facilities and equipment of China's container terminal, in order to provide medium and long-term planning ideas for the development of port in Ghana.

4.1. Determination of Model Parameters. Referring to the China's container station, for the medium-term and long-term planning of port in Ghana, the paper assumes there are two loading/unloading lines in container loading/unloading operation area in Takoradi container terminal. Arrival loaded containers are stored at line 9–12; dispatched loaded containers are stored at line 4–8. This paper selects 6 hours as the plan period and researches on the scheduling problem of container operation in 6 hours. Needed parameters and data can be calculated using the collected data from the station.

Parameters and data includes: Table 3, time table of trains, Table 4, relative parameters of gantry crane, Table 5, layout of loading/unloading operation region, Table 6, relative parameters of railway cars, trailers, container slots, Table 7, parameters of layout of the container terminal.

4.2. Loading/Unloading Operation. This thesis based on the medium-term planning operating rules of the Takoradi container terminal, designs loading/unloading operations for 160 containers finished in 6 hours. There are 57 dispatched containers stored in main container block, waiting to be loaded on railway flatcar. There are 23 dispatched containers arrived with trucks, waiting to be loaded on railway flatcar. There are 31 arrival containers arrived with railway flatcar, waiting be loaded on trucks. There are 49 arrival containers arrived with railway flatcar, waiting to be unloaded in main container block. Table 8 shows the operations of trailers, which is relative to railway flatcar.

Loaded trucks and railway flatcars can produce a deadlock (Lu and Liang 2009). Therefore, loading/unloading operations are pre-processed in this thesis, that is, check if there is deadlock between operations. If there is a deadlock, extra scheduling operation is added to unlock the deadlock. There are three groups of deadlocks in this thesis, between operation 4 and 84, operation 36 and 116, operation 42, 122, 137 and 57. So, an extra scheduling operation is added for each group of deadlocks, as Table 9 shows.

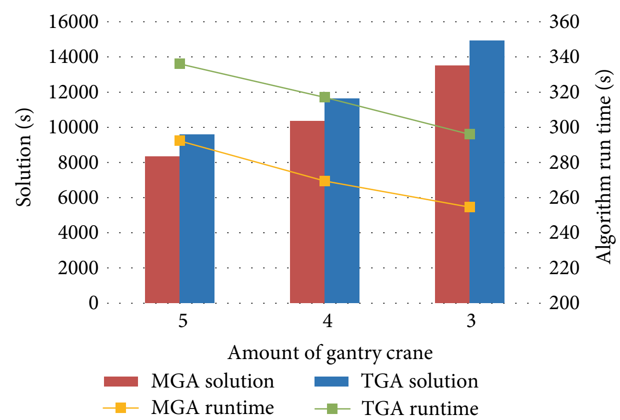

Figure 9: Comparison between multilayer GA and traditional GA.

4.3. Solving Process and Result. Loading/unloading scheduling problem of container central station belongs to NP-hard problem; it is difficult to solve it with exact algorithm. This paper designs multilevel coding genetic algorithm with feasibility judgment of chromosomes to solve the model. At the same time, the traditional GA algorithm is used to be compared to multilevel coding genetic algorithm. The paper compares the advantages and disadvantages of multi-layer genetic algorithm and traditional genetic algorithm from the difference between operation speed and optimal result. Set population size NP as 60, the maximum number of iterations is 200, crossover rate is 0.9, mutation rate is 0.2, the amount of gantry cranes can be 3, 4, 5, calculate for 30 times respectively. Tables 10 and 11 show the operation time by different algorithm, and Table 12 shows the comparison between multilayer GA and traditional GA, Figure 9 shows the comparison of algorithm runtime between multilayer GA and traditional GA.

As shown in the Table 12, the traditional genetic algorithm is not as good as the multi-layer genetic algorithm, both in terms of the accuracy of the result and the speed of the algorithm. The running time of the algorithm is prolonged with the increase of the number of gantry crane. The algorithm running speed of the multi-layer genetic algorithm is nearly 15% faster than the traditional genetic algorithm, and the calculated optimal average operation time is nearly 10% faster than the traditional genetic algorithm.

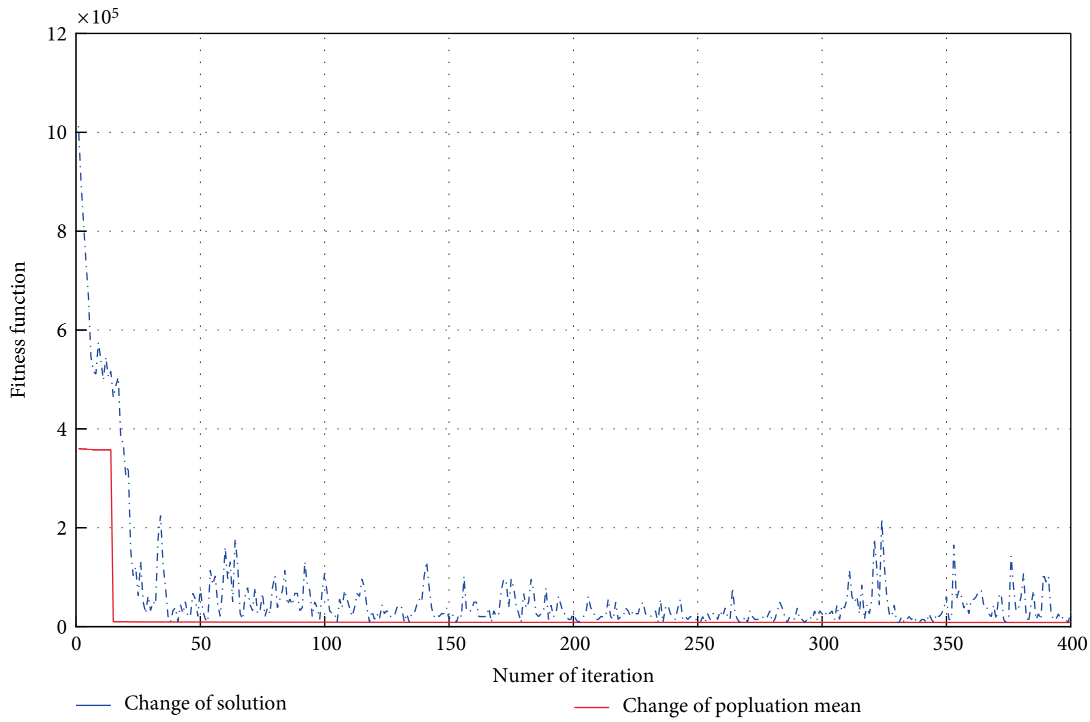

Figure 10: Iterative procedure of genetic algorithm.

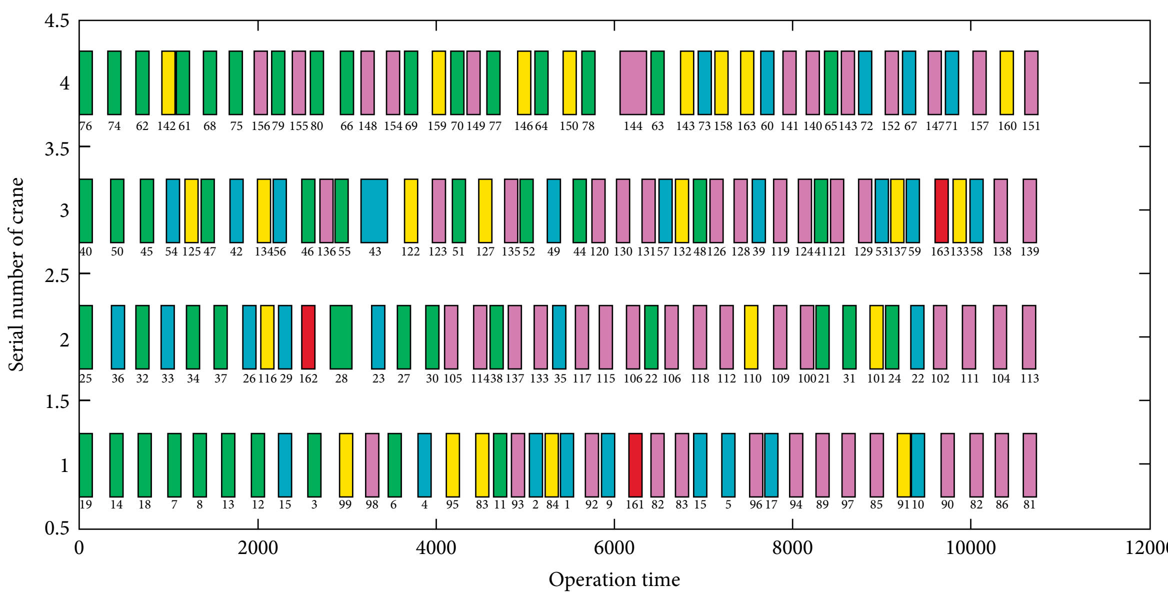

Figure 11: Gantt chart of scheduling operation of gantry cranes.

After comparing the performance of two algorithm, four gantry cranes are used in this scheduling, by taking remaining time of railway flatcars and operation costs into consideration, and the optimized result, which is the closest to average value, it is used as the appointment arrival time of trucks. The total operation time is 10331 s. Figure 10 shows the iterative procedure.

Figure 11 shows the Gantt chart of scheduling operation of gantry cranes. The purple operations represent the operation of dispatched containers stored in main container block, waiting to be loaded on railway cars. The yellow operations represent the operation of dispatched containers arrived with trucks, waiting to be loaded on railway flatcars. The blue operations represent the operation of arrival containers arrived with railway flatcars, waiting be loaded on trucks. The green operations represent the operation of arrival containers arrived with railway flatcars, waiting to be unloaded in main container block. The red operations represent the extra scheduling

Table 13: Optimal operation schedule of gantry cranes.

Number of gantry crane	Optimal operation schedule
Gantry crane 1	19—14—18—7—8—13—12—15—3—99—98—6—4—95—83—11—93—2—84—1—92—9—161—82—88—16—5—96—17—94—89—97—85—91—10—90—87—86—81
Gantry crane 2	25—36—32—33—34—37—26—116—29—162—28—23—27—30—105—114—38—107—103—35—117—115—108—20—106—118—112—110—109—100—21—31—101—24—22—102—111—104—113
Gantry crane 3	40—50—45—54—125—47—42—134—56—46—136—55—43—122—123—51—127—135—52—49—44—120—130—131—57—132—48—126—128—39—119—124—41—121—129—53—137—59—163—133—58—138—139
Gantry crane 4	76—74—62—142—61—68—75—156—79—155—80—66—148—154—69—159—70—149—77—146—64—150—78—144—63—143—73—158—153—60—141—140—65—145—72—152—67—147—71—157—160—151

Table 14: Scheduled arrival time of trucks.

Trucks number	Scheduled arrival time	Trucks number	Scheduled arrival time
1	9:44	19	10:44
2	9:54	20	10:45
3	11:13	21	9:00
4	10:11	22	9:46
5	9:29	23	11:32
6	11:08	24	10:10
7	8:55	25	10:04
8	8:46	26	9:17
9	10:31	27	10:48
10	9:08	28	9:35
11	9:55	29	9:11
12	10:32	30	8:58
13	9:41	31	10:09
14	11:23	32	9:33
15	9:13	33	8:56
16	10:02	34	9:16
17	10:39	35	10:47
18	8:40		

operations added to unlock deadlocks. Table 13 shows the optimal operation schedule of gantry cranes, based on Figure 11.

Based on the optimal scheduling operation sequence of gantry cranes and the planning arrival time of the railway flatcars, the logistics information platform can announce the exact arrival moment of trucks calculated by this model, so that the drivers can drive the trucks to the stations according to the scheduled amounts and appointment arrival time of trucks (as shown by Table 14) by getting information from the logistics information platform, which can realise the seamless link of rail-road transportation based on the minimum operation time of gantry cranes and minimum staying time of railway flatcars and trucks.

In summary, the paper gives an optimal operation schedule of gantry cranes table and the timetable of trucks. Then the dispatcher can assign the operation task to every trucks with the task table of gantry crane and the related truck drivers can know the exact moment arriving at container central station through the timetable which is published on the logistic information platform established by "Internet +" technology.

5. Conclusion

This paper uses "Internet +" technology to construct logistics information platform of container terminal, which makes the trucks share platform information to obtain the license quantity and the accurate time of arrival station by the way of booking, and realizes the demand matching between the railway flatcars and the trucks on the loading and unloading line and the seamless link of the rail-road transportation. On the premise that the loaded trucks arrives at the station according to the booking time, taking the optimal loading and unloading order of loading and unloading machinery as the condition, taking the shortest time of loading and unloading machinery and the shortest time of railway flatcars and trucks in the station as the objective, the paper establishes the optimal model of the synchronous loading and unloading of the Gantry Crane, which integrates the equilibrium operation and the flexible scheduling to complete transfer operation between the train/truck and container and solve the problem of handling resource scheduling in container terminal based on seamless link between highway and railway, and realize the optimal efficiency of the intermodal transport system. In order to improve the efficiency and accuracy of the model, a multilayer coded genetic algorithm with chromosome feasibility is designed to obtain the optimal moment of booking and the optimal loading and unloading sequence for the flexible scheduling of the container terminal. Referring to the China's container station, the paper takes Takoradi container terminal as case study, and the results show the accuracy and validity of the model and algorithm and provide medium and long-term planning ideas for the development of port in Ghana.

Data Availability

Referring to the China's container station (like Wuhan Container station), for the medium-term and long-term planning of port in Ghana, the paper assumes there are two loading/unloading lines in container loading/unloading operation area in Takoradi container terminal. The "case study" data used to support the findings of this study are included within the article, for further informaton, please contact with Mr. Zhuang, 15120956@bjtu.edu.cn.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Funding

These positions are funded by 2016 China's National Key Research and Strategic International Science and Technology Innovation Cooperation Project, which is titled "the Belt and Road" Land Transport International Intermodal Research and Exchange Centre under Grant [2016YFE0201700].

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