Hindawi
Discrete Dynamics in Nature and Society
Volume 2019, Article ID 2493638, 11 pages
https://doi.org/10.1155/2019/2493638

Research Article

Simulation Optimization of Discrete Logistics Processes: A Case Study on Logistics of an E-Commerce Enterprise in Shanghai

Xiang Xu, Yue Li, and Ruiyun Tang

School of Management, Shanghai University, Shang Da Road 99, Shanghai 200444, China

Correspondence should be addressed to Ruiyun Tang; try19970814@163.com

Received 23 November 2018; Revised 29 December 2018; Accepted 3 January 2019; Published 20 January 2019

Guest Editor: Xinchang Wang

With the rapid development of online shopping in recent years, logistics distribution has received much attention from enterprises and online consumers. Logistics distribution involves many factors and complex processes; conventional qualitative methods are unable to provide an effective analysis. Thus, this paper sets a framework to solve the above problem. A case study of an E-commerce enterprise in Shanghai on logistics distribution is proposed to discretize the whole process and minimize the total costs. Then the AnyLogic software is used to simulate and optimize the system from three aspects, including routes selection, warehouses quantity, and warehouses layout. Finally, this paper analyzes the simulation results, which would provide some valuable references for practical logistics.

1. Introduction

In recent years, E-commerce industry has developed rapidly. Online shopping is almost necessary to everyone. Logistics distribution is the last link of online shopping whose importance is rising as society demand increases. Whether goods can be delivered to consumers in time affects the consumers satisfaction of this shopping directly. Especially in the annual "Double Eleven" shopping festival, parcel quantities in various regions have increased rapidly and many delivery points have exploded. As shown in Figure 1, the logistics orders of Double Eleven in 2018 have set a new record. Logistics industry has also transformed into the rapid development stage. It is estimated that distribution costs account for over 50% of the total operational costs. This problem needs to be solved urgently. Besides, logistics distribution as one of the three major contents (distribution, storage, and management) in the logistics field includes scheduling management, distribution tools, distribution routes, delivery time, natural environment, human resources, and so on. More are getting to the importance of logistics distribution. Therefore, in this paper, much attention is paid to optimize and analyze the logistics distribution, shorten the delivery time, improve the distribution efficiency, and reduce the distribution costs. The distribution tools are necessary in the whole process which occupy considerable resources under demands uncertainty. To lower the logistics costs dramatically, reducing this consumption is significant through optimization [1]. Hence this paper considers the vehicle as the breakthrough point to analyze the costs optimization in system.

Meanwhile, the research on vehicle is not a theoretical problem in logistics distribution process. Lots of factors are contained including vehicles quantity, distribution terminal, delivery time, unloading time, and demand changes. Conventional qualitative methods are not insufficient to solve it. In recent years, computational technology including hardware and software has developed rapidly. This technology characterizes reflecting on complicated processes or behaviors to solve problems through simulation. Simulation is a new subject that has gradually formed with the development of computer technology. It was firstly proposed in the early 20th century and was mainly utilized in water conservancy research. Simulation is the process of experimental research on the system by establishing and using the real system model. Similar to the application of algorithm on theoretical issues, simulation has significant effects on practical problems, particularly the complex and practical problems like logistics distribution. By discretizing and dividing the whole

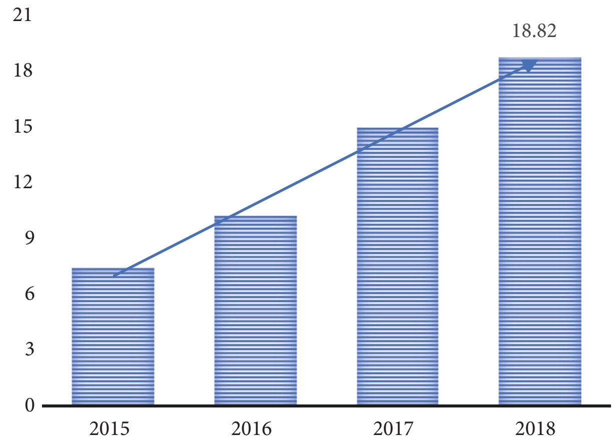

Figure 1: Parcel quantities during the "Double Eleven".

process into different parts, an integrated model is established and analyzed for every part to obtain the system data. According to the obtained data, optimal results are calculated [2]. The methods have more practical value than the theoretical algorithm. Better simulation methods have been presented in recent years as the computer technology develops. Simulation on the application of logistics distribution will have broader prospects.

This paper studies the discrete logistics processes which include many stochastic variables and factors. The method of mathematical modeling is not suitable. Therefore, the simulation is used to optimize the logistics distribution system and get the practical results.

For the simulation research of logistics distribution problems, the GPSS language (The General Purpose Systems Simulator) was firstly presented by American Geoffrey Gordon in 1961, which is a solution to discrete events, particularly the queuing phenomenon [3]. Considering the combination of continuous system and discrete system, simulation language of hybrid system occurred after the 1970s, for instance, SLAM language (Simulation Language for Alternative Modeling), which translates the program into FORTRAN language and then compiles it into machine codes with high execution rate. The language can be used in discrete systems, continuous systems, and hybrid systems consisting of both [4]. KV has established an interactive model to support the logistics planning on container operations, which can provide the evaluation of the ports performance, optimize the utilization rate of ports, and shorten the turnaround time of ships [5]. Ila et al. proposed an eight-step simulation model development process (SMDP) to the design, implementation, and evaluation of logistics and supply chain study by adopting discrete events [6]. Meng et al. modeled the problem of free delivery in E-commerce companies with uncertain demands and discussed the influence of uncertain factors on the optimal solution [7]. Geng et al. established a self-organized elastic supply chain model based on MAS and designed the local fitness function, neighbor structure, and community interaction rules with the enterprises as agent. The results indicate that the system has an aggregation effect and its evolution can be controlled by MAS parameters [8]. Cui et al. transformed one step of RUL estimate of simulation model in discrete events logistics system into two steps. An instance validated the effectiveness and testified the performance of the two-step RUL estimation which is better than the one-step estimation [9]. Li et al. established a nonlinear model for vehicle routing planning problems subject to time windows which considered the influence of road irregularities on fresh fruits and vegetables. Compared to the results with the conventional models, the new model is superior to the prior one [10]. Lin et al. constructed a method of using transit signals first in the case of emergency evacuation among a sudden disaster without a specialized-transit channel. The bus signal priority dominated by four factors which could evacuate personnel and lessen time as much as possible. Paramics is utilized to simulate this method which is better than the other methods [11]. Thies et al. studied the effects of resources sharing on potential savings in logistics industry through a model of discrete instances and the resource utilization in installation stage of offshore wind energy generator based on Agent. The simulation results show that weather has a significant influence on the installation time, use time, and resources utilization rate. Meanwhile, the resources sharing has a potential saving on the installation of offshore wind energy generator [12]. Li et al. adopted the method of dynamic traffic network analysis and discussed the optimization of regional traffic organization. Then they simulated it with self-developed software and proposed the optimized model and algorithm to prove the method on availability and feasibility [13]. Wei et al. identified that, in a discrete-time VMI supply chain system composing of one retailer and one manufacturer, production fluctuations can be interestingly stable even if the retailer subsystem is fluctuant. Simulation experiments are used to verify the theoretical results on inventory and production fluctuation [14]. Teodor Gabriel et al. proposed an innovative classification method for the use of simulation in a complicated system of multimodal transportation with multi-participant. This method identifies the main findings, trends, and future routes in multi-dimension of multimodal transportation [15]. Mandi et al. presented a grouping formula based on the branch pricing to study the opportunity-constrained vehicle routing problem with stochastic demands and enhanced the solution quality by simulation experiments and sensitivity analysis [16]. Hu et al. proposed an urban traffic model (AUTM) for predicting and avoiding the traffic congestion. This model is used to the simulation of large-scale practical cases in different cities under different congestion conditions and has satisfactory results [17]. In response to the increasingly complicated logistics systems studies on discrete or continuous process, the number of simulation software arises with the rapid development of computer technology in related fields [18], which has developed a tendency to visualization, modularity, and intelligence. Modeling speed is accelerated and simulation effect is improved through prefabrication of various components. Many simulation platforms in this area are commonly seen on the market, for instance, Arean, Witness, Flexsim, Promodel, Automod, and so on.

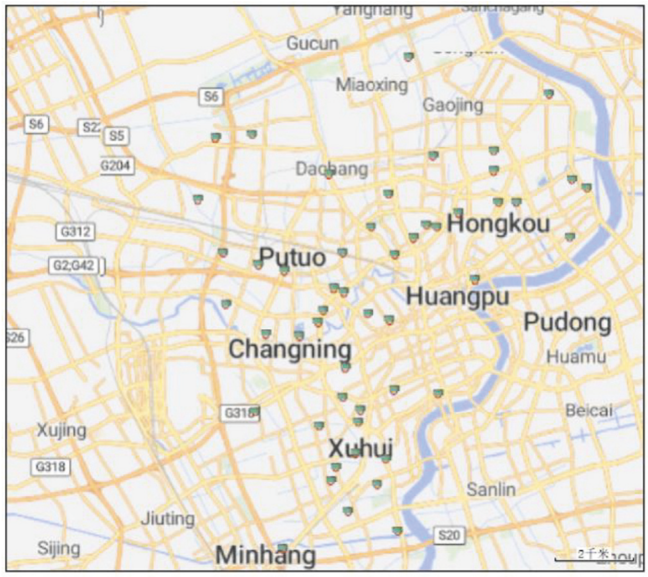

Figure 2: Distribution of self-raising points in main urban area of Puxi.

This paper considers adopting a simulation tool, Anylogic software, which is developed early in this century to visualize modeling with a wide application scope. Complicated logistics distribution problems are discretized and simulated from the perspective of different processes. Moreover, one E-commerce enterprise in Shanghai is studied as a case. This paper starts with continuous changes of warehouse quantities and demands and optimizes the route selection, warehouses quantity, and warehouses layout. Ultimately, some optimization suggestions are raised based on simulation results of the software.

2. Application of AnyLogic Simulation Platform in Logistics Distribution Field

AnyLogic, a commercial simulation software released in 2000 by the AnyLogic Company, is a powerful simulation platform which can be applied in a wide range of fields, including logistics simulation, supply chain simulation, virus pervasion, road traffic, pedestrian evacuation, military simulation, and so on. This platform can also be used in discrete events modeling, agent-based modeling, and dynamics system modeling. This paper combines the AnyLogic technology with a case of an E-commerce enterprise in Shanghai on logistics distribution to propose the optimization suggestions.

The detailed introduction on the distribution case of an E-commerce enterprise in Shanghai is shown as follows.

E-commerce enterprises usually distribute goods to customers in two steps: (1) deliver goods from large-scale warehouses to distribution stations; (2) deliver goods from distribution station to customers with numerous manpower and material resources. Thus, two-part costs occur. The second costs are much more than the first one due to the large number of involving personnel. Moreover, higher risks of traffic accidents and loss of goods are generated. Hence, to save costs and reduce risks, the E-commerce company in Shanghai has established commodity self-raising points in various regions. The company only dispatches vehicles transferring goods to the distribution points and customers pick up the goods themselves so that the costs of the second part can be completely saved. At the same time, the injury of the delivery personnel and the loss of the goods are dramatically reduced.

According to statistics, 51 self-raising points have been established in the main urban area of Puxi by the E-commerce company. The distribution map is obtained through the AnyLogic platform as follows in Figure 2.

Firstly, one large-scale warehouse is considered to construct in Northwest of Shanghai outside the main urban area, which is responsible for goods distribution to self-raising points in main urban area of Puxi. The location is shown in Figure 3.

The AnyLogic simulation is used to model and calculate the cost and the time requirement of completing 51 self-raising points on vehicles, which are salient criterion for assessing the solution.

Many practical factors need to be considered before starting the simulation. For instance, the time requirements for delivery beyond the limits are causing the compensation to the customer called tardiness cost which increases the total costs. Besides, the number of goods from every self-raising point affects the total delivery time and some time-sensitive delivery requirements for subsequent points.

Because of the different situations every day, the above two factors of every self-raising point can generate the orders quantity and the delivery time requirement through a random function as the fundamentals of the simulation. Thus, the following four items are included in every self-raising point: (1) name; (2) location; (3) goods quantity; (4) time limits.

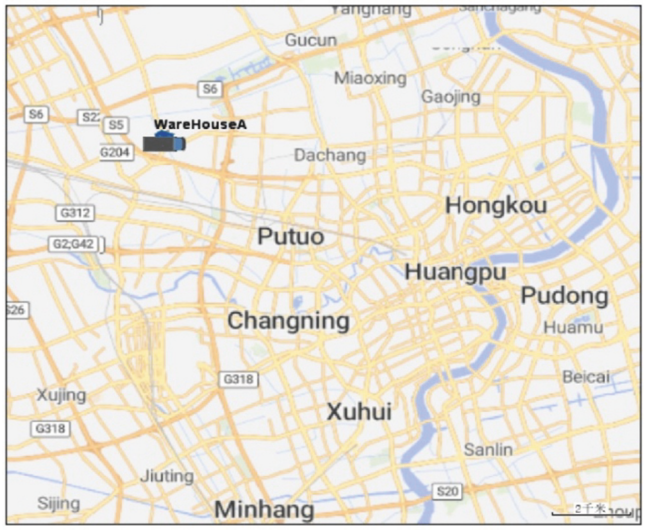

FIGURE 3: Single warehouse location.

While large-scale warehouses only involve delivery, only the following two items need to be considered: (1) name; (2) location.

Two solutions are considered in this paper for route planning: (1) the shortest route solution, which calculates the shortest route between two locations as the real path for vehicles travelling; (2) the time-limited precedence solution, which considers firstly to deliver the goods with time-sensitive requirements and then the shortest route solution is adopted. Solution one can reduce the vehicles travelling costs and increase the tardiness costs while solution two is completely the opposite. Ultimately, the simulation results are used to compare the two solutions on the total costs and the total time.

Setting up three agents for the simulation of this problem, they are as follows: (1) self-raising point agent; (2) warehouse agent, (3) distribution vehicle agent.

The distribution vehicle agent is the main activity target, including controlling the vehicle from the warehouse, searching for the closest self-raising point and unloading the goods, continuously searching for a new point, and returning to the warehouse until all goods are unloaded.

The time to accomplish the delivery of the self-raising points is calculated to compute the travelling costs. The time span consists of the vehicle travelling time from one point to another and the unloading time at the terminal.

The calculation formula of total costs is as follows:

$$C_{total} = C_{run} + C_{delay} \tag{1}$$

where

$$C_{run} = T_{run} * perMinCost \tag{2}$$

$$C_{delay} = T_{delay} * perMinCost \tag{3}$$

$$C_{total} = C_{run} + C_{delay} \tag{4}$$

$$T_{run} = t_{arrive} - t_{start} \tag{5}$$

$$T_{delay} = t_{arrive} - t_{limit} \quad (if\ t_{limit} < t_{arrive}) \tag{6}$$

$$T_{delay} = 0 \quad (if\ t_{limit} > t_{arrive}) \tag{7}$$

Meanwhile, the total time of entire system is calculated to judge if the delivery solution meets the criterion.

The calculation formula is

$$T_{total} = \sum_{i=1}^{n} T_{rum}^{i} + T_{unload}^{i} \tag{8}$$

where

$$T_{unload} = orderNum * perMinUnloa \tag{9}$$

The logical structure to implement the functions of the distribution vehicle agents is composed of four states, six transitions, and one selection structure, as shown in Figure 4.

The following operation interface can be obtained through the above analysis and modeling, which is shown in Figure 5.

Simulation to the self-raising points of the E-commerce enterprise vehicle distribution can be performed by selecting the route planning mode and clicking the running button. Relevant data is obtained.

3. Simulation Performance and Optimization Analysis

This paper considers the logistics distribution settings under single warehouse, double warehouses, and three warehouses. The raw data of these three settings are all in Table 1. In a sharp increase of orders for special events like "Double Eleven", we have increased the order number by ten times on the basis of the original data, which makes the research more realistic. Finally, we compare the results of simulation and provide suggestions for improvements.

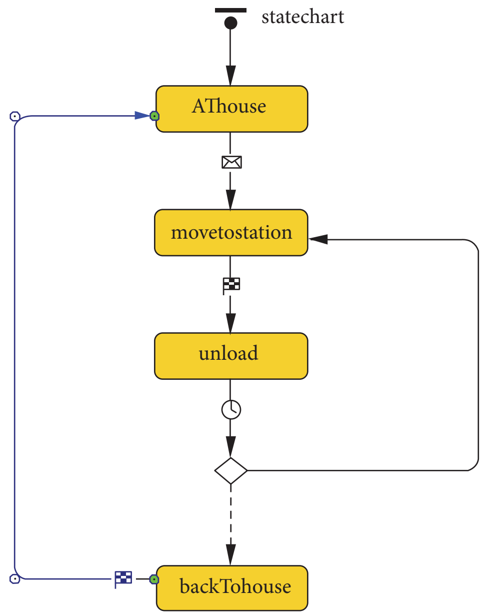

Figure 4: Logical structure of vehicle agent.

3.1. Comparison of Two Solutions in Single Warehouse Mode. Only one delivery at all distribution points is accomplished in this mode. Assuming the shortest route solution is selected to the next point, the following results are obtained by running the AnyLogic:

TotalRunCost:41657.899;

TotalDelayCost:1074320.791;

TotalCost:1115978.69.

Meanwhile, some critical data on the sequence of every distribution point, time nodes, and time length during distribution processes are shown in Table 2.

According to Table 2, obviously the total time accomplishing the whole process (among vehicle departing and returning to the warehouse) is 1541.58 virtual time with single warehouse (the shortest route solution).

As shown in Table 2, some goods have time-restricted requirements that must be delivered before time limits, or tardiness costs occurred. The time-limited precedence solution is utilized to minimize the tardiness costs when the next station route needs to be selected. In other words, the goods with time requirements should be delivered first and then the shortest route solution is adopted to deliver goods without time requirements.

Through AnyLogic platform, the results of distribution costs in single warehouse (time-limited precedence solution) are as follows:

TotalRunCost:49796.137;

TotalDelayCost:59418.424;

TotalCost:109214.56.

Meanwhile, 1622.96 virtual times are required to accomplish the entire distribution procedure.

Comparisons of the results on the shortest route solution and the time-limited precedence solution in single warehouse mode are shown in Table 3.

As presented in Table 3, the time-limited precedence solution causes the increments in total traveling costs by 19.54% and the abatements in total tardiness costs by 94.47%. The total costs are also reduced by 90.21%, because this solution can reduce the tardiness costs of the self-raising points with time limits effectively. Nevertheless, without adopting the shortest route solution, the vehicle travelling costs are raised and the total distribution time also increases by 5.28%. Because the amount of cost reduction is far larger than the increments, the total costs are reduced. In summary, under the circumstances of generating order number randomly, to the self-raising points with time-restricted requirements, the time-limited precedence solution has lower tardiness costs and total costs, but the traveling costs and distribution time increased merely.

Moreover, the total time span to complete the distribution is long whatever the two solutions are. In practice, reducing the delivery time to the customers significantly is an important problem the E-commerce companies face. This paper considers adding one warehouse, that is, double warehouses mode to solve this problem.

3.2. Simulation Comparison of Double Warehouses Mode and Single Warehouse Mode. The distribution in double warehouses mode is delivering goods to all the self-raising points simultaneously with two warehouses. According to the warehouse layout of the E-commerce enterprise, the distribution warehouse is added to the west of Shanghai interplaying with the original one. The distribution of double warehouses and self-raising points is shown in Figure 6.

The simulation consequences of double warehouses in the shortest route solution by AnyLogic are shown as follows:

TotalRunCost:42067.155;

TotalDelayCost:377939.599;

TotalCost:420006.754.

It takes 848.60 virtual time to accomplish the entire distribution process.

Similarly, following consequences of double warehouses can be obtained in the time-limited precedence solution:

TotalRunCost:51287.608;

TotalDelayCost:45760.399;

TotalCost:97048.007.

It takes 890.88 virtual time to accomplish.

The consequences of two solutions are compared in Table 4.

As shown in the Table 4, in double warehouses mode with the time-limited precedence solution, the total traveling costs and delivery time increase by 21.92% and 4.98%, the total tardiness costs and the total costs reduce by 87.89% and 76.89%. The reasons are the same as the single warehouse mode that without adopting the shortest route solution results in an increase in the travelling costs and entire delivery time. Nevertheless, the tardiness costs are significantly reduced so that the total costs are reduced.

In order to comprehend the influence of the warehouse quantity on the distribution costs and the delivery time, above results are compared to gain Tables 5 and 6.

By comparing Tables 5 and 6, the double warehouses model can significantly reduce the total time compared to

Table 1: Raw data.

Name	Latitude	Longitude	Number of orders	Product category	Delivery Time
s1	31.1431986	121.4210407	100	1	100
s2	31.15728268	121.4120836	50	1	150
s3	31.15546308	121.4371571	10	2	0
s4	31.16333719	121.4147434	90	1	200
s5	31.1343072	121.4481408	30	1	250
s6	31.16970695	121.4252906	20	2	0
s7	31.16707584	121.4416896	30	2	0
s8	31.18410185	121.4266127	40	2	0
s9	31.18935785	121.4276737	40	2	0
s10	31.19520877	121.4184094	100	1	300
s11	31.1988346	121.4461166	30	2	0
s12	31.18874702	121.371578	20	2	0
s13	31.20861033	121.4197887	50	1	350
s14	31.2231975	121.3954163	30	2	0
s15	31.27327301	121.4338336	40	2	0
s16	31.26069097	121.4462738	30	2	0
s17	31.26820805	121.4564257	100	1	400
s18	31.28828157	121.4429477	20	2	0
s19	31.29730166	121.4110734	40	2	0
s20	31.24911288	121.4890998	60	1	450
s21	31.27418872	121.4633177	40	2	0
s22	31.27321697	121.4688453	30	2	0
s23	31.2796735	121.4802926	80	1	500
s24	31.30568695	121.4669172	20	2	0
s25	31.23087848	121.4437099	40	2	0
s26	31.28454415	121.5018165	90	1	550
s27	31.26859412	121.5399282	20	2	0
s28	31.28451296	121.5115345	30	2	0
s29	31.29881095	121.499463	100	1	600
s30	31.30787625	121.4993919	90	1	650
s31	31.29473544	121.5409558	30	2	0
s32	31.2911163	121.5489509	80	1	700
s33	31.33387484	121.5288115	40	2	0
s34	31.31553869	121.3699688	30	2	0
s35	31.31371912	121.3505742	20	2	0
s36	31.35066483	121.4538375	40	2	0
s37	31.1259537	121.3866134	20	2	0
s38	31.18216029	121.4056214	40	2	0
s39	31.22972111	121.4052614	100	1	750
s40	31.22416167	121.3773722	30	2	0
s41	31.23514491	121.4078012	40	2	0
s42	31.23383979	121.4318426	30	2	0
s43	31.24339301	121.418824	20	2	0
s44	31.24539919	121.4137998	30	2	0
s45	31.23813096	121.355908	40	2	0
s46	31.25328122	121.3872342	30	2	0
s47	31.26148927	121.4184197	20	2	0
s48	31.25603512	121.3732177	30	2	0
s49	31.26155358	121.3545372	30	2	0
s50	31.28576633	121.3412785	40	2	0
s51	31.19722065	121.4698344	40	2	0

Table 2: Simulation results in single warehouse mode (the shortest route solution).

Name	Arrive Time	Left Time	Run Length	Unload Length	delayLength	runCost	Delay Cost	House Name
WareHouseA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	WareHouseA
s50	8.04	28.04	8.04	20.00	0.00	804.00	0.00	WareHouseA
s35	35.18	45.18	7.14	10.00	0.00	714.00	0.00	WareHouseA
s48	59.11	74.11	13.94	15.00	0.00	1394.00	0.00	WareHouseA
s46	76.46	91.46	2.34	15.00	0.00	234.00	0.00	WareHouseA
s49	97.33	112.33	5.87	15.00	0.00	587.00	0.00	WareHouseA
s45	119.04	139.04	6.71	20.00	0.00	671.00	0.00	WareHouseA
s40	143.81	158.81	4.77	15.00	0.00	477.00	0.00	WareHouseA
s14	163.05	178.05	4.24	15.00	0.00	424.00	0.00	WareHouseA
s41	182.12	202.12	4.07	20.00	0.00	407.00	0.00	WareHouseA
s39	204.91	254.91	2.79	50.00	0.00	279.00	0.00	WareHouseA
s43	259.37	269.37	4.46	10.00	0.00	446.00	0.00	WareHouseA
s44	271.22	286.22	1.85	15.00	0.00	185.00	0.00	WareHouseA
s42	292.76	307.76	6.55	15.00	0.00	655.00	0.00	WareHouseA
s25	311.13	331.13	3.36	20.00	0.00	336.00	0.00	WareHouseA
s13	337.75	362.75	6.62	25.00	0.00	662.00	0.00	WareHouseA
s10	367.06	417.06	4.31	50.00	67.06	431.00	13412.	WareHouseA
s9	419.23	439.23	2.18	20.00	0.00	218.00	0.00	WareHouseA
s8	441.26	461.26	2.03	20.00	0.00	203.00	0.00	WareHouseA
s38	465.79	485.79	4.52	20.00	0.00	452.00	0.00	WareHouseA
s4	490.17	535.17	4.38	45.00	290.1	438.00	58032	WareHouseA
s2	536.73	561.73	1.57	25.00	386.7	157.00	77346	WareHouseA
s1	566.45	616.45	4.71	50.00	466.4	471.00	93290	WareHouseA
s3	621.10	626.10	4.65	5.00	0.00	465.00	0.00	WareHouseA
s6	633.17	643.17	7.07	10.00	0.00	707.00	0.00	WareHouseA
s7	648.96	663.96	5.79	15.00	0.00	579.00	0.00	WareHouseA
s11	671.47	686.47	7.52	15.00	0.00	752.00	0.00	WareHouseA
s51	691.79	711.79	5.32	20.00	0.00	532.00	0.00	WareHouseA
s20	724.95	754.95	13.16	30.00	274.9	1316.00	54990	WareHouseA
s23	762.95	802.95	8.00	40.00	262.9	800.00	52590	WareHouseA
s22	806.11	821.11	3.16	15.00	0.00	316.00	0.00	WareHouseA
s21	823.64	843.64	2.53	20.00	0.00	253.00	0.00	WareHouseA
s17	845.93	895.93	2.29	50.00	445.9	229.00	89186	WareHouseA
s16	898.68	913.68	2.75	15.00	0.00	275.00	0.00	WareHouseA
s15	917.43	937.43	3.75	20.00	0.00	375.00	0.00	WareHouseA
s18	942.59	952.59	5.16	10.00	0.00	516.00	0.00	WareHouseA
s19	959.43	979.43	6.84	20.00	0.00	684.00	0.00	WareHouseA
s47	989.60	999.60	10.17	10.00	0.00	1017.00	0.00	WareHouseA
s24	1014.17	1024.17	14.57	10.00	0.00	1457.00	0.00	WareHouseA
s30	1030.21	1075.21	6.03	45.00	380.2	603.00	76042	WareHouseA
s29	1077.77	1127.77	2.56	50.00	477.7	256.00	95554	WareHouseA
s26	1131.39	1176.39	3.62	45.00	581.3	362.00	116278	WareHouseA
s28	1178.76	1193.76	2.37	15.00	0.00	237.00	0.00	WareHouseA
s31	1200.60	1215.60	6.84	15.00	0.00	684.00	0.00	WareHouseA
s32	1217.66	1257.66	2.06	40.00	517.6	206.00	103532	WareHouseA
s27	1264.99	1274.99	7.33	10.00	0.00	733.00	0.00	WareHouseA
s33	1288.87	1308.87	13.88	20.00	0.00	1388.00	0.00	WareHouseA
s36	1325.59	1345.59	16.72	20.00	0.00	1672.00	0.00	WareHouseA
s34	1371.66	1386.66	26.07	15.00	0.00	2607.00	0.00	WareHouseA
s12	1419.80	1429.80	33.13	10.00	0.00	3313.00	0.00	WareHouseA
s37	1446.56	1456.56	16.76	10.00	0.00	1676.00	0.00	WareHouseA
s5	1470.34	1485.34	13.78	15.00	1220	1378.00	244068	WareHouseA
WareHouseA	1541.58	1541.58	56.24	0.00	0.00	5624.00	0.00	WareHouseA

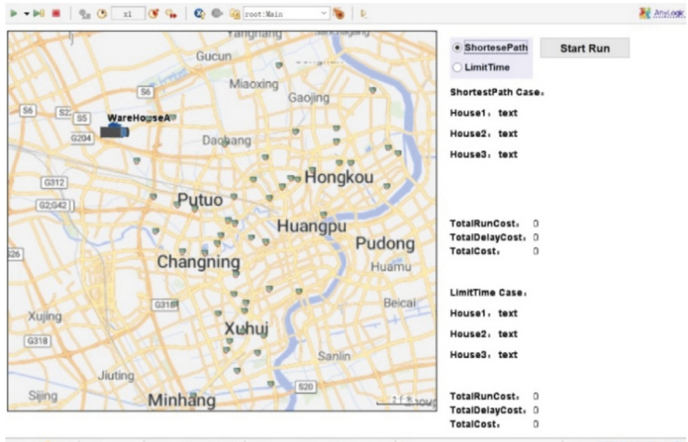

Figure 5: Operation interface of simulation platform.

Figure 6: Distribution of double warehouses and self-raising points.

Table 3: Comparison results of two solutions in single warehouse mode.

	ShortestPath	LimitTime	Compare Result
TotalRunCost	41657.899	49796.137	+19.54%
TotalDelayCost	1074320.791	59418.424	-94.47%
TotalCost	1115978.69	109214.561	-90.21%
FinishTime	1541.580	1622.960	+5.28%

Table 4: Comparison of two solutions in double warehouses mode.

	ShortestPath	LimitTime	Compare Result
TotalRunCost	42067.155	51287.608	+21.92%
TotalDelayCost	377939.599	45760.399	-87.89%
TotalCost	420006.754	97048.007	-76.89%
FinishTime	848.600	890.880	+4.98%

Table 5: Comparison results of two modes in shortest route solution.

	SingleHouse	DoubleHouse	Compare Result
TotalRunCost	41657.899	42067.155	+1%
TotalDelayCost	1074320.791	377939.599	-64.82%
TotalCost	1115978.690	420006.754	-62.36%
FinishTime	1541.580	848.600	-44.95%

Table 6: Comparison results of two modes in time-limited precedence solution.

	Single House	Double House	Compare Result
TotalRunCost	49796.137	51287.608	+3%
TotalDelayCost	59418.424	45760.399	-22.99%
TotalCost	109214.561	97048.007	-11.14%
FinishTime	1622.960	890.880	-45.11%

the single warehouse model in the two solutions. Particularly under the circumstances of the shortest route solution, the tardiness costs and the total costs are reduced dramatically, because the two warehouses distribute goods simultaneously

Table 7: Comparison between normal order number and ten times of the shortest route solution in double warehouses mode.

	NomalOrders	10timesOrders	Compare Result
TotalRunCost	42067.155	42067.155	+0%
TotalDelayCost	377939.599	8148314.73	+2055.98%
TotalCost	420006.754	8190381.884	+1850.06%
FinishTime	848.600	6428.600	+657.55%

Table 8: Comparison between normal order number and ten times of the time-limited precedence solution in double warehouses mode.

	NomalOrders	10timesOrders	Compare Result
TotalRunCost	51287.608	51287.608	+0%
TotalDelayCost	45760.399	2758085.139	+5927.23%
TotalCost	97048.007	2809372.747	+2794.83%
FinishTime	890.880	6870.880	+671.25%

to different self-raising points which reduces the time. In the shortest route solution, the delay time is so long that reducing delivery time can have great effects, while, in the time-limited precedence solution, the delay time is tiny without evident efficiency. In conclusion, the double warehouses mode has more effects than the single one in tardiness costs and total costs in the shortest route solution.

Moreover, in special shopping festivals, for instance, 11.11, 618, and so on, goods quantities increase dramatically on every self-raising point of the E-commerce companies. Therefore, this article will enlarge ten times of the order number for each point to study this problem with AnyLogic.

Simulation results of double warehouses in the shortest route solution are shown (the order number is magnified by ten times):

TotalRunCost:42067.155;

TotalDelayCost:8148314.73;

TotalCost:8190381.884.

Meanwhile, the overall distribution time is 6428.60 virtual time.

Simulation time of double warehouses in the time-limited precedence solution is as follows (the order number is magnified by ten times):

TotalRunCost:51287.608;

TotalDelayCost:2758085.139;

TotalCost:2809372.747.

Meanwhile, the overall distribution time is 6470.88 virtual time.

Compared with the normal order number, two tables are obtained as in Tables 7 and 8.

As shown in Tables 7 and 8, the tardiness costs, the total costs, and the time requirements are many times larger than the normal one during the special shopping festival. The double warehouses model is completely incapable of meeting the practical demands. Therefore, this paper considers adding another warehouse to reduce the time and costs in three warehouses mode.

3.3. Three-Warehouse Mode and the Influence of Distribution Area Adjustment on the Simulation Results

Three warehouses are utilized to be distributed simultaneously in three-warehouse mode which is also the fundament for multiple warehouse distribution research. In this paper, the warehouse location of the E-commerce enterprise in Shanghai is taken as example. We expand the double one to three-warehouse model. The distribution of warehouses and self-raising points are shown in Figure 7.

The simulation consequences of three warehouses in the shortest route solution can be obtained by AnyLogic as follows:

TotalRunCost:45398.807;

TotalDelayCost:132487.919;

TotalCost:177886.726.

Meanwhile, the overall distribution time is 641.76 virtual time.

Similarly, the simulation consequences of three warehouses in the time-limited precedence solution are obtained as follows:

TotalRunCost:52468.394;

TotalDelayCost:15795.939;

TotalCost:68264.333.

Meanwhile, the overall distribution time is 676.48 virtual time.

Comparing the mentioned consequences with the two warehouses in two solutions, a significant improvement has occurred. However, by observing the three warehouses and distribution sites in Figure 7, the new warehouse WareHouseC is close to the WareHouseB. Therefore, the location of WareHouseC is adjusted to the southwest of Shanghai so that the nearby self-raising points have a relatively close warehouse to save the delivery time and total costs. The distribution of the adjusted warehouse and self-raising points are shown in Figure 8.

As shown in Figure 8, the WareHouseC is located in the southwest of Shanghai and these three warehouses are distributed evenly after adjustment of the location.

With the AnyLogic, the simulation consequences of three warehouses (adjusted location) in the shortest route solution can be obtained:

TotalRunCost:42057.032;

TotalDelayCost:49689.094;

TotalCost:91746.126.

Meanwhile, the overall distribution time is 697.08 virtual time.

Similarly, the simulation consequences of three warehouses (adjusted location) in the time-limited precedence solution can be obtained:

TotalRunCost:49418.701;

TotalDelayCost:0;

TotalCost:49418.701.

Meanwhile, the overall distribution time is 747.00 virtual time.

Comparison of the simulation results in three warehouses mode without adjusting, Tables 9 and 10, is obtained.

As shown in Tables 9 and 10, after the adjustment of warehouse location, the traveling costs, the tardiness costs, and the total costs are reduced, particularly in the

Figure 7: Distribution of three warehouses and stations.

Figure 8: Distribution of three warehouses (adjusted location) and stations.

Table 9: Comparison between original location and adjusted location of three warehouses in the shortest route solution.

	Original	Changed	Compare Result
TotalRunCost	45398.807	42057.032	-7.36%
TotalDelayCost	132487.919	49689.094	-62.5%
TotalCost	177886.726	91746.126	-48.42%
FinishTime	641.760	697.080	+8.62%

Table 10: Comparison between original location and adjusted location of three warehouses in the time-limited precedence solution.

	Original	Changed	Compare Result
TotalRunCost	52468.394	49418.701	-5.81%
TotalDelayCost	15795.939	0	-100%
TotalCost	68264.333	49418.701	-27.61%
FinishTime	676.480	747.000	+10.42%

time-limited precedence solution. All the time requirements in initialization data are met as the warehouse location adjusts and the tardiness costs are not generated. In this paper, the overall distribution time increases, which is primarily due to comprehensive conditions of self-raising points. If differences are shown, then the overall distribution time may be decreased.

4. Conclusions

This paper uses AnyLogic simulation software to model and simulate the vehicle distribution process. Then the results are analyzed and optimized on three factors including routes selection, warehouses quantity, and warehouses layout. As shown in the simulation consequences, the time-limited precedence solution can dramatically reduce the tardiness costs and the total costs; increasing the warehouses quantity can significantly lessen the overall delivery time; vehicle travelling costs, tardiness costs, and total costs can also be reduced by distribution of warehouse locations reasonably, which also have an influence on the overall delivery time. What can also be observed from the results is that the method studying logistics distribution by AnyLogic is feasible, which can visualize complicated problems and improve operability effectively. More optimal methods and algorithms like heuristic can be used in future research. The optimization module also can be contained.

Data Availability

All the data used to support the findings of this study are included in our manuscript and are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] L. Zhen, "Tactical berth allocation under uncertainty," *European Journal of Operational Research*, vol. 247, no. 3, pp. 928–944, 2015.

[2] L. Zhen, E. P. Chew, and L. H. Lee, "An integrated model for berth template and yard template planning in transshipment hubs," *Transportation Science*, vol. 45, no. 4, pp. 483–504, 2011.

[3] P. F. I. Casas and J. Casanovas, "JGPSS, an open source GPSS framework to teach simulation," in *Proceedings of the 2009 Winter Simulation Conference, WSC 2009*, vol. 1-4, pp. 256–267, IEEE, Austin, Tex, USA, December 2009.

[4] C. D. Pegden, A. Alan, and B. Pritsker, "SLAM: Simulation language for alternative modeling," *Simulation*, vol. 33, no. 5, pp. 145–157, 1979.

[5] K. V. Ramani, "An Interactive Simulation Model for the Logistics Planning of Container Operations in Seaports," *Simulation*, vol. 66, no. 5, pp. 291–300, 1996.

[6] I. Manuj, J. T. Mentzer, and M. R. Bowers, "Improving the rigor of discrete-event simulation in logistics and supply chain research," *International Journal of Physical Distribution & Logistics Management*, vol. 39, no. 3, pp. 172–201, 2009.

[7] Q.-C. Meng, T. Zhang, M. Li, and X.-X. Rong, "Optimal order strategy in uncertain demands with free shipping option," *Discrete Dynamics in Nature and Society*, Art. ID 578280, 6 pages, 2014.

[8] L. Geng, R. B. Xiao, and X. Xu, "Research on MAS-based supply chain resilience and its self-organized criticality," *Discrete Dynamics in Nature and Society*, vol. 2014, Article ID 621341, 14 pages, 2014.

[9] Y. Cui, J. Shi, and Z. Wang, "Discrete Event Logistics Systems (DELS) simulation modeling incorporating two-step Remaining Useful Life (RUL) estimation," *Computers in Industry*, vol. 72, pp. 68–81, 2015.

[10] P. Q. Li, J. He, D. Y. Zheng, Y. S. Huang, and C. H. Fan, "Vehicle routing problem with soft time windows based on improved genetic algorithm for fruits and vegetables distribution," *Discrete Dynamics in Nature and Society*, vol. 2015, Article ID 483830, 8 pages, 2015.

[11] C. Y. Lin and B. W. Gong, "Transit-based emergency evacuation with transit signal priority in sudden-onset disaster," *Discrete Dynamics in Nature and Society*, vol. 2016, Article ID 3625342, 13 pages, 2016.

[12] T. Beinke, A. Ait Alla, and M. Freitag, "Resource Sharing in the Logistics of the Offshore Wind Farm Installation Process based on a Simulation Study," *International Journal of e-Navigation and Maritime Economy*, vol. 7, pp. 42–54, 2017.

[13] S. B. Li, G. M. Wang, T. Wang, and H. L. Ren, "Research on the Method of Traffic Organization and Optimization Based on Dynamic Traffic Flow Model," *Discrete Dynamics in Nature and Society*, vol. 2017, Article ID 5292616, 9 pages, 2017.

[14] Y. Wei, F. Chen, and H. Wang, "Inventory and production dynamics in a discrete-time vendor-managed inventory supply chain system," *Discrete Dynamics in Nature and Society*, vol. 2018, Article ID 6091946, 15 pages, 2018.

[15] T. G. Crainic, G. Perboli, and M. Rosano, "Simulation of intermodal freight transportation systems: a taxonomy," *European Journal of Operational Research*, vol. 270, no. 2, pp. 401–418, 2018.

[16] M. Noorizadegan and B. Chen, "Vehicle routing with probabilistic capacity constraints," *European Journal of Operational Research*, vol. 270, no. 2, pp. 544–555, 2018.

[17] W. B. Hu, H. Wang, Z. Y. Qiu, L. P. Yan, C. Nie, and B. Du, "An urban traffic simulation model for traffic congestion predicting and avoiding," *Neural Computing Applications*, vol. 30, no. 6, pp. 1769–1781, 2018.

[18] L. Zhen, "Modeling of yard congestion and optimization of yard template in container ports," *Transportation Research Part B: Methodological*, vol. 90, pp. 83–104, 2016.