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Research on Arena Simulation Application for Parcel Pickup Queuing System

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Abstract. With the continuous improvement of people's living standards, especially under the influence of shopping festivals such as "618", "Double 11," and "Double 12", the competition in the express delivery industry is becoming increasingly fierce. Since there is no express cabinet in many areas, it is necessary to go to the express station to pick up the parcel in person. Therefore, pick-up efficiency affects the customer's satisfaction with the express station. To improve customer satisfaction, we must first improve the efficiency of pick-up. Many express companies now adopt a combination of self-service and manual methods to solve the problem of too long waiting times in picking up parcels. However, it is still inevitable that there will be too long waiting times in shopping festivals due to the explosion of express delivery. In order to improve the pick-up efficiency, this paper uses Arena to establish a simulation model to simulate the pick-up waiting situation and allocate the number of self-service pick-up machines and manual services to solve the problem of excessively long waiting times during pick-up.

Keywords. Arena software, Simulation, Pick up the parcel

1. Introduction

With the rapid development of the economy, the rise of e-commerce, and the continuous improvement of people's living standards, the express delivery industry has become an indispensable part of our lives. Especially in the "618", "Double Eleven," "Double Twelve," and other shopping carnival activities, the express delivery business has shown explosive growth, and the competition in the express delivery industry has become increasingly fierce. However, many regions do not have universal delivery cabinets. Customers need to pick-up parcels in person at the Courier point, and pick-up efficiency significantly impacts customer satisfaction. Therefore, how to improve delivery efficiency to enhance customer satisfaction has become an urgent problem to be solved in the express delivery industry.

Many scholars have carried out relevant research on the problem of picking up items. Wen H et al. proposed a DeepRoute model to predict the future pick-up route of couriers based on the decision-making experience of couriers' historical spatiotemporal behavior. This model can help the scheduling system more intelligently assign packages to couriers,

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thus improving pick-up efficiency [1]. Wang Y et al. established a collaborative alliance and allocated truck transportation resources based on time-space (TS) network attributes to minimize the total operating cost. They designed an optimal collaboration strategy to solve the collaborative logistics pick-up problem of CLPDPE [2]. Hong F et al. proposed a new package receiving and receiving mode and system in which multiple drones and automatic devices work together. In this mode, automatic devices are set up in the free area on the top of residential buildings as delivery and pick-up points for packages, and drones are used to transport packages between buildings and warehouses [3]. In order to optimize parcel collection and delivery in rural areas, Yang C et al. established a vehicle routing model integrating parcel collection and delivery in rural areas. To solve the model, they designed a two-stage algorithm based on an improved K-means clustering algorithm and a genetic algorithm [4]. Scholars have much research on the pick-up problem, but there is a lack of discussion on the problem of too long queuing time during the pick-up process.

At present, many express delivery companies adopt a combination of self-help and manual methods to solve the long waiting time problem in picking up items. A self-service pick-up machine enables customers to complete the pick-up at the express point, significantly reducing the waiting time in line. However, how to allocate the number of self-service pick-up machines and manual services to ensure the efficiency of pick-up while not causing a waste of resources is a problem that needs in-depth research. Especially during the shopping carnival, due to the explosion of express delivery volume, the problem of long queuing time is more prominent. This problem affects the customer's pick-up experience and challenges the service quality of express delivery companies. Therefore, how to rationally allocate the number of self-service pick-up machines and manual services scientifically to improve pick-up efficiency is an urgent problem for the express delivery industry.

This paper aims to use Arena to build a simulation model to simulate the pick-up queuing situation and optimize the number of self-service pick-up machines and manual services to solve the problem of too long queuing time during pick-up. Through this research, we hope to provide a scientific and effective method for the express delivery industry to improve pick-up efficiency and enhance customer satisfaction to promote the sustainable development of the express delivery industry.

2. Literature Review

With the continuous development and upgrading of Arena software, its functions and applications have been further expanded. Guseva E et al. used Arena to establish a simulation model of patient service management to evaluate the workload of clinicians to determine the number of doctors such as general practitioners, surgeons, and other specialists required for patient services [5]. In order to shorten the waiting time of patients and optimize the staffing, Sasanfar et al. used Arena simulation technology to simulate the new layout of the emergency department of a hospital and gave layout design suggestions based on the research results, which significantly improved the work efficiency of the emergency department [6]. Aziati A. N et al. used Arena simulation software to simulate patients' waiting time and service time at the outpatient counter and proposed corresponding strategies to improve patients' waiting time and service rate by observing problems in the simulation process [7]. Tavakoli M et al. simulated the patient flow process through Arena software to predict the situation of future patients entering

the hospital. Simulations showed that the system crashed after 14 days. Researchers improve the system by analyzing the problems in the simulation [8]. Kalwar MA et al. used Arena software to model and simulate the queuing system of the outpatient department of gastroenterology in the hospital, analyze the waiting time of patients in four scenarios, and adjust the number of doctors and work schedule according to the simulation results to solve the problem of excessively long waiting time of patients [9]. Derni O et al. aims to minimize the total waiting time to increase patient flow and improve the quality of patient monitoring. They used Arena software to build models and conduct simulation experiments to assess the impact of the proposed solution [10].

In order to study the production process of aluminum brake brackets in the factory, find out the bottleneck in the production, and calculate the production efficiency and workforce demand of the unit, Neeraj R et al. used Arena software to conduct a discrete event simulation of a manufacturing unit, and combined the process analyzer (PAN) with Opt Quest to propose a better model [11]. In order to expand the application research of computer simulation technology in the production line balance of the garment industry, Sime H et al. adopted Arena software for modeling and simulation [12]. In order to analyze the current situation of A manufacturing industry and design a future state diagram to optimize the process flow, Mishra A K et al. used Arena software to simulate the method. The research results show that this method can reduce the cost and the impact on the environment [13]. To mitigate the consequences of the channel closure so that a new bridge could be built over the channel, Rahimikelarijani B et al. used the discrete event model in Arena to conduct a simulation analysis of ship traffic and operations in the Houston Channel. By simulating different shutdown scenarios, the shutdown scheme with the least waiting time is selected [14]. In order to solve the problems in the sewing stage and improve garment productivity, Yemane A et al. used Arena software to simulate and measure the existing and proposed pants sewing thread models and conducted statistical analysis on the collected data to determine the statistical significance and determine the expression for simulation modeling, to develop a new sewing assembly line model [15]. Bajjou MS et al. developed a lean simulation model using Arena software to study the impact of lean building principles on the performance of these processes. Studies have found that lean principles effectively improve the performance of selected construction processes [16]. In summary, Arena simulation software has been widely used in many fields and will continue to be used in other aspects.

3. Model Building

Arena simulation software is used to collect the user's arrival time and pick-up parcel service time during the user's pick-up process, and the pick-up time is used to represent the user's waiting time. The simulation results are analyzed, and the scientific number of self-service pick-up machines and pick-up service personnel are allocated to the express station.

The pick-up simulation system has two pick-up modes: self-service and manual. After receiving the parcel, the user determines whether it is small. If it is a small parcel and meets the conditions of self-service pick-up, the user directly goes to the self-service pick-up machine to pick up the parcel and leave. If the conditions for self-service pick-up are not met, go to the manual service desk for manual processing. If it is not a small parcel, enter the manual acceptance area; if it meets the manual acceptance conditions, directly pick up the parcel and leave. The manual service desk is used for manual

processing if the manual acceptance conditions are unmet. The parcel pick-up flow chart is shown in Fig. 1. Arena software was used to establish a simulation model for the above pick-up process, as shown in Fig. 2.

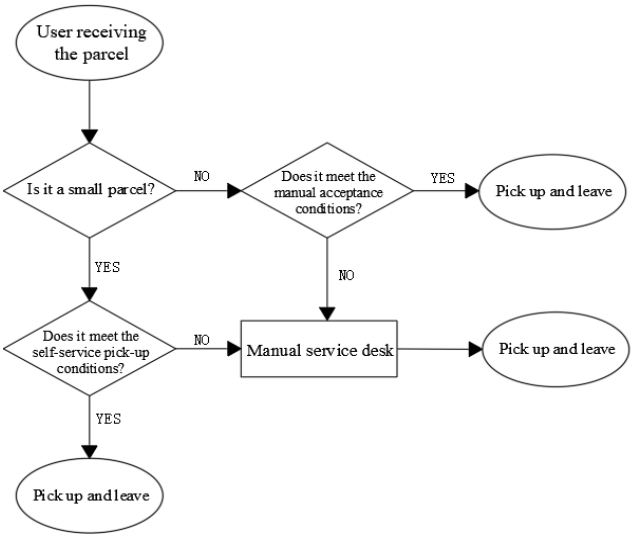

Figure 1. The parcel pick-up flow chart

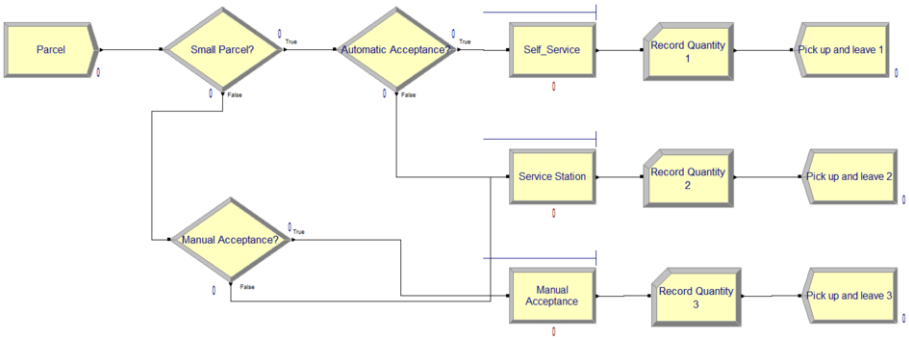

Figure 2. Pick up parcel simulation model diagram

Module and parameter setting:

(1) First, create a create module to simulate the user receiving the parcel. The module, named “Parcel,” follows an exponential distribution with an average of 2 minutes, the number of arrivals is 1, the maximum number of arrivals is infinite, and the initial value is 0.

(2) Create three decide modules of type 2-way by chance. The first one is called "Small Parcel?" to determine whether it is a small parcel, and the pass rate is 70%. The second one is called "Automatic Acceptance?" to check whether the conditions for self-service pickup are met. The pass rate is 95%. Moreover, the third one is called "Manual Acceptance?" to determine whether the manual acceptance conditions are met, and the pass rate is 80%.

(3) Create three process modules. The first is named “Self_Service,” indicating the self-service pick-up machine. Action selects Seize Delay Release; delay type is

Triangular with the minimum value of 1, the maximum value of 5, and the value of 2; the unit is minutes, and the number of automatic pick-up machines is 1. The second is named “Service Station” for a human service desk. Action selects Seize Delay Release; delay type is Triangular with a minimum value of 5, a maximum value of 8, and a value of 6; the unit is minutes, and the number of manual service stations is 1. The third is called “Manual Acceptance,” which means manual acceptance. Action selects Seize Delay Release; delay type is Triangular with a minimum value of 3, a maximum value of 6, and a value of 5; the unit is minutes, and the number of manual acceptance workers is 1.

(4) Create three record modules to record the fetching information, named “Record Quantity 1”, “Record Quantity 2”, and “Record Quantity 3”, respectively.

(5) Create three dispose modules to indicate that users pick up and leave, respectively named "Pick up and leave 1", "Pick up and leave 2", and "Pick up and leave 3".

(6) Set operating conditions. The daily working time is 8 hours or 480 minutes, and the operating cycle is ten days.

4. Output Report Analysis

A partial report of the output of this pick-up simulation model is shown in Fig. 3. Table 1 shows the data from ten simulations. After analysis, the following conclusions can be obtained:

(1) The average number of people waiting for self-service pick-up is 2.96, and the average waiting time is 8.74 minutes. The waiting time is long, so the number of self-service pick-up machines can be appropriately increased to reduce the waiting time;

(2) The average number of people waiting for manual acceptance is 1.14, and the average waiting time is 8.72 minutes. Although the waiting time is long, the number of people waiting is small, which is more feasible;

(3) The average number of people waiting at the manual service desk is 0.42, and the average waiting time is 8.74 minutes. The number of people waiting is less than one, which is also feasible.

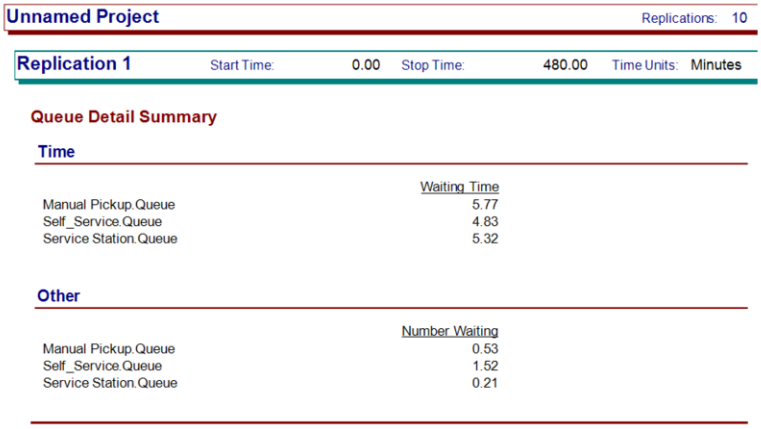

Figure 3. Part of simulation report

Table 1. Waiting Time

	Waiting Time			Number Waiting		
	Self-Service	Manual Acceptance	Service Station	Self-Service	Manual Acceptance	Service Station
1	4.83	5.77	5.32	0.53	1.52	0.21
2	9.23	6.18	8.97	3.19	0.83	0.42
3	7.35	8.46	7.16	2.71	1.26	0.30
4	5.99	9.37	8.52	1.97	0.90	0.41
5	6.01	4.04	4.72	1.99	0.42	0.13
6	10.99	4.72	4.61	3.99	0.55	0.21
7	3.64	15.32	15.35	1.12	2.07	0.70
8	4.65	11.01	14.52	1.43	1.26	0.80
9	27.85	7.25	6.54	10.17	1.01	0.22
10	6.90	15.07	11.70	2.49	1.59	0.81
average	8.74	8.72	8.74	2.96	1.14	0.42

5. Conclusion

In order to solve the problem of too long queuing time of pick-up the parcel, this paper uses Arena to establish a simulation model to simulate the queuing situation and optimize the number of self-service pick-up machines and manual services. Through the application of a simulation model, this paper simulates and analyzes different pick-up strategies to find the best pick-up strategy. The simulation results show that the waiting time can be reduced effectively, and customer satisfaction can be improved under the appropriate strategy. The research results of this paper provide helpful references and enlightenment for express companies in the face of the shopping carnival and other rush hours.

First, according to the simulation results, we can find that the reasonable allocation of self-service pick-up machines and manual services is crucial to improving pick-up efficiency. During the shopping carnival, express delivery companies can ease the queuing pressure by increasing the number of self-service pick-up machines and, simultaneously, ensure a certain number of manual services to cope with emergencies and meet special needs.

Secondly, express companies must adjust the pick-up strategy according to the situation. For example, during peak periods such as shopping carnivals, measures such as temporarily increasing the number of self-service pick-up machines and manual services and extending business hours can be taken to cope with many pick-up demands in a short period. Regularly, resources can be reasonably allocated according to customer needs and business volumes to improve operational efficiency.

Finally, express companies can use extensive data analysis and other technical means to understand customers' pick-up habits and need to develop a more accurate pick-up strategy. In addition, express delivery companies can strengthen cooperation with partners such as e-commerce platforms, promote the coordinated development of the express delivery industry and e-commerce industry, and improve pick-up efficiency and customer satisfaction.

In short, by using Arena to establish a simulation model, this paper optimizes the number of self-service pick-up machines and manual services. It provides an effective strategy to solve the problem of waiting in the pick-up queue. These strategies are of great significance to improve customer satisfaction, reduce operating costs, and provide certain competitive advantages for express delivery companies in an environment facing fierce competition.

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