Simulation Study of Medical Disposable Infusion Bottles (Bags) Reverse Logistics System Based on Flexsim

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Abstract. With the continued growth of the medical industry and the backdrop of the COVID-19 outbreak, there is a significant increase in demand for disposable medical supplies. The resulting problem of how to properly and reasonably dispose of a large number of used disposable medical supplies deserves the attention of society. According to the survey, a large part of these disposable medical supplies have recycling value. The most typical are the medical disposable infusion bottles (bags). In order to build a highly efficient reverse logistics system for medical disposable infusion bottles (bags), the operational processes of relevant qualified firm was collected. Flexsim software was used to create the simulation model, and the simulation system's operating efficiency was examined in all aspects to identify bottlenecks for continual optimization. The optimized system saves space and reduces operating costs, which can provide some reference value for managers. At the same time, a specific collection and removal mechanism is summed up to provide a guide for improving the amount of medical waste that can be thrown away. This is done to improve the efficiency of getting rid of medical waste that could spread disease during the current epidemic.

Keywords: COVID-19 · reverse logistics · renewable resource · Flexsim

1 Introduction

Nucleic acid testing is currently the most precise and quick method of verification in the current recurring outbreaks of COVID-19 in order to stop the further spread of the virus and to effectively prevent and manage the COVID-19 pandemic. As a result, nucleic acid testing sites have been established across the country. At the same time, the establishment of each mobile cabin hospital has provided an important guarantee for centralized treatment and isolation of confirmed patients. Disposable medical supplies are widely used in clinical medicine, nucleic acid testing sites and rescue sites because they are hygienic and simple to use. If these used medical supplies are not disposed of properly and reasonably, it will not only increase the cost of medical institutions but also result in a great waste of resources. Therefore, the issue of how to properly and effectively dispose of these medical supplies needs to be addressed.

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According to the National Health Commission, the Ministry of Ecology and Environment released the "Notice on the Issuance of the Medical Waste Classification Catalog (2021 version)". Medical institutions that generate medical waste are divided into the following categories:

(1) Infectious waste.
(2) Injurious waste.
(3) Pathological waste.
(4) Pharmaceutical waste.
(5) Chemical waste.

At the same time, the catalog also provides that disposable medical supplies used in the non-communicable disease risk area are not medical waste and can be disposed in a different way than medical waste.

In conclusion, there are two types of single-use medical supplies that are produced by medical institutions: recyclable and non-recyclable. Therefore, unlike the general wards, most of the medical supplies after use in the nucleic acid testing sites and each rescue site have infectious risks and are non-recyclable medical waste, requiring more stringent disposal methods than other medical waste. In contrast, there are medical supplies with recycling value among the medical supplies generated in general wards. The most typical of these is medical disposable infusion bottles (bags). Disposable infusion bottles (bags) are general solids, which are allowed to be recycled [1]. In addition, the rubber stopper and label paper on the infusion bottles (bags) are renewable resources. Hao Xue'an et al. [2] found that if the unified disposal of recyclable disposable medical supplies in medical institutions at all levels is put into place, only the medical institutions above the second level in Jining City can save more than 2 million yuan a year on medical waste disposal costs and increase economic benefits by more than 700,000 yuan.

2 Problem Description

However, most medical institutions combine non-recyclable medical supplies with recyclable medical supplies for incineration or landfill in order to avoid trouble and the risks associated with improper disposal. Such a disposal method will, on the one hand, increase the cost of medical waste disposal. On the other hand, it also causes waste of recycled resources and aggravates environmental pollution. At the same time, research on reverse logistics for connected recyclable medical supplies only has a small portion. Additionally, not many mature businesses have been established to handle recyclable disposable infusion bottles (bags).

In this paper, I construct a realistic simulation model of a reverse logistics system for disposable infusion bottles (bags) through Flexsim software, and optimize the model to improve its operation efficiency. It also summarizes a systematic approach to the disposal of medical waste with an infectious risk. The aim is to provide relevant organizations with decision-making recommendations for the disposal or recycling of medical supplies, thereby achieving the goals of reducing the risk of infection and resource waste, saving costs, and achieving sustainable social development.

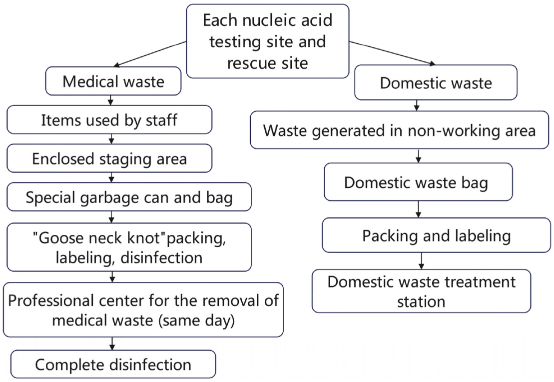

Fig. 1. Flowchart of reverse logistics of medical waste generated at each nucleic acid testing site and rescue site

3 Reverse Logistics of Medical Waste at Each Nucleic Acid Testing Site and Rescue Site

Since the outbreak of the COVID-19 epidemic, medical waste has shown explosive growth worldwide. As a graphic example, improper disposal methods could lead to a dramatic increase in COVID-19 waste from 40 tons per day to 240 tons per day in Wuhan and an estimated increase from 5 million tons per year to 2.5 million tons per month in the United States, which is a very frightening figure. The COVID-19 that caused this infectious disease can survive on medical waste (e.g., disposable protective clothing) for up to 7 days. Therefore, medical waste with an infectious risk needs to be handled properly to reduce the threat of epidemic transmission. The following supplies are regarded as medical waste under the COVID-19 epidemic: disposable protective gowns, goggles, sterile gloves, caps and shoe covers, discarded masks, and sample swabs used by medical staff at each nucleic acid testing site and rescue site. In addition, medical waste is strictly prohibited from being mixed with domestic waste. Domestic waste refers to things like lunch boxes or mineral water bottles that people leave behind in the "rest area," which is where staff doesn't work.

Figure 1 depicts the flow chart for the collection and removal of medical waste produced at each site for nucleic acid testing and rescue.

4 Model Construction

Establishing a reverse logistics system for medical disposable infusion bottles (bags) through Flexsim.

As showed in Fig. 2, set a source to create entities in two colors. Medical disposable infusion bottles (bags) with recycling value are represented by the green entity, whereas those without recycling value are represented by the red entity. Four processors are set up to simulate different processes, i.e., sorting, crushing, separating rubber and aluminum covers, dehydrating, and drying. Two multi-processors are set up to simulate the cleaning

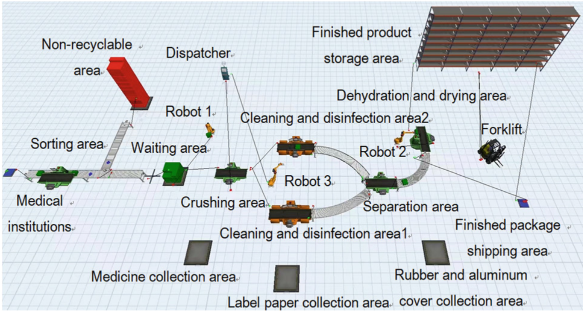

Fig. 2. Reverse logistics system layout model for medical disposable infusion bottles (bags)

and disinfection process of the entity. The processing time is 10 s. The robot and forklift simulate the handling of temporary entities, and the whole process is mechanized to reduce manual labor and improve operational efficiency.

5 Simulation Output and Optimization

5.1 Analysis of Results

From the statistical results in Table 1, it can be seen that:

(1) The finished product storage area produces 134 temporary entities, but the average capacity is only 0.32. In other words, since the completed medical disposable infusion bottles (bags) are just placed on the rack and immediately transported by forklift to the packaging area, there isn't a huge demand for rack storage of medical disposable infusion bottles (bags).
(2) The waiting area input temporary entity has 181, while only 138 entities were output, with an average stay time of 355.30 s for entities in the waiting for processing area. The medical disposable infusion bottles (bags) for processing area showed signs of stagnation, which shows that the next processing link's efficiency level is low and cannot satisfy the output needs of the area to be processed.
(3) Temporary entities in the non-recyclable area are constantly piling up and cannot be output in a timely manner. This will gradually reduce the space utilization of the factory. When the factory is fully loaded, the new medical disposable infusion bottles (bags) will not be able to enter the factory properly.

5.2 Solutions for Optimization

The simulation model has been improved as a result of the aforementioned issues, as showed in Fig. 3.

(1) To solve the problem of low rack utilization rate for placing the processed entities, the rack is abandoned and the entities are directly transported to the packaging area

Table 1. Statistics after running medical disposable infusion bottles (bags) reverse logistics system

Entity Type	Current capacity (pcs)	Maximum capacity (pcs)	Average capacity (pcs)	Input	Output	Minimum stay time (s)	Maximum stay time (s)	Average stay time (s)
Medical institutions	0	0	0.00	0	384	0.00	0.60	0.02
Non-recyclable area	201	201	95.09	201	0	0.00	0.00	0.00
Waiting area	43	46	18.29	181	138	5.00	839.12	355.3
Crushing area	0	1	0.57	137	137	15.00	15.00	15.00
Separation area	0	1	0.38	136	136	10.00	10.00	10.00
Finished product storage area	0	1	0.32	134	134	5.05	10.35	8.56
Packaging area	1	1	0.95	134	0	0.00	0.00	0.00
Cleaning and disinfection 1	1	1	0.20	72	71	10.00	10.00	10.00
Cleaning and disinfection 2	0	1	0.18	65	65	10.00	10.00	10.00
Dehydration and drying	0	1	0.56	135	135	15.00	15.00	15.00
Robot 1	1	1	0.19	138	137	5.00	5.00	5.00
Robot 2	1	1	0.19	135	134	5.00	5.00	5.00
Robot 3	0	1	0.19	137	137	5.00	5.00	5.00
Forklift 1	0	1	0.28	134	134	6.87	8.74	7.63

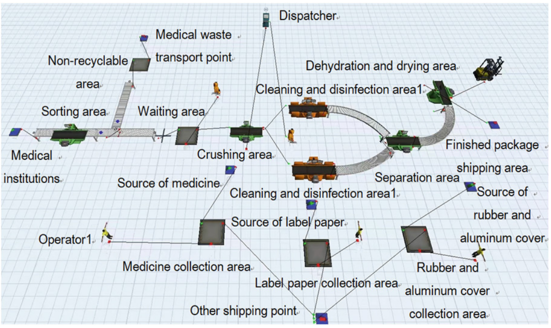

Fig. 3. Optimized reverse logistics system layout model for medical disposable infusion bottles (bags)

by forklift. This optimization not only saves space but also reduces the company's costs.

(2) The main cause of the backlog of entities in the waiting area is the downstream link's low processing efficiency, which prevents entities from moving on to the subsequent procedure in a timely manner. To solve this problem, the processing

speed of downstream machines and equipment can be improved. In reality, this initiative can be achieved by regular maintenance or upgrading of facilities and equipment.

(3) To solve the problem that in the non-recyclable area, entities only have inputs and no outputs, which causes a pileup, a sink is directly set up to simulate the realistic central collection of medical waste that can't be recycled and its transport to a processing site that is only used to burn and dump medical waste.

(4) The processing outside the primary production line was adjusted to better reflect the actual processing procedure in the model. To imitate residual liquid, self-adhesive label paper, and rubber and aluminum covers produced during the manufacture of medical disposable infusion bottles (bags), set up three sources. To gather, package, and distribute the produced other resources to the appropriate transit points, three operators are set up. The non-significant production line has a low workload, and manual processes are employed to reduce the expense of purchasing and maintaining machinery and equipment.

The model optimization effect is remarkable, as shown in Table 2. The processing speed of the optimized crushing area is accelerated, and working effectiveness is significantly increased. Additionally, the waiting area's backlog issue has greatly improved, and the time taken by entities there has decreased by almost 60% since optimization. The non-recyclable entities were output in time, solving the problem of the entry of new entities due to piling up.

6 Conclusion

In order to create a reverse logistics system for medical disposable infusion bottles, Flexsim software is used in this research to examine the issue of operational efficiency of the logistics system for recycling medical disposable infusion bottles (bags). At the same time, combined with the current background of the COVID-19 epidemic, the infectious medical waste reverse logistics operation process and disposal points are summarized.

The use of reverse logistics to achieve the goal of resource recycling and cost reduction is less obvious than the implementation of control from the source. Therefore, the government should encourage the use of reusable medical supplies instead of disposable medical supplies to achieve source reduction. In addition, the current society in general does not pay enough attention to recyclable medical disposable infusion bottles (bags), the construction of centralized disposal facilities is at a low level of development, and the relevant legislation is still not ideal. To attain the goals of cost savings and sustainable development, the government should concentrate on the development value of recyclable medical supplies, tighten control over medical waste, and boost the reverse logistics of these items.

Table 2. The comparison of the simulation model's before- and after-optimization

Entity Type	Status	Current capacity (pcs)	Maximum capacity (pcs)	Average capacity (pcs)	Input	Output	Minimum stay time (s)	Maximum stay time (s)	Average stay time (s)
Crushing area	Before	0	1	0.57	137	137	15.00	15.00	15.00
	After	0	1	0.43	155	155	10.00	10.00	10.00
Waiting area	Before	43	46	18.29	181	138	5.00	839.12	355.3
	After	7	11	2.92	163	156	5.00	202.49	64.96
Non-recyclable area	Before	201	201	95.09	201	0	0.00	0.00	0.00
	After	0	1	0.00	167	167	0.00	0.00	0.00

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