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DEVELOPMENT OF CONSTRUCTION LOGISTICS SYSTEM USING RADIO FREQUENCY IDENTIFICATION

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ABSTRACT

The authors have developed a construction logistics system using a radio frequency identification technology for finely controlling several construction sites in order to improve the transportation and handling of construction materials. This system was experimentally applied to some small construction sites in the Tokyo metropolitan area for a few months twice, in 2005 and 2006. Through the two experiments, we applied the system to 26 kinds of 93 finish and equipment construction materials. This system comprises three items: 1) a distribution center, called the Logistics Service Center, for a lot of construction materials between construction sites and materials factories, 2) a Construction Logistics Control System via the Internet, and 3) a Construction Material Traceability Management System with radio frequency identification technology. From the results of the two experimental applications of this logistics system, we found the following: 1) carbon dioxide emissions from transportation vehicles were reduced by over 22 percent, 2) carbon dioxide emissions from the transportation vehicles to construction sites were reduced by 30 percent, and 3) the transportation vehicle loading rate was increased by 14 percent.

KEYWORDS

Logistics, Radio Frequency Identification, Supply Chain Management, Traceability

1. INTRODUCTION

In recent years, global environmental problems have worsened, and resources need to be recycled in order to create a sustainable society for maintaining economic development and the global environment. To construct such a society, it is important to manage information for recycling and reusing building materials, and to manage the circulation of materials from the manufacturing to disposal stages. However, in Japan, construction materials are typically ordered from the materials factory individually by each construction site, and then delivered from the factory to the site individually. Therefore, the loading ratio of transportation vehicles is low. The number and total mileage of vehicles could be reduced by improving the distribution efficiency, and this would also reduce carbon dioxide emissions from transportation vehicles.

The authors have developed a construction logistics system using a radio frequency identification technology for finely controlling several construction sites in order to improve the transportation and handling of construction materials. This system was experimentally applied to some small construction sites in the Tokyo metropolitan area for a few months, in 2005 and 2006. This paper outlines the system and the results of two experimental applications.

2. OUTLINE OF DEVELOPMENT

2.1. Background and Target of Development

It is important for improving the efficiency of distribution to consolidate distribution information [1], and to distribute the delivery demand in the mornings. Construction workers want to start working after carrying their materials in the morning. As a result, each material factory must send many trucks carrying small amounts of materials to each construction site.

We focused on small- and medium-sized construction sites, aiming to create a system of continuously delivering materials from the material factory to the construction site, and to achieve the following:

1) Promote recycling of construction materials;

2) Reduce the carrying of surplus material to construction sites by distribution processing;

3) Reduce waste by accurately managing the amount of materials;

4) Reduce negative environmental impacts such as carbon dioxide emissions;

5) Organize materials etc. to improve the efficiency of delivery

2.2. Outline of Computer Management Tools

2.2.1. Joint delivery system

A joint delivery center (LSC: Logistics Service Center) is set up between the factory which produces the construction materials and the construction site. The materials are received with a heavy vehicle going round the factories as shown in Figure 1. Distribution processing such as unpacking, taking to pieces and piling up are executed at LSC. Joint delivery raises the carrying efficiency of the truck, thus reducing environmental impacts such as carbon dioxide emissions as fewer trucks are needed.

2.2.2. Construction logistics control system

This system enables logistics information to be shared among the materials manufacturers, contractors, and construction site offices via the Internet. As a result, the whole distribution plan can be optimized, and the efficiency of distribution and distribution management can be improved. Distribution plan information is transmitted to all project participants by mail via the Internet and cellular phone, and delivery is performed. Figures 2 and 3 show example screen displays of the system, which was developed based on the existing system [2].

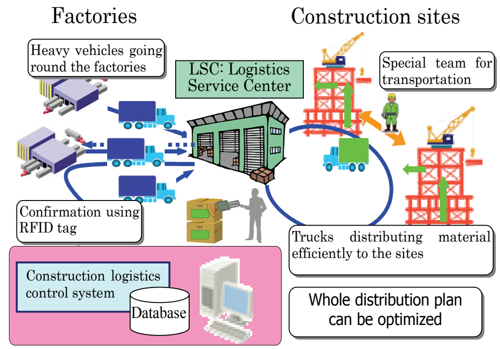

Figure 1 Outline of Construction Logistics System

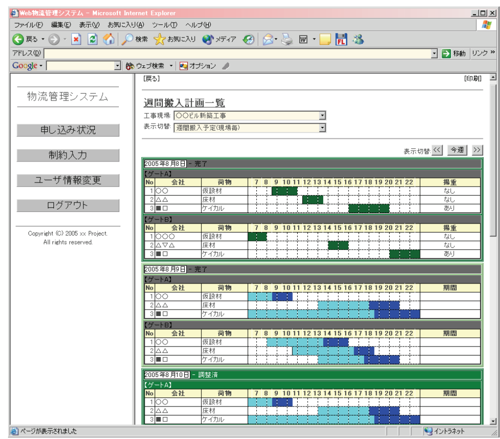

Figure 2 Construction Logistics Control System

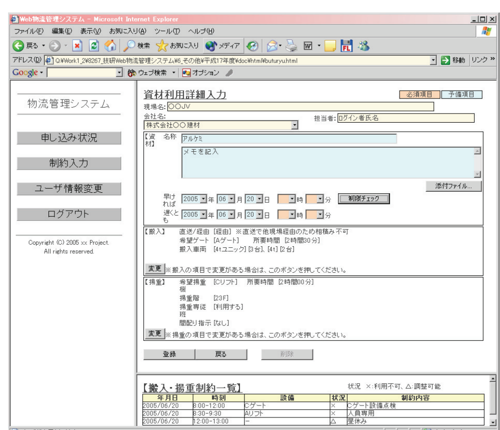

Figure 3 Construction Logistics Control System

2.2.3. Construction material traceability management system

This system is for inspecting the shipment of construction materials from LSC and checking their arrival at construction sites. It tracks the delivery status with RFID (Radio Frequency Identification) technology in real time. The RFID tag of "Unit of delivery" of the construction material or each "Unit of product" such as shown in Fig. 4 is installed, and delivery history information is then collected by the LSC and construction sites. RFID tags can use both an ultra-high-frequency and high-frequency band, because of restrictions on using RFID in Japan. It is necessary to accurately confirm whether to deliver materials to each construction site in order to go to more construction sites and reduce the load by joint delivery. Because data on the shipment and arrival of materials can be immediately known by using RFID tags, real-time delivery can be confirmed as shown in Fig. 5.

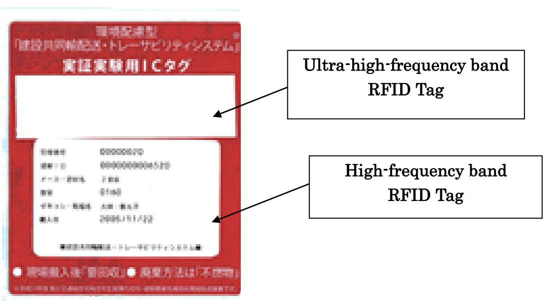

Figure 4 Radio Frequency Identification Tag

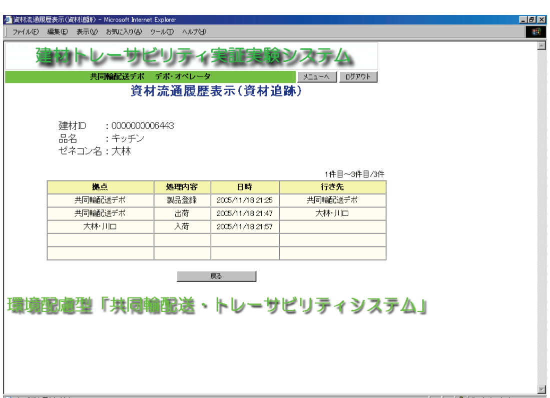

Figure 5 Traceability Management System

3. RESULT OF EXPERIMENTAL APPLICATION

3.1. Outline of Experimental Application

3.1.1. Time and construction sites of application

The joint delivery experiment in 2005 was conducted from October 24 to December 17.

Seven housing complex construction projects in the metropolitan area were selected for the experimental application, each with an average total floor of about 5,000 m^2.

3.1.2. Management of LSC and materials

LSC borrowed part of a warehouse of a delivery company located in central Tokyo (about 500 m^2) during the experiment. The information center for managing the information system and dealing with participants was established in the building with the warehouse. Personal computers and telephones/faxes were installed at the information center, which was staffed by the person in charge of the delivery plan and joint delivery/person in charge of the loading during the experiment period.

The delivery materials were 26 kinds of 93 finish and equipment construction materials such as exterior tiles, length scale seats, wallpaper, electricity, equipment, stone, lumber, floor material, and imported materials. These materials were sorted into one or two or more construction sites, were kept for a certain period such as the imported materials, were kits at LSC, and made the best use of the distribution functions of keeping, sorting, and distribution processing of LSC.

3.2. Preparation and Situation of Experimental Application

3.2.1. Joint delivery system

The stacking of materials and construction sites was promoted as shown in Photos 1, 2 and 3 to improve the distribution efficiency that was the main aim of the experiment. The stacking for two or more construction sites involved two types of delivery: different materials to the same construction site (photos 2 and 3) and different materials to different construction sites (Photo 1).

Photo 4 shows the stacking at LSC. Palettes and racks were used to effectively use the warehouse space.

Photo 1 Situation of Joint Delivery

Photo 2 Situation of Joint Delivery

Photo 3 Situation of Joint Delivery

Photo 4 Stacking Material at LSC

3.2.2. Construction material traceability management system

When the forklift passed the gate upon shipping from in LSC, the UHF band RFID tag was read with a pair of placed type readers shown in photo 5. Also, the truck driver from the LSC read the HF band (13.56 MHz) tag with a portable type reader when inspecting the construction sites shown in photo 6. After the RFID tags had been read at the construction sites, the driver detached it from materials and took it back.

Photo 5 Reading RFID Tag at LSC

Photo 6 Reading RFID Tag at Construction Site

3.3. Experiment Result and Consideration

3.3.1. Joint delivery system

Figure 6 shows the vehicle operation results for about two months. One operation is defined as going out from and returning to the LSC. The total number of such operations to construction sites was 127 times, and the maximum each day was eight times. There were three cases of joint delivery. The first case was to deliver two or more kinds of material to two or more construction sites. The second case was to deliver one kind of material to two or more construction sites. The third case was to deliver one kind of material to one construction site; this case was not joint delivery. The first case accounted for half of the total, and the second case for about 30 percent. The average loading rate of vehicles was improved by about 14 points by stacking and matching materials compared with about 70 percent and the conventional system. The number of vehicles entering the construction sites was reduced by about 30 percent compared with the conventional system. Moreover, the effect of using the LSC was high for materials containing many parts, because these could be made into a kit at the LSC.

The mileage of all vehicles was reduced by the higher efficiency of distribution, and carbon dioxide emissions from transportation vehicles were reduced by at least 22%, even though bringing together materials from the maker's factory in LSC with heavy vehicles was limited to just two months in this experiment and transportation was partial.

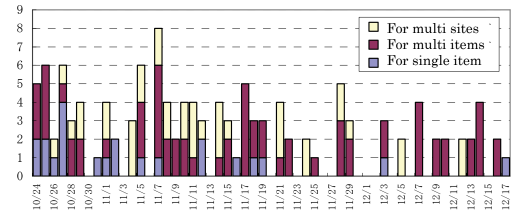

Figure 6 Operation Results of Transportation Vehicle

3.3.2. Construction logistics control system

The access log of the construction logistics control system was analyzed, and 45 users were found to have used it. The total number of logins was 1,237, and the maximum accesses each day was 70. The results are shown in Fig. 7 for accesses to the system. The number of accesses during regular working hours at the construction sites (8:00 AM to 5:00 PM) was 932, which was about 75% of the whole as shown in the figure. Access in the early morning and during the night (5:00 AM and 11:00 PM) became possible by using the Internet.

In this experimental application, it was important whether the delivery time could be adjusted by the LSC based on the transportation demand time. It is important in joint delivery how to allocate width (flexible time) to transportation demand. The result of the transportation demand time from the access log of the construction logistics control system is shown in Fig. 8. Event though some half the number of transportation demands became carrying at the specified time without the flexibility, the order that allows the flexibility of eight hours accounted for close to a quarter of the whole. In future, to increase the flexible time based on such data, we will consider incentives such as reducing the transportation cost.

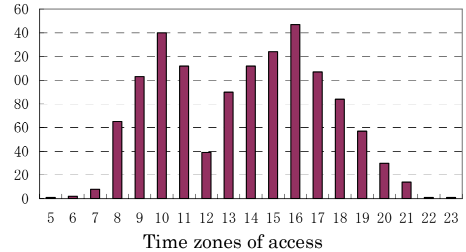

Figure 7 Access Time to Logistics Control System

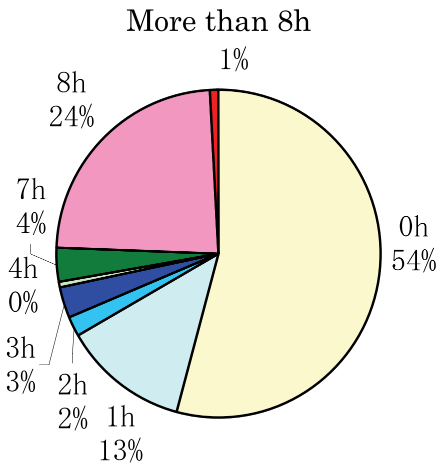

Figure 8 Width of Transportation Demand Time

3.3.3. Construction material traceability management system

This system was applied about one month after the LSC had been established. Previously, the LSC manager checked many kinds of material data, such as the name, product number, scheduled shipment date, delivery address, and amount. Especially, in the case of delivering two or more kinds of material to two or more construction sites, checking took 23 minutes. The work of inspecting construction materials upon shipment, including the above-mentioned paperwork, was decreased by about 1/3 by applying the RFID tags of this system.

4. PROBLEM FROM EXPERIMENTAL APPLICATIONS AND REMODELLING OF SYSTEM

4.1. Problem from Experimental Applications

4.1.1. Joint delivery system

The experiment was conducted for a limited period and at temporary LSC facilities, so there are some problems for the joint delivery system as follows:

- The change of the number of operations for transportation vehicles was large, and the storage space at the LSC, loading members, and equipment were excessive occasionally.
- It is necessary to clarify the cost allocation business model, contract, and method of adjusting joint delivery.
- Large construction sites are unsuitable for joint delivery.
- Some materials need special transportation such as by special vehicles.

It is necessary to secure more construction materials to solve these problems, by securing an appropriate number of construction sites and expanding the kind and amount of materials.

4.1.2. Two kinds of computer management tools

The issues for the two kinds of management tool, namely the construction logistics control system and construction material traceability management system, were as follows:

- Use by cellular phone is indispensable.
- The procedures became complex occasionally because the contract form was not changed.
- It was sometimes difficult to read the RFID tags stuck on some materials such as plywood and kitchen tiles, as shown in Photo 7.
- Readout is not possible if the forklift moves too fast.
- RFID tags became stuck at the LSC, so it took time.

As mentioned above, RFID tags have different readout rates according to the material and location where the tags are stuck. It is necessary to ensure that RFID tags at the LSC can be read by slowing down the forklift and so on.

4.2. Remodeling of Construction Logistics Control System

Most of the users of the construction logistics control system could not use the personal computer in the site office at any time because they are usually working outdoors, so there were strong demands for use by cellular phone. Therefore, a function was added as shown in Fig. 9.

- Reservation of delivery demand information and confirmation of delivery schedule

Leg of floor material

Wooden floor joist

Wallpaper

Furniture door

Photo 7 Example of Materials that were Difficult to Read

- Replenishment request of LSC to material factory
- Change in delivery schedule to construction sites

The input items of this system were limited so that everyone could use it easily. For example, the system sends a mail that requesting the users to make an input. The users can inspect the Web homepage automatically and directly upon receiving the message.

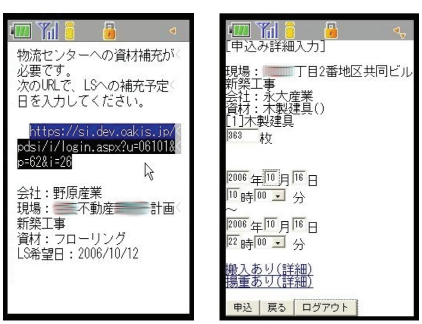

Figure 9 Example of Screen of Cellular Phone

5. CONCLUSION

We have developed a construction logistics system using a radio frequency identification technology for finely controlling several construction sites in order to improve the transportation and handling of construction materials. This system comprises three items: 1) a distribution center, called a Logistics Service Center, for handling many construction materials between construction sites and materials factories, 2) a Construction Logistics Control System via the Internet, and 3) a Construction Material Traceability Management System with radio frequency identification technology.

This system was experimentally applied to some small construction sites in the Tokyo metropolitan area for a few months, in 2005 and 2006. From the results of two experimental applications of this logistics system, we found the following: 1) carbon dioxide emissions from transportation vehicles were reduced by over 22 percent, 2) carbon dioxide emissions from the transportation vehicles to construction sites were reduced by 30 percent, and 3) the transportation vehicle loading rate was increased by 14 percent.

Moreover, we solved the problems clarified in the experimental applications in 2005, improved the system and added a new function.

6. ACKNOWLEDGMENT

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