# Solution for Improving Efficiency in Distribution Centers

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**ABSTRACT**

In recent years, distribution centers have become advanced in functionality and large scale in order to meet the needs of various distribution services such as just-in-time service. Meanwhile, distribution center work still relies heavily on manual labor, and thus, such centers are in need of a more efficient system adapted to the actual operation. For transfer centers which have struggled to improve efficiency by using the conventional system, Fuji Electric is providing a distribution solution based on the following 3 functions to eliminate dependence on individual operator skills and improve operation efficiency. The functions include a "transportation amount prediction function" for predicting the amount of transportation arriving and shipping at distribution centers, an "operation support function" for helping develop optimal plans, and a "vehicle guiding function" for completing transportation/delivery operations within time constraints.

## 1. Introduction

Along with the recent advancements in distribution services, such as same-day delivery at omni channels and Internet shops or just-in-time service, the domestic freight transportation sector has been increasingly dependent on truck (vehicle) transportation. Distribution centers are the key to vehicle operation and management for truck-based distribution services so that the number and amount of investments in them and their total floor space are increasing.

Distribution centers can be categorized based on their types: a transfer center (TC), a distribution center (DC) and a transfer-distribution center (TC/DC). DCs have been provided with package software or systems that enable efficient inventory control and vehicle operation by combining a warehouse management system (WMS) and a vehicle assignment and delivery planning system.

Unfortunately, such conventional package software and systems do not work effectively in large-scale TCs that handle several hundreds of thousands of packages per day and are equipped with 50 or more truck berths.

This paper describes a solution using a system consisting of a "transportation amount prediction function," an "operation support function" and a "vehicle guiding function" that Fuji Electric offers for large-scale TCs.

## 2. Issues in Distribution Centers

Figure 1 shows an outline of the work in a distribution center. Under the present conditions, most types of work have been relying heavily on manual labor except for sorting and some other tasks.

In a distribution center, there are various disturbances such as vehicle departure and arrival and facility operations, and the amount of transportation varies depending on the time period or loading truck berth. Consequently, in order to improve the operation effi-

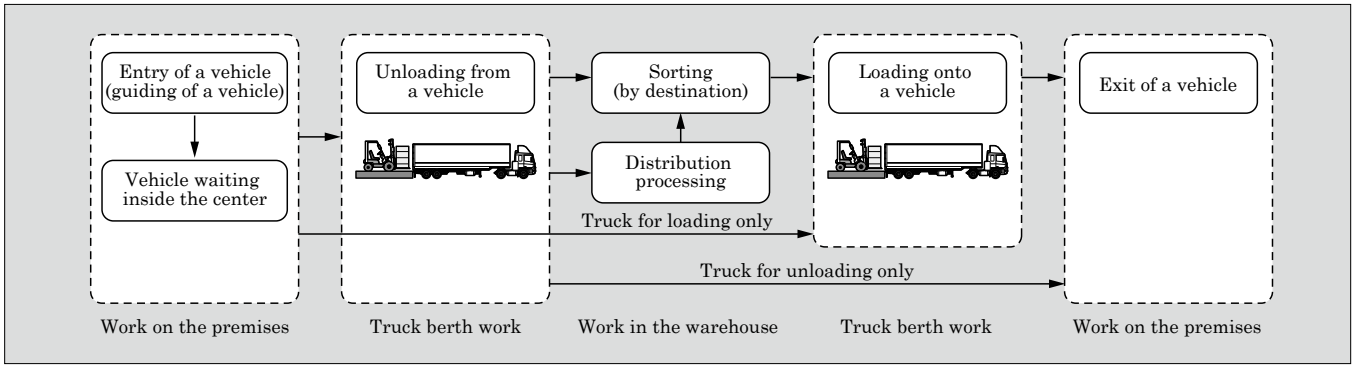


Fig.1 Overview of work in distribution center

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ciency of the center, it is important to assign labor according to these disturbances and the varying amount of transportation.

The following are 3 major issues in distribution centers (mainly TC):

(1) Eliminating the dependence of distribution center operations on individual operator skills

At DCs, it is possible to know the order quantity determined against the inventory of the center. Since the necessary transportation style can be planned to some extent in advance, it is easy to make an operation plan of the center (workforce, vehicle arrangement).

On the other hand, TCs are positioned at the middle of a distribution network as shown in Fig. 2. The amount of transportation arriving at and departing from the distribution center is unknown until immediately before transportation. The difficulty of predicting the amount of transportation beforehand is apparent when you assume a scene where multiple consumers do Internet shopping at multiple stores and individually specify delivery times and dates including same-day delivery. In many cases, specific staff members in a distribution center make plans related to workforce and vehicle arrangements based on their experience and dependent on individual skills. The level of data visualization (such as operation efficiency or track record of the number of transferred packages) is often insufficient.

(2) Better satisfaction of transportation time constraints

When multiple trucks arrive in a distribution center for loading in the same time period, it is necessary to guide the vehicles in view of moving distances so that all trucks can finish delivering their freight by the scheduled time.

(3) Eliminating heavy traffic of trucks due to a cause that exists inside the distribution center

Recently, distribution centers have been designed to be larger in scale and the amount of arriving and departing transportation sometimes reaches a level of 1 million packages per day (200 trucks/hour). Retaining vehicles in a distribution center due to various factors may cause heavy traffic in the neighborhood roads outside the center, leading to the risk of presenting social problems.

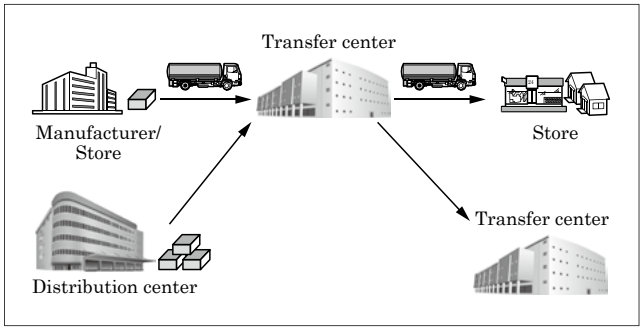


Fig.2 Overview of distribution network

Table 1 Relationship between issues and solutions

| Issue to be solved | Distribution solution | | |
|---|---|---|---|
| | Major function | Sub function | Collaborating sensors, systems, etc. |
| ○ Eliminating the dependence of distribution center operations on individual operator skills | Operation support | External collaboration | Personnel-related management system (worker information, etc.) |
| | | Workforce planning | Package position sensor<br>Worker position sensor, work record terminal |
| | | Facility operation planning | Facility (PLC, etc.) |
| ○ Better satisfaction of transportation time constraints<br>○ Eliminating heavy traffic of trucks due to a cause that exists inside the distribution center | Vehicle guiding | External collaboration | Truck operation management system (external system, departure/arrival schedule of trucks) |
| | | Truck state management (position, state) | Vehicle position sensor |
| | | Truck guiding | Truck indicator |
| ○ Eliminating the dependence of distribution center operations on individual operator skills<br>○ Eliminating heavy traffic of trucks due to a cause that exists inside the distribution center | Transportation amount prediction | – | Transportation track record management system (external system)<br>Vehicle guiding function, operation support function |

Table 1 lists the functions of Fuji Electric's distribution solution for solving these issues and improving the operation efficiency of distribution centers.

## 3. Distribution Solution for Solving the Issues

The distribution solution that Fuji Electric provides for solving the issues described in Chapter 2 uses the following 3 functions to eliminate the dependence on individual operator skills and improve operation efficiency.

The functions include a "transportation amount prediction function" for predicting the amount of transportation arriving at and departing from distribution centers, an "operation support function" for helping the development of optimal plans on workforce and facility operation by using the transportation amount prediction and various sensor information and a "vehicle guiding function" for completing transportation and delivery operations within time constraints and eliminating heavy traffic by combining the 2 functions above.

### 3.1 Transportation amount prediction function

The transportation amount prediction function predicts the amount of transportation arriving at and departing from a distribution center based on past

track records. The predicted amount of transportation is important information that will be used as a base for making vehicle guidance, workforce and facility operation plans in a distribution center.

This function can visualize the difference between the past track record and real-time data. Accurate prediction of the amount of transportation with a daily error of less than 5% can be achieved based on past track record data on the same day of the week in the same month of the previous year or the same day of the week in the previous week of the same year, with a correction made using the real-time data of the same day. Moreover, the amount can be visualized for each destination, and this helps the operation manager of the distribution center to make decisions.

From now on, we will proceed with research and development for more accurate prediction and segmentalized prediction such as by time period. We will do so by applying a combination of further data trend analysis and various prediction techniques (such as exponential smoothing, moving average and regression modeling).

### 3.2 Operation support function

(1) Workforce planning function

The workforce planning function visualizes the workforce arrangement plan and track record in each workplace or process in a distribution center and collaborates with the vehicle guiding function.

By obtaining worker information in the center through the method described in Section 4.3, the function calculates the work productivity from equation 1 for each work process. It then substitutes the result and the amount of transportation for each time period into equation 2 to make an optimal workforce arrangement plan.

$$\text{Work productivity} = \frac{\text{Number of packages}}{\text{Work rate}} \quad \text{..... (1)}$$

$$\text{Workforce} = \frac{\text{Amount of transportation}}{\text{Work productivity}} \quad \text{..... (2)}$$

The workforce plan can be constantly corrected based on real-time data of the amount of transportation and be reflected in work instructions. It is also possible to provide automatic voice instructions when the difference between the predicted amount of transportation and real-time data exceeds a predefined threshold value.

(2) Facility operation planning function

The facility operation planning function visualizes the present operation condition and schedule of each facility in a distribution center and collaborates with the vehicle guiding function.

Facility operation planning can visualize the present condition by receiving a track record of the amount of transportation, facility operation capacity (packages/hour) and a failure and stop state from facilities via power line communication (PLC) or another method. Using the facility operation capacity and transportation amount prediction allows staff members to make a facility operation plan. Note, however, that most facilities in a distribution center do not complete work by themselves. When a sorter is used for sorting work, the loading of a truck after sorting is done manually. Consequently, considering the facility operation plan and workforce plan together can improve the efficiency of the distribution center operation.

### 3.3 Vehicle guiding function

The vehicle guiding function collaborates with the transportation amount prediction function and operation support function and guides vehicles in an optimal way inside and outside the distribution center. It does so by acquiring vehicle positional information through the method described in Section 4.1.

Even if the transportation amount prediction is accurate and the workforce and facility operation plan is appropriate, it is impossible to improve the operation efficiency of a distribution center unless vehicles are guided properly. The vehicle guiding function is intended to designate a truck berth for each truck for loading or unloading. It is an important function for the efficient operation of a distribution center.

Vehicle guiding is affected by the following factors and this function guides vehicles based on a comprehensive judgment of them.

(1) Factors affecting the guiding of vehicles toward the distribution center

The following 2 factors affect the guiding of vehicles coming from the outside to the inside of a distribution center.

(a) Information on the vacancy inside the distribution center (truck berth, waiting area)

If there is no vacancy in the truck berths and waiting area inside the distribution center or if there is an accident inside the center, trucks arriving near the distribution center cannot enter. Such trucks go around the neighborhood roads or wait on the roads, resulting in harmful effects such as traffic congestion. To solve this problem, it is necessary to give instructions telling drivers to wait or circulate in a remote area.

(b) Priority (time constraint depending on truck destination)

Even when there is a vacancy in the truck berths or other areas of the distribution center, guiding trucks simply in the order of arrival without considering their destinations may lead to there being no vacancy in the truck berths. This would make it impossible to guide a truck with less time to spare for reasons such as it needing to go to a distant destination. Consequently, it is necessary to guide trucks according to the priority based on the amount of transportation of the packages to be unloaded by destination and on the destination of the

truck.

(2) Vehicle guiding inside the distribution center

The following 3 factors affect the guiding of vehicles to the truck berths inside the distribution center.

(a) Truck berth setting (unloading berth, destination after loading, etc.) and priority

There are different truck berth settings such as for unloading only or for specific destinations. These settings may also be changed based on time periods. It is necessary to guide trucks according to these settings while considering the priority factors such as packages and destinations.

(b) Vacancy of the truck berths (vacant, no vacancy or to be vacant)

The time when a truck berth becomes vacant is predicted from factors such as the start time of unloading and loading and work productivity. The guiding should consider the period of time that the truck requires to move from the present position to the truck berth.

(c) Amount of transportation of packages to be unloaded by destination (reduction of sorting time)

The guiding should consider equipment configuration including the layout of the truck berths and sorting devices to determine which truck berth can be used for unloading packages to complete sorting and other mechanical operations fastest.

## 4. Information Acquisition Technologies Supporting Distribution Solution

### 4.1 Vehicle position and truck berth vacancy information

The purpose of keeping track of vehicle positions and states varies depending on whether a vehicle is inside or outside the distribution center.

When a vehicle is outside the distribution center, it is necessary to determine when the vehicle will arrive at the distribution center and whether it can be guided into the center or not, based on information about the present vehicle position. For this purpose, an accuracy of several meters or less is unnecessary for the location information and generally-used GPS-based positional information (accuracy of about 10 m) is sufficient. Consequently, the solution uses GPS-based positional information services provided by various companies.

On the other hand, when a vehicle is inside the distribution center, it is necessary to recognize and estimate the following conditions to guide vehicles smoothly.

(a) Recognition of the vehicles that enter and exit the center

(b) Recognition of the vacancy of the truck berths

(c) Estimation of the time for guiding the vehicle from the waiting position to the truck berth when the distribution center has large premises

Accordingly, inside the distribution center, the position of a vehicle should be recognized with high accuracy and sensors with the characteristics shown in Table 2 are used to keep track of the positional information. When providing the system as a solution, Fuji Electric recommends loop coil sensors or magnetic detection sensors that are less affected by rain, dust, human access or other factors in the environments where vehicle recognition is conducted.

The system correlates the positional information inside and outside the distribution center with vehicle-specific information (license plate, driver, smartphone, etc.) and uses them for the vehicle guiding function.

### 4.2 Package positional information inside distribution center

Positional information on packages is not only required for improving the work efficiency in distribution centers but also indispensable for assuring traceability and security.

To acquire such information, you can use the data obtained by reading the barcode attached on each package with a handy terminal or the information detected with distribution equipment such as conveyors or sorters installed in distribution sites.

By using these measures, you can track the packages unloaded at the distribution center until they are transported by several workers or machines and loaded into a truck. Moreover, if a package was transported to a spot other than the scheduled internal route due to an accident or theft, it is necessary to

Table 2 Characteristics of vehicle recognition sensors

| Characteristics / Sensor | Protection against surrounding environment | | Detection characteristics | | | Burying construction |
|---|---|---|---|---|---|---|
| | Dust, dirt, rain, etc. (○: Not affected, ×: Affected) | Surrounding metal, magnetism (○: Not affected, △: Somewhat affected, ×: Affected) | Responding to metals only (○: Possible, ×: Impossible) | Passage detection (○: Possible, ×: Impossible) | Detecting range (○: Wide, △: Somewhat narrow, ×: Narrow) | |
| Camera | × | ○ | × | ○ | ○ | Unnecessary |
| Loop coil | ○ | △ | ○ | ○ | ○ | Necessary |
| Magnetic detection | ○ | × | ○ | ○ | △ | Unnecessary |
| Photoelectric | × | ○ | × | ○ | ○ | Unnecessary |
| Ultrasonic | × | ○ | × | × | △ | Unnecessary |
| Illumination detection | × | ○ | × | × | × | Unnecessary |

Table 3 Method of detecting positional information of packages and workers

| Characteristics \ Detection method | IMES | BLE | RFID (active) | RFID (passive) | Ultrasonic | Wireless LAN (Wi-Fi) | Acceleration sensor | Camera + Color barcode |
|---|---|---|---|---|---|---|---|---|
| Overview | GPS is extended for indoor use | Bluetooth radio waves are used | Radio waves generated from a TAG are used | Radio waves generated from an antenna are used | Sound waves are used instead of radio waves | Radio waves of wireless LAN are used for measurement | Displacement from the initial position of TAG is calculated | Image recognition of color barcodes |
| Recognition distance (varies depending on obstructions) | About 10 m | About 5 to 10 m | About 10 m | About 3 m or less | About 10 m | About 100 m or less | About 100 m or less | Depending on the environment |
| Operability | ○ | △ Battery replacement required | △ Battery replacement required | ○ | △ Battery replacement required | × Triangulation measurement is not suitable for the recognition of a large amount of targets | × Displacement measurement is not suitable for the recognition of a large amount of targets | △ Image recognition is easily affected by environments |
| Initial cost (relative level within the table) | Middle to high | Middle | Middle to high | Middle | High | High | High | Low |
| Running cost (relative level within the table) | High | Middle | High | Middle | High | High | High | Low |

○: Best, △: Having room for improvement, ×: Not acceptable

assure security by acquiring positional information. For this purpose, it is essential to constantly acquire positional information inside the distribution center building through the use of the sensor recognition technologies shown in Table 3. These detection methods and mechanisms, however, have advantages and disadvantages. It is necessary to select an optimal detection method with consideration given to costs and the required accuracy of the detection position. Furthermore, it is not realistic in terms of costs and recognition accuracy to use sensors to keep track of all transportation in a large-scale TCs where several hundreds of thousands of packages are transferred.

Fuji Electric therefore proposes a system that is focused on only valuables and insured packages requiring special traceability and security, and can track these inside and outside the distribution center. This is a combination of an indoor messaging system (IMES) that can be used with smartphones or other relatively affordable terminals and Bluetooth Low Energy (BLE).

### 4.3 Worker information inside distribution center

The following are the reasons why it is necessary to grasp information relating to workers inside the distribution center:

(1) Efficiency improvement through the management of work track record

The acquired work track record is visualized and used for calculating productivity or a key performance indicator (KPI) to improve work efficiency.

As with the traceability information of packages, improving efficiency thorough the management of work track records is generally done by grasping work track records using handy terminals or wearable terminals. There are many cases where this track record information is used for writing daily reports or collecting and aggregating track records to create the base data for efficiency improvement.

(2) Work efficiency improvement through the analysis of work traffic paths

In order to keep track of workforce information, it is necessary to acquire the work track record of workers and their time-based positional information while they are working.

Analyzing the work traffic paths makes it possible to find waste during operation and improve efficiency. With conventional systems, acquiring the work traffic paths required on-site behavior observation or analysis cases recorded with a camera. The targets for tracing the work traffic paths in this system are around 100 people and this number is significantly smaller compared with the number of packages that reaches several hundreds of thousands. Consequently, there is an advantage that the sensors described in Section 4.2 can be used for collecting the data automatically.

## 5. Summary

Introducing Fuji Electric's distribution system enables visualization of various kinds of information, and vehicles can be guided accurately based on this information. This leads to a solution allowing even inexperienced distribution center operators to operate the center at a level equivalent to highly experienced operators. This paper mainly focused on large-scale TCs; however, this solution is beneficial also for small- and medium-scale distribution centers and companies operating EC sites. EC site operating companies can enjoy reduced distribution costs and other advantages

by using traceability information and efficiency-improved distribution centers through the introduction of a distribution solution provided by Fuji Electric.

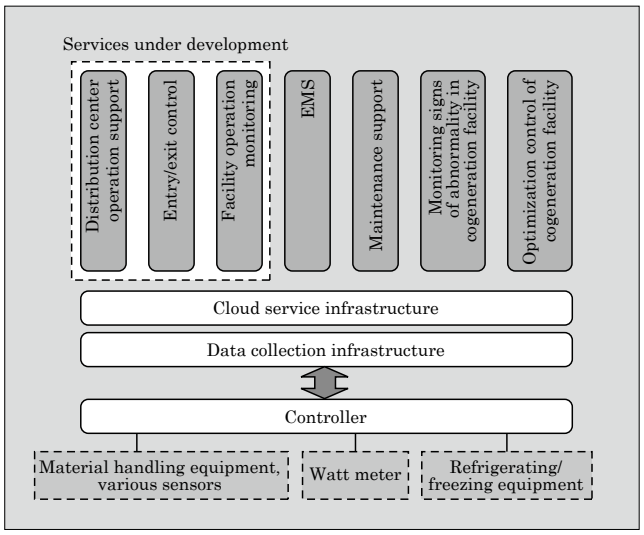


Fig.3 Overview of Fuji Electric's cloud service

Furthermore, we have enabled selective introduction of the necessary functions to reduce introduction costs and propose a solution available even for small- and medium-scale distribution centers.

We plan to provide a solution using the cloud service shown in Fig. 3 in the future. We will also connect the system described in this paper with the facility operation monitoring service or the entry and exit control service that can keep track of the field condition of a distribution center. We will then provide a solution as a distribution center operation support service.

## 6. Postscript

This paper described a solution for improving efficiency in distribution centers. The demands for the services of distribution, transportation and delivery are expected to become further advanced and diversified in the future. We intend to propose solutions through technological development that satisfies market needs such as predicting the transportation amount and analyzing human traffic paths.

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