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Pre-evaluation of Kaizen Plan Considering Efficiency and Employee Satisfaction by Simulation Using Data Assimilation -Toward Constructing Kaizen Support Framework-

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Abstract

Efficiency of work and employee satisfaction are important issues in distribution warehouses. However, operations, employees and layouts are totally different in each distribution warehouse. So it is necessary to develop the Kaizen Support Framework (KSF) including a simulator using data assimilation for appropriately realizing kaizen by considering such differences between various situations. In this study, we first designed the picking work model based on sensing data as a core part of the KSF, second developed the simulator with the model, and finally evaluated quantitatively zone picking as a kaizen plan by simulation. We confirmed that the kaizen plan is better than the current situation based on single picking in both efficiency and employee satisfaction. The evaluation result suggests the feasibility of supporting the kaizen activity using the simulator in the KSF.

Keywords:

Kaizen Support Framework, Pre-evaluation in simulation using data assimilation, The picking work model, Indoor positioning system, Efficiency, Employees satisfaction.

1 INTRODUCTION

1.1 Current status and issue of the warehouse service

Efficiency of work in distribution warehouses is an important issue in the field of supply chain management with increasing the number of internet commerce users. In addition to this, it is also urgently necessary to improve working conditions of employees because the number of labors are decreasing in Japan. Because operations, employees and layouts are totally different in each distribution warehouse, it is necessary to provide specific and suitable kaizen plans. Therefore, we have been developing the Kaizen Support Framework (KSF) including a simulator using data assimilation for appropriately realizing kaizen by considering the difference between various situations. Figure 1 shows the conceptual scheme of KSF. Conventionally, managers are often likely to reduce the number of employees for improving operational efficiency. However, the employees sacrifice quality of services to handle operations in such situations (Fujii and Shimmura 2013). Because the quality of services provided by employee effects directly the customer satisfaction, it is necessary to design the evaluation indicator for working process whether the kaizen plan is not only shortening operation time but also having time to spare in work for improving quality of services. The purpose of this study is the support that provides information to design a kaizen plan. So we designed the picking work model considering worker's skill levels based on the sensing data, and evaluated quantitatively the current situation and the kaizen plan with simulation using the model. In this study, we measured positions of employees and carts by using Visible Light Communication System and Warehouse Management System, and estimated trajectories of employees and carts. We figured out some problems of the current situation through analysis of the trajectories, and design a kaizen plan with zone picking. We compare the current situation and the kaizen plan by simulation using our picking work model. As a result, we could quantitatively confirm that the kaizen plan will increase efficiency of picking process, reduce the work time as a team, balance the operation time among employees, and give time to spare to the employees.

1.2 Related study

In the field of Operations Research, in order to improve efficiency of picking work, some optimization methods of shelf position are investigated. Kofler et. Al. proposed an optimization method for reassignment of the shelf position (Kofler and Reitinger 2010). Iwasaki et. Al. proposed a method for optimization of shelf position for solving crowded situation in passages (Iwasaki and Furukawa 2012). However, these studies are assuming simple shelves layout and difficult to apply on the actual situation. Iwao et. Al. showed a systematic analysis on the optimization simulation of picking operations by using the model estimated

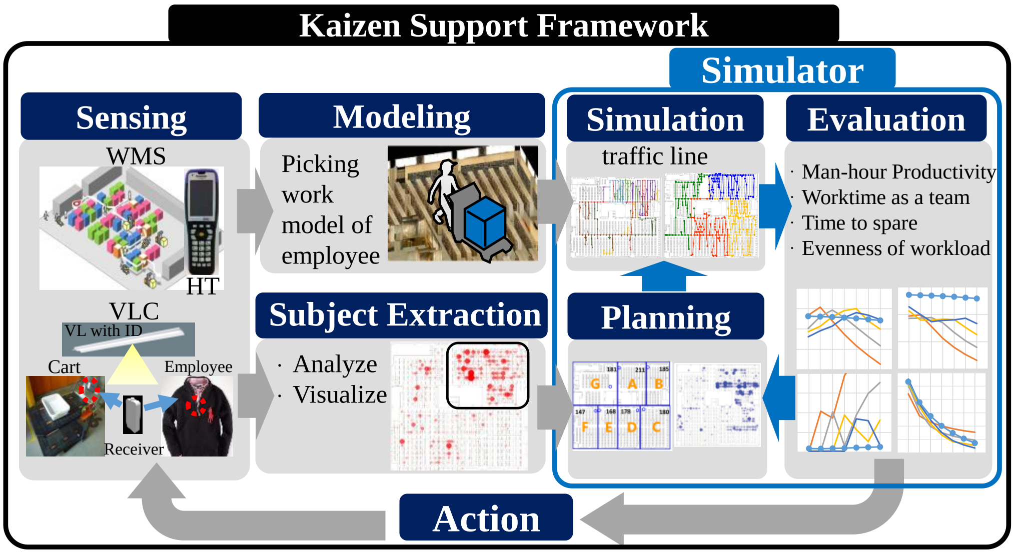


Figure 1 The conceptual scheme of Kaizen Support Framework.

qualitatively (Iwao 2009). Shiwang et. Al. also showed a simulation with the picking work model based on the order data for the decision making (Shiwang 2013). However, the picking work models of both studies are not derived from the results of measurement. In order to reproduce the actual behavior of the picking work, the model should be reflected in the actual detail behavior of employees.

There exists a study of the picking work that is considering the psychological and physical human factors from the perspective of human engineering (Grosse and Neumann 2015), however, the behavior of employees is not measured in this study. Especially service of picking work in the warehouse depends on each employee and is complicated. Therefore, it is necessary to see how employees carry out the picking work and to reflect the difference of environment and operations in each warehouse in the picking work model as data assimilation.

This paper is organized as follows. First, we overview the warehouse, and describe the measurement system to record employees position. In the following sections, we describe the picking work model based on the sensing data, and the verification of the model whether the simulation using the model is able to reproduce the actual situation. Then, we discuss the results of simulation and argue superiority of the kaizen plan and summarize this study.

2 OVERVIEW OF THE MEASUREMENT FIELD

2.1 Overview of the warehouse

In this study, a research field is a domestic distribution warehouse. The target of this research is the picking work which account for 60 percent of all works in the warehouses. The floor is a rectangle and the long side is 54 meters and the short side is 50 meters.

The number of items which is handled in the warehouse is 76,000. During the measurement term, the half of the all items was only picked up two times or less. However, the largest number of picked up times for one item was 230. It accounts for 39.3 percent of the number of picked up times. There are narrow and wide passages in the warehouse. Many employees can pass through on the wide passage but only one employee can pass through on the narrow passage. Therefore, the employees leave their carts when they pick up items placed on a narrow passage. There are four zones addressed as zone A, B, C, and D in the floor.

2.2 Measurement system the traffic lines

In the previous research (Myokan and Kurata 2015), we measure the behavior of 16 employees during working hours for two months. The employees are divided into three categories with their skill levels of the picking work. We use for Visible Light Communication System (VLC System) and Warehouse Management system (WMS) to measure and record the position of employees and carts.

The VLC is a wireless communication system using visible light. In VLC, main transmitters are LEDs, and receivers are photodiodes and image sensors. An LED can emit data such as the ID superimposed on visible light. The receiver can demodulate the ID from the received signals (Haruyama 2010). In this experiment, we measure and record the position of the employee and carts that are equipped the receiver with timestamp.

The WMS manages items in the warehouse. It gives employees information about orders from customers and items in the order, such as the number of stocks and stocked position. When the employees pick up an ordered item, they are required to scan a barcode corresponded to the item with their handy terminal for making pick-up record and update the database in the system. By trusting these records, we can estimate the positions of the employee with timestamp.

In this study, we estimated the trajectories of employees and carts using data from both VLC system and WMS.

3 PICKING WORK MODEL CONSTRUCTED AND VERIFICATION OF REPRODUCTION

3.1 Picking work model

In this study, we construct the model of picking work with the cart restriction. The cart restriction is that employees can move on the wide passages with their cart but cannot move on narrow passages with the cart. This restriction is appropriate because only 1% of the received data by receiver set on the carts are sent from LEDs set over the narrow passage. Then we incorporate an operation into the picking work model. The operation is that the employee leaves his own cart when he enters into the narrow passage, and returns to the cart position after he picked up some items on the passage.

The steps of the picking work model are shown below.

I. Confirm the orders using the handy terminal.
II. Towards the shelf in which ordered items stored, move on the wide passage carrying his cart.
III. Put the cart near the shelf on the wide passage.
IV. Leave the cart and enter into the narrow passage along the shelf.
V. Pick up the items stored in the shelf and read a bar code of the items with the handy terminal.
VI. Return to the cart and put the picked-up items on the cart.

In the picking work model, the employee basically handles plural orders repeating this steps.

3.2 Extracting parameters from the actual value

We divide the data into the training data and the test data considering that the number of employees for each the skill levels is equal. We use the training data to extract parameters of the picking work model and use the order data as the test data to verify reproducibility of the model.

As the parameters, we extract moving speed of employees, moving speed of employee during carrying the cart, picking work time, work time in front of the cart after picking, and correction value. The correction value is introduced for fill the time gap based on the difference between the distance of an actual path and the distance of a shortest path. Because, the route search method in the simulation always outputs the shortest path, but human employee does not always move along the shortest path. We extract these parameters for each skill levels.

3.3 Validation of reproducibility

We verified the reproducibility of the picking work model. In the verification, we computed the work time and the moving distance using the test data, and compared them with those of simulated value using corresponding order data. Figure 2 shows the boxplot of the distribution of moving distance and work time. This graph shows that the simulation distribution closes to the actual distribution in the both of results. We statistically verify whether the simulation value is significantly different from the actual value by using Wilcoxon signed-rank test. There were no significant differences between the two groups ($p > 0.01$). Therefore, it is no exaggeration to say that the picking work model constructed in this study is high reproducibility.

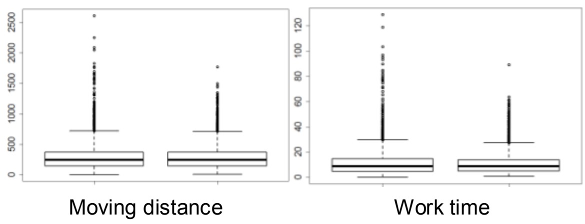
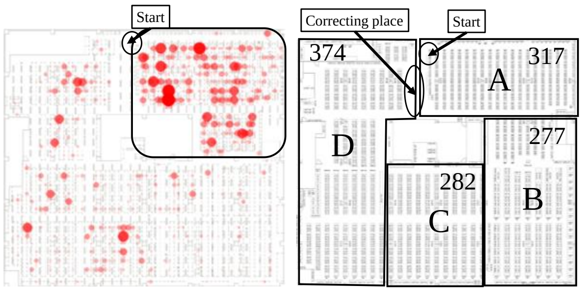


Figure 2: The comparison of moving distance and work time beteween the actual values and the simulated values.



(α) Before (β) After

Figure 3: Floor images of the warehouse

(α) Shipping frequency in actual shelf position,

(β) Changed shelf position.

4 SUGGESTION FOR KAIZEN PLAN

4.1 Issue of the actual method

We mention the three issues of the current situation in the warehouse according to the analysis of trajectories.

I. Discontinuous picking

When employees carry out the picking work, employees put their cart on the wide passage and move in front of the shelf stored items on the narrow passage. When a set item, which consists of plural parts, is ordered, the employee has to pack all parts into a small sack in front of the cart. So he needs to go back to his cart after he pick up all parts. In addition, because the amount he can hold in hands is limited, he cannot pick up all parts continuously.

II. Crowded environment

Items that is frequently ordered are stored concentrated in the zone A (Figure 3(α)). When a number of employees carry out the picking work at the same time, some narrow passages in the zone A is crowded. It is considered that the congestion is one of the factors decreasing the efficiency of picking work.

III. Dependence on highly skilled employees

We confirmed that the employees basically pick up items in order indicated by WMS, even the order is not optimized. However, some highly skilled employees change the picking order and uniquely improve efficiency based on experiences and intuition. Figure 4 shows the number of items picked per minute by an employee of each skill level and we confirmed that the picking speed of employees with skill level C (low) is lower than the one with skill level A (high) and B (middle). The sense of unfairness and dissatisfaction might be held by the highly skilled workers because their work amount increase as they work more effectively. Decreasing dependence on the highly skilled employees is essential to increase efficiency persistently.

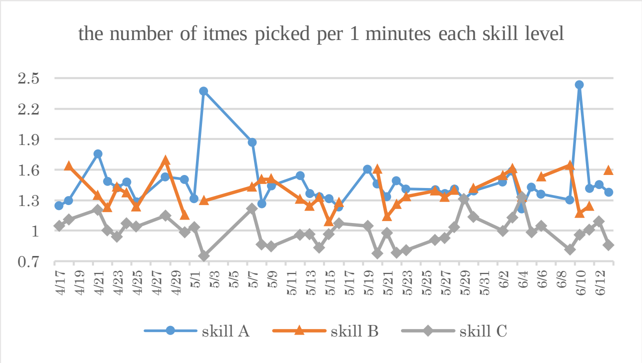


Figure 4: The numbers of items picked up per minute by an employee with each skill level.

4.2 Kaizen plan

In this study, we design a kaizen plan based on a zone picking method. Zone picking is the method that each employee takes charge of only one zone. We considered some plans in which the number of zones is from 4 to 7. The current situation is based on a single picking method. Single picking is the method in which each employee picks up the all items ordered by each shipping destination at once. The points of difference between the method of single picking and zone picking are how to deal with the orders and shelf layouts. In zone picking, each order is divided into plural sub-orders based on stored zone. Then, zone-packages are made by combination of the same zone sub-orders. After that, each employee processes a zone-package and brings it to sorting place. Finally, package for each original order is made by combining sub-orders from plural zone-packages in the sorting place. Shelves that stored frequently ordered items are distributed equally for every zone, and placed in frequency order along meandering path (Figure 3(β)).

Introducing zone picking as the kaizen plan, each employee can be assigned to different zone, not to make every zone crowded. In such a situation, it becomes possible to go through narrow passages with a cart. So employee can carry out the picking work with pushing cart in the narrow passage and can continuously pick up a number of items. Moving range of the zone picking method is smaller than that of the single picking method. Moreover, the shelves placement way based on the picking frequency allows employees to move around only in narrow range in most cases, and can pick up all items along a single stroke like that of the brush. Therefore, even skill level of an employee is low, he can work efficiently. It is also considered that the work quantity is balanced.

5 EVALUATION EXPERIMENT

5.1 Evaluation indicator

In this study, we design four evaluation indicators; Man-hour productivity, work time as a team, time to spare in work, and evenness of workload. Man-hour productivity and work time as a team are evaluation indicators to measure efficiency. Time to spare in work and evenness of workload are evaluation indicator affecting employee satisfaction.

"Man-hour productivity" is defined as the number of items picked up per person hour.

"Work time as a team" is defined as a duration from the time when the first order of a day is started handling by some team member until the time when the last order of the day is finished. We can evaluate how short the total work time as a team is using this indicator.

"Time to spare" is defined as the percentage of the total time spent for picking and sorting work of all employee to the total direct labor hours of all employee. This indicator evaluates the time to spare in the working process.

"Evenness of workload" is defined by the standard deviation of all work time in both picking work and sorting work for each employees. This indicator evaluates how the working amount is balanced.

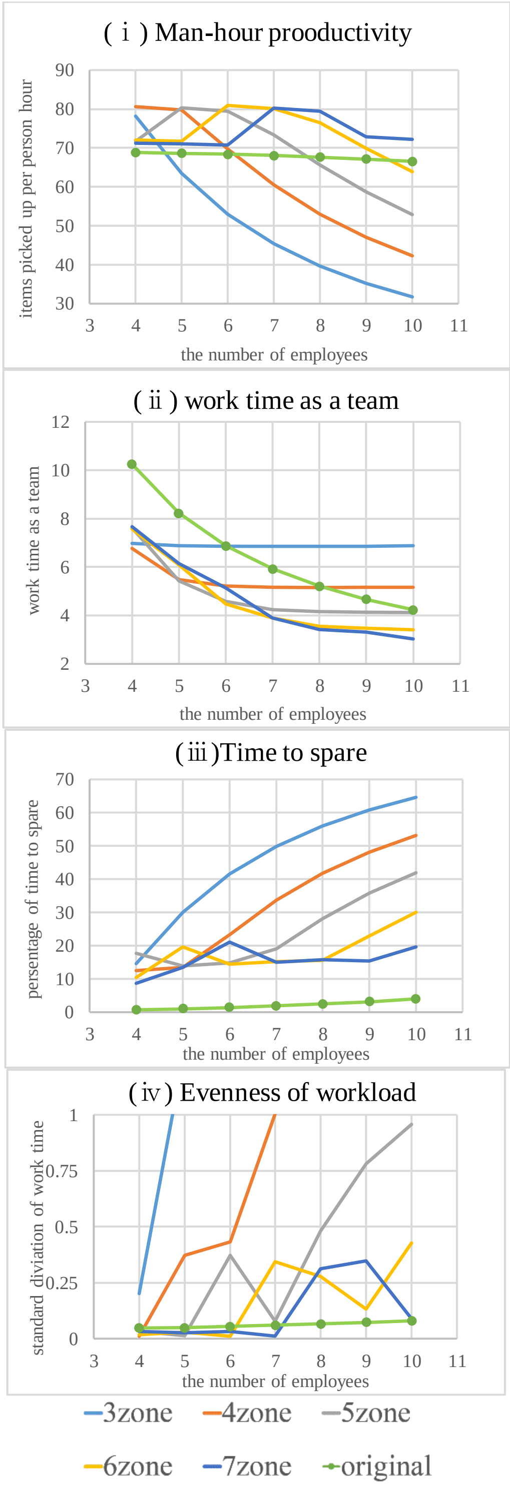
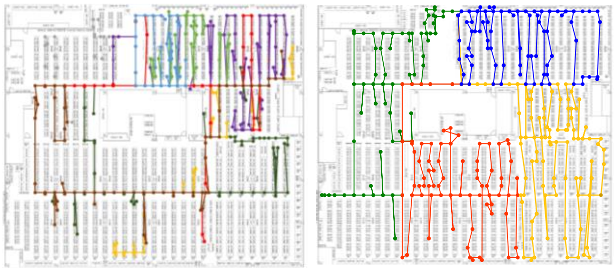


Figure 5: Evaluation results of the actual method and the kaizen plans with four indicators.



Single picking Zone picking

Figure 6: Trajectories of employees superimposed on the floor image of the warehouse.

Table 1: The result of comparison between actual method and kaizen plan in simulation.

		Actual method (Single picking)	Kaizen plan (Zone picking)				
	# of zone - # of employees	N - 7	3 - 4	4 - 4	5 - 5	6 - 7	7 - 7
Efficiency	Man-hour productivity	M	H	H	H	H	H
	Work time as a team	M	H	M	M	L	L
Employee Satisfaction	Time to spare	L	L	L	L	M	M
	Evenness of workload	M	M	L	L	M	L

bad good

5.2 Results of simulation

In this study, we simulated single picking as the current situation and zone picking as kaizen plans by using the picking work model constructed based on the sensing data. We set the following variables as conditions of simulation: the number of employees (from four to ten), and the number of zones (from three to seven). The number of orders that one employee processes at once is set to two considering the capacity of the cart. In this simulation, the sorting time is set based on the time putting an item in collapsible container categorized by each shipping destination, the number of items, and the time moving in front of the collapsible containers. The time putting an item in the collapsible container is defined as 10 seconds. When the number of the employees is larger than the number of the zones, the number of the employees as many as the number of the zones is assigned to picking work for each zone, and other employees are assigned to sorting work.

In this simulation, the interaction between employees, such as obstructing each other in narrow passage, is not considered. The simulated work time in single picking with the interaction will be longer than the one without the interaction, and that of zone picking does not depend on the interaction simulation. Even if the interaction is considered, it has a disadvantageous effect for single picking.

Figure 5 shows graphs of the simulation result for each evaluation indicator and Figure 6 shows the floor images of the warehouse superimposed the trajectory of employees. In this graphs, line and maker indicate the simulated results of the current situation, and line indicates the result of the kaizen plan. These lines of the kaizen plans are distinguished by color for each the number of zones. X-axis shows the number of employees.

- *Man-hour productivity*

With the single picking, the number of items decreases as the number of employees increase. However, the rate of decrease in the productivity is small. In case of the number of employee is same as the number of zone and only one or two employees are assigned to sorting work, man-hour productivity is higher than that of the single picking.

However, when more than two employees are assigned to the sorting work, the man-hour productivity decreases. Consequently, in the man-hour productivity aspect, when the number of the employees are the same as the number of zones or one more employee is working, the zone picking plan will be efficient.

- *Work time as a team*

Totally, the work time of zone picking is shorter than the work time of single picking in a team. As the number of employee increases, the work time as a team decreases in regard to both single picking and zone picking. However, the result indicates that the value in zone picking is almost constant when the number of the employees exceeds the number of zone,

- *Time to spare*

In single picking, the rate of increase in time to spare against to increase in the number of employees is low. So it is confirmed that the amount of increase in the number of employees doesn't affect to this indicator in single picking. In zone picking, basically, the time to spare increase as the number of employee increase. However, during the number of employees is from the number of zones to two more, the value of this indicator stays around 15%.

- *Evenness of workload*

In single picking, the value of evenness of workload keeps to almost 0, which indicates there is no difference in work amount of employees. In zone picking, this indicator tends upward as the number of the employees increase. However, when from even to three more employees than the number of the zone works, increase and decrease in the indicator is observed.

Table 1 shows the best combinations of efficiency and employee satisfaction in zone picking for each number of zone and the ones in single picking.

In this table, each indicator is labeled high, middle, and low respectively based on the value of the indicator. The criteria of the label are the top 25th percentile (first quartile) and bottom 25th percentile (third quartile) of the distribution for each indicator.

6 DISCUSSION

6.1 Picking and sorting in zone picking

As the feature of all results, it is verified that the number of employees assigned to the sorting work influences greatly the manner of change in all indicators, because it the manner of change appears only when the number of employees exceeds the number of zones.

If an employee is assigned to the sorting work, the picking work and the sorting work are carried out at the same time and "work time as a team" can be reduced. However, when the number of employees exceeds the number of zones, the increase of employees influences only the sorting work, not work time as a team, because the number of employees working for picking in a zone is limited to only one in the simulation. So the sorting work time is shortened by adding employees, but the picking work time doesn't change. That makes the difference between the sorting work time and the picking work time get greater gradually. As a result, "time to spare" and "evenness of workload" show increasing trends.

Regarding "man-hour productivity", it is defined as the number of items picked up per person hour in this study as mentioned in section 5.1. When the number of employees exceeds the number of zones, only the denominator of this indicator increases according to the increase of employees and thereby man-hour productivity shows decreasing trend.

6.2 Restriction in a zone

The restriction that the number of employees working for picking in a zone is limited to only one is considered one of the reasons for the above trends in the simulation results. We designed the restriction to avoid congestion in a passage. There would be a more relaxed restriction in which an employee can start the picking work in a zone just after other employee finished the picking work in the same zone so as to be able to not only improve the efficiency of picking but avoid the congestion.

However, with this relaxed restriction, an employee has to wait his turn while another employee is working in the same zone. So, it is necessary to investigate the influence on the waiting time and to confirm whether it is possible to level out the workload of each employee.

6.3 Reproducibility in single picking

Although the actual employees select the next order by their own decision when they return to the starting position, it cannot be reproduced in the single picking simulation. Thus the single picking is simulated based on the condition that all employees are skill level A and the next order is given to them on a first-come first-served basis just after they return to the starting position. So the waiting time between two successive picking works is not considered in this simulation and the variance of workload becomes small for evenly distributed orders. Consequently, "time to spare" and "evenness of workload" indicators are unvarying and actual evenness and short rests are not reproduced in the single picking simulation.

6.4 Allowance

In the field of time study, there is the concept of "allowance" which is indispensable "time to spare" in carrying out any work with human resource (Rastogi 2010). One of allowances is "relaxation allowance". The relaxation allowance is time for overcoming fatigue and for personal needs such as toilet break and water intake. It is usually supposed to account for 10 to 20 percent of the normal work time.

In zone picking, "man-hour productivity" is higher than single picking and also "time to spare" accounts for 10 to 20 percent of total work time when the number of employee is same as the number of zones or one or two employees are assigned to the sorting work. Therefore, zone picking is not only the efficient method but the method gives time to spare reasonably to employees.

In actual situations, it is considered that shortage of employees may occur suddenly. However, as shown in Figure 5, some of indicators drastically varies according to the number of employees. On that account, it is necessary to discuss and evaluate the robustness of kaizen plans. There is "contingency allowance" as another types of allowance which is time applicable for handling infrequent situations such as the shortage of employees and the delay of work due to mistakes by employees. As future work, we are going to discuss the contingency allowance as an additional indicator in order to verify the robustness of kaizen plans.

7 CONCLUSIONS

We are aiming at supporting the decision making by using the KSF which can provide quantitative pre-evaluation without strongly depending on intuition and experience. As mentioned at the beginning, managers are often likely to reduce the number of employees for improving only operational efficiency. However, the picking work is carried out by human operation. So it is necessary to take into account not only work efficiency but also the employees' point of view in order to improve the working processes practically and sustainably.

Accordingly, we designed the indicators such as "evenness of workload" and "time to spare" that are assumed to be relevant to employee satisfaction. In addition, we constructed the picking work model based on the sensing data and verified the reproducibility by comparing the simulated values in moving distance and work time with the actual ones. Therefore, we could conduct valid pre-evaluations with simulation, and also we made it clear that the work efficiency and the employee-satisfaction-related factors can be both highly satisfied if we take the zone picking method with some parameter settings through the evaluation experiment.

The KSF including the sensing method and the simulator as its core part should have the versatility so as to be able to apply it to other distribution warehouses. We plan to verify the versatility besides tackling the issues mentioned in section 6 as future works.

8 ACKNOWLEDGMENTS

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