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Maintenance Model of Agricultural Facilities Using CBR

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Abstract

As we move from the industrial age to the information age, domestic industries are changing rapidly, and rural society is also laying the foundation to make use of information technologies. Through this kind of modernization, the size of agricultural facilities has been increasing on a significant scale. But, in reality, there are many difficulties in the maintenance of agricultural facilities in proportion to their growing number. Accordingly, this research aims to solve the fundamental problems that occur with agricultural facilities in the maintenance stage. In addition, it aims to provide information on how to maintain and manage facilities for farmers. The presentation of the maintenance information was conducted using a case-based reasoning method that solves current problems based on past cases. The tool of case-based reasoning was applied to define the establishment of the base for cases, characteristic variables and maintenance measures. The effectiveness of a CBR model was examined through the case study. The use of the case-based reasoning method is judged to be effective as a tool to support the decisions of farmers regarding maintenance. When the maintenance measures derived through the CBR model are offered to farmers, the fundamental problems of maintaining agricultural facilities will be solved, and the damage to such facilities minimized.

Keywords : agricultural facility, maintenance, case-based reasoning

1. Introduction

1.1 Research background and objective

As the information age has brought about rapid changes in domestic industries, including agriculture, the demand in rural communities for knowledge, information and technological innovation in agriculture has been on the rise. In response to such demands, the government formed a base for information utilization in rural communities by establishing a 5-year informatization plan for the agriculture industry and rural society. In addition, it has provided a modernization policy to raise the information literacy of farmers, which includes enhancing their education in the area of information technologies[1].

Although the modernization policy has allowed agricultural facilities to increase in size since the 1990s, the damage to the facilities has been reported as increasing in proportion to the growing number of agricultural facilities. In addition, most agricultural facilities are provisional structures, and their economic life expectancy is generally very short. Therefore, the agricultural facilities need to be maintained, and often to be rebuilt. As agricultural facilities such as greenhouses and glasshouses are usually small in size and are also not technically difficult to build, the farmers themselves build and maintain the facilities. Nonetheless, they have difficulty maintaining the facilities due to a lack of information and knowledge[2].

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For these reasons, this study reviews methods of applying information technology to the maintenance process of the agricultural facilities. Case-based reasoning (CBR) is based on a simple idea that 'the solutions that were used to resolve problems in the past can be used to resolve a new problem.' Hence, it aims to provide a method of maintaining agricultural facilities using CBR in order for farmers to obtain the necessary information from similar past cases.

1.2 Research scope and method

Agricultural facilities can be divided into various types, such as greenhouses, glasshouses, cattle shed or pigsty, and storehouse. Based on statistics from the last 5 years, the greenhouse growing area accounts for more than 95 percent of the entire growing area. Greenhouse facilities are built repeatedly and are maintained every year due to natural disasters, defects, and decrepit materials. The research scope is restricted to greenhouses that are vulnerable to natural disaster and do not have any systemic maintenance process.

To analyze the damage status of the agricultural facilities and build the maintenance model, cases of damage to agricultural facilities were collected and analyzed. In addition, interviews were performed, not only with the farmers who run the greenhouses but also with greenhouse construction specialists, in conjunction with a review on the previous studies and literature. A total of 170 CBR applied cases were collected from local autonomous bodies across Korea during a 6-year period from 2005 to 2010 to establish the case base and perform verification.

1.3 Review of the previous studies

The representative studies on the maintenance of agricultural facilities and the application of CBR to construction management are indicated in Table 1. Cho et al.[2] researched the maintenance of agricultural facilities and suggested the current status and problems of agricultural facilities, construction process analysis of agricultural facilities, and improvements for each stage. Lee et al.[3] studied the informatization of agricultural facilities and provided an integrated agriculture information DB with 9 information categories including production, logistics and agricultural technology. Yoon[4] presented ways to digitalize rural areas to bring about agricultural competitiveness and improve the quality of life in rural areas.

Table 1. Previous studies

Researcher	Highlights
Choi et al. [2]	Suggest directions for developing agricultural facilities by surveying how they operate
Lee et al.[3]	A Development for Application System of integrated agriculture information.
Yoon[4]	Study ways to digitalize rural areas dedicated to taking their competitiveness to a higher level and raise quality of life
Yau et al.[5]	Applying case-based reasoning technique to retaining wall selection
Kim et al.[6]	A selection model of retaining wall methods using case-based reasoning
Morocous et al.[7]	Case-Based Reasoning System for Modeling Infrastructure Deterioration
Yae[8]	Reasoning model of Case-based construction safety management system

Research on the application of AI including CBR to construction management has been actively conducted. The following are some good examples of CBR application to construction management. Yau et al.[5] and Kim et al.[6] used CBR to select a retaining wall method appropriate for the structures. Morocous et al.[7] developed the 'CBRMID' system to model the performance of the underground-lying structure, and Yae[8] built a reasoning model of a case-based construction safety management system.

However, research related to the maintenance and informatization of the agricultural facilities has remained rare. In addition, the AI-based technologies, including CBR, were mostly introduced to construction method selection, performance estimation and safety management. For this reason, there are few studies on the application of CBR to the maintenance of agricultural facilities.

2. Current status of the maintenance of agricultural facilities, and review of CBR theories

2.1 Maintenance status of agricultural facilities

It is found that maintenance - a very critical stage for the long-term operation of agricultural facilities - is usually done by the users themselves. This is because the users can repair and replace the material or parts for themselves. However, when it is done by non-professional workers, the facilities can be vulnerable to deterioration in durability and natural disaster. Moreover, the users of agricultural facilities are also found to have a hard time obtaining the professional skills and knowledge required to perform maintenance correctly. Figure 1 shows the areas that users have found difficult[2].

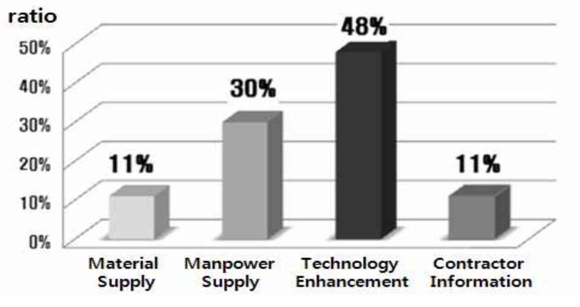


Figure 1. Maintenance status of agricultural facility

2.2 Technical causes of damage to agricultural facilities

Based on the analysis of the damage cases collected for this research, the technical causes of damage to agricultural facilities were derived. The causes can be divided into uncontrollable factors such as natural disaster (snowstorm or typhoon), and construction-related technical causes. Figure 2 indicates the causes in detail. The most frequently reported cause was failure to meet pipe specification, followed by failure to meet rafter interval, facilities width/height, and the number of ledgers, in that order.

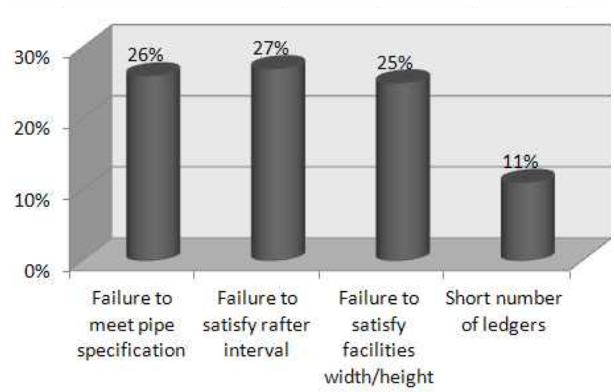


Figure 2. Damage status of agriculture facilities

2.3 Maintenance measures

Maintenance measures for each damage type are needed. For this reason, this research defined the maintenance measures as indicated in Table 2 based on the analysis of cases of damage and interviews with specialized agricultural companies and farmers. The 9 measures include setting up extra columns, installing steel wires, installing bracing and reinforcing ledgers.

Table 2. Classification of maintenance methods

Counteraction	Definition
① Set up extra columns	Set up extra columns in ledgers of vinyl house roof to give more bearing power
② Install of snow removing equipment	Remove snow promptly to reduce facilities damage
③ Put steel wires	Put steel wires in rafters located at side columns on both sides to keep facilities from widening
④ Tear covers	Tear green vinyl house covers to keep snow from piling up
⑤ Burn straws	Run heater or burn straws to keep snow from piling up
⑥ Put bracing	Add bracing to the external rafter pipe to add stress against snow load
⑦ Use shade net/ lagging cover	Roll up shade net and lagging cover to keep facilities from collapsing
⑧ Add ledgers	Add ledgers
⑨ Remove snow promptly	Remove snow when there is a heavy snow forecast to keep snow from piling up

2.2 Review of the CBR theory

2.2.1 Summary of CBR

CBR is based on the idea that humans use a solution for past incidents in the course of reasoning by modifying it to appropriately address a new problem. That is, a new solution is drawn from the solution to a similar past problem. Human memory finds an already-solved problem similar to the present one, and modifies the solution to make it appropriate for the present problem by analyzing the differences between the past problem and the present one.

So far, Rule-based Reasoning (RBR) has mainly been used in specialized systems. In the RBR-applied system, all the related knowledge factors are extracted as rules and then built into the Rule Base. A solution is reasoned based on the Rule Base. However, not only is it almost impossible to consider all the rules for a problem in advance, but it is also difficult to solve the problem if it does not match the rules. In addition, the RBR considers the related rules from the top, and thus as more rules are added, performance inevitably deteriorates.

On the other hand, when a given problem is similar to past problems, the CBR derives a solution without any special reasoning. Using the past methods as knowledge, the CBR presents a solution by matching the given problem with the past cases. The CBR is very efficient in fields such as the selection of the retaining wall construction method, where problems are complex or where the problem area is not clearly found [9].

2.2.2 CBR cycle

Figure 3 illustrates the case reasoning process, which is the core of the CBR. The following are simple descriptions of the 4 REs comprising the CBR[10].

1) REtrieve

REtrieve refers to finding the case that is the most similar to the given problem. That is, one or more cases are retrieved from the case base. Upon retrieval, defining the 'match' is an important issue, and one or more cases that are most matched to the given problem are presented, as there is very low possibility of finding a completely matched case.

2) REuse

REuse refers to using the information and knowledge of retrieved cases again to solve a given problem.

3) REvise

REvise refers to the step of modifying the presented solution.

4) REtain

REtain refers to storing the solution for a new problem in the case base for future use [11].

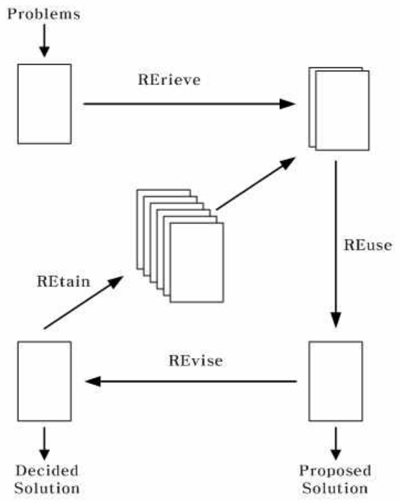


Figure 3. CBR cycle

3. Build-up of the CBR model

3.1 The structure of the CBR maintenance model

The structure of the CBR maintenance model for agricultural facilities was composed as illustrated in Figure 4. The model largely consists of the CBR system and user interface (input, output). Damage cases of agricultural facilities are input to calculate a weight and provide a solution through the input part. The output window is provided to give the user the damage cause and maintenance measures for the input problem.

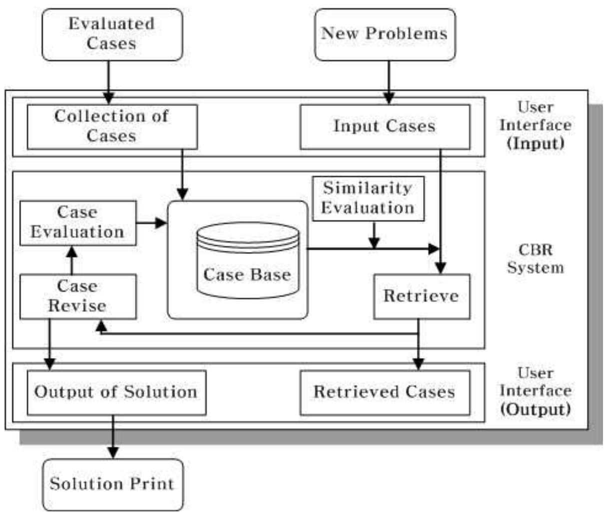


Figure 4. Structure of CBR model

3.2 Definition of maintenance

3.2.1 Classification of input and output variables

CBR is based on cases. Therefore, it is very important to define variables. If too many variables are used to express a case, the case base becomes too large as it expands, which leads to a deterioration in the reasoning efficiency of the case base system. Therefore, it is important to properly select main factors to express the problem[8].

The variables of the damage cases of agricultural facilities were defined based on the type of case information related to the agricultural facilities indicated in previous studies and the literature, as well as through interviews with specialists. Table 3 indicates variables defined by case. The input variables include the general information of the facility (pipe size and thickness, rafter interval, number of ledgers, width and height of the facility) and disaster information (disaster occurrence time and date, amount of snowfall), and the output variables include disaster causes and the maintenance measures.

Table 3. Definition of input and output variables

Large-scale classification		Medium-scale classification	Small-scale classification
Input	General facilities information	Materials in use (pipe)	Size
			Thickness
		Types of facilities	Rafter interval
			Number of ledgers
			Facilities width
			Facilities height
	Disaster situation	Date of breakout	-
		Amount of snowfall	-
Output	Technical Causes of Damage		
	Maintenance methods		

3.2.2 Definition of input and output variables

To input a past case to the case base, the variables that define the case should first be defined. Therefore, Tables 4 and 5 indicate the characteristics of the input and output variables. FreeCBR, the program used in this research, is set to sort the cases by type into 'String,' 'Float,' 'int,' Multi-string,' and 'Bool(T/F)' based on the type expressed by the definition of each variable.

Table 4. Characteristic of input variables

Variable		Unit	Type	Data characteristic
Date of breakout		Numerical value(month)	Discrete type	Mark in 'month'
Amount of snowfall		Numerical value(cm)	Discrete type	Marked in 'cm'
Pipe	Size	Numerical value(Ø)	Continuous type	Marked in 'Ø'
Pipe	Thickness	Numerical value(t)	Continuous type	Marked in 't'
Rafter interval		Numerical value(cm)	Discrete type	Marked in 'cm'
Number of ledgers		Numerical value(no.)	Discrete type	Marked in 'number'
Facilities	Width	Numerical value(m)	Continuous type	Marked in 'm'
Facilities	Height	Numerical value(m)	Continuous type	Marked in 'm'

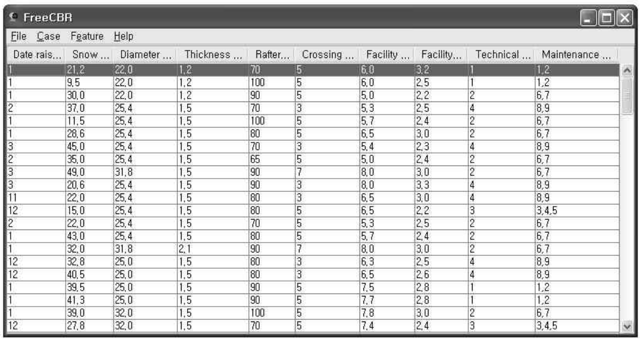
Table 5. Characteristic of output variables

Variable	Unit	Data type	Data characteristic
Technical causes	Numerical value(no.)	Discrete type	Marked in 'number'
Maintenance strategies	Numerical value(no.)	Discrete type	Marked in 'number'

3.3 Inputting and retrieval of a case

3.3.1 Inputting a case

The program used in this study enables a user to input a damage case of the CBR model in the window shown in Figure 5.



Date rais...	Snow ...	Diameter ...	Thickness ...	Rafter...	Crossing ...	Facility ...	Facility...	Technical ...	Maintenance ...
1	21.2	22.0	1.2	70	5	6.0	3.2	1	1,2
1	9.5	22.0	1.2	100	5	6.0	2.5	1	1,2
1	30.0	22.0	1.2	90	5	5.0	2.2	2	6,7
2	37.0	25.4	1.5	70	3	5.3	2.5	4	8,9
1	11.5	25.4	1.5	100	5	5.7	2.4	2	6,7
1	28.6	25.4	1.5	80	5	6.5	3.0	2	6,7
3	45.0	25.4	1.5	70	3	5.4	2.3	4	8,9
2	35.0	25.4	1.5	65	5	5.0	2.4	2	6,7
3	49.0	31.8	1.5	90	7	8.0	3.0	2	6,7
3	20.6	25.4	1.5	90	3	8.0	3.3	4	8,9
11	22.0	25.4	1.5	80	3	6.5	3.0	4	8,9
12	15.0	25.4	1.5	80	5	6.5	2.2	3	3,4,5
2	22.0	25.4	1.5	70	5	5.3	2.5	2	6,7
1	43.0	25.4	1.5	80	5	5.7	2.4	2	6,7
1	32.0	31.8	2.1	90	7	8.0	3.0	2	6,7
12	32.8	25.0	1.5	80	3	6.3	2.5	4	8,9
12	40.5	25.0	1.5	80	3	6.5	2.6	4	8,9
1	39.5	25.0	1.5	90	5	7.5	2.8	1	1,2
1	41.3	25.0	1.5	90	5	7.7	2.8	1	1,2
1	39.0	32.0	1.5	100	5	7.8	3.0	2	6,7
12	27.8	32.0	1.5	70	5	7.4	2.4	3	3,4,5

Figure 5. Input of case data

3.3.2 Similarity evaluation

The CBR system is based on the idea that the solution for a given problem is presented by exploring similar past cases. The similarity evaluation is used to determine one or more similar past cases in the case base compared to the given problem. The similarity function is expressed as Eq. (1).

$$S = \frac{\sum_{i=1}^{n}(W_i \times SS_i)}{\sum_{i=1}^{n}(W_i)} \times 100 \quad \text{---------} \quad (1)$$

S in Eq. (1) is for 'the evaluated value of similarity,' that was set to have a value between 0 and 100 in this research. W is for a weight by variable, and SS for an evaluated value of similarity for each variable. Weight for each variable is calculated by applying the gradient descent method

The data format of variables set in this research can be divided into numerical data and string data. Therefore, SS of each variable should be defined accordingly. For this reason, the numerical data was assigned '1' if it satisfied Eq. (2), but '0' if it did not. V_{case} in Eq. (2) refers to the variable value of the case in the case base, and $V_{problem}$ to the variable value of the newly given problem. In addition, M% was set to 10%, as recommended by the previous studies and FreeCBR.

$$SS = |V_{case} - V_{problem}| \leq V_{problem} \times M\% \text{ -- (2)}$$

For the string data, SS was assigned '1' if the string was completely matched, but '0' if not.

3.3.3 Case retrieval

The maintenance model for the agricultural facilities provides the results with higher similarity evaluation value higher in the list. Figure 6 is the output window, and shows the technical causes (Figure 2) and maintenance measures (Table 2) by aligning the cases in the higher evaluation value order when entering the input variables, such as amount of snowfall and pipe size (see Table 3).

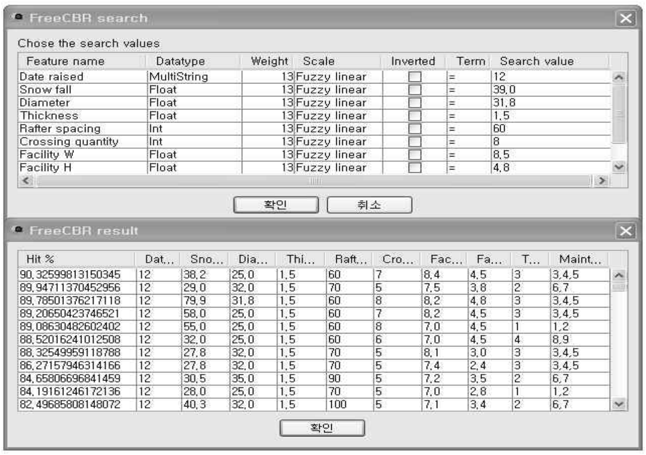


Figure 6. Retrieve result

4. Case study

4.1 Summary of cases

160 of the total of 170 cases collected for this research were used as the case base. 10 randomly selected cases are summarized in Table 7.

4.2 Case retrieval

To evaluate the model, the 10 randomly selected cases were compared with the 160 cases stored in the case base to determine the similarity. Table 8 indicates the results of retrieval of the 10 cases. 4 cases most highly matched to the entered cases were retrieved. The retrieval results are output in the form of maintenance measure number (technical cause no. - similarity evolution value).

Likewise, the CBR method not only provides one recommended solution, but also acceptable solutions. That is, it offers the results evaluated according to the variables for similarity evaluation, and the final decision is made by the decision-maker himself/herself based on the retrieved results, which is another advantage of the method.

4.3 Analysis of the results

The maintenance measures and technical causes retrieved from the model evaluation can be analyzed as the applicable maintenance measures (solution). In addition, the information of the case found to have the highest similarity can be seen as the recommendable solution, and the other three as applicable solutions. From the analysis of the retrieval results, 9 cases have a recommendable solution and the other has an acceptable one. Applying the method presented in this research is believed to help users to make more reasonable decisions, since they can utilize the information retrieved from the system. Namely, although the number of variables acceptable to the system is restricted, the system is considered to provide better information for users to make their final decision. Therefore, the CBR maintenance model is considered effective as a decision-making support tool for the maintenance of agricultural facilities.

Table 7. Cases for evaluation of the model

Case number	Month	Amount of snowfall (cm)	Pipe		Rafter interval (m)	Number of ledgers	Facilities		Technical factors	Maintenance measures
			Size(∅)	Thickness(t)			Width(m)	Height(m)		
1	1	30	25.4	1.5	90	1	5.2	2.2	4	8,9
2	12	32.5	22	1.5	90	5	6.2	2.7	1	1,2
3	12	15	25	1.5	70	5	8.1	3.1	3	3,4,5
4	1	32.3	25	1.5	80	5	6	3.3	2	6,7
5	2	28.8	25	1.5	90	5	7.6	3.5	1	1,2
6	2	21.4	22	1.2	50	3	5.3	2.6	4	8,9
7	3	26.4	22	1.2	80	5	5.1	3	2	6,7
8	1	25	22	1.2	100	4	5.3	2.8	3	3,4,5
9	2	33.2	22	1.2	50	5	6.2	2.7	3	3,4,5
10	12	39	31.8	1.5	60	8	8.5	4.8	3	3,4,5

Table 8. Retrieve result from the model

Case number	Result			retrieve result (Factor-Similarity%)			
	Factor	Measures	Result	1	2	3	4
1	4	8,9	O	8,9(4-95.9)	8,9(4-94.8)	8,9(3-93.4)	8,9(4-93.3)
2	1	1,2	O	1,2(1-96.7)	1,2(1-96.6)	1,2(1-96.0)	1,2(1-93.9)
3	3	3,4,5	O	3,4,5(3-94.5)	3,4,5(3-94.4)	3,4,5(3-93.3)	1,2(1-92.3)
4	2	6,7	O	6,7(2-98.2)	3,4,5(3-97.2)	3,4,5(3-96.9)	3,4,5(3-96.2)
5	1	1,2	O	1,2(1-94.7)	1,2(1-94.5)	1,2(1-94.4)	6,7(2-94.4)
6	4	8,9	O	8,9(4-96.8)	1,2(1-93.6)	3,4,5(3-92.8)	3,4,5(3-91.2)
7	2	6,7	O	6,7(2-96.1)	3,4,5(3-95.5)	3,4,5(3-94.1)	1,2(1-93.4)
8	3	3,4,5	X	6,7(2-95.86)	1,2(1-94.67)	3,4,5(3-94.3)	6,7(2-93.7)
9	3	3,4,5	O	3,4,5(3-97.3)	1,2(1-96.8)	8,9(4-95.9)	3,4,5(3-94.1)
10	3	3,4,5	O	3,4,5(3-91.3)	3,4,5(3-90.9)	6,7(2-90.0)	3,4,5(3-88.3)

5. Conclusion

This research aims to present an effective CBR maintenance method for agricultural facilities. To derive the effective CBR maintenance method, farmers and specialists were interviewed in order to understand the current status of domestic agricultural facilities. In addition, the maintenance measures as well as the types and technical causes of damage to agricultural facilities were classified. Using the CBR that solves a given problem based on similar past cases, the maintenance method for agricultural facilities is suggested.

To verify the CBR maintenance method presented in this study, 10 randomly selected cases were used, the similarities of which were evaluated compared to the cases in the case base. From the retrieval results, 9 cases had a recommendable solution and the other had an acceptable solution. Therefore, the CBR maintenance method has the advantage of providing not only a recommendable solution but also acceptable solutions. Farmers can make their final decision on maintenance based on the retrieved results. For this reason, the applicability of the CBR maintenance model is believed to be sufficient.

However, the research scope is restricted to the basic design of the CBR maintenance model in order to solve the problems at the maintenance step. Hence, to solve problems found in the overall construction process, wider data collection and analysis should be done in the future.

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