DEVELOPMENT OF PERFORMANCE EVALUATION MODEL FOR OLD AGRICULTURE INFRASTRUCTURE (FOCUS ON PUMPING AND DRAINAGE STATION)

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ABSTRACT

The purpose of this study is to analyse the reason of performance degradation and suggest their countermeasures through field survey. Onthis study the performance evaluation model was developed using the factors related to performance degradation of pumping and drainage facilities. We focused on the pumping and drainage stations belonging to each climatic zone separated by the Korea geographical climatic classification system. The performance evaluation model was developed using three different statistical models of POLS, RE, and LASSO.

Keywords: Agricultural infrastructure,Degradationfactor,Performance evaluation model,LASSO,Performance prediction

1. INTRODUCTION

The proportion of new supply will gradually decrease and that of existing facilities management will increase as the country develops, not only the general social overhead capital but also the agricultural SOC.Appropriate systems are being developed through research and technology development that can safely maintain the functions of facilities with efficient investment of the national budget.MAP-21 in the United States (July 6, 2012) and Australia's International Infrastructure Management Manual (IIMM) are good examples.The United States enacted MAP-21 to introduce a performance-based management system for the strategic maintenance of social infrastructures centering on land transportation facilities for long-term economic growth.IIMM emphasizes the importance of preventive maintenance in order to maximize the economic efficiency of public facilities, and provides a way to prioritize urgent maintenance considering the ranking of budget allocation through manual.In the Republic of Korea, the revision (July 17, 2017) was added to the "Special Act on Facilities Safety and Maintenance (abbreviated as the Facility Security Act)" to include the incorporation of the third type facilities and the introduction of a performance-based maintenance management system(table 1). The municipalities such as the Seoul Metropolitan Government set up the 'Improvement of Performance and Longevity Improvement of Old Age Facilities' to improve the safety and efficiency of old facilities. Article 40 (Performance Evaluation of Facilities) According to Paragraph 1 of the Facility Security Act, it is stipulated that the management of the facility should conductthe performance evaluation once or more every five years.

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Table 1. Performance Evaluation Period of Infrastructure

Safety Rating	Precision Safety Inspection		Precision Safety Diagnosis	Performance Evaluation
	Building	Other Facilities		
Class A	More than once every four years	More than once every three years	More than once every six years	More than once every five years
Class B·C	More than once every three years	More than once every two years	More than once every five years	
Class D·E	More than once every two years	More than once every year	More than once every four years	

Therefore, in this study, we analyzed the causes of performance degradation and suggested ways to improve performance of agricultural infrastructure. We also aimed to provide an objective and effective performance evaluation method.The facilities of this study were pumping and drainage facilities among many agricultural facilities.In this paper, we describe the causes of performance degradation analyzed through field surveys and performance evaluation methods using statistical techniques.

2. ANALYSIS AND COUNTERMEASURES AGAINST PERFORMANCE DEGRADATION

2.1 Field Survey

Korea's agricultural infrastructure is managed by Korea Rural Community Cooperation (KRC) and Local Government (LOG) as shown in figure 1. Estimated Statistical Yearbook of Land and Water Development for Agriculture 2016 the number of pumping and drainage station is 8,256.4,496 of them are managed by KRC, and 3,760 are managed by LOG.The degree of operation of the pump in the pumping and drainage station can be easily understood by looking at the power consumption. 98.5% of the total power consumption is from the KRC competent water storage and the remaining 1.5% is from the LOG control water storage. It has been 30 years since the completion of 43% of the water storage facilities.

Table 2. Status for Pumping & Drainage Station per Each Size Group

Division		Total power (㎾)	Number	Less than 0.1MW	Less than 0.2MW	Less than 0.5MW	Less than 1MW	Less than 2MW	2MW or more
SUM	Total	1,45,101	8,026	6,301	552	608	328	160	77
	P.S.	529,899	6,870	2,765	399	248	97	45	31
	P&D.S.	85,292	119	19	10	37	22	23	8
	D.S.	464,910	1,037	232	143	323	209	99	38
KRC	Sub total	969,706	4,266	2,793	419	534	300	147	73
	P.S.	430,282	3,376	2,674	308	225	95	43	31
	P&D.S.	82,400	100	8	7	33	21	23	8
	D.S.	457,024	790	111	104	276	184	81	34
LOG	Sub total	175,395	3,760	3,508	133	74	28	13	4
	P.S.	99,617	3,494	3,376	91	23	2	2	-
	P&D.S.	2,892	19	11	3	4	1	-	-
	D.S.	7,886	247	121	39	47	25	11	4

*P.S. : Pumping Station, P&D.S : Pumping and Drainage Station, D.S. : Drainage Station

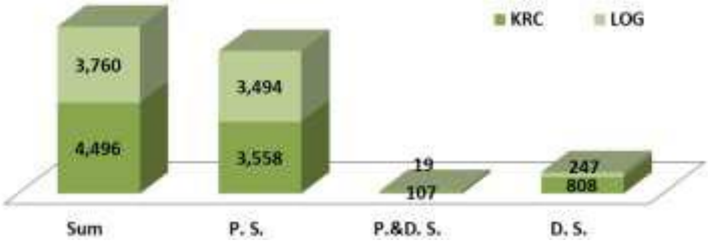


Figure 1. Pumping & Drainage stations Number per each ManagementAuthority

As a result of analyzing the operation status of 605 pumping stations in recent 5 years, KRC 's regional headquarters and project office analyzed annual average electricity consumption of 328,425kW, operation time of 1,763hr and electricity charge of 8,635dollars.KRC's 7,387 personnel and 1,551 employees (30.3% of the total) are engaged in the operation of the KRC's control and distribution facilities. The maintenance budget is an average of USD340.5million for the past seven years (national budget support :about 44% of them). In the other hand, in the case of other institutions such as the Korea Water Resources Corporation, which is in charge of the management of multipurpose dams, which are not general agricultural facilities, it is surveyed that main facilities are undergoing outsourcing.

In order to analyze the major performance deterioration factors of the pumping and drainage stations(figure 2), we divided the Republic of Korea into the northern, central and southern regions and surveyed 25 facilities described in table3.

Table 3. Target Facilities per each districts

Office	Northern Region	Centeral Region		Southern Region			Total
	Pyeongtaek	Buyeo	Geumsan, Nonsan	Uiseong, Gunwi	Kunsan	Geumgang Project	
1st Class	Gilum P.	Topjung P.	Gunsu2 D.	Yangseo P.	-	Napo P. Seapo P.	6
2ndCalss	Jwagyo D. Yulbuk D	Bongwha P. Wonnam P.	Majung D. Gito P. Sukwoo2 D.	-	Sungsan P.	-	8
3rd Class	Yulbuk P. Heachang P.	Gayagok P. Woogi P.	Hoam P.	Cheondong D. Angae1 P. Bian 1 P. Nakjung P.	Guam P.	Dongam P.	11

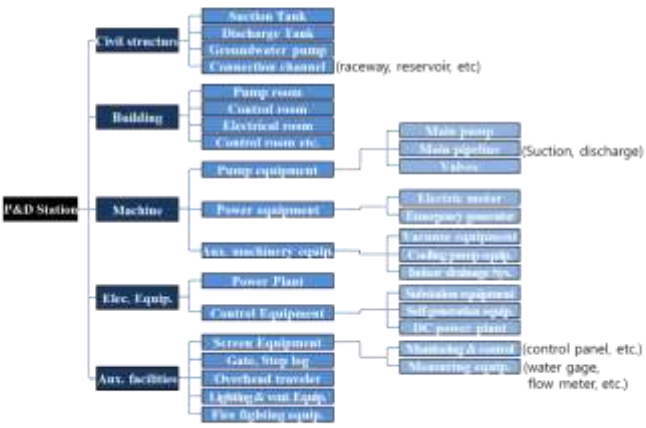


Figure 2. Constitution of Pumping and Drainage Station

2.2 Wet Machine Room Management

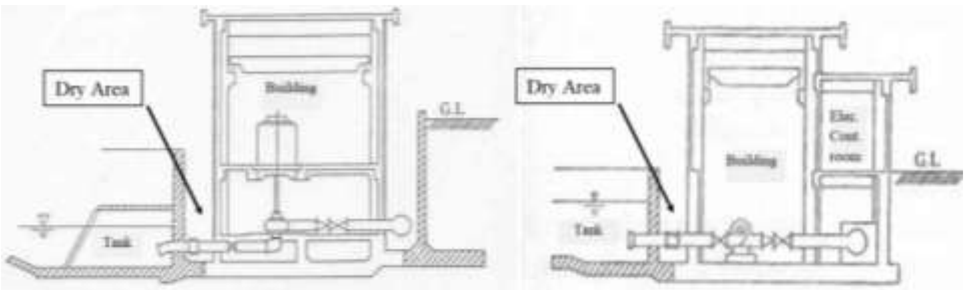
The reasons for the deterioration of the pumping & drainage station discovered from the field survey were the floating waste problem, the wet environment of the underground machine room, the sand coming from the river, and the high pumping head. As a countermeasure against this, we proposed a screen installation, a dry area installation, a grit chamber installation, and a proper pumping head design. The major problems of each region according to geographical features and the degree of urban development were summarized at table 4.

Table 4. Performance Degradation Reasons at each District

Metropolitan Area	Nakdong River	Keum Gang	Inland
Inflow of floating waste	Sand inflow	Sediment inflow	High water level
· Frequent mechanical disassembly · Vortex occurrence · Inelastic flow	·Pump wear · Dredging at intake canal	· Sedimentation at intake canal, decrease of flow capacity	· High suction lift occurrence due to suction water level decrease

(a)Rotary type screen | (b) Hydraulic type screen

Figure 4 Rotary and Hydroric type Screen for floating wastes



(a) Under the G.L., two stage, vertical axis, centrifugal type

(b) Under the G.L., one stage, horizontal axis, centrifugal

Figure 5. Dry Area between Machine room and Water Tank Wall

2.3 Standardization for Electric Systems

The second causes and countermeasures are the standardization for simplification of the operation and management of machinery and electric devices, and the introduction of the inter-agency collaboration system for streamlining the procedures for opening the electricity inflow responsibility (C.O.S) memorandum.

Until now, electric power has been turned on and off only through official letters due to the problem of safety of high-voltage electric power. However, in order to streamline and simplify facility management work, through the consultation between KEPCO and Korea Rural CommunityCooperation(KRC).

2.4 Renewal of periodic design criteria

As the last cause of performance degradation and countermeasures analyzed through the on-site survey, it is necessary to design a design that can select architectural design and interior / exterior materials considering the scenery and durability.It has been found that the flat roofs of the drainage basins that have been applied for a long time cause deterioration of performance, such as the occurrence of water ponding and the peeling of the interior ceiling paint(figure 6).Therefore, it is necessary to prepare updated design standards that present design examples of gable roofs and pent house roofs.

Figure 6. Roof ponding, Flat Roof and Paint Peeling on ceiling

3. PERFORMANCE EVALUATION MODEL

3.1 Introduction

The safety inspection currently being carried out as the current evaluation method for the pumping and drainage stations is evaluated based on operator's engineering judgment, so it can be different under the subjective judgment (Kim et al., 2013). Therefore, it is necessary to develop a model for evaluating the objective performance of the pumping and drainage facilities.Currently, there are few research on the prediction of the performance of agricultural infrastructures considering climate change in Korea.Therefore it is urgently required to develop vulnerability assessment and adaptation measures for agricultural infrastructure. In this study, we proposed a statistical evaluation model of the relationship between performance factors and climatic factors and performance evaluation of pumping and drainage facility. Also, weconducted the prediction of performance evaluation in response to climate change.

3.2 Target Facility

Since pumping and drainage station are located across the whole of Korea, they are exposed to environments which can cause degradation such as salt stress or freeze-thawing, and such environments differ from region to region (Park, 2017). Hence, in this study, regions were divided by meteorological and geographical factors, and object facilities were selected for each region, then what factors are influential in degradation of the facilities for agricultural productions was evaluated. geographical and meteorological classification system for regions of Korea (Kim, 1976) was used for dividing the regions. Excluding North Korea extent and island area, 8 of 13 regions were selected. facilities were limited to pumping station or pumping and drainage station, and at least 3 facilities were selected for each region. Table 5shows the total selected facilities.

Table 5. Selection of study sites according to geographical classification system

Station No.	Climate zone type	Area	Name	Station No.	Climate zone type	Area	Name
1	Central west coastal region	Hongseong	Waryong1	15	South inland region	Wanju	Bongdong
2		Seosan	Sungyeon	16		Wanju	Jugyo
3		Seosan	Daesan	17		Namwon	Yongsan
4		Paju	Daedanwi	18		Geochang	Seokgang1
5	Central inland region	Hongcheon	Oesanpo	19		Hapcheon	Sinpyeong
6		Wonju	Seomgang	20		Uiseong	Yangseo
7		Cheongju*	Seopyeong	21		Uiseong	Nakjeong
8	South west coastal region	Buan	Nansan	22		Miryang	Naei
9		Buan	Dangsang	23		Miryang	Banwol
10		Gochang	Sachang	24	Dea-gu region	Daegu	Hyeonpung
11		Gochang	Geumpyeong	25		Daegu*	Jidong
12	South east coastal region	Gangneung		26		Daegu	Daeam
13		Yeongdeok	Buheung	27	South coastal region	Goheung	Jangam2
14		Uljin	Oeseonmi1	28		Goheung	Bongam
-		-	-	29		Gimhae	Machal
-		-	-	30		Gimhae*	Saengnim

* Pumping and drainage station

3.3 Analysis of performance degradation factor and construction of evaluation data

For development of an objective evaluation model, we excluded subjective perspective and composed quantitative model based on time-series data. Degradation factors including meteorological factors and maintenance system of pumping and drainage station, all items were classified by performance (completion / dimension / integration) and response variable. Performance evaluation procedure was classified to machine, civil engineering and electricity, and climate change correspondence variable was composed of exposure, sensitivity and the adaptability. Kim et al. (2013) defined three factors, exposure, sensitivity and the adaptability, as fundamental factors increasing or decreasing the cost and risk caused by climate change.

Facility outline and current situation data were acquired from preliminary investigation using Korea Rural Community Corporation RIMS DB for choice of model-related variable, and the following items were collected, organized, and database based on facility specifications, operation monthly report, maintenance status, electricity usage fee, periodic safety factor and precision safety diagnosis result (Table 2). Model-related variables for constructing the performance evaluation model are created separately from the degradation factors into input and output variables. Factors relevant to performance degradation were used as an independent variable of the performance evaluation model. Factors no relevant to performance degradation, do not directly cause performance degradation, but indirectly affect degree of degradation. They are excluded from the model configuration. Performance evaluation data referred to periodic safety factor, and used in performance evaluation as dependent variable. In this study, the performance of the facility was assumed to vary from 0 to 100, which is derived from the performance evaluation data and the performance evaluation model, and the difference between the performance prediction value and the observation value of the performance evaluation data.

The input and output variables related to the performance evaluation model are composed of various types such as weather data, facility specification data, and periodic safety factor categorized as A to E. The data conversion and unit adjustment was conducted to form the regression equation. Periodic safety factor, A, B, C, D and E, was quantified as score 100, 80, 60, 40, 20, respectively, and average score for each year was used. The 'distinction of pumping station / pumping and drainage station' variable was converted into a dummy variable with the pumping station set to 0 and pumping and drainage station set to 1. The 'maintenance cost' and 'facility renovation costs' variable are converted into dummy variables that give 1 if there was maintenance cost or repair facility repair cost in the previous year, and it was used as an index that judges whether maintenance or facility renovation has been implemented in the previous year. All data units were based on the basic units used in the Korea Rural Community Corporation DB (RIMS). However, the size of the unit was adjusted because it is not easy to compare and analyze the parameters when the scale of the independent variables varies greatly.

3.4 Multivariate analysis for performance evaluation model

In this study, multivariate analysis was conducted to characterize the causality between degradation factors and climate change response variables in order to understand the relationship between performance degradation and the climatefactos.The same data can be interpreted differently depending on the analysis method. Therefore, it is important to select and analyse the appropriate statistical model to analyze the influence of various variables. When there are many variables to be analyzed, it is necessary to solve the multicollinear problem adequately because it can make the model unstable and difficult to interpret because of the multicollinear problem between variables (Choi et al., 2017).The data used to develop the performance evaluation model of the pumping and the drainage facilities are the annual panel data for 10 years from 2008 to 2017 for each facility of a total of 30 facilities. 80% of the total data was used as the input data for the learning of the model and the remaining 20% was used for the validation of the model. The total score obtained by converting the results of periodic safety inspections were set as dependent variable, and the remaining parameters were set as independent variables. For the multivariate analysis,POLS (pooled ordinary least squares),RE (panel random effects), and LASSO(least absolute shrinkage and selection operator) models were established, andthe model with the smallest error was finally selected through the mean squared error (MSE)validation.POLS is a method of deriving parameters by OLS (method of least squares) with integrating panel data at various points of view. It can be easily estimated by transforming the difference of observation time into time dummy variables and simplifying the analysis method. However, If there is a time series correlation in the error term since only the relationship can be estimated, the POLS estimator may not be efficient. (Han, 2017).RE can use the parallax variables of the panel data together with the cross-sectional data to simultaneously consider the time-series and cross-sectional aspects and provide efficient estimates (Min and Choi, 2009), using the variance-covariance matrix of generalized least square.LASSO is the regression analysis method that increases the explanatory power of the model and obtains an efficient estimator by simultaneously performing variable selection and normalization. By imposing a constraint on the parameters of the independent variable in the basic least squares estimation method, only the subset related to the explanatory power of the model among the independent variables is selected.

When there are a large number of variables included in the model, multicollinear problems can occur or the explanatory power of the model can be overestimated. In order to solve this problem, only 20 variables were included as variables in POLS and RE, except for those variables with zero parameters, which cause multicollinearity problem through LASSO analysis among 41 independent variables of existing data. We selected only one of the multiple statistical data that has a representative value and a small number of missing or suspected errors, and reflected only one or two data for each weather factor.Asa result, average temperature for the temperature, average humidity for the humidity, average wind speed and storm days for the wind speed, and total precipitation for the precipitation were applied respectively.

3.5 Application of climate change scenario for prediction of performance evaluation

The prediction of performance evaluation was conducted considering the RCP 6.0 climate change scenario, which was assumed that the greenhouse gas reduction policy is realized to some extent provided by KMA. For the meteorological factors among the independent variables, the annual mean temperature and its squares, and the annual precipitation were appliedusing RCP 6.0 scenario, and the other meteorological factors not provided in the RCP scenario were applied with the mean values of the meteorological data of 2008~2017. Using the highest explanatory power of the regression analysis results and RCP 6.0 scenario, prediction of performance evaluation of 30 pumping and drainage stations for next 10 years was conducted.

4. RESULTS AND DISCUSSION OF EVALUATION MODELS

4.1 Development of performance evaluation model considering meteorological factors

The results of the regression analysis of each statistical model of POLS, RE, and LASSO are shown in Table 4. In all three models, regardless of the statistical significance, it was found that the performance evaluation results were significantly affected by the average annual temperature and the facility renovation cost.The average annual temperature and its square was the only meteorological factors that statistically significant at the 5% level in the result of POLS. In addition to the meteorological factors, the independent parameters related to the facility specifications include 'elapsed time', 'benefited area', frequency of drought',‘embankment elevation’, 'maximum discharge,' total power of the motor', ‘flood frequency’, and ‘Average daily operation hour’ were statistically significant at the 5% significance level.Therefore, the results of the performance evaluation showed that the variables related to the facility specifications were more statistically significant than the meteorological factors. Most of the parameters using RE were not statistically significant compared with the simple regression analysis model, suggesting that the model setting was not appropriate. In the result of POLS, only the temperature-related meteorological factors were statistically significant, whereas in LASSO, meteorological factors such as temperature, humidity, wind speed, storm days, and precipitation were not removed during the parameter selection process.However, since the parameters of the meteorological factors except temperature and storm days were close to zero, it was analyzed that those factors have a small effect on the performance of the facility.

The validation results of POLS and LASSO are shown in Table 5. The validation of the models was conducted based on MSE, which can determine the accuracy of the estimated data (Nau, 2018; Singh, 2019).Therefore, LASSO with a small MSE was selected for the evaluation model by comparing the MSE between the two models. As the result of the validation of performance evaluation model using LASSO, the MSE was 161.82, and the root mean square error (RMSE) was 12.72. Based on the results of the periodic safety inspection of the facilities, this study estimated that the difference between the true and estimated value was less than 20, and the random sampling test of the selected LASSO evaluation model showed aestimation accuracy of 91.2%.

4.2 Prediction of performance considering climate change

Prediction of performance evaluation was carried out in consideration of climate change using the RCP 6.0 scenario, with the selected LASSO model.

In the case of the variables related to the facility specification parameters, the elapsed time was applied considering the future year, and thevariables of maintenance cost, and facility renovation cost were set to zero.Otherfacility specificationparameters were applied as they were.In order to show the degree of performance degradation, we used the difference of the performance evaluation value as the result of the statistical model. The performance degradationwas defined as the performance degradation when the value of the performance evaluation falls compared to the previous year, and was defined as 0 when there is no change or increase in the value. Table 8 shows the result of the prediction of 30 pumping and drainage facilities' performances.

Table 6. Result of statistical analysis by POLS, RE, and LASSO regression method.

Components		POLS		RE		LASSO
		β_i	Pr(>|t|)	β_i	Pr(>|z|)	β_i
(Intercept)	(β_0)	-348.598	0.005***	-57.295	0.664	-252.840
Average annual temperature (℃)	X_1	63.452	0.001***	18.256	0.349	49.014
Average annual temperature^2	X_2	-2.398	0.001***	-0.691	0.355	-1.848
Average relative humidity (%)	X_3	0.028	0.889	-0.051	0.830	0.030
Average wind speed (m/s)	X_4	0.161	0.470	0.372	0.075	0.140
Storm days (Day)	X_5	2.246	0.060*	1.643	0.088	2.108
Annual precipitation (100mm)	X_6	-0.219	0.442	-0.127	0.588	-0.258
Elapsed time (year)	X_7	-0.469	0.000***	0.009	0.949	-0.472
Benefited area (ha)	X_8	0.008	0.000***	0.011	0.030**	0.008
Frequency of drought (year)	X_9	1.348	0.000***	1.277	0.016**	1.321
Flood frequency (year)	X_{10}	-0.093	0.019**	-0.106	0.261	-0.091
Embankment elevation (m)	X_{11}	0.118	0.001***	0.155	0.053*	0.116
Maximum discharge (m^3/sec)	X_{12}	-2.093	0.010***	-3.402	0.090*	-2.037
Average daily operation hour (hr)	X_{13}	-0.397	0.030**	-0.443	0.331	-0.387
Osmotic volume (mm)	X_{14}	-0.257	0.308	-0.192	0.758	-0.237
Waterway loss (%)	X_{15}	0.572	0.003***	0.352	0.474	0.545
Total power of the motor (HP)	X_{16}	0.000	0.941	0.001	0.696	0.000
Power uptime (hr)	X_{17}	0.000	0.514	-0.001	0.202	0.000
Maintenance cost (Dummy)	X_{18}	-0.021	0.994	3.060	0.174	-0.047
Facility renovation cost (Dummy)	X_{19}	19.348	0.135	18.828	0.016**	19.077
Distance to the coast (km)	X_{20}	0.072	0.228	0.043	0.742	0.066
* 10 % statistical significance at significance level						
** 5 % statistical significance at significance level						
*** 1 % statistical significance at significance level						

Table 7. Validation results of performance evaluation model using statistical analysis

Sample	True value	POLS estimate	LASSO estimate	Sample	True value	POLS estimate	LASSO estimate
1	60.00	69.17	68.82	31	80.00	86.13	85.51
2	60.00	66.23	65.92	32	80.00	85.28	84.67
3	80.00	63.51	63.68	33	80.00	90.16	89.88
4	70.00	62.61	62.60	34	80.00	79.29	79.76
5	80.00	96.72	96.77	35	80.00	76.31	77.61
6	100.00	94.40	93.94	36	100.00	81.67	81.07
7	60.00	87.61	87.46	37	100.00	81.07	80.71
8	60.00	89.34	88.79	38	100.00	81.36	81.39
9	100.00	100.00	100.00	39	80.00	80.27	79.80
10	80.00	74.92	75.30	40	80.00	73.91	73.75
11	80.00	77.21	76.57	41	80.00	86.04	85.17
12	80.00	76.78	76.15	42	100.00	99.55	98.80
13	80.00	73.46	73.57	43	85.00	97.91	97.43
14	60.00	63.03	63.69	44	80.00	95.58	95.14
15	60.00	63.86	64.64	45	80.00	97.29	96.93
16	60.00	60.64	61.58	46	93.33	85.15	85.17
17	50.00	64.62	64.88	47	100.00	87.76	86.89
18	80.00	76.66	77.28	48	64.00	64.15	64.20
19	100.00	79.45	81.54	49	80.00	66.44	66.21
20	80.00	79.29	78.81	50	100.00	94.49	94.00
21	80.00	79.00	78.56	51	100.00	100.00	100.00
22	65.00	74.95	75.47	52	96.67	83.13	83.13
23	60.00	73.68	73.17	53	60.00	71.24	71.08
24	60.00	75.16	74.50	54	60.00	69.56	69.85
25	60.00	72.34	71.84	55	80.00	76.24	75.78
26	60.00	68.85	69.20	56	80.00	73.92	74.02
27	80.00	65.56	65.90	57	100.00	68.58	69.55
28	40.00	65.48	65.07	58	60.00	69.41	69.36
29	40.00	62.73	62.48	59	80.00	66.25	66.27
30	80.00	60.96	61.17	60	80.00	66.99	66.85
M S E						185.84	161.82

Table 8. Performance evaluation score prediction using performance evaluation model

No	17'	18'		19'		20'		21'		22'		23'		24'		25'		26'	
	Rating*	δ**	Rating	δ	Rating	δ	Rating	δ	Rating	δ	Rating	δ	Rating	δ	Rating	δ	Rating	δ	Rating
1	80	0	80	-5.5	74.5	0	74.5	-0.1	74.4	0	74.3	-1.9	72.4	-4.8	67.7	0	67.7	-0.2	67.4
2	50	0	50	-5.5	44.5	0	44.5	0	44.5	-0.2	44.3	-2.7	41.6	-4.6	37.1	0	37.1	0	37.1
3	50	0	50	-4.5	45.5	0	45.5	0	45.5	-0.5	45	-1.1	43.9	-5.8	38.1	0	38.1	-0.1	38.1
4	80	0	80	-9	71	0	71	0	71	-0.7	70.3	-5.2	65.2	-6.5	58.7	0	58.7	0	58.7
5	100	0	100	-14	85.7	0	85.7	0	85.7	0	85.7	-9	76.7	-7.2	69.5	0	69.5	0	69.5
6	80	0	80	-9.2	70.8	0	70.8	-1.5	69.3	0	69.3	-6.8	62.6	-7.3	55.3	0	55.3	0	55.3
7	80	0	80	-5.2	74.8	0	74.8	-1.2	73.6	0	73.6	-2.9	70.7	-2.8	67.9	0	67.9	0	67.9
8	100	0	100	-2.4	97.6	0	97.6	-0.7	96.9	-0.2	96.7	-1.1	95.6	-0.8	94.9	0	94.9	-0.8	94.1
9	80	0	80	-2.7	77.3	0	77.3	-0.6	76.7	-0.1	76.6	-0.9	75.7	-1.4	74.3	0	74.3	-0.8	73.5
10	80	0	80	-3.5	76.5	0	76.5	-0.6	75.8	0	75.8	-1.5	74.3	-0.8	73.5	0	73.5	-0.4	73.1
11	100	0	100	-2.7	97.3	0	97.3	-0.7	96.6	-0.2	96.4	-0.8	95.6	-0.9	94.8	0	94.7	-0.9	93.8
12	60	-3.2	56.8	-8.4	48.4	0	48.4	-2.8	45.7	-3.2	42.4	0	42.4	-5	37.4	0	37.4	0	37.4
13	80	-0.9	79.1	-9.2	69.9	0	69.9	-3.6	66.2	0	66.2	-1	65.3	-3.6	61.7	0	61.7	0	61.7
14	100	-2.2	97.8	-11	86.5	0	86.5	-5.5	81	0	81	-0.3	80.7	-4.9	75.8	0	75.8	0	75.8
15	60	0	60	-2.6	57.4	0	57.4	-0.7	56.7	-0.3	56.4	-2	54.4	-1.2	53.1	0	53.1	-0.8	52.4
16	40	0	40	-1.9	38.1	0	38.1	-0.6	37.5	-0.4	37	-1.7	35.3	-1.1	34.2	0	34.2	-1.1	33.1
17	80	0	80	-3.6	76.4	0	76.4	-1.5	74.9	0	74.9	-3.6	71.2	-0.7	70.6	0	70.6	0	70.6
18	80	-0.6	79.4	-9.8	69.7	0	69.7	-5.5	64.2	0	64.2	-3.8	60.4	-1.5	58.9	0	58.9	0	58.9
19	80	-0.4	79.6	-4.3	75.4	0	75.4	-2.1	73.3	0	73.3	-1.9	71.4	-0.9	70.6	0	70.5	0	70.5
20	100	-0.8	99.2	-5.4	93.8	0	93.8	-2.5	91.4	0	91.4	-2.6	88.8	-3.1	85.7	0	85.7	0	85.7
21	100	-0.8	99.2	-5.2	94	0	94	-2.4	91.6	0	91.6	-2.4	89.2	-2.2	87	0	87	0	87
22	80	-1	79	-0.7	78.3	0	78.3	-1.1	77.1	0	77.1	-0.8	76.3	-0.6	75.7	-1	74.7	-0.5	74.2
23	65	-1	64	-0.9	63.1	0	63.1	-1.1	62	0	62	-0.9	61.1	-0.5	60.5	-1.2	59.4	-0.2	59.2
24	80	-0.9	79.1	-0.5	78.6	-0.7	78	0	78	-0.7	77.3	-0.3	76.9	-0.4	76.5	-1.1	75.4	-1.5	73.9
25	40	-0.9	39.1	-0.5	38.6	-0.7	38	0	38	-0.7	37.3	-0.3	36.9	-0.4	36.5	-1.1	35.4	-1.5	33.9
26	85	-0.9	84.1	-1.3	82.8	0	82.8	-0.1	82.7	-0.5	82.2	-0.5	81.7	-0.6	81.2	-1	80.2	-0.9	79.2
27	60	-0.5	59.5	-0.3	59.2	-0.2	59	-0.6	58.4	-0.8	57.6	-0.3	57.3	-0.1	57.3	-1.2	56	-1.5	54.6
28	80	-1.7	78.3	0	78.3	-2	76.3	-0.7	75.6	-1.9	73.7	-0.1	73.6	0	73.6	-2.3	71.2	-3.6	67.6
29	85	-1.5	83.5	0	83.5	-4.6	78.9	0	78.9	-1.4	77.5	0	77.5	0	77.5	-3.4	74.1	-3.3	70.8
30	80	-0.8	79.2	-1.4	77.8	0	77.8	-1.5	76.3	0	76.3	-1.1	75.2	-0.5	74.7	-1.2	73.5	-0.1	73.4

* Measurement data

** Performance degradation

It was predicted that the performance evaluation value of 100 in 2017 will drop to 69.5 in 2026 due to the performance degradation of 30.5 at the Oesanpopumping station. It was predicted that the lowest performance degradation will occur at the rate of 5.4 at the Jangam2 pumping station, and that the performance evaluation value of 60 in 2017 will drop to 54.6 in 2026.By region, the degradation of performance due to climate change was not significant, and the performance gradually deteriorate in the next 10 years in the south inland region, Dae-guregion, and south coastal region.However, overall performance degradation has been observed in the south-east coastal region, central inland region, and Paju and Geochangarea.This results show that the degree of performance degradation varies depending on the climate zone.When we compared the meteorological data from 2008 to 2017 and the meteorological data from climate change scenarios applied from 2018 to 2026, which were used to build the performance evaluation model, there were significant changes in seven facilities. This was because the uncertainty of the climate change scenario itself is a predictive model, and thus it can be shown that the forecasting accuracy of the short term (1 to 4 years) has decreased.

5. CONCLUSIONS

In order to identify the cause of performance degradation in the field, 25 sites were divided into North, Central and South regions.Floating waste problem, improvement of wet environment of underground machine room with 'Dry Area' construction, standardization of electric device for simple operation and management, simple official confirming system on web for opening of the account of electricity inflow (C.O.S.), And suggests the improvement of periodic design standards as improvements, preparation of design criteria for long-life architectural design and inner and outer materials selection, periodic regarding design criteria upgrade, and etc. were suggested as renovation items.

Objective performance evaluation model development was appliedand some results could be summarized like bellows. In the performance evaluation of the facility considering the influence of the climate, in order to extract the input variables.As a result of the model test, the LASSO regression model was selected as the final evaluation model. Based on the climate change RCP 6.0 scenario, we propose a prediction model for the performance evaluation up to 2020 according to the meteorological load.By constructing big data of factors related to performance degradation, it is expected that we can overcome average annual temperature dependancelimitations and improve the accuracy of performance evaluation model.

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