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FACTOR ANALYSIS OF INFLUENCING FACTORS IN THE RSMS FOR RAPID ROAD SNOW REMOVAL

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ABSTRACT
The cost of road snow removal has increased constantly. Thus, it is necessary to establish a measure to increase the efficiency of the road snow removal system management, where a large amount of the budget is spent. It is also necessary to have the overall and systematic management of road snow removal meet the demands of qualitative improvements, such as convenience and safety enhancements for the road users. Since early 2015, a Road Snow-removal Management System (RSMS) has been adopted and operated by the Ministry of Land, Infrastructure, and Transport to manage the snow removal system efficiently.
This paper aims to find the most important input factors for a rapid response during heavy snow and search for efficient measures to address these factors accordingly. To do this, this study utilizes the following variables: the amount of snow-removal equipment in the RSMS, the number of closed-circuit televisions, the number of personnel for snow removal work, the number of the snow removal agent warehouses, the number of emergent personnel, the number of snowfall days, the number of emergence working days, the number of snow removal working days, calcium chloride output, salt output, the number of heavy-snowfall warnings issued, and the amount of snow removal equipment, to produce the most effective solutions during heavy snowfall events through an exploratory factor analysis.

KEYWORDS: Road Snow, Snow Removal, Principal component

I. INTRODUCTION
In recent years, much attention has been paid to climate changes and the related environmental issues in Korea. In addition, unexpected heavy snowfall and record-breaking cold waves due to climate change and abnormal weather have caused a continuous increase in social and human damage, mainly due to vehicle accidents and careless driving in these changing conditions. The number of heavy-snowfall watch days was 488 in 2010 and 2011, and heavy snowfall warnings, which are issued when the 24-hour snowfall amount is more than 20cm, have been issued 84 times, which is an increase of four times than the amount issued in 2009 (19 heavy snowfall warnings) (Yoon, 2012).
The cost of road snow removal has constantly increased. Thus, it is necessary to establish a measure to increase the efficiency of the road snow removal system management, where a large amount of the budget is spent. It is also necessary to have the overall and systematic management of road snow removal meet the demands of qualitative improvements, such as convenience and safety enhancements for the road users. Since early 2015, a road snow-removal management system (RSMS) has been adopted and operated to manage the snow removal system efficiently by the Ministry of Land, Infrastructure, and Transport.
The data related to snow removal was collected in the RSMS, which is run by the Ministry of Land, Infrastructure, and Transport. The principal component analysis was conducted based on the collected data. The statistical processing program, "IBM SPSS statistics Version 22" on a Windows Operating System was used to conduct the principal component analysis in order to derive study results. The SPSS's factor analysis is an exploratory factor analysis, which refers to conducting studies that are not yet established or systematized by current theories in an exploratory manner in order to derive the future study directions. Basically, the principal components were found by extracting two or three principal components for the classification of variables. Fig. 1 shows the schematic study process diagram, in which data collection and principal component analysis was followed by the identification of factors.
This paper aims to find the most important input factors for a rapid response during heavy snow and search for the efficient measure to deal with these factors accordingly. To do this, this study utilizes the following variables:

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the amount of snow-removal equipment in the RSMS, the number of CCTVs, the number of personnel for snow removal work, the number of the snow removal agent warehouses, the number of emergent personnel, the number of snowfall days, the number of emergence working days, the number of snow removal working days, calcium chloride output, salt output, the number of heavy-snowfall warnings issued, and the amount of snow removal equipment, to produce the most effective solution during heavy snowfall events through an exploratory factor analysis.

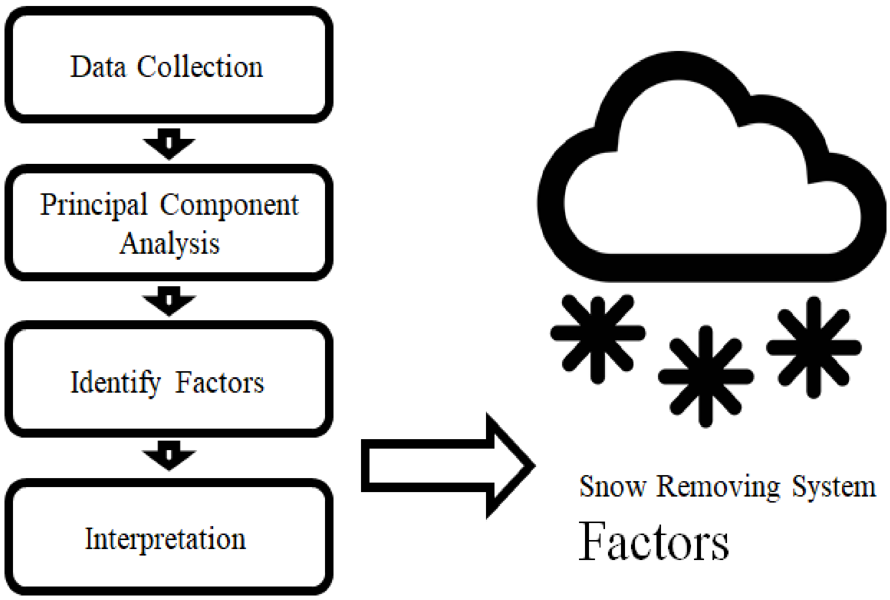

Fig. The Study Process

II. MATERIALS AND METHODS

Principal component analysis (PCA) refers to a method to reduce dimensionality while maintaining the variance of closely related variables and multidimensional data as much as possible. That is, it is a technique to reduce the variance of multi-dimensional variables into a smaller number of variables. The first principal component refers to the variable that explains the variance of the original variables the most, and then the second principal component explains the remaining variance portion that is not explained by the first principal component, and so on. As described in the above, the principal components are calculated sequentially. However, if the number of principal components is equal to the number of variables, it does not meet the purpose of the analysis. For the selection of the number of principal components, three methods are considered and these are, their contribution to the total variance, the size of their eigenvalues, and the use of these figures. In this study, the selection criterion chosen were based on the order of their size of contribution to the total variance to simplify the analysis by reducing the dimensionality through the summarized data or a linear relationship equation. The Kaiser-Meyer-Olkin (KMO) test is to study the correlation between variables. It refers to a degree of sampling adequacy that determines whether the number of variables used in the factor analysis and the number of cases are appropriate. If this value is 0.6 or larger, it means the sampling is adequate to be used in the factor analysis. The Bartlett test is to examine the correlation matrix, which is used also during factor analysis. It is to test whether the correlation matrix is diagonal. If the correlation is a diagonal matrix there is no correlation between variables, which means that the variables used are not adequate for the factor analysis. If the p-value in the Bartlett test is smaller than 0.05, it means it is not a diagonal matrix (Park, 2017). The factor analysis conducted in SPSS is also called an exploratory factor analysis, which also means conducting studies that are not yet established or systematized by current theories in an exploratory manner to derive future study directions. In addition, the principal components were derived through a principal component analysis, which is one of the factor analysis methodologies.

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III. RESULTS AND DISCUSSION

This study conducted a principal component analysis based on yearly data to respond to heavy snowfall quickly with numerical information using the RSMS. These data are numerical data selected as they are closely related during heavy snowfall events. These data are selected as the most beneficial data to derive solution measures during heavy snowfall events.

Table 1. Descriptive statistic

Variable name	No. of cases	Mean	Standard deviation	Minimum	Maximum
Heavy snowfall warnings	215	.93	1.539	0	10
No. of snowfall days	215	24.38	20.624	0	185
No. of emergent working days	215	34.91	36.226	0	257
No. of emergency personnel	215	236.11	281.873	0	1816
No. of snow removal working days	215	29.68	21.714	0	176
No. of personnel for snow removal work	215	1135.80	2153.456	0	19656
No. of guaranteed snow-removal equipment	215	156.10	307.319	0	2253
No. of snow removal input equipment	215	1680.24	1938.556	0	11343
No. of CCTVs	215	101.14	204.013	0	1107
No. of snow removal agent warehouses	215	7.92	8.693	0	44
Calcium chloride	215	16.46	55.567	0	459
Salt	215	37.34	132.716	0	963

Table 9. Comparison table for motoring mode

	PI	PID	FUZZY
SPEED(rpm)	1500	1500	1500
Settling time of speed	0.8	1.8	0.4
Speed fluctuations	±20rpm	±10rpm	-
Torque ripples	±6	±0.5	±0.05

The factor analysis was conducted with regard to the data based on 215 cases out of 380 total events for the principal component analysis. A total of 12 variables were proposed, as presented in Table 1, through exploratory factor analysis. The 12 variables that were considered the most influential factors to heavy snowfall removal were composed as follows: the amount of snow-removal equipment in the RSMS, the number of CCTVs, the number of input personnel for snow removal work, the number of the snow removal agent warehouses, the number of emergent personnel, the number of snowfall days, the number of emergence working days, the number of snow removal working days, calcium chloride output, salt output, the number of heavy-snowfall warnings issued, and the amount of snow removal input equipment.

Table 2. Communality

Variable	Beginning	Extraction
Heavy snowfall warnings	1.000	.746
No. of snowfall days	1.000	.856
No. of emergent working days	1.000	.782
No. of emergency personnel	1.000	.680
No. of snow removal working days	1.000	.823
No. of personnel for snow removal work	1.000	.593
No of guaranteed snow-removal equipment	1.000	.864
No of snow removal input equipment	1.000	.779
No. of CCTVs	1.000	.816
No. of snow removal agent warehouses	1.000	.734
Calcium chloride	1.000	.891
Salt	1.000	.887

· Extraction method : principal component analysis.

Table 2 presents the initial values of the variables and the communality of each variable found through the principal component analysis. Communality refers to the proportion of that factor that is explained by extracted factors. Since the communality of heavy snowfall warnings is 0.746, the factor "heavy snowfall warnings" can explain the heavy snowfall removal by 74% approximately. The variables whose communality is low should be removed from the analysis. If the value is 0.4 or lower, these variables are judged as having low communality, so they are deemed unacceptable. However, all variables in this study exceeded 0.4 . Thus, they were defined as acceptable variables.

Table 3. Total Variance

Ingredient	The initial eigenvalues			Extract sum			Rotate sum		
	all	%Dispersion	Cumulative%	all	%Dispersion	Cumulative%	all	%Dispersion	Cumulative%
1	4.409	36.744	36.744	4.409	36.744	36.744	3.327	27.725	27.725
2	2.150	17.914	54.657	2.150	17.914	54.657	2.586	21.550	49.275
3	1.769	14.742	69.399	1.769	14.742	69.399	1.801	15.010	64.285
4	1.122	9.350	78.749	1.122	9.350	78.749	1.736	14.464	78.749
5	.694	5.782	84.531						
6	.450	3.747	88.278						
7	.361	3.009	91.287						
8	.308	2.571	93.858						

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9	.216	1.803	95.661						
10	.208	1.731	97.392						
11	.183	1.522	98.914						
12	.130	1.086	100.000						

· Extraction method : principal component analysis.

The eigenvalues of the extracted four principal components were 4.409, 2.150, 1.769, and 1,122, which reveals the total variance explained in Table 3. These four factors are: principal component (PC) 1, PC 2, PC 3 and PC 4, which explained 36.744%, 17.914%, 14.742%, and 9.35% of the total variance, respectively. The data in relation to the variables for the solution of heavy snowfall removal, resulting in explaining a total of 78.749% of the total (accumulated) variance. The eigenvalues of the extracted four PCs were 4.409, 2.150, 1.769, and 1,122 respectively. The PCs whose eigenvalue was greater than 1.0 were extracted. Since the eigenvalue of the PC indicated an amount of variance that can be accounted for by the PC, PCs whose eigenvalue were greater would become a more principal component.

Table 4. Each principal Component Variables

PC 1	PC 2	PC 3	PC 4
No. of guaranteed snow-removal equipment No. of CCTVs No. of personnel for snow removal work No. of snow removal agent warehouses No. of emergency personnel	No. of snowfall days No. of emergent working days No. of snow removal working days	Calcium chloride Salt	Heavy snowfall warnings No. of snow removal input equipment

In Table 4, the rotated component matrix is exhibited, which are rotation results obtained after four iterative calculations in accordance with the Varimax rule. The results in the table show that the five variables bound to PC 1 were: No. of guaranteed snow-removal equipment, No. of CCTVs, No. of personnel for snow removal work, No. of snow removal agent warehouses, and No. of emergency personnel. The variables tied to PC 2 were: No. of snowfall days, No. of emergent working days, and No. of snow removal working days. The variables bound to PC 3 were: calcium chloride and salt, and the variables tied to PC 4 were: heavy snowfall warnings and No. of snow removal input equipment. Note that the data that are most closely related to heavy snowfalls, heavy snowfall warnings and the No. of snow removal input equipment, and these factors were all bound to the same component. Through this process, variables can be found in each of the PCs. The above classifications implied that PC 1 was about components related to "snow removal infrastructure" largely, and PC 2 was about components related to the "No. of weather-related days", PC 3 was about components related to "snow removal agents", and PC 4 was about components related to "heavy snowfall warning instructions". The characteristics of each factor can be identified through a principal component analysis.

IV. CONCLUSION

This paper aims to find the most important input factors for the rapid response during heavy snow events and searches for the efficient measure to deal with these factors accordingly. To do this, this study utilizes the following variables: the amount of data snow-removal equipment in the RSMS, the number of CCTVs, the number of input personnel for snow removal work, the number of the snow removal agent warehouses, the number of emergent personnel, the number of snowfall days, the number of emergence working days, the number of snow removal working days, calcium chloride output, salt output, the number of heavy-snowfall warnings issued, and the number of snow removal equipment. Through an exploratory factor analysis, the most effective measure to deal with heavy snowfall was to input the effective number of snow removal equipment when a heavy snowfall

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warning is issue, which would prevent the heavy snow-related accidents the most efficiently. This study contributed to establishing an effective information technology system and providing preventive measures to safety related disasters through the input of equipment quickly, rather than ensuring the number of snow removal equipment during the heavy snowfall warning period. For future studies, it is necessary to conduct a policy and practical study to respond to heavy snowfall effectively by linking the equipment management system and the snow removal system for a rapid input of snow removal equipment.

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