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Methodology for effective operation of road management equipment

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Abstract This paper presents a methodology for effective operation of road management equipment. The primary goal of this research is to aid public agencies with day-to-day road management within limited financial resources. In order to demonstrate the value of this approach, we present a case study using data collected for eighteen regional offices of the South Korean Ministry of Land, Transport and Maritime Affairs. Road agencies want to know whether they currently have sufficient equipment to handle work demands, but this is difficult to predict. Thus, a methodology was developed to employ historical data on road management equipment, and two evaluation indicators were identified. Using our method, equipment can be classified into four groups: 1) frequently used and important, 2) relatively less used and important, 3) barely used and low importance, and 4) frequently used and low importance. In our case study we show that these can be used by regional offices to determine either to lend or borrow among offices or to consider purchase for both long and short term use. While our study focuses on a specific case study, the overall methodology can easily be applied by similar decision makers in other countries.

Keywords Analytical hierarchy process, Day-to-day road management operations, Normalization, Sensitivity analysis

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1. Introduction

Equipment for road management can be used for a wide variety of tasks and is typically assigned to a regular schedule of activities. Each piece of equipment has its own expected lifetime, but actual useful life varies based on the frequency of use and working conditions. This paper presents a methodology for effective operation of road management equipment. The main purpose of this research is to aid efficient road equipment management by public agencies who must work within a given budget. In order to demonstrate the value of this approach, a case study using data collected for eighteen regional offices of the South Korean Ministry of Land, Transport and Maritime Affairs was examined. The types of equipment of interest in this case study are presented in Table 1.

Table 1 Types of equipment examined in this study

General Car	1	Roller	21
Jeep	2	Mower	22
Mini-Bus	3	Vehicle Loading Sign Board	23
Overweight enforce vehicle	4	Hydraulic Breaker	24
Bongo Truck	5	Tunnel Cleaner	25
Bridge Inspection Support Vehicle	6	Guardrail Cleaner	26
Double-Cab Cargo Truck	7	Front Loader	27
Multipurpose Snow Removal Vehicle	8	Sand Collection Equipment	28
Dump Truck (5-ton)	9	High-Pressure Cleaning Equipment	29
Sweeper	10	Crane	30
Equipment Transport Truck	11	Snowplow	31
Multiuse Road Maintenance Vehicle	12	Snow Blower	32
Tractor	13	Sand Spreader	33
Dump Truck (15-ton)	14	Sand and Salt Spreader	34
Excavator	15	Wet-Salt Spreader	35
Wheel Loader	16	Crusher	36
Snow Removal Loader	17	Fixed axle Scale	37
Fork Lift	18	Portable axle Scale	38
Motor Grader	19	Road Surface Friction Coefficient Measuring	39
Bridge Inspection Vehicle	20	Lane Luminance Measurement Device	40

In the beginning of the 1960s, countrywide highway construction in South Korea was given the first priority in transport planning. Through the end of the 1980s investment in national highway construction had increased markedly. As of March 2010, the total length of the national highways was approximately 13,812km, and the national expressways had a total length of 3,859km (MLTM, 2010). Summing across all road classifications including special metropolitan city roads, metropolitan city roads, provincial roads, and city and county roads, the total length of South Korea’s transportation network includes nearly 88 thousand kilometers. However, the road supply rate, which is based on the length per population, still remains in the lower ranks among OECD (the Organization for Economic Cooperation and Development) members. In addition, because of recent economic and political conditions, investment in road construction during the last five years has been insufficient to meet the growing demand for travel. However, during the same period investment in the repair and maintenance of the national highways has increased significantly. This increase is the result of a wide variety of factors including an aging infrastructure and the high expectations of drivers with respect to the roadway level of service (LOS). For example, an increase in civil complaints about road surface conditions, especially during the winter season, led to changes in the way snow is typically removed in South Korea. Even though, from a road agency standpoint, solid deicing materials are considered reasonable, both with respect to cost and performance, the use of these materials is no longer allowed at roadway sections with relatively high travel speeds. Because drivers believe that solid deicers make the LOS worse, they complained to the road authorities. As an alternative, the use of liquid deicers was strongly encouraged to prevent road freezing from ice and snow cover.

Regional offices of the Ministry of Land, Transport and Maritime Affairs in South Korea record operational histories and monitor the current condition of road management equipment. Road agencies want to know whether they currently have sufficient equipment to handle their expected workload, but they find it hard to predict based on available historical data. Our study considers eighteen regional offices which are collectively charged with management of the national highway networks. We exclude, however, manpower from consideration in our study because it is beyond the scope of this research, and instead focus only on maintenance of equipment, though further research could be extended to consider workers as well. Figure 1 shows the Korean peninsula and the physical locations of the regional offices.

Fig.1 The Korean peninsula and the physical locations of the regional offices

2. Literature Review

The analytical hierarchy process (AHP) has been used many times for determining priorities of potential alternatives and estimating weights of given criteria in the transportation policy. This is a structured technique for analyzing complex decisions based on a solid mathematical foundation and widely accepted robust psychological assumptions. The AHP was developed by Professor Thomas Saaty in 1971 (Saaty and Vargas, 1981; Saaty, 1990). He suggested an arbitrary rating scale for the relative importance of criteria ranging from 1 to 9 based on psychological experiments. These showed that people are not generally able to compare more than seven items without becoming confused. The suggested scales are ordinal ones because they describe the relative significance of criteria. Table 2 defines of each point on the scale.

Table 2 Scales for intensity of importance

Intensity of importance	Definition
1	Equal importance
3	Marginally strong
5	Strong importance
7	Very strong
9	Extremely strong
2,4,6,8	When compromise is needed (Fuzzy condition)

Source: Saaty (1990). The logic of priorities: application in business, energy, health, and transportation

While a score of 1 indicates no difference in relative importance between two criteria, a score of 9 shows that one criterion is of absolute importance compared to the other. Let $C_1, C_2, \ldots\ldots\ldots, C_n$ be the set of activities. The quantified judgments on pairs of activities C_i, C_j are represented by an n-by-n matrix, and the entries a_{ij} are defined by the following two components.

1) If $a_{ij} = \alpha$, then $a_{ji} = 1/\alpha$, $\alpha \neq 0$
2) If two criteria i and j, are identically important, then $a_{ij} = a_{ji} = 1$

For now, a judgment matrix A ($n \times n$) can be written as:

$$A = \begin{bmatrix} 1 & a_{12} & \ldots & a_{1n} \\ 1/a_{12} & 1 & \ldots & a_{2n} \\ \ldots & \ldots & \ldots & \ldots \\ 1/a_{1n} & 1/a_{2n} & \ldots & 1 \end{bmatrix}$$

In cases where the judgment matrix satisfies transitivity for all pair-wise comparisons, it is said to be consistent. Therefore, consistency is highly significance in this analysis since it describes the perturbation of decision-makers' thoughts and preferences. The AHP allows inconsistency, but provides a measure of the inconsistency in each set of comparisons. The consistency of the comparison matrix is determined by the consistency ratio (CR), defined as: $CR = CI / RI$. The random index (RI) measures the average consistencies of randomly generated matrices Saaty (Saaty, 1990). The consistency index (CI) for a matrix of order n is defined as $CI = (\lambda_{\max} - n)/(n-1)$. For example, if the CR is larger than 0.1, the comparison matrix is considered to have a high degree of randomness. In that case, judgments may not be reliable and the matrix should be reconstructed. Otherwise, it can be concluded that the generated matrices are consistent. For the assessment of consistency of the pair-wise comparison matrix, it is customary to use the matrix's eignvalues and its corresponding eigenvectors. A pair-wise comparison matrix of dimension n may have as many as n eigenvalues, each with a corresponding set of eigenvectors. The largest eigenvalue is of particular interest, because it is most stable with respect to small perturbations in judgment. Thus,

$$Aw = \lambda_{\max} w$$

Where,

A : A pair-wise comparison matrix

w : The eigenvector corresponding to the largest eigenvalue

$\lambda_{\max}$: The largest eigenvalue

In the study of Holguin-Veras (Holguin-Veras, 1995), the author performed a comparative examination of multi-criteria decision analysis methods by applying both the AHP and the multi-attribute value method. This was a case study involving the evaluation of the roadway system in the Dominican Republic. Three different alternatives such as climbing lanes, new two-lane roads, and new four-lane roads were considered for the project. The objective was to compare two models based on their theoretical validity, practicality, and ability to reflect the decision-makers preferences. Although he came to the conclusion that the decision-makers would not completely accept the results of either model, he felt that the results were favorable because of the insights gained from the procedure. Kim and Vince conducted research involving the prioritization of major highway capital investments (Kim and Bernardin, 2000). Generally, transportation agencies or decision-makers examine and prioritize numerous transportation projects at one time. To support this decision-making process, the authors provided a model using AHP that can be used to prioritize a list of transportation projects. They point out that their earlier prioritization approach which was used by the Indiana Department of Transportation in the U.S has several deficiencies, but that the proposed AHP method, based on a series of sensitivity analyses, appeared to be sound. The AHP method improves the ability to analyze multiple and conflicting priorities and allows decision-makers to integrate qualitative and quantitative aspects simultaneously (Kirkwood 1996; Bhushan and Rai 2004; Sohn 2008; Tanadtang et al 2005; Yang and Regan 2012).

3. Methodology

Figure 2 shows the overall methodology used to evaluate the adequacy of road management equipment operations in regional offices. Two approaches are considered to capture specific characteristics, depending on the type of equipment. Some had a long operational distances or hours but few operating days, and vice versa. Therefore, in addition to historically recorded quantitative metrics, qualitative aspects might be needed. This is closely related to the relative importance of ordinary road maintenance operations. With these approaches, two types of indicators are developed, and thus the equipment for the 18 regional offices can be objectively and quantitatively compared.

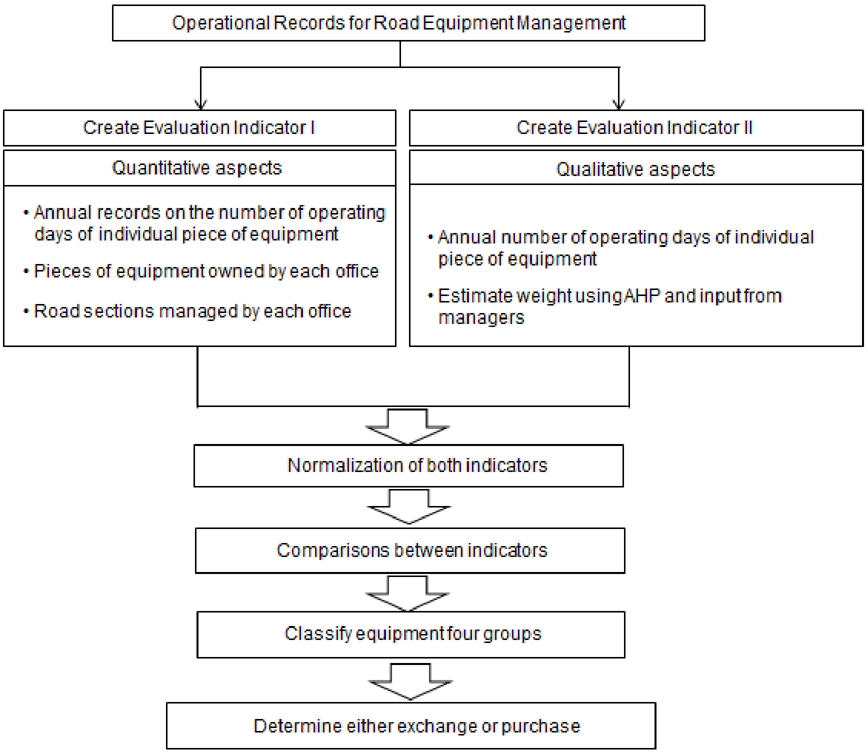

Fig. 2 Conceptual diagram of an operational methodology

3.1 Evaluation indicator I

In order to estimate evaluation indicator I, two sets of equations are introduced. First, the annual operation distance/hours can be found by subtracting the accumulated distance/hour in the previous year from the accumulated distance/hours of the present year, as in equations 1-1 and 1-2. This was done because the collected historical data only records the accumulated operating distance/hours of equipment. Equipment can be assigned to two categories. One is called "Primary equipment". This is shown in "km" for vehicles such as dump trucks and road cleaning vehicles. The other is called "subsidiary equipment", and is shown in "hours" for construction equipment such as excavators, motorized graders, forklifts, snowplows and sprinklers. Based on these data, the annual operation distance/hours of operation of each of piece equipment, equipment inventory for each regional office, and road sections under the management of each office were analyzed. Of course, "Primary equipment" and "Subsidiary equipment" cannot be directly compared.

$$\text{km at end of present year - km at end of previous year} = \text{the annual operation distance} \qquad \textbf{Eq.1-1}$$

$$\text{hours at end of present year - hours at end of previous year} = \text{the annual operation hours} \qquad \textbf{Eq.1-2}$$

Evaluation indicator I represents the operation distance or hour of the equipment. This can be derived using data as shown in equations 2-1 and 2-2.

$$\text{Evaluation Indicator I} = \frac{\text{(Operation distance (km}\cdot\text{veh)/total vehicles owned by the offices)}}{\text{The size of management area (km)}} \qquad \textbf{Eq.2-1}$$

$$\text{Evaluation Indicator I} = \frac{\text{(Operation hours (veh}\cdot\text{hr)/vehicles owned by the offices)}}{\text{The total annual operation hours}} \qquad \textbf{Eq.2-2}$$

3.2 Evaluation indicator II

Unlike the annual operating distance, the number of operating days is recorded as “days”. The AHP is used for this analysis, and thus weights based on the different types of work are estimated. These estimated weights are quantified based on the office manager’s perception of the significance of management tasks that are considered very meaningful. Following this, the operation ratio is calculated based on the annual number of operating days for each type of equipment as shown in equation 3.

$$\text{Operation ratio} = \frac{\text{the number of operating days for each type of equipment}}{\text{total number of operating days of a certain type of equipment}} \qquad \textbf{Eq.3}$$

Equipment managers from the 18 regional offices were participated in the AHP survey, and the criteria are identical with the work classification of the 18 regional offices. Figure 3 illustrates the AHP structure.

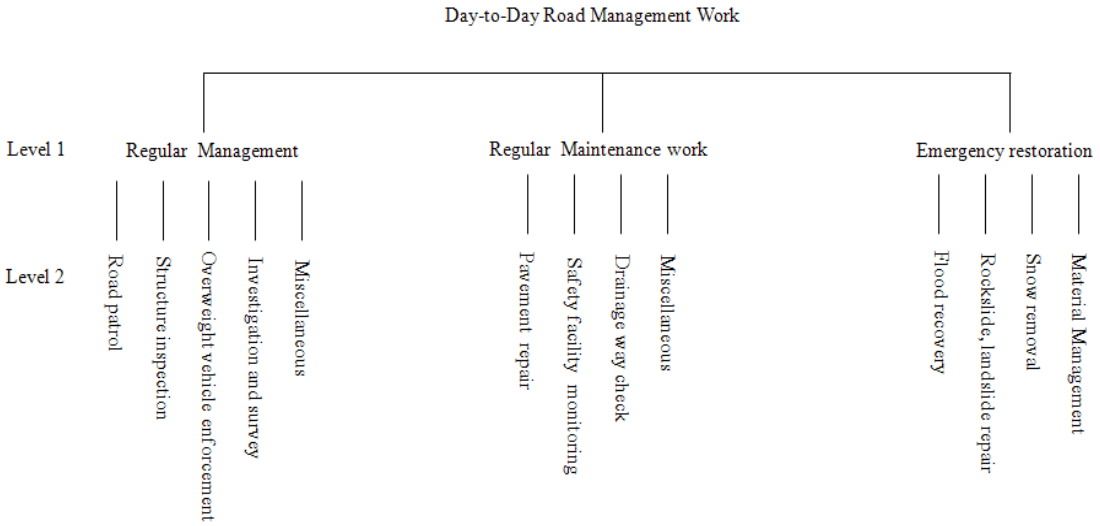

Fig.3 AHP Structure

4. Data Collection

Our study used historically recorded data for equipment and ordinary maintenance from the 18 regional offices in South Korea. They include various data as shown in Table 3. Also, it shows the properties of the data and their applicability to the study.

Table 3 Data properties and study applicability

Data	Description	Applicability
Equipment Title	Equipment name owned by each regional office	YES
Specifications	Capacity, weight and other description of vehicles	YES
Serial Number	Serial number of equipment	YES
Number of Operating Days	Records on operation of equipment by work types	YES
Working Hours	Actual operating hours	NO

Operating Hours by Equipment	Accumulated operating distance or time	YES
Operating Cost	Driver's wage, maintenance cost, other manpower cost	NO

The data on the working hours were not used for the analysis because they did not contain specific information on the operating hours by work types. The operating cost was also not used because the study did not consider manpower as mentioned previously. To establish a study methodology, data from road equipment records between 2010 and 2011 were collected from 18 regional offices.

5. Analysis

Evaluation indicator I for office "A"

Among the 18 regional offices, for example, office "A" which is located in the Gangwon area is in charge of maintaining about 815km of national highways, based on the 2010 data. Evaluation indicator I is found based on the historical records and all the results are summarized in Table 4.

Table 4 Results of office "A" for evaluation indicator I

Primary Equipment	Total Vehicle Miles (veh-km)	Total # of Equipment (veh)	Management lengths of "A" Regional office (km)	Evaluation Indicator I
Passenger Car	17,100	1	815	21
Mini-Bus	31,380	1		14
Overweight Enforcement Vehicle	71,648	2		38
Bongo Truck	26,310	2		**44**
Bridge Inspection Support Vehicle	20,520	1		16
Multi-Purpose Snow Removal Vehicle	6,620	1		**8**
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Subsidiary Equipment	Total Vehicle Hours (veh-hour)	Total # of Equipment (veh)	Total Operation hour of "A" Regional office (hr)	Evaluation Indicator I
Excavators	230	3	1,500	0.46
Snowplows	80	20		1.07
Sprinklers	650	30		15
.	.	.		.

Evaluation indicator I shows the average operation distance per individual piece of equipment for the length of the maintenance area of each regional office. To illustrate, a greater value shows that the equipment was more actively used compared to the length of the maintenance area, whereas equipment with a lower value was recognized as having relatively low applicability compared to that with higher values. In the case of office "A", the value of evaluation indicator I was the highest (44) for an overweight enforcement vehicle and lowest (8) for a multipurpose snow removal vehicle. This implies that evaluation indicator I normally has a high value for vehicles that are widely used for ordinary road management work, and is low for vehicles with limited purposes such as snow plowing. Therefore, this alone neither reflects the significance of management tasks, nor provides accurate information on the operation condition of equipment.

Evaluation indicator II for office "A"

The survey participants were allowed to choose multiple criteria that they regarded as the most important in each level as shown in Figure 3. The results show that, in the first level, 79% of the respondents thought regular management was the most important; in the second level, 71% indicated that structure inspection, and 64% indicated that road patrol were the most important. Among the regular maintenance works in the second level, safety facility monitoring was considered the most important (93%), followed by pavement repair (71%). As for emergency restoration in the second level, snow removal was considered the most critical (79%) followed by flood recovery (64%). Based on survey results and an arbitrary rating scale developed by Saaty, a pair-wise comparison matrix was developed. Weights for each element of the levels can be determined with a set of eigenvectors corresponding to the largest eigenvalue. After applying the consistency tests based on Saaty's rules mentioned above, consistency ratios (CRs) were obtained with regard to the first and second level of the hierarchy. Table 5 shows estimated weights for the first and second level of the hierarchy.

Table 5 Weights and consistency verification

Level 1	Estimated weights (a)	
Regular Management	0.109	
Regular Maintenance work	0.582	
Emergency Restoration	0.309	
CI /CR	0.003/ 0.006	
Level 2		
Regular Management	Estimated weights (b1)	Final Weights (a)×(b1)
Road patrol	0.309	0.034
Structure inspection	0.406	0.044
Overweight vehicle enforcement	0.188	0.020
Investigation and survey	0.058	0.006
Miscellaneous	0.039	0.004
CI /CR	0.0073/0.065	N/A
Regular Maintenance work	Estimated weights (b2)	Final Weights (a)×(b2)
Pavement repair	0.281	0.163
Safety facility monitoring	0.524	0.304
Drainage way check	0.151	0.088
Miscellaneous	0.044	0.026

CI /CR	0.032/0.035	N/A
Emergency Restoration	Estimated weights (b3)	Final Weights (a)×(b3)
Flood recovery	0.168	0.052
Rockslide, landslide repair	0.238	0.074
Snow removal	0.517	0.160
Material management	0.077	0.024
CI /CR	0.035/0.039	N/A

Since the CR is less than 10% in both levels, the developed pair-wise comparison matrices appear to be logically valid. Because the eigenvalues of some matrices are sensitive to perturbations, an inverse square law analysis was employed here to test the sensitivity of the estimated weights for levels 1 and 2. Although this law generally says that a specified physical strength (p) is inversely proportional to the square of the distance ($1/r^2$) from the source, it is believed to apply well to other areas of perception or thought (Saaty 1990; Yang and Regan 2012). Table 6 shows the results of an inverse square law analysis. Deviations between final values and estimated weights were very small. In addition, the medians of each of the deviation values were all less than 0.1. Thus, it can be concluded that the sensitivity of the estimated weights is very close to the original responses of 18 respondents.

Table 6 An inverse square law for the sensitivity of estimated weights

LEVEL 1								
Criteria	PAR [3]	Normalized PAR	Square of Previous column	Reciprocal of previous column	Normalized reciprocal	Final Values	Estimated weights	Median of deviation vector
Regular Management	6	0.222	0.049	20.250	0.603	0.198	0.164	**-0.07**
Regular Maintenance Work	11	0.407	0.166	6.025	0.179	0.410	0.871	
Emergency Restoration	10	0.370	0.137	7.290	0.217	0.391	0.463	
LEVEL 2 - Regular Management								
Criteria	PAR	Normalized PAR	Square of Previous column	Reciprocal of previous column	Normalized reciprocal	Final Values	Estimated weights	Median of deviation vector
Road patrol	9	0.290	0.084	11.864	0.022	0.140	0.309	**-0.01**
Structure inspection	11	0.355	0.126	7.942	0.014	0.141	0.406	

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[3] Public agency's original response

Overweight vehicle enforcement	8	0.258	0.067	15.016	0.027	0.139	0.187	
Investigation and survey	2	0.065	0.004	240.250	0.437	0.080	0.058	
Miscellaneous	1	0.032	0.001	275.072	0.500	0.500	0.039	
LEVEL 2 - Regular Maintenance Work								
Criteria	PAR	Normalized PAR	Square of Previous column	Reciprocal of previous column	Normalized reciprocal	Final Values	Estimated weights	Median of deviation vector
Pavement repair	10	0.303	0.092	10.890	0.011	0.330	0.281	**0.02**
Safety facility monitoring	13	0.394	0.155	6.444	0.006	0.331	0.524	
Drainage way check	9	0.273	0.074	13.444	0.014	0.329	0.150	
Miscellaneous	1	0.032	0.001	961.00	0.969	0.010	0.004	
LEVEL 2 - Emergency Restoration								
Criteria	PAR	Normalized TRR	Square of Previous column	Reciprocal of previous column	Normalized reciprocal	Final Values	Estimated weights	Median of deviation vector
Flood recovery	9	0.310	0.096	10.383	0.012	0.329	0.168	**0.01**
Rockslide, landslide repair	8	0.276	0.076	13.141	0.015	0.328	0.238	
Snow removal	11	0.379	0.144	6.950	0.008	0.331	0.517	
Material management	1	0.034	0.001	841.000	0.965	0.012	0.077	

Evaluation indicator II can be calculated by multiplying the final weights in Table 5 by the operation ratio for the different type of equipment in each regional office as shown in equation 4. This is because the operation ratio can reflect the share of equipment in different types of work. Table 7 indicates how to calculate evaluation indicator II using a passenger car belonging to office "A" as an example.

$$\text{Evaluation Indicator II} = \sum \text{the final weights} \times \text{operation ratio} \qquad \textbf{Eq.4}$$

Table 7 Example of evaluation indicator II for passenger car in "A" office

Day-to-day management operation	Passenger car			
Regular Management	Final Weights	# of operating days	Operation ratio	Indicator II
Road patrol	0.034	104	0.825	0.0281

Structure inspection	0.044	0	0.000	0.0000
Overweight vehicle enforcement	0.020	1	0.008	0.0002
Investigation and survey	0.006	0	0.000	0.0000
Miscellaneous	0.004	21	0.167	0.0007
Regular Maintenance work	Final Weights	-	-	-
Pavement repair	0.163	0	0.000	0.0000
Safety facility monitoring	0.304	0	0.000	0.0000
Drainage way check	0.087	0	0.000	0.0000
Miscellaneous	0.026	0	0.000	0.0000
Emergency Restoration	Final Weights	-	-	-
Flood recovery	0.052	0	0.000	0.0000
Rockslide, landslide repair	0.074	0	0.000	0.0000
Snow removal	0.160	0	0.000	0.0000
Material management	0.024	0	0.000	0.0000
Total	1.000	126	1.000	0.0289

Evaluation indicators I and II, were normalized for accurate comparison based on equation 5. This is because the units of operational records of equipment are different as described previously. All results across 18 regional offices were graphically described as shown in figure 4.

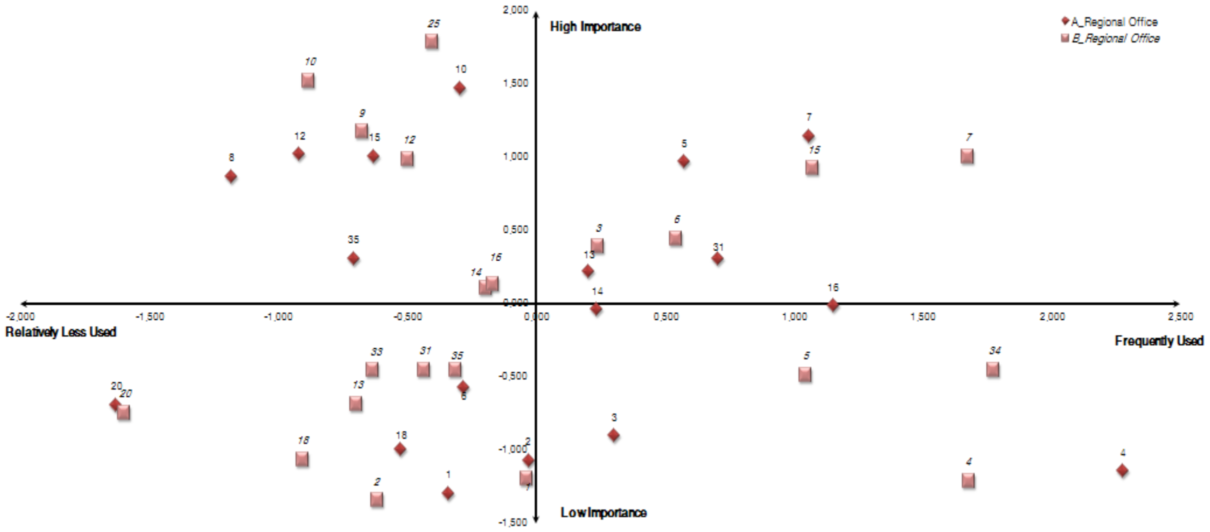
$$Z = \frac{X - \mu}{\sigma}$$ **Eq. 5**

Where,

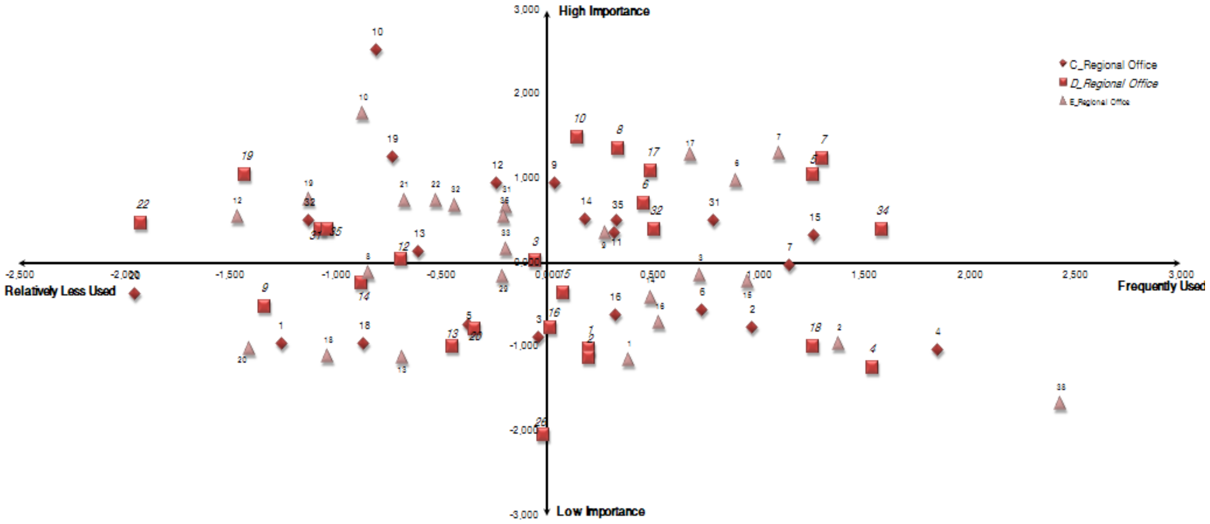
$X =$ Evaluation indicator I or II by equipment

$\mu =$ Average of evaluation indicator I or II by equipment

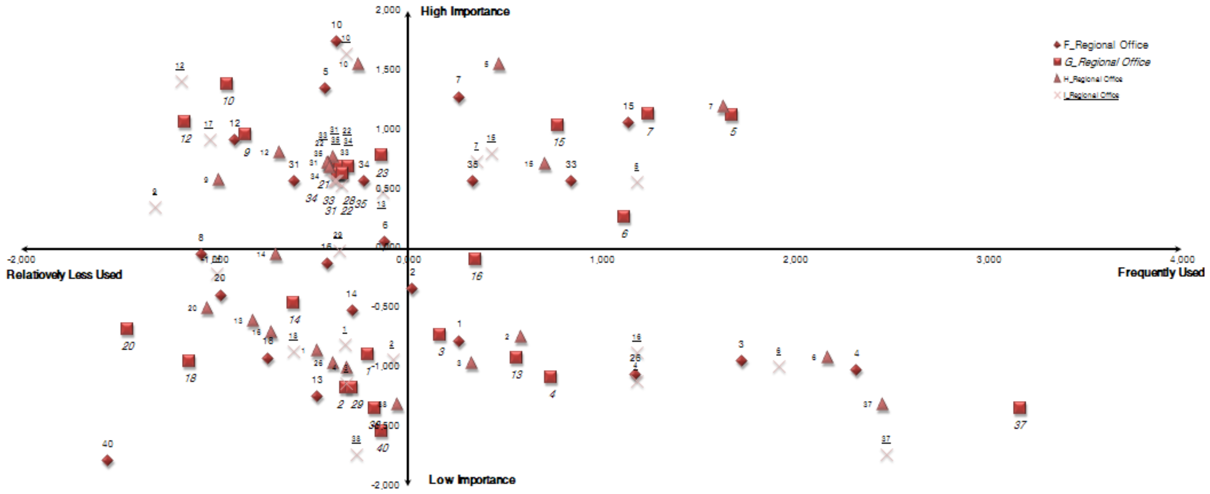
$\sigma =$ Standard deviation of evaluation indicator I or II



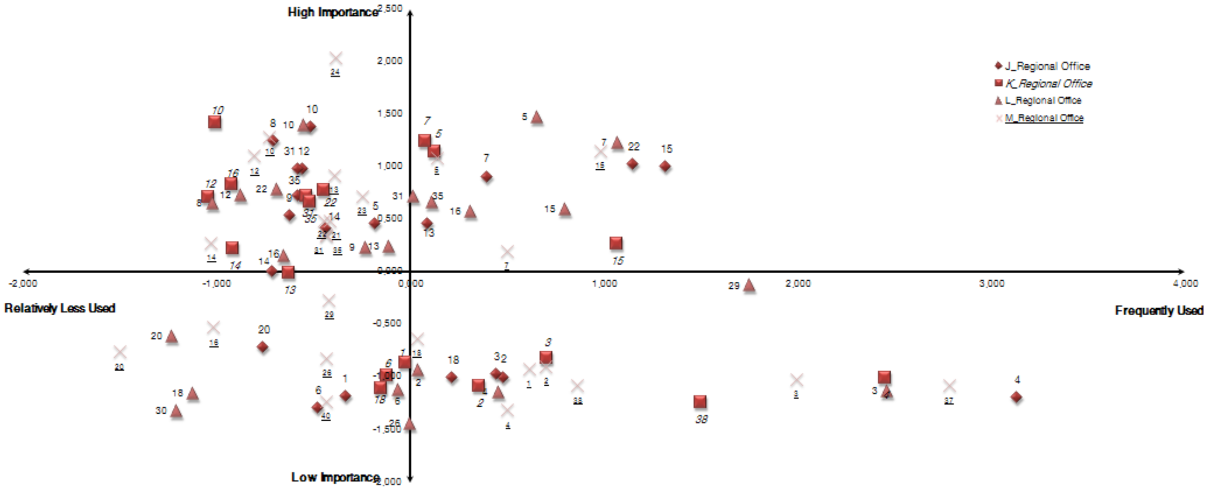
(a) Regional Offices located at Seoul Metropolitan Area



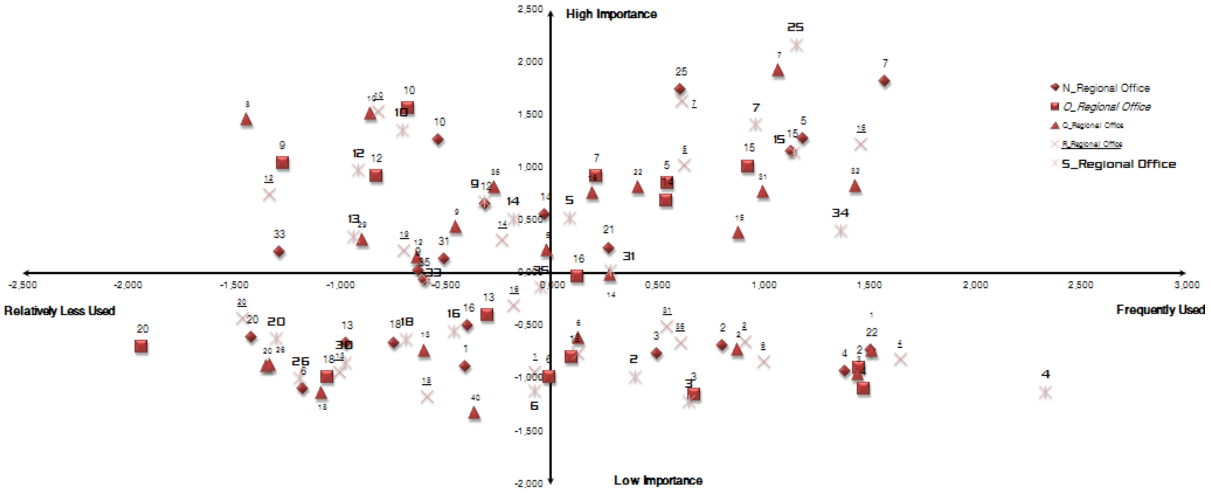
(b) Regional Offices located at Gangwon Area



(c) Regional Offices located at ChungChen Area



(d) Regional Offices located at HoNam Area



(e) Regional Offices located at YoungNam Area

Fig.4 Graphical descriptions of the final results by areas

The equipment in the first quadrant of graphs is both important and frequently used; that in the second quadrant is important but relatively less used. The third quadrant indicates low importance and low use, and the fourth quadrant implies low importance and frequent use. In the analysis, some equipment was excluded because it was considered to be unused or there was a lack of records for its use for the years 2010 and 2011.

6. Conclusions

The two regional offices in the Seoul metropolitan area were in charge of national highways with significantly greater population and traffic loads. Drivers expressed relatively high expectation for the level of service for these roads. The analysis showed that double-cab cargo trucks were frequently used and considered important. These are used for pavement repair and the monitoring of safety facilities, which are included in regular maintenance work. That is, double-cab cargo trucks were deemed important for the maintenance of the road surface condition and safety facilities. In the Ganwon region, snow-removal equipment, including snowplows, dump trucks and deicer sprinklers were regarded as important and were used frequently because the region has heavy snowfall and a longer winter season than other areas. Interestingly, road surface cleaning vehicles and multi-use road maintenance vehicles were also regarded as important. This was because cleaning the deicer and dust off the road surface and facilities is also an important task when the winter is over. In the Chungcheon region, the equipment use showed a similar pattern to that in the Seoul metropolitan area, In the Honam region, excavators and double-cab cargo trucks were deemed important and used frequently to fend off flood damage in summertime. This suggests that equipment use is closely related to the regional climate characteristics. In this aspect, the Youngnam region showed a similar pattern to the Honam region, but, the use of snow-removing equipment rose sharply recently because of unexpected snowfalls. Based on the results of our methodology, road management equipment can be classified into four groups: 1) frequently used and important, 2) relatively less used and important, 3) barely used and low importance, and 4) frequently used and low importance.

As the last step in the methodology, after classification, Figure 5 presents an example of how regional offices can determine either to lend or borrow among offices or purchase additional road equipment for both long and short term use. As seen in figure 5, only equipment that belongs to group III can be considered for either lending or borrowing. By doing so, financial resources can be saved for the maintenance of road management equipment. Our methodology provides flexible for decision-makers facing similar resource allocation problems across other applications and in other countries. The policy implications of this work are simply that by cooperating, agencies might find opportunities for reducing costs that they would otherwise miss out on.

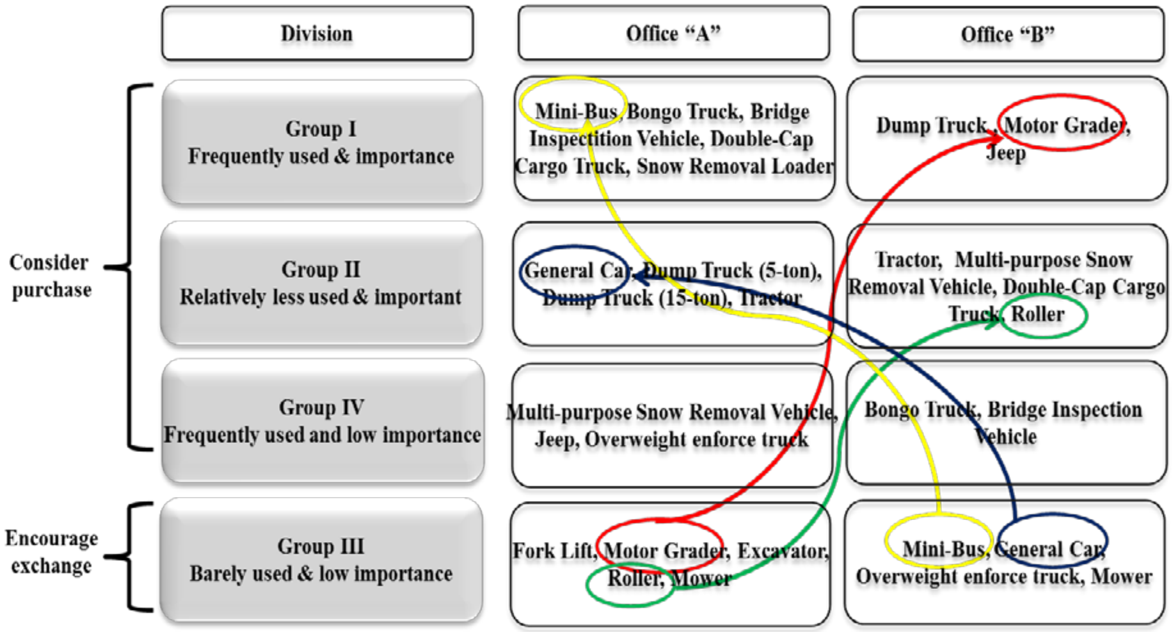


Fig.5 A simple example applying the methodology

7. Future Improvements and Extensions

As discussed in our introductory section, we could not include manpower in our analysis because of a lack of reliable data. Perhaps even more important would be to extend this methodology to provide an estimate of the cost savings possible from sharing under-used equipment and possibly by delaying purchases of equipment as the result of this analysis. We are working with appropriate government agencies to see if such data could be obtained in the future, though it is not available in a useful capacity at this time. Finally we should point out that the fact that there is no way to distinguish in the KAMIS data between miles (or hours) accumulated during short and long trips, lending decisions must be carefully examined by operations managers so that indispensable equipment is not mistaken for that which could be easily lent out. Agencies wishing to adopt this or related tools for future use could work to change reporting requirements so that the tools would be even more useful in the future.

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