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A STUDY OF VULNERABLE ROADWAY SECTIONDETERMINING METHOD FOR SNOW REMOVAL USING A GIS

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ABSTRACT
This paper presents how to determine priorities of RWIS installation on national highways within the limited budget. Analytical hierarchy process was employed to develop the entire methodology. In addition to this, various data such as vulnerable roadway section for snow removal, RWIS, AWS, AADT, and traffic accident were properly collected and analyzed for the future analysis. Then, GIS analysis was performed to find out the final candidate vulnerable roadway section for snow removal. In the end, expert survey was conducted to estimate weights for evaluation criteria. Results showed that metropolitan area has the most high priority, and Gangwon area, ChungCheung, and Honam in order. The main contribution of this paper is to suggest a logical methodology to prioritize RWIS installation within the limited budget, and thus snow removal operation during the winter season can improve in terms of getting more valuable information.

Keywords: *Vulnerable roadway, Snow removal, RWIS, AWS, GIS*

I. INTRODUCTION
Climate changes, such as abnormal climate, manifest through unforeseen snowstorm and record-breaking cold weather, which leads to the trends where human/social damages continue increasing due to soaring number of traffic accidents including isolation of vehicle and driver on the roads and sliding incidents.

Recent snow damage cases, such as snowstorm and road surface freezing, include continuous cold wave due to expansion of continental anticyclone in January, 2010, which led to a heavy snow throughout central areas with snowfalls of 31.5cm in Daegwallyeong, 23cm in Chuncheon/Icheon and 22.3cm in Incheon. It was quite an unprecedented case as 25.8cm of snowfall in Seoul was the highest since fresh snow cover was first measured in 1937. And in March, 2010, heavy snow - amount of snow cover with 10cm or higher- was recorded in 10 cities and provinces, and property damages were worth 21.6 million dollar. Because of repetitive snows and rains, 2.7 to 3 times of the normal load was landed on facilities, which led to severe damages. In December of 2010, heavy snow hit 6 cities and provinces left 25.7 million dollar worth property damages. In 2010, a total of 60.3 million dollar property damage was recorded due to heavy snow [1]. Again in January, 2011, heavy snow mainly focused on the east coast area, where Pohang and Ulsan renewed their records of worst fresh snow cover in January -28.7cm in Pohang. In December of the same year, heavy snow hit Gangwon-do, which also renewed the records of fresh snow cover in December with 35.3cm in Sokcho and 43cm in North Gangneung. In 2011, property damages topped 43.9 million dollar due to heavy snow [1].

In 2010 and 2011, a total of 488 heavy snow warnings and advisories were taken. Especially, heavy snow advisory, which takes effect when 24-hour fresh snow cover reaches 20cm or higher, was taken 84 times, 400% increase from 2009 - 19 heavy snow advisories [2].

For the purpose of road management in winter season, road management agencies selected vulnerable sections for snow removal operation, and established a snow removal operation plan based on available equipment and human resources, which is currently in operation. Vulnerable sections for snow removal operation represent a section where a regulatory control is anticipated during heavy snow due to rugged terrain, a section where traffic cannot be allowed without snow removal operation, entrances and exits of bridges or tunnels and a section anticipating road surface freezing [3, 4,5].

This study is to propose an effective method selecting vulnerable sections for snow removal operation for the purpose of helping help efficient road management in winter season in order to respond ever-increasing heavy snow and cold wave. At the same time, road surface freezing is becoming invisible risk factor to drivers during nighttime in addition to its seriousness during daytime. Thus, this study also aims to provide drivers information on freezing which

II. LITERATURE REVIEW

Because drivers cannot easily recognize road surface freezing in winter season, it is very important to forecast sections anticipating to be frozen.

During the road design phase, analysis and evaluation studies are being conducted on the sections anticipating road surface freezing targeting scheduled construction areas based on road design drawings, data on topography altitude and analysis on access to sunlight using sun's altitude. In order to evaluate and forecast the sunlight impact when planning the road routes, analysis was performed on the sections with road surface freezing by using design drawings [6, 7]. For methods forecasting the section with road surface freezing by using design drawings, however, existing studies experienced restrictions when analyzing the sections without design drawings or as-built drawings.
The study conducted a research to develop the standards to determine installation priority for the Road Weather Information System (RWIS) to obtain various information on vulnerable sections for snow removal operation [8, 9].
The characteristics or information of necessary topography can be effectively expressed by properly using light direction, topography, scale and color depending on the objective or user of shaded relief map or shaded status map [10].

According to the Guideline on Road Snow Removal Operation by the Ministry of Land, Infrastructure and Transport, air temperature and geographical elements are taken into consideration in order to determine vulnerable sections for snow removal operation, and the guideline suggests selection criteria on vulnerable sections for snow removal operation as follows:

- Sections with prior records of traffic control or sections anticipating traffic control during heavy snow due to rugged terrain;
- Significant routs with heavy traffic, routes located distant from road management agencies or routs with main connecting roads between regions.

Selection criteria on vulnerable sections for snow removal operation presented at the Highway Disaster Management Manual [11, 12] are as follows:

- Sections with prior records of traffic control or sections anticipating traffic control during heavy snow due to rugged terrain;
- Sections concerned for road surface freezing due to extended hours of being shaded area;
- Sections with steep slope - 3% or higher of longitudinal section- or section with limited uphill driving condition during heavy snow due to long extension;
- Significant routs with heavy traffic, routes located distant from road management agencies or routs with main connecting roads between regions
.

III. METHODOLOGY

Research Method and Target Area

This study extracted data on contour and elevation point in relation to altitude of the terrain from digital maps as shown at figure 1, and it also used the road network, bridges and tunnels from the Highway Management System (HMS) managing maintenance information on general national roads. For traffic data, it was spatialized by using text data and road network data which are surveyed every quarter.

After generating grid data on Digital Elevation Model (DEM) by using extracted topography altitude data, shaded relief data was finally generated by entering data on sun's altitude and azimuth from the areas subject to analysis. Moreover, extracted data on road network and bridges as well as spatialized traffic data was converted to the grid format.

Using the data processing and generated data above, it is to finally select vulnerable sections for snow removal operation using spatial information through spatial analysis -overlap analysis and adjacency analysis (Figure 1).

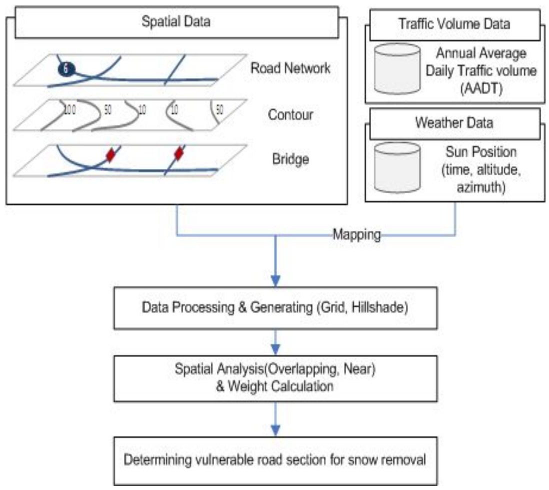

Figure 1:Methodology of research

Spatial scope of target area for analysis in this study is Pyeongchang-gun, Gangwon-do; and the routes subject to analysis are Route 6, 31, 42 and 59 of the general national roads, as shown at figure 2.

Figure 2:Map of research target area

Extraction of Topography Altitude and Generation of DEM

This study extracted its analysis subjects of data contour and elevation point data from a digital map (scale 1:5,000) where the standard layer code of extracted spatial information is displayed at table 1 [13].

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Table 1. The amount of roadkill on expressways and in Seoul City

Layer Code	Contents
7110	Unclassified contour
7111	intermediate contour
7112	Half intervalcontour
7113	Supplementary contour
7114	indexcontour
7117	Elevation point

Source: the Korea National Geographic Institute

Extracted contour data was again extracted to points (1pint/m), and elevation point data was overlapped. DEM (30mx30m), grid topography data, was generated in order to generate shaded relief data by using sun's altitude and azimuth. For interpolation method to generate DEM, Kriging interpolation method, a method to estimate the values of interpolated points, was used by using elevation value of neighboring basing points.

Kriging interpolation method employs semivariogram verifying spatial structure and correlation of point observational data by calculating semi variance induced from the distance under statistical significance. Since it applies optimized technique to determine neighboring values by selecting proper mathematical function model, this interpolation method is called optimized linearization technique (Figure 3).

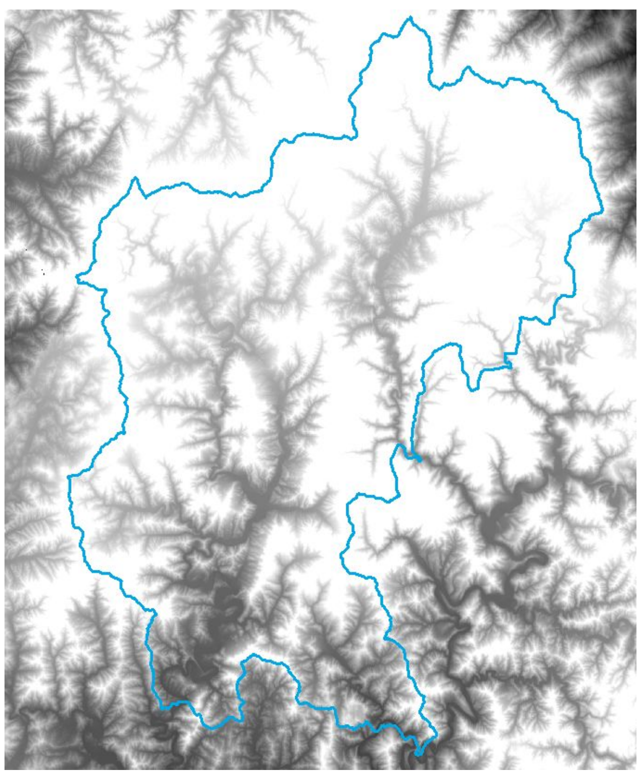

*Figure 3:Digital Elevation Model(DEM), 30m*30m*

Generation of Grid Data for Road Network

Using HMS road network data, data was converted and generated to 30mx30m lattice identical with shaded data (Figure 4).

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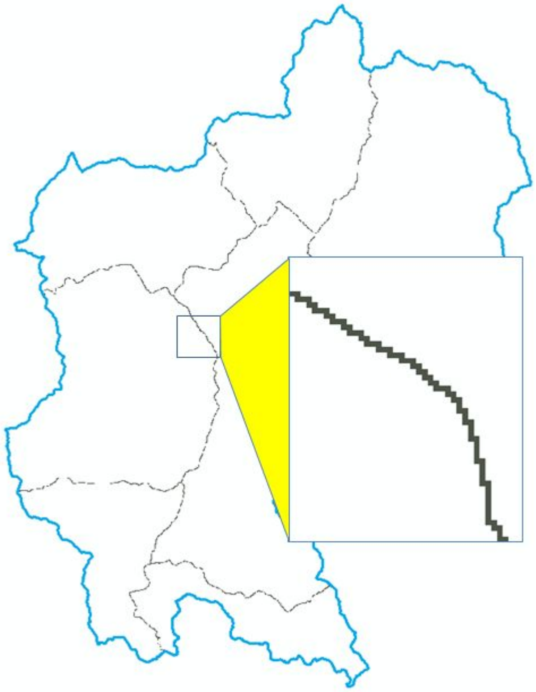

Figure3:Road network – Grid data

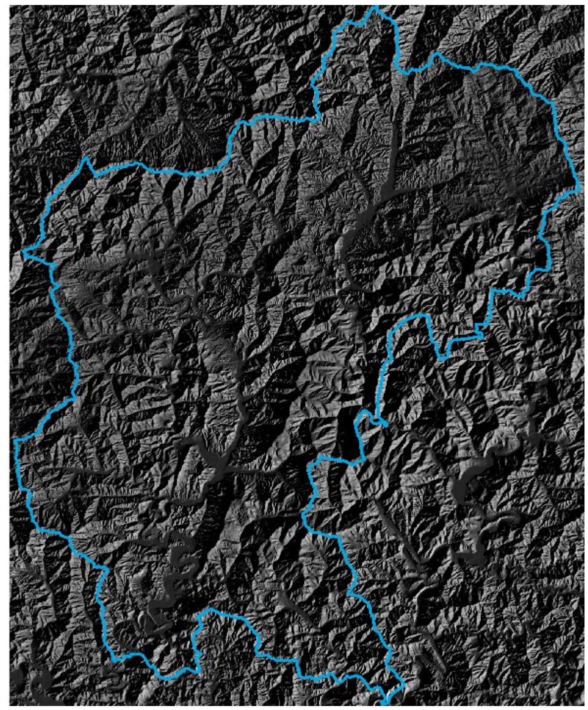

Figure5:Hill shade : November – AM 8

Generation of Shaded Relief Data using Altitude and Azimuth of Sun

Sun's altitude represents the angle between the horizon and sun, where its unit is degree (°) between 0°and 90°. Azimuth means each data of sun measure in a direction from the north to east, where its unit is degree (°). For sun's altitude and azimuth used for this study, the study employed altitude/azimuth calculation data provided by the Astronomy and Space Science Information [14].

Solar radiation depends on sun's altitude, azimuth and topography. In order to analyze solar radiation transmitted to terrains, shaded relief data (30mx30m) by hours was generated by using Hill shade technique of ArcGIS displaying shaded areas after using DEM, sun's altitude and azimuth.

Figure 5 shows shaded relief data generated using average sun's altitude and azimuth at 8 o'clock in the morning during the month of November, 2012, where black colored sections are shaded areas.

Sun's altitude and azimuth used at this study were based on the date between November, 2012 and February, 2013. And considering the sunrise and sunset at the target area of this study, sun's altitude and azimuth were taken at 8, 10, 12, 14 and 16 o'clock and averaged before being used (Table 2).

Table 2. Azimuth and altitude of Sun

Month	time	Azimuth(°)	Altitude(°)	Month	time	Azimuth(°)	Altitude(°)
11	8h	121.29722	8.70395	1	8h	119.05058	3.03214
	10h	144.87381	26.32579		10h	140.84156	21.34839
	12h	176.66838	34.08368		12h	170.17676	31.36320
	14h	209.47358	28.57735		14h	202.53423	28.69463
	16h	234.62861	12.51325		16h	228.81010	14.70294
12	8h	122.89871	3.75953	1	8h	47.01364	7.48031

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	10h	145.03676	20.96461		10h	54.56935	27.34634
	12h	174.12948	29.38109		12h	65.90281	39.03757
	14h	204.91612	25.37328		14h	75.66148	36.54931
	16h	229.65050	10.84359		16h	77.58170	21.45862

Generation of Shaded Relief Data under the Consideration of Temperature Weighted Value

In order to overlap individual shaded relief data, weighted values of temperature were applied. Weighted values based on temperature were divided into 2 phases and applied to individual shaded relief data. Monthly data was generated by applying monthly weighted values by hours to shaded relief date by hours. The weighted values based on the temperature by hours used at this study are as shown at Table 3.

Table 3. Temperature weight

Month	time	Average(℃)	Weight	Month	time	Average(℃)	Weight
11	8h	-0.07	0.196143155	1	8h	-11.49	0.194990236
	10h	2.56	0.198318938		10h	-8.88	0.197245408
	12h	5.69	0.200908369		12h	-5.03	0.200572001
	14h	7.61	0.202496774		14h	-1.84	0.203328322
	16h	7.17	0.202132764		16h	-1.22	0.203864033
12	8h	-10.07	0.195779056	1	8h	-7.27	0.195268835
	10h	-7.35	0.198124025		10h	-4.14	0.197927461
	12h	-4.37	0.200693145		12h	-0.58	0.200951329
	14h	-2.08	0.202667402		14h	1.55	0.202760554
	16h	-2	0.202736372		16h	1.94	0.20309182

Final shaded relief data was generated by applying weighted value of monthly average temperature as shown at table 4 below to the monthly shaded relief data generated as described above.

Table 4. Adjusted temperature weight

Month	time	Average(℃)	Weight
11	24 Hours	2.66	0.256799589
12	24 Hours	-6.57	0.246916092
1	24 Hours	-7.57	0.245845291
2	24 Hours	-3.28	0.250439029

Figure 6 represents shaded relief data between November of 2012 and February of 2013 generated after applying temperature weighted values.

Road network data in vector shape was gridded in order to conduct overlap analysis on shaded relief data and road network data. After overlapping two grid data, the value of shaded relief data was entered into road network data through spatial operation. Shaded relief data entered was classified into 3 phases; and figure 6 shows the visualization of those data where red color represents shaded area, green color shows the borderline area between shaded and sunny areas, and blue color displays sunny area.

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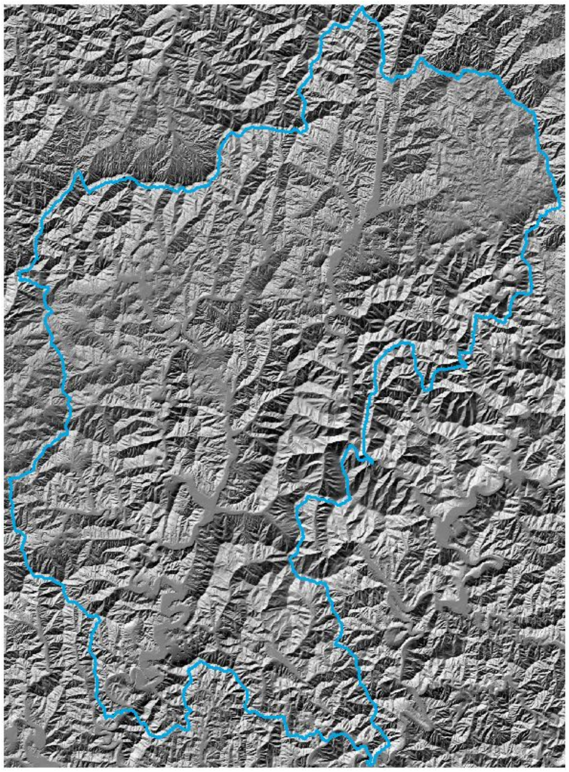

Figure6:Hill shade : Nov. ~ – Feb.

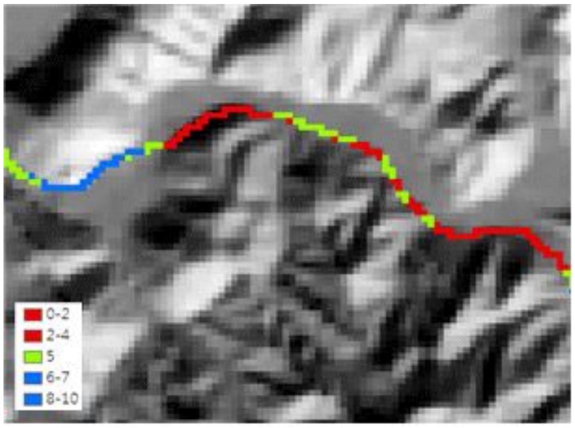

Figure7:Classification of hill shade data on road network

Selection of Vulnerable Sections for Snow Removal

Current criteria on selection of vulnerable sections for snow removal operation prescribe that those sections represent a section where a regulatory control is anticipated during heavy snow due to rugged terrain, a section where traffic cannot be allowed without snow removal operation, entrances and exits of bridges or tunnels and a section anticipating road surface freezing [15].

Average shaded relief data between November of 2012 and February of 2013 was generated through spatial operation after overlapping shaded relief data generated by hours. The values of shaded relief data was entered into the road network data through spatial operation based on the overlap and adjacent distance. The shaded sections

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from the road shaded relief data entered as described above can be the sections anticipating road surface freezing in winter season since those sections are attaining less solar radiation than other sections.

Final vulnerable sections for snow removal operation were selected through spatial operation by overlapping 4-month average shaded sections and location data of bridges and tunnels (Figure 8).

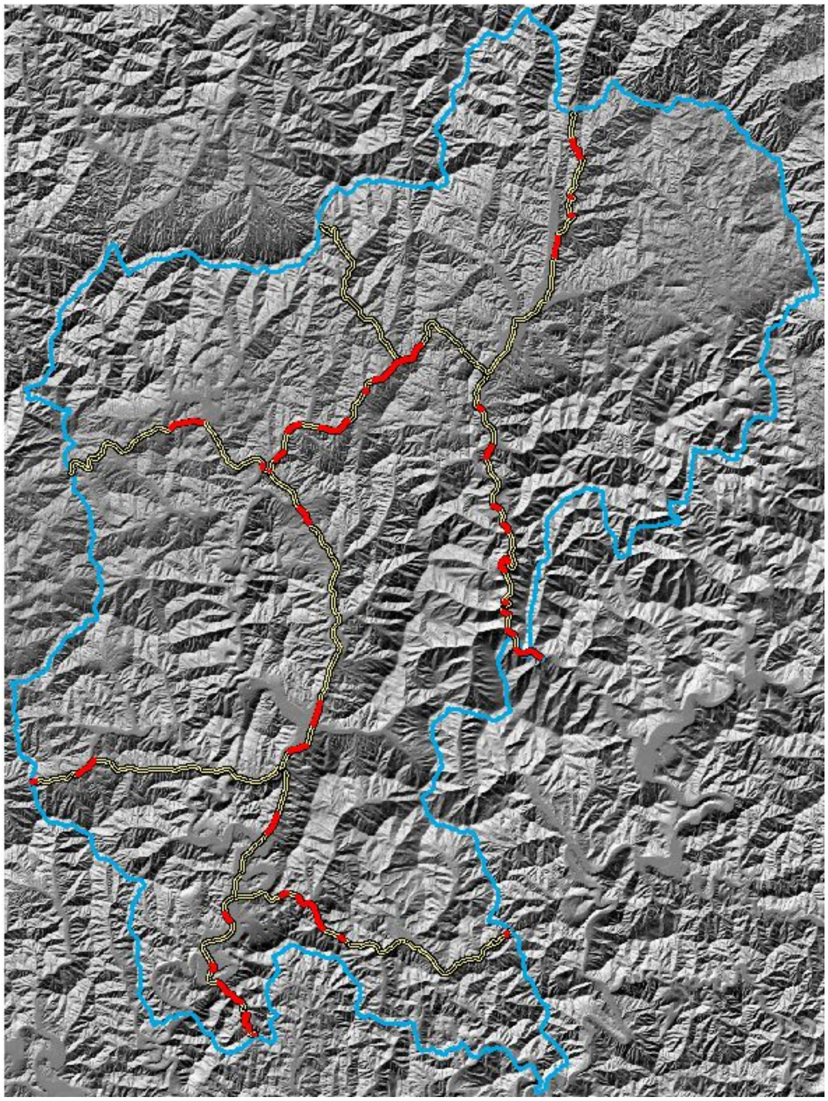

Figure8:Selection result of vulnerable sections for snow removal

IV. CONCLUSION

This study established methodology capable of analyzing and selecting the current selection criteria on vulnerable sections for snow removal operation through qualitative data. In other words, this study, by using shaded relief data, selected the sections anticipating road surface freezing and made final selections on vulnerable sections for snow removal operation through spatial operation and data on entrances and exits of bridges and tunnels.

If weather information (e.g. temperature, wind speed) is integrated into the outcome of sun radiation analysis representing shaded relief data in the future, it is believed that more accurate forecast on road surface freezing can be obtained. Moreover, this study provides drivers freezing-related information which poses invisible threats during

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nighttime as well as daytime in advance, and it further ensured administrators to take preemptive responsive measures.

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