Analysis of Road Accident according to road Surface Condition

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Abstract

In this study, the mean profile depth (MPD) that expresses roughness of road pavements was calculated using the road survey equipment vehicle and the calculated MPD was compared with the real number of traffic accidents. The analysis method used in this study was to classify the appropriate clustering in relation to traffic accidents using the K-means clustering and to compare this with the presence of traffic accidents via the MPDs to derive the result. K-means clustering was used in the analysis method and four clusters were found using the clustering analysis results. The center of each cluster was 0.627, 0.850, 1.118, and 1.237, respectively. The result of this study is expected to be utilized as foundational research in the traffic safety area.

1. BACKGROUND

The road environment is divided into three factors: personal factor, road environmental factor, and vehicle factor. In relation to traffic accidents, personal, road environmental, and vehicle factors are known to contribute 93%, 34%, and 13% of traffic accident approximately. Among the three factors, the road environmental factor affects traffic accidents via geometric road structure and damage or defects of road (safety) facilities. In appropriate road environmental factors can jeopardy the balance between driver and vehicle thereby causing a risk factor to traffic safety. Furthermore, a condition of road pavements can also be highly important to influence traffic accidents. In particular, a relationship of road pavement conditions with traffic accidents can be meaningful and ensuring a friction factor at the same road condition is highly important.

However, in-depth studies on the relationship with real accidents revealed that not only the friction factor but also degrading road safety due to rutting or pothole as well as crack on the road pavements can increase the severity of traffic accident significantly.

A change in road pavement surface can be caused by heavy vehicle traffic and poor quality of mixtures. The change in pavement surface not only increases a risk of accidents as it can prevent safety vehicle driving due to inadequate draining during rainfall but also degrade skid resistance significantly due to standing water in the road, resulting in hydroplaning and making vehicle steering difficult to increase a risk of accidents. The analysis on the traffic accidents for three years (2010–2012) showed that fatality of traffic accidents was 2.7, which was higher than that of total traffic accidents (2.4). This result explains that severity of rain-related traffic is very high. Moreover, standing water in the road which occurs more often due to the climate change around the world can cause frost roads (in particular, tunnel connecting parts or shaded area in bridges) in winter thereby becoming a cause of hindrance to traffic safety.

In this study, the mean profile depth (MPD) that expresses roughness of road pavements was calculated using the road survey equipment vehicle and the calculated MPD was compared with the real number of traffic accidents. The MPD is an index to indicate a state of the road surface and roughness of the road surface can be found through the comparison of MPDs. The analysis method used in this study was to classify the appropriate clustering in relation to traffic accidents using the K-means clustering and to compare this with the presence of traffic accidents via the MPDs to derive the result.

2. LITERATURE REVIEW

In this chapter, road surface-related studies performed in Korea and other nations were reviewed. Korea Institute of Civil Engineering and Building Technology (1997) identified a correlation between standing water in the road and skid resistance and hydroplaning according to road conditions and skid resistance was reduced as a vehicle speed increased at wet road conditions due to rainfall [1]. Chan et al. performed a study on analysis on effects between asphalt road condition and traffic accidents utilizing the pavement management system (PMS) data. They utilized the negative binomial model for the analysis and reported that there was a correlation of traffic accidents with the number of total traffic accidents, daytime driving, good weather condition, and traffic peak hour ratio when a model using plastic deformation was applied [2]. Kwon (2009) reported that a grade of road pavement was closely related to traffic accidents and analyzed that a traffic accident rate was up to 25 times difference due to the pavement grade. He also analyzed the importance of the factors in the Fish-Bone and structural equation model thereby verifying that plastic deformation and misalignment were the main factors of standing water in the road [3]. The Korea Expressway Corporation (2004) reported that vulnerable areas of standing water and road drainage were main reasons for vulnerability due to superelevation runoff among the geometric structural causes in expressways in Korea and traffic accidents occurred frequently due to the poor drainage when 0.3–0.5% of the minimum vertical gradient was applied at a section where a superelevation was 0% [4]. Hankook Tire (2000) reported that when hydroplaning occurred, tires in the axes where driving force was not transferred experienced deceleration of rotational speed due to the resistance with water and the driving axle was in idling state, resulting in vehicle driving with only inertial force and a loss of breaking function as well as motion function of tires thereby leading to lost control of vehicle. The company suggested that the minimum depth of water was 2.5 mm–10.0 mm although it varied according to tire speed, a level of wear, and roughness of the road surface [5].

3. RESEARCH OVERVIEW

3.1. Process for Research

The analysis process in this study is shown in Figure 1.

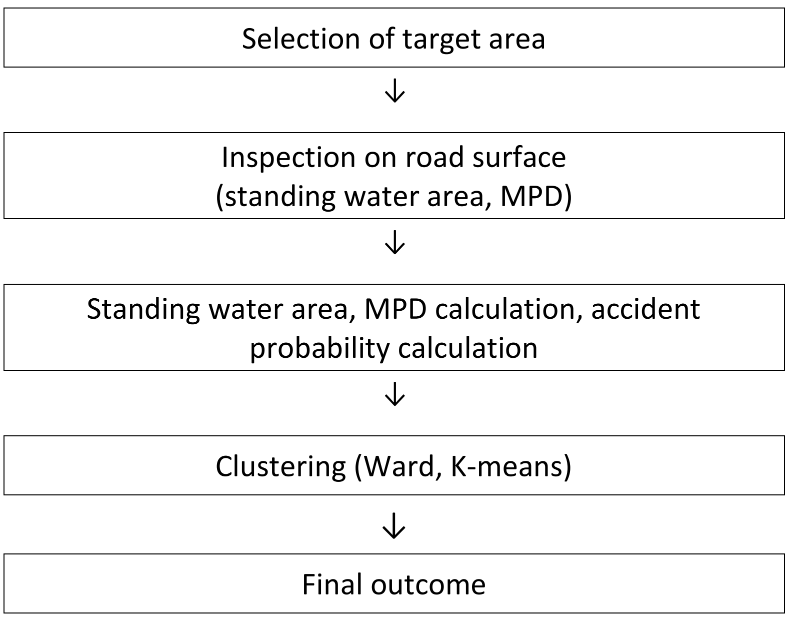

Figure 1. Analysis Methodology

The criterion of the analysis area was divided into straight section and curve sections (circular curve, transition curve) and MPD and the number of traffic accidents were investigated and calculated for each section. In addition, traffic accidents occurred at the study area and traffic accidents occurred at each section were compared to derive an accident probability and identified a correlation between accidents through clustering analysis.

3.2. Data Acquisition

In this study, some sections in National Highway No. 43 and 37 were selected to collect the road surface data, which is shown in Figure 2.

Figure 2. Example of Analysis Target Section

In order to acquire data, equipment calibration was conducted and sections where standing water was likely to occur due to poor plastic deformation were selected at fine days to acquire data accurately and standing water occurrence sections were checked during rainfall. Then, the site survey data were compared and the result was R^2=0.98, ensuring the reliability. In addition, an area and volume of standing water as well as a difference in plastic deformation showed similar results in every 10 m sub-section.

The road surface data that represented road surface conditions were surveyed using a state-of-the-art safety inspection vehicle. In the state-of-the-art safety inspection vehicle, texture laser equipment was attached, which can measure a road texture in every 1mm. In general, a number of ultrasonic and laser displacement sensors were used for transverse deformation measurement that was applied to automatic pavement condition survey equipment. That is, sensors were arranged horizontally with the road surface and relative position of the sensor with the road surface was determined to measure a curvature. This method required a measurement device whose size was the same with the road surface width and a safety issue was also concerned. Thus, a vision processing method was employed to measure a curvature height of the width to be measured in this study.

This method can predict a curvature height in the study area by not only improving data acquisition safely through high speed driving through the plastic deformation measurement equipment but also upgrading plastic performance measurement module through using a representative value of transverse displacement in every 50 cm, which was 10 m in the previous method, modelling a similar profile with real road shape, and developing software that can be implementable. Moreover, MPD was measured using 64 Khz-1 point laser in this study and the international roughness index (IRI) was measured through an accelerometer.

In this system, a distance measurement device was used together to measure transverse MPD of 1m area and MPD per unit distance (m) was calculated using the developed software. The state-of-the-art safety inspection vehicle and texture laser equipment were proposed and standing water in the road was calculated by using “the Road Surface Information Measurement Software” and the software t hat calculates the MPD values in real time is shown in Figure 3 and Figure 4.

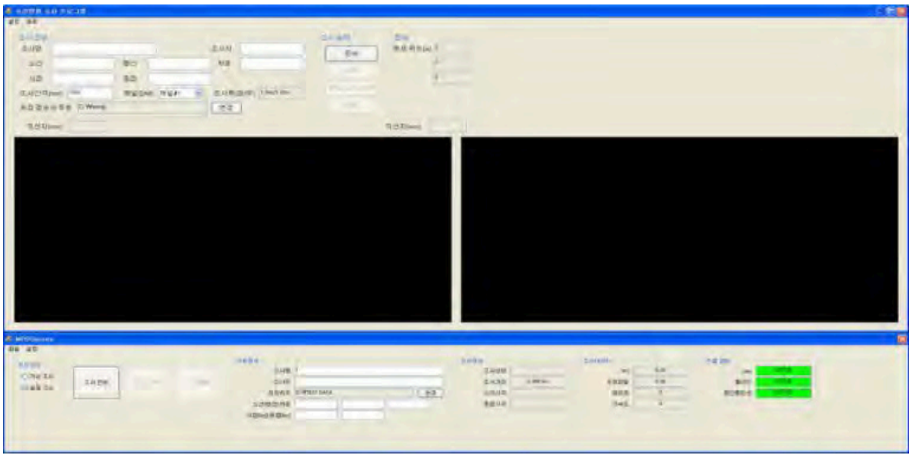

Figure 3. Configuration of the Road Surface Information Measurement Software

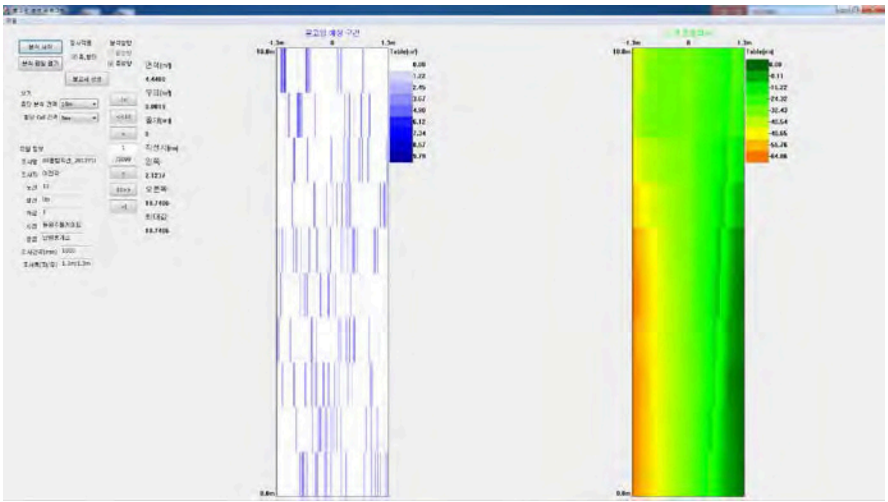

Figure 4. Example of Calculation with Road Surface Analysis Software

3.3. Methodology for Research

In general, International Friction Index (IFI) is used to calculate the skid number (SN) but in this study, it was used to match the MPD value and accidents in every subsection.

The MPD can be used to determine material separation of aggregates during paving but it can be also used to calculate the IFI, which is a new index to measure a friction of pavement in recent years ((It is an international safety evaluation index that is measured by considering micro and macro texture for accurate safety evaluation by the Permanent International Association of Road Congresses (PIARC)).

The MPD in every subsection was surveyed using the road surface measurement equipment-mounted vehicle. The MPD is one of the factors that evaluate macro textures. The MPD is calculated by averaging the first highest value (Peak Level 1st) in the first 50 mm section in the unit section and the highest value (Peak level 2nd) in the second 50 mm section after measuring a profile depth as shown in the figure via the macro texture data measured in every 1 mm gap and then a mean profile depth is cal culated by calculating a difference between the profile mean within 100 mm in the total unit section and a mean value of the two highest values. Eq. (1) shows this measurement equation.

$$MPD = \frac{(P.L1st) + (P.L.2nd)}{2} - A.L. \qquad [1]$$

- MPD : Average Profile Depth
- P.L 1^{st} : The High Value at 1^{st} 50mm Section
- P.L 2^{nd} : The High Value at 2^{nd} 50mm Section
- A.L : Average Profile at 100mm

In addition, hierarchical clustering analysis and non-hierarchical clustering analysis were used to anal yze the MPD setup statistically. The hierarchical clustering analysis produced bendrogram. This was a nalyzed by applying a member cluster of K-means, which was a non-hierarchical clustering method.

4. ANALYSIS RESULT

The geometric structure of National Highway No. 24 and Local Road No. 897 was divided into circular curve and tangent curve using the state-of-the-art safety inspection vehicle. The MPD calculation res ults are summarized in Table 1. The circular curve and tangent curve sections were divided into 27 se ctions and the maximum and minimum values of the MPD after the analysis were 1.366 and 0.497 an d a mean MPD was 0.907. Moreover, a probability in each section was revealed and the accident pro bability maximum was 0.185 and the minimum was 0.000 in the analyzed section.

Table 1. Result of MPD calculation by geometric structure

	MPD	P(A)		MPD	P(A)
Circular Curve 1	0.760	0.000	Tangent Curve 1	0.564	0.074
Circular Curve 2	1.128	0.000	Tangent Curve 2	0.497	0.000
Circular Curve 3	0.942	0.037	Tangent Curve 3	0.585	0.000
Circular Curve 4	0.750	0.111	Tangent Curve 4	0.571	0.185
Circular Curve 5	0.706	0.000	Tangent Curve 5	0.596	0.000
Circular Curve 6	0.652	0.000	Tangent Curve 6	0.560	0.000
Circular Curve 7	0.643	0.000	Tangent Curve 7	0.713	0.074
Circular Curve 8	0.758	0.000	Tangent Curve 8	0.691	0.000
Circular Curve 9	0.788	0.037	Tangent Curve 9	0.821	0.000
Circular Curve 10	0.647	0.074	Tangent Curve 10	0.707	0.000
Circular Curve 11	0.873	0.111	Tangent Curve 11	0.930	0.000
Circular Curve 12	0.658	0.037	Tangent Curve 12	0.664	0.000
Circular Curve 13	0.641	0.037	Tangent Curve 13	0.592	0.000
Circular Curve 14	0.933	0.000	Tangent Curve 14	1.160	0.000
Circular Curve 15	1.044	0.000	Tangent Curve 15	0.921	0.074
Circular Curve 16	0.842	0.037	Tangent Curve 16	0.602	0.000
Circular Curve 17	1.084	0.000	Tangent Curve 17	1.148	0.000
Circular Curve 18	0.970	0.000	Tangent Curve 18	1.012	0.000
Circular Curve 19	0.758	0.000	Tangent Curve 19	1.188	0.037

	MPD	P(A)		MPD	P(A)
Circular Curve 20	1.192	0.000	Tangent Curve 20	1.266	0.000
Circular Curve 21	1.222	0.037	Tangent Curve 21	1.212	0.000
Circular Curve 22	1.156	0.000	Tangent Curve 22	1.168	0.000
Circular Curve 23	1.366	0.000	Tangent Curve 23	1.139	0.000
Circular Curve 24	1.276	0.000	Tangent Curve 24	1.224	0.000
Circular Curve 25	1.227	0.000	Tangent Curve 25	1.061	0.000
Circular Curve 26	1.170	0.000	Tangent Curve 26	0.855	0.000
Circular Curve 27	1.139	0.037	Tangent Curve 27	1.199	0.000

The MPD calculation results were analyzed using the clustering analysis so that four groups were ma de. The bendrogram according to clustering is shown in Figure 5.

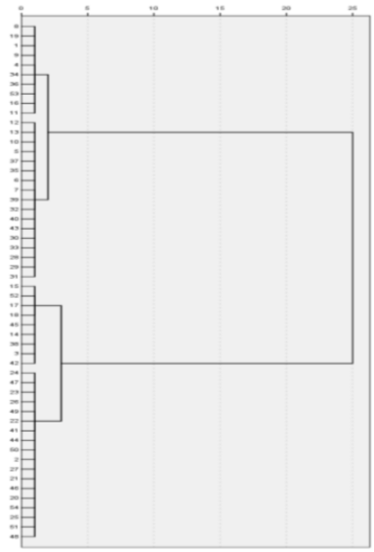

Figure 5. Bendrogram

In addition, Tables 2, 3, and 4 present the analysis results determined by the number of clustering in the K-means for four clusters derived by the hierarchical clustering method. The number of clusterin g was four and the number of members in each cluster was 18, 10, 14, and 12, respectively. The cent er of the cluster was as follows: 0.627 for clustering 1, 1.237 for clustering 2, 0.850 for clustering 3, a nd 1.118 for clustering 4. The accident probability for each cluster was 0.027, 0.007, 0.029, and 0.003 , respectively. The result showed that the larger the MPD on the basis of the center of the cluster, th e more the accident likely to occur.

Table 2. Result of clustering analysis

	Clustering			
	1	2	3	4
MPD	0.627	1.237	0.850	1.118

P(A)	0.027	0.007	0.029	0.003

Table 3. Final distance between clustering center

Clustering	1	2	3	4
1	-	0.610	0.223	0.491
2	0.610	-	0.388	0.120
3	0.223	0.388	-	0.269
4	0.491	0.120	0.269	-

Table 4. Number of cases in each cluster

Clustering	1	18.000
	2	10.000
	3	14.000
	4	12.000

5. CONCLUSION AND FUTURE RESEARCH

The road environment is divided into three factors: personal factor, road environmental factor, and v ehicle factor. In relation to traffic accidents, personal, road environmental, and vehicle factors are kn own to contribute 93%, 34%, and 13% of traffic accident approximately. In this study, analysis on envi ronmental factor and traffic accidents was conducted among the three factors. In particular, in this st udy, a correlation between road surface condition and accidents was analyzed using the MPD, which represented the roughness of road surface, in order to analyze a relationship between road surface a nd traffic accident. The study on road surface was analyzed using a state-of-the-art safety inspection vehicle and an accident probability was analyzed through matching with real accidents.
K-means clustering was used in the analysis method and four clusters were found using the clustering analysis results. The center of each cluster was 0.627, 0.850, 1.118, and 1.237, respectively. The com parison result of accident probability according to the center of the cluster showed that the larger th e MPD on the basis of the center of the cluster, the more the accident likely to occur.
In order to advance the study result, the following contents shall be complemented. First, additional analysis is needed to collect data from various road sections through additional survey on the study a rea. Second, it is necessary to add research that identifies a relationship of accidents under various c onditions by adding more variables that represent the road surface conditions.
The result of this study is expected to be utilized as foundational research in the traffic safety area.

REFERENCES

Korea Institute of Civil Engineering and Building Technology, A Study on Side Friction Factor and Radius of curve, 1997
Chun Yip Chan, Baoshan Huang, Xuedong Yan, Stephen Richards, Effect of Asphalt Pavement Conditions on Traffic Accidents in Tennessee Utilizing Pavement Management System(PMS), Southeastern Transportation Center, University of Tennessee,

2008
Jaesuk Kwon, An analysis of factors affecting water-resovoir phenomenon in rainy situation on highway, Hanyang Univ. Master’s degree, 2009
Korea Expressway Corporation, Establishing criteria for evaluation of distress and safety on pavements, 2004
Hankook Tire, Tire hydroplaning, 2000