RESEARCHERID
THOMSON REUTERS

[Kim, 4(12): December 2017]
DOI- 10.5281/zenodo.1133317

ISSN 2348 – 8034
Impact Factor- 4.022

GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCHES

ALTERNATIVES OF ACCIDENT PREVENTION FOR WINTER ROAD IN SOUTH KOREA

Young Rok Kim[*1], **Chun Joo Yoon**[2] **& Jun Hwa Jeong**[3]

[*1&2]Senior Researcher, Korea Institute of Civil Engineering and Building Technology, Korea
[3]Senior Research Fellow, Korea Institute of Civil Engineering and Building Technology, Korea

ABSTRACT

This study was conducted to develop a new strategy for managing habitually iced roadway segments in winter. In this study, characteristics of habitually iced roadway segments in S. Korea were analyzed firstly including average operating speed, temperature on the roadway surface, and surface slip. Based on these characteristics, systematic strategies for efficient management of habitually iced roadway segments in Korea were developed. In the strategy, those roadway segments were classified to corresponding with 6 safety levels, and then sub-strategies for each safety level were developed. As part of safety strategies, an advanced iced warning system and an automated de-ice liquid spray system to provide information regarding iced roadways and treat iced roadways, respectively, were developed

Keywords: *Winter road, South Korea, Accident, Prevention, Alternatives*

I. INTRODUCTION

A habitually iced road segment is defined as a road segment that is frequently iced and makes safety problems due to iced road surface. These segments are generally located in places with insufficient amount of sunshine or highway structures which are likely to lose heat from road surfaces, for example, bridge or ramp areas. Since accident frequency or accident severities are relatively high in these road segments, special management strategies in the winter are required. On the iced roadway surface, vehicles can be out of control when drivers step on a brake or turn handles suddenly. Since drivers are normally hard to recognize the iced road segment with the naked eyes, the safety problems in the habitually iced road segment are more severe than in other road segments. Some safety treatments for these road segments are already used in Korea such as, installation of iced road warning signs, guardrails, or storages of de-icier or sand. However, these treatments were conducted after many accidents had already occurred in the past, and they were not a systematic safety management for habitually iced road segments. Another problem is that snow removal is considered as more important than safety management for habitually iced road segments in Korea.

As shown in table 1, a number of accidents occurring on the dry roadway surface are relatively higher than that on other surface condition in Korea. However, a number of fatalities per 100 accidents are higher on the wet or iced roadway than those on the dry roadway. These statistics indicate typical safety problems of iced road segment. Under these circumstances, efficient safety management strategies for habitually iced road segments are required to improve safety of iced road segment in the winter.

Table 1. Statistics of Accident Characteristics Based on Road Surface Conditions (source : [9] p.165.)

Road Surface Conditions	Dry	Wet	Iced	Snow
Accident Rates (%)	84.0	13.2	1.9	0.9
Number of Fatality per 100 Accidents	2.3	3.0	2.9	1.6

In this study, currently used safety treatments for the iced road segments are reviewed, and then a new strategy to manage efficiently habitually iced roadway were established. In the strategy, those road segments were classified with six safety levels based on evaluation of driving conditions and then sub-strategies for each safety level were developed.

ISSN 2348 – 8034
Impact Factor- 4.022

II. REVIEW OF CURRENT SAFE TREATMENTS FOR ICED ROAD SEGMENTS

A habitually iced road segment is easily created at bridge segments and shaded road segments. It is known that iced moisture on the roadway surface in these segments frequently causes accidents related to vehicle sliding [6]. Figure 1 explains safety problems of habitually iced road segment and potential solutions.

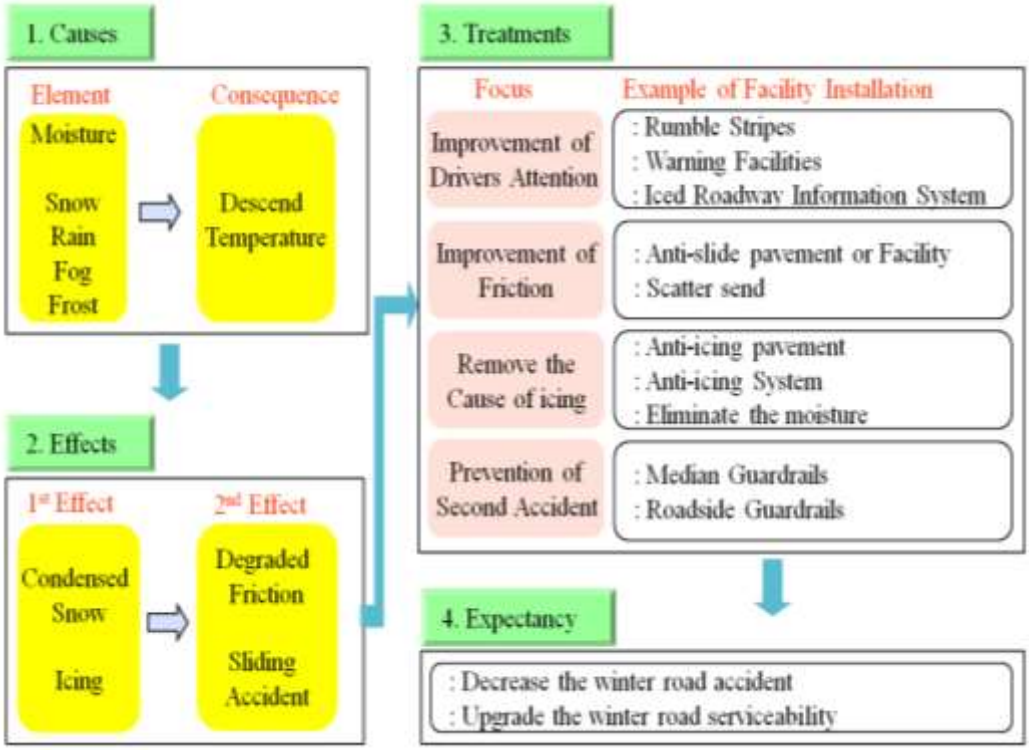

Figure 1. Safety Problems of Habitually Iced Road segment and Potential Solutions

Some of moistures from snow, rain, fog, dew, and frost remain on the roadway surface until nighttime, and the moisture may be frozen during nighttime. This ice on the bridge areas or shaded road segments is not melt even during day time. The iced road segments developed by the processes mentioned above cause accidents related to vehicle sliding. To improve safety in these conditions, several alternative safety treatments can be considered, for example, to increase road friction, to warn drivers, to remove or diminish elements producing iced road segments element, and to reduce the secondary accidents [7]. To increase road friction, installation of grooving pavement on travel lane or use of sand can be applied. To warn drivers, installations of safety facilities helping drivers perceive such as rumble strips [1] or use of advanced information technologies warning drivers [4].

To remove or diminish elements producing iced road segments element, methods to reduce time during moisture remains on the roadway surface or methods to protect iced roadway using de-icier fluid[5] or heating road surface system [2,3] can be applied. Improvement of guardrails can be applied to reduce the secondary accidents [3].

Table 2 summarizes these safety problems and potential treatments for habitually iced road segments.

ISSN 2348 – 8034
Impact Factor- 4.022

Table 2. Safety Treatments for Habitually Iced Road segments

Problem		Safety Treatment
Recognition of iced road segment	Visible	-Warning signs -VMS or Portable VMS -Recognizable pavement[9]
	Physical	-Rumble strips
Existence of Moisture on the road surface		-Grooving pavement
Occurrence of iced road surface		-Automatic de-icier spray system -Technology heating road surface
Vehicle sliding		-Grooving pavement
Secondary accident		-Improvement of guardrails

Based on the safety problems of habitually iced road segments mentioned above, each treatment could be systemized with two approaches including warning system and installation of safety facilities. Table 3 introduces the developed systematic safety treatment of habitually iced road segments.

Table 3. Systematic Safety Treatment of Habitually Iced Road segments

Classification	Technology	Function	ID
System	Warning Tech.	Provide various information using VMS or Portable VMS	A11
	Safety Tech.	Use auto de-icier spray	A21
		Order road management experts	A22
Individual Facility	Warning Tech.	Provide information of ahead iced road segment using warning signs	B11
		Provide information of ahead iced road segment using visualized facility such as pavement marking, delineator or rumble strips	B12
	Safety Tech.	Use pavement to drain roadway surface efficiently	B21
		Improve roadway friction (grooving)	B22
		Protect secondary accidents (guardrail)	B23

III. DEVELOPMENT OF A SAFETY MANAGEMENT STRATEGY OF HABITUALLY ICED ROAD SEGMENTS

For safety management of habitually iced road segments, a new safety management strategy of habitually iced road segments was developed in this study. First step in the strategy is to check whether the segment is iced habitually or not. Second step is to evaluate safety level based on the geometric condition of the segments and speed differential**.** If the safety problem of the evaluated road segment is found, the road segment will be managed using the developed safety management strategies. Third step is to select appropriate safety management strategy.

Three treatments of safety management strategies were developed as follows:

- 1st Treatment: The first order urgent management
- 2nd Treatment: Special safety management
- 3rd Treatment: Regular safety management

These treatments of safety management strategies are selected based on the historical accident data and relative functional importance level of the corresponding road segment. The three safety management strategies are corresponded to the six management technologies of habitually iced road segments explained in figure 2. Figure 2 illustrates those processes of the safety management strategy.

ISSN 2348 – 8034
Impact Factor- 4.022

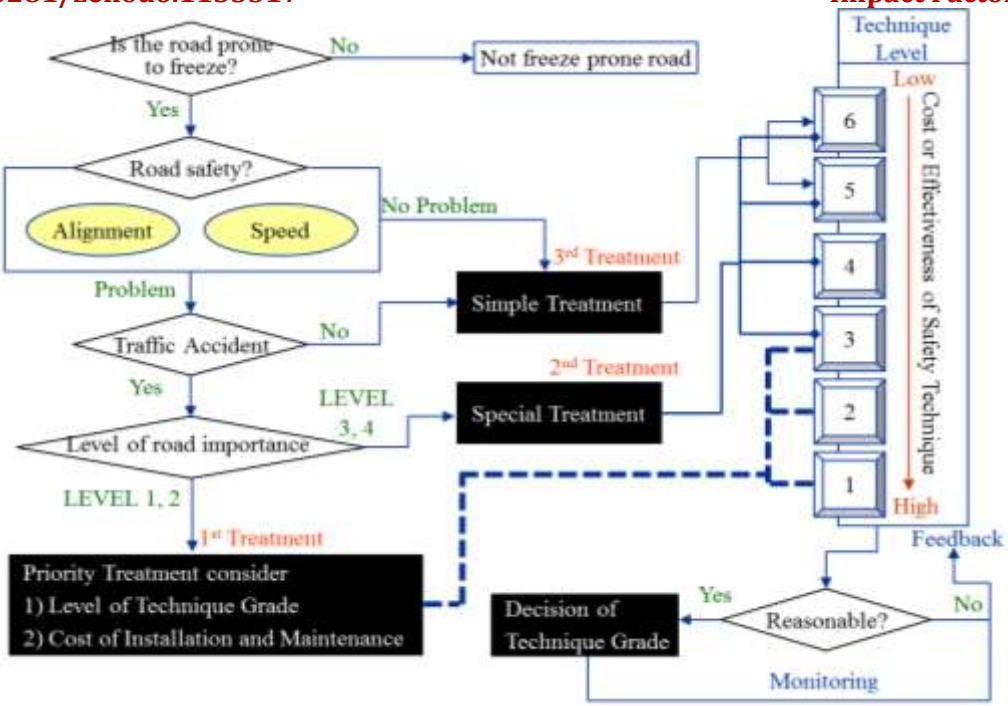

Figure 2. Illustration of the Process of the Developed Safety Management Strategy of the Habitually Iced Road segment

In the above process, four criteria for classifying problems were used to apply three levels of the safety management strategies.

The four criteria are as follows:

- Identification of habitually iced road segment,
- Evaluation of safety degree based on the geometric condition of the segments and speed differential,
- Check of historical accident data, and
- Check of functional importance of corresponding road segments.

Using above criteria, an appropriate safety management technology is selected, and then the selected safety management technology is conducted after reviewing the selection. Table 4 explains four criteria in more detail and Table 5 explains functional importance of the road segments [10].

Table 4. Four Criteria for classifying Safety Problems of the Road segment

Criteria	Classification Process
Identification	Identify habitually iced road segment by corresponding road management authorities.
Evaluation of Safety Degree	Evaluate safety degree considering horizontal curvature and speed reduction around iced road segment with 10km/h as a threshold
Review of Accident Data	Review historical accident data (rural roadway: ≥ 1 accident, urban roadway: ≥ 2 accident)
Review of Functional Importance	Review functional importance of the road segments based on travel speed and topography (table 4)

ISSN 2348 – 8034
Impact Factor- 4.022

Table 5. Functional Importance of the Road segments

Functional Importance	Topography	Speed(km/h)	Highway Class
Level I	Terrain	≥ 80	Principal Arterial I
Level II		70 ~ 79	Principal Arterial II
Level III		60 ~ 69	Minor Arterial
	Mountainous	60 ~ 69	Principal Arterial I
Level IV		50 ~ 59	Principal Arterial II
		50 ~ 59	Minor Arterial

Figure 3 illustrates those six safety management technology.

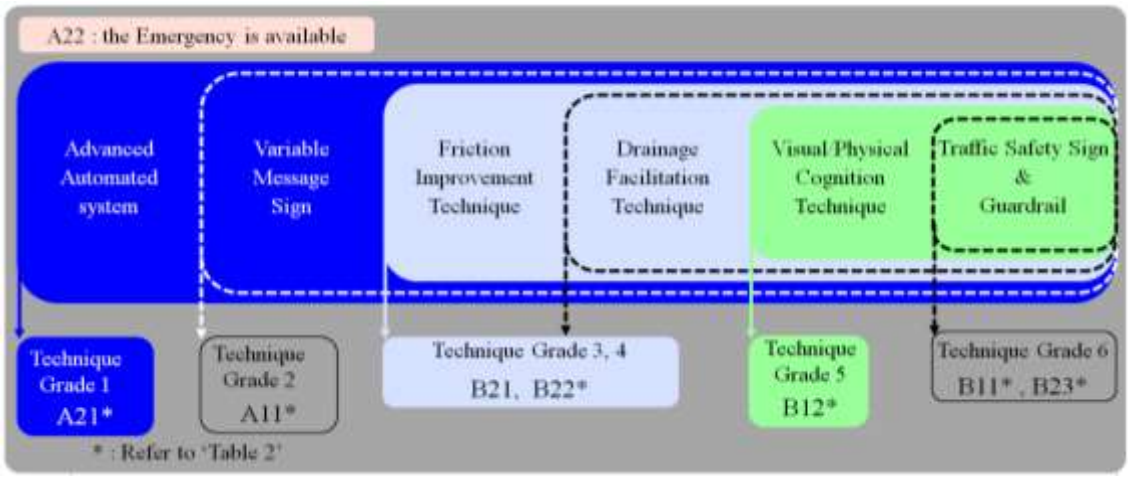

Figure 3. Application of the Six Safety Management Technologies

The level of six safety management technologies were developed refer to the table 6.

Table 6. Installation cost for six safety management technologies

Item	Unit	Price($)
Traffic Sign(slippery road)	Each	125
Grooving	100*3.5m	834
Guardrail	100m	1,250
Driving Speed Feedback sign	1 set	2,917
VMS	1 set	23,334
auto de-icier spray	1set(200m)	734,000

*This is the interview with general vendors.

IV. EXAMPLE OF APPLICATION OF THE SIX SAFETY MANAGEMENT TECHNOLOGY

In the application of six safety management technologies, use of one technology cannot solve the safety problem of habitually iced road segment in many cases. Therefore, each safety management technology was designed to apply cumulatively from low safety level to high safety level in the developed safety management strategy. There are two or three safety management technologies that can be applied in a safety strategy. Since the selection of the most suitable technology is difficult, this study recommends applying safety management technology of lower level in order. For example, when a road segment is tested as the road required to 1st management level, third safety

management technology, which is the lowest safety management technology in the 1st management level, is firstly used. If the severity becomes worse, the second and first safety management technologies are applied orderly. Figure 4 illustrates an example applying the highest safety management technology, which includes all safety techniques, is applied.

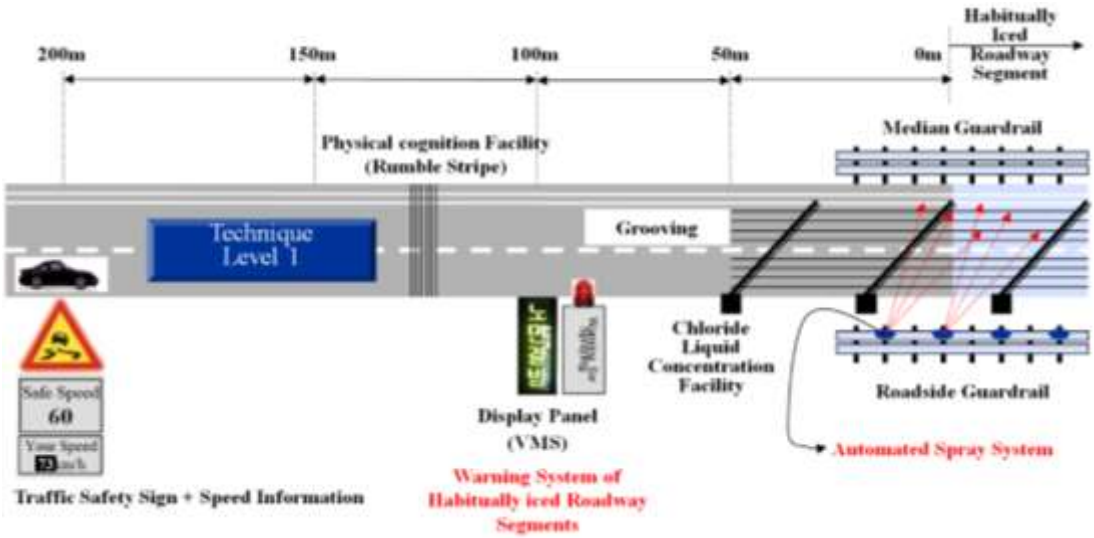

Figure 4. An Example Applying the Safety Management Technology

A warning system of an iced road segment and grooving pavement are installed 100 meter ahead and 50 meter ahead of the iced road segment, respectively. Also the automated spray system is installed 25 meter ahead of the iced road segment.

V. ANTICIPATED EFFECTS OF THE DEVELOPED WINTER SAFETY MANAGEMENT SYSTEM

Since the developed system have not been installed and operated on the real road in this study, numerical and detailed evaluation of effects for example, before and after study, could not conducted through this study. Therefore in this study, effects of the developed safety management system of habitually iced road segments were evaluated in draft based on social benefits.

To evaluate social benefits from this system, numerical effects of accident reduction from the safety management technique of iced road segment are estimated because the system can mainly contribute to reduce the accidents.
In general, it is known that numbers of accidents in winter are about 31 percent of total numbers of accident, and about 30 percent of accidents are generated from the insufficient road environment problems. Out of these accidents from the insufficient road environment problems, about 15 percent accidents are occurred by problems of slipping road surfaces. Accidents at habitually iced road segments are just small parts of the accidents. Under these circumstances, social benefits from the developed safety management system of habitually iced road segments might be about 10 million dollars or more every year as shown in the table 7. In addition, there are lots of benefits from improvement of technique related to winter road safety technique.

Table 7. Social Benefits form the Safety Management Technique of Iced Road segment

	Number of Accident	Fatality (Person)	Injured (Person)
Accidents in 2010*[1)]	226,878	5,505	352,458
Accidents in Winter*[1)]	51,776	1,334	81,817
Accidents from Road Environmental Problem*[2)]	15,533	400	24,545
Accidents from Slipping Road Surface*[2)]	2,330	60	3,682
Accidents at Habitually Iced Road Surface*[3)]	466	12	736
Potential Accident Reduction from the System*[3)]	140	4	221
Unit Cost of Accident ($)*[4)]	16,570	389,402	29,694
Total Social Benefit from the System (1,000$)	2,317	1,403	6,660
Total	Sum: $ 10,380,000/yr.		

*1) Source: [9] P.135., *2) Source: [9] p.138., *3) Hypothesis.
*4) Jeong Bok. Yu et al., "Estimation Methodology of Accident Cost In 2001 Korea", Korea Transport Institute, 2002.

VI. CONCLUSIONS

This study was conducted to develop a strategy for managing habitually iced road segments in Korea. In this study, characteristics of habitually iced road segments in Korea were analyzed firstly including average operating speed, temperature on the roadway surface, and surface slip.

Based on these characteristics, systematic strategies for efficient management of habitually iced segments in Korea were developed. As part of safety strategies, an advanced iced warning system and an automated de-ice liquid spray system to provide information regarding iced roadways and treat iced roadways, respectively, were recommended. However, the developed system herein has not been in practice, and it should be evaluated and improved after operating on the real roads condition in future.

REFERENCES

1. *D.W. Harwood, Use of Rumble Strips to Enhance Safety, 1995.*
2. *Edward J. Hoppe, Evaluation of Virginia's First Heated Bridge –Final Report, Virginia, Transportation Research Council, 2000.*
3. *FHWA, Improving Highway Safety at Bridges on Local Roads and Streets, 1998*
4. *FHWA, Best Practices for Road Weather Management, version 2. (http://www.itsdocs,fhwa.dot.gov), 2003.*
5. *Kentucky Transportation Center, Evaluation of Automated Bridge Deck Anti-Icing System, University of Kentucky, 2001.*
6. *Korea Institute of Construction Technology, Translation edition – Slip of Surface: Road, Runway, Bridge, 1997*
7. *Korea Ministry of Construction and Transportation, Manual on Installation and Management for Road Safety Facility, 2002.*
8. *Korea National Police Agency, Manual on Installation and Management for Traffic Safety Facility, 2000.*
9. *Korea Road Traffic Authority, Statistical Analysis of Annual Traffic Accidents, 2011.*
10. *Weon Eui. Kang, "National Highway's Design Criteria Based on Analysis of Functional Classification", Journal of Korea Society of Transportation, 19(1), 53-61, 2001.*
11. *Young rok. Kim et al. "Development of Safety Management Technologies of Habitually Iced Road Segments" 10th International Symposium on Advanced Applications of Transportation Technology, Athens, Greece, 2008*