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Traffic accident severity analysis with rain-related factors using structural equation modeling – A case study of Seoul City

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ABSTRACT

Weather conditions are strongly correlated with traffic accident severity. In particular, rain-related factors are an important cause of traffic accidents due to the poor visibility and reduced friction resulting from slippery road conditions. This paper presents a systematic approach to analyze the extent to which the rainfall intensity and level of water depth are responsible for traffic accidents using Seoul City, Korea, as a case study. The rainfall and traffic accident data over a nine-year period (from 2007 to 2015) for Seoul were analyzed through Structural Equation Modeling to identify the relationships among variables by handling endogenous and exogenous variables simultaneously. In the model, four latent variables, namely those representing the road; traffic, environmental, and human factors; and rain and water depth factors, were defined and the coefficients of the latent, endogenous, and exogenous variables were estimated to obtain the level of accident severity. Furthermore, a statistical goodness of fit index was suggested for model fitting. In conclusion, traffic, environmental, and human factors; rain and water depth factors; and road factors are mutually correlated with the level of accident severity. Compact cars, young drivers, female drivers, heavy rain, deep water, and roads with a long drainage length are more likely to be associated with an increase in the level of accident severity, as are features like a tangent, down slope, right-hand curve, and shorter curve length.

1. Introduction

The increase in occurrence of traffic accidents in many cities has been attributed to an increase in the number of vehicles. Crash severity is a major concern in traffic accident research and many models have been proposed for predicting its severity; these include statistical models such as logit/probit model (Shibata and Fukuda, 1994; Chen et al., 2016; Jafari Anarkooli et al., 2017), logistic regression (Fitzpatrick et al., 2017), mixed multinomial logit (Zeng et al., 2017), Bayesian (Chen et al., 2016; Shi et al., 2016; Kitali and Thobias Sando, 2017) and artificial intelligence including neural network (Zeng et al., 2014).

According to the National Highway Traffic Safety Administration (NHTSA), the causes of traffic accident can be categorized into three types: driver-related, vehicle-related, and environment-related critical reasons. Driver-related factors include recognition error, decision error, performance error, and others. Vehicle-related factors include tire/wheel-related, brake-related, steering-related, and other reasons. Environment-related critical reasons for crashes are slick roads, glare, view obstructions, fog/rain/snow, road design, and others. Therefore, traffic accidents usually arise owing to complex reasons. Among these, this study focuses on the rain-related factors. Although rain cannot be said to cause accidents, rainfall may result in driving hazards (Mondal et al., 2011). Hence, more specific and detailed analysis is required to reveal complex factors; this study analyzes various factors including road, traffic, environmental, and human factors with a focus on rain-related factors.

Rainfall and wet pavement conditions on roads are cited as one of the significant weather-related factors responsible for increasing the likelihood of a collision (Edwards, 1999; Mondal et al., 2011). For instance, a study conducted in six Canadian cities showed a 45% increase in related injuries resulting from rain-related factors over a four-year period from 1995 to 1998 (Andrey et al., 2003).

According to the Korean Transportation Safety Authority, the total number of fatalities in road traffic accidents in the country has decreased, but rain-related road deaths increased from 430 in 2013 to 463 in 2016. In particular, in Seoul city, traffic fatality rates on rainy days were the highest of all cities (KoROAD, 2016).

Rainy weather has the potential to affect the road surface conditions and the driver's behavior (Jung et al., 2010). During a storm, the water

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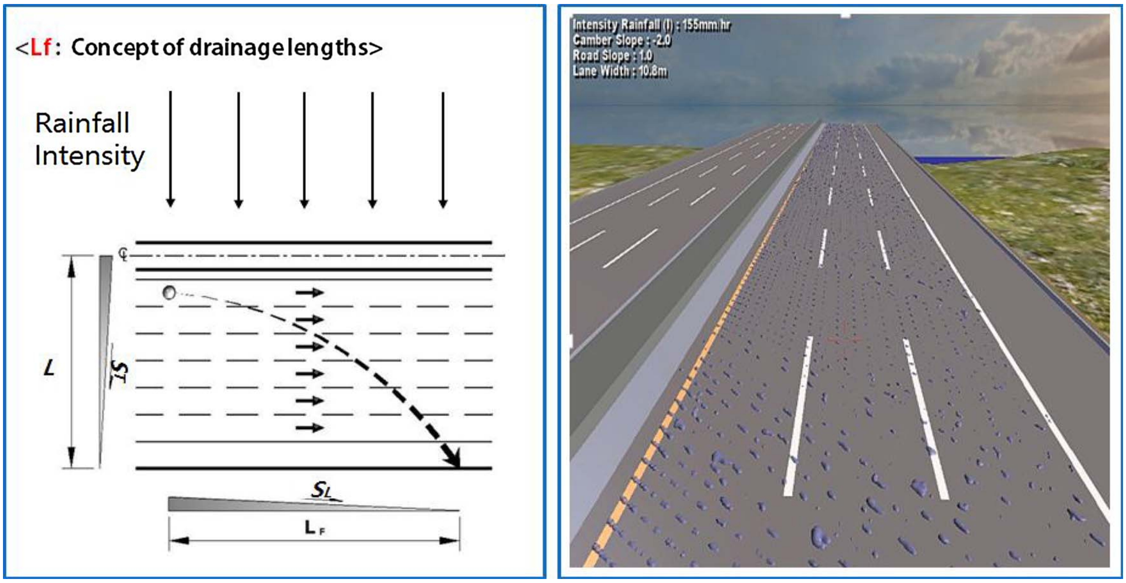

Fig. 1. Concept of drainage lengths.

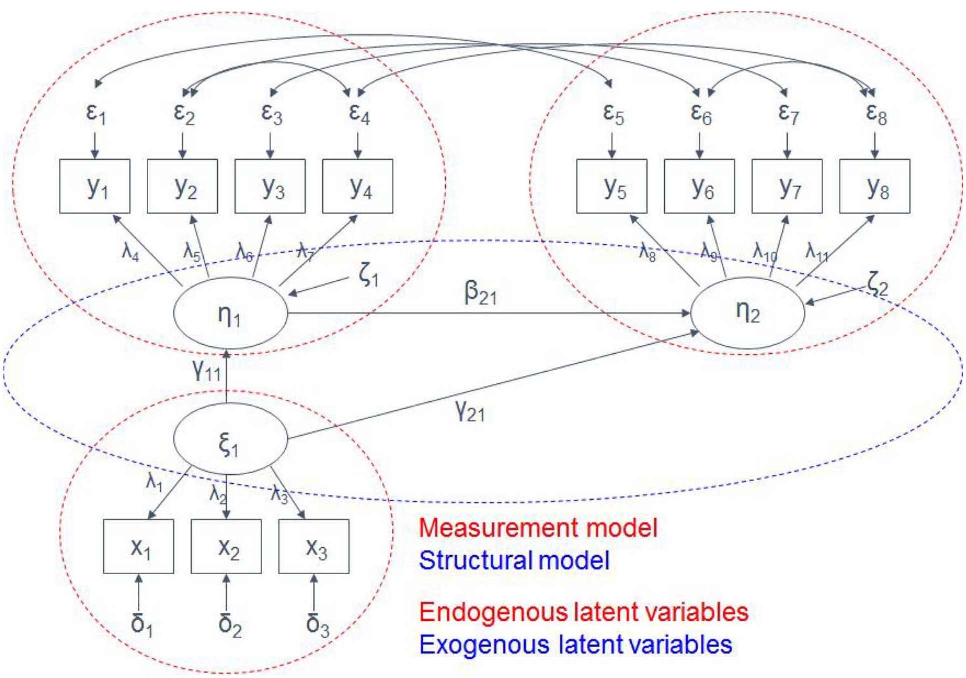

Fig. 2. Concept of structural equation modeling.

depth on the road surface can cause a reduction in skid resistance and increase the possibility of accidents (Kabbach et al., 2011). Especially, wet road conditions on roads with a downward incline of 3% or more are closely associated with the number and severity of traffic accidents (Park et al., 2010). These conditions contribute to a sizable portion of severe accidents due to a combination of negative factors (Fridstrom et al., 1995; Edwards, 2002).

Previous studies proved that traffic accidents could be affected strongly by rain-related factors (Lee et al., 2008; Bae et al., 2013); however, these methods attempted to solve the problem using a general approach, which cannot explain traffic accident severity according to the levels of water depth on the roads because of limited data such as the use of dummy variables to represent information about wet or dry conditions.

Unlike previous research, this study estimated the road water film thickness by a method suggested by the British Road Research Laboratory (Ross and Russan, 1968; National Association of Australian State Road Authorities, 1974) and the rainfall intensity on traffic accident hotspots on the roads to prove the extent to which rain-related factors influence the severity of accidents by using data from a nine-year period (2007–2015).

In order to investigate the relationship, Structural Equation Modeling (SEM) is adopted because this model is capable of handling the complex interrelationship among endogenous and exogenous variables simultaneously. SEM was proposed in the research fields of natural science, transportation and safety, and other fields (Kuppam and Pendyala, 2001; Ulleberg and Pundmo, 2003). In the process of modelling, exogenous latent variables such as road factors, the traffic environment & human factors, rain & level of water depth were created to identify latent relationships for the "level of accident severity" of an endogenous variable.

This paper introduces methodologies for water depth estimation and SEMs. Data in use are described in this study. The results are shown as the estimation of the coefficients of latent, endogenous, and exogenous

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