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論　文　要　旨
Thesis Abstract

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主論文題名　（Title）Exploring analytical approaches to data-driven safety management for mountainous highways

内容の要旨　（Abstract）

Road safety is a critical global issue with significant challenges that need to be addressed immediately. Though the yearly road crash fatality has reduced in recent years, it is still among the top ten most common reasons for human death. The status of road safety in low- and middle-income countries (LMICs) is more threatening because more than 90% of the world's road crashes occur in those countries and the loss due to these crashes accounts for around 3% of the respective country's gross domestic product (GDP). This shows the urgency for mitigating fatal and severe injury (FSI) crashes. Road safety management is a systematic and planned approach aimed at preventing road crashes and reducing the severity of injuries resulting from crashes. It involves identifying safety problems, devising strategies to address these issues, and implementing interventions to improve road safety. The recent shift towards strategies like Vision Zero and Safe Systems, which use proactive measures for mitigating the FSI crashes has proved to be more effective than the conventional approaches. Safety management of mountainous roads is challenging because of the involvement of multiple features that need to be considered. Also, the cost of improvement is usually high. Mountainous roads have unique and diverse characteristics. Features like steep terrain, sharp curves, narrow carriageways, reduced sight distance, and visibility are some of the characteristics of mountainous roads, and such roads with poor safety measures can be very lethal both in terms of crash occurrence and severity.

This research explores different data-driven analytical approaches for road safety management for mountainous highways. The primary objectives include developing predictive models for road crash occurrence, frequency, and severity by exploring different statistical and machine-learning algorithms. To formulate these models, a comprehensive review of literature was initially performed to identify different safety attributes deemed significant in evaluating the safety performance of a mountainous highway. The study highway was divided into finer segments and information on the safety attributes identified earlier was gathered through the primary and secondary sources. Speed plays a fundamental role in crash occurrence and severity, hence initially vehicle operating speed prediction model was developed to estimate the

speed of vehicles in road segments. The crash predictive models were built using previous crash records along with significant features like vehicle speed, traffic volume, and the selected safety attributes related to road geometry, roadside environment, pavement condition, and existing safety measures. Developed predictive models were examined for their accuracy and the best models were used for estimation of future crashes. These models not only predicted future crashes but also provided valuable information on the significant variables that impact crash occurrence, frequency, and severity.

The secondary objective of the study was to use prescriptive models for decision-making. The predictive models developed were used to evaluate the effectiveness of safety interventions in reducing fatal and serious injury (FSI) crashes. Generally, decision-making regarding the selection of safety interventions for safety improvement is instinct-driven rather than data-driven, and as a result, the return from the investment cannot be guaranteed. Furthermore, the budget for safety improvement is usually scarce in the context of the LMICs and the cost of interventions for mountainous roads is relatively higher. In the absence of a tool for budget optimization and allocation, there is a chance that effective interventions may not be selected and implemented. This research proposes a data-driven decision support framework where predictive models are used to develop a prescriptive model to identify interventions in road segments, such that there is a maximum reduction in FSI crashes. Information on the possible set of interventions, their cost and effectiveness, and the allocated budget is fed to the budget optimization model to select the most effective interventions.

The framework developed through this study comprises data-driven predictive and prescriptive models, which are based on machine-learning algorithms that showed fair prediction accuracy. Therefore, the use of this framework is expected to provide reliable results and hence can be used by road agencies for execution in real life to improve the safety condition of mountainous roads. The predictive models were assessed for external validation using data from another highway and most of them were found to generalize well. Therefore, they can be easily used for other mountainous highways. Furthermore, it is believed that this study will provide immense knowledge to other researchers working in the same domain about attributes of mountainous highways that showed a significant relationship with crash occurrence and severity. Furthermore, the analytical modeling approaches taken in this study can provide other researchers with ideas on how these models can be used along with the data in the best way for effective road safety management.

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