Generalized Leading Indicator Model for Infrequent Events in Safety-Critical Systems and its Application to Marine Transportation Systems

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ABSTRACT

In safety-critical systems, such as marine transportation systems, when an adverse event, such as an accident, happens, organizations suffer economic losses, workplace injuries, and even fatalities. These are the consequences of adverse events, which are called lagging indicators. Lagging indicators measure the historical performance and have limited predictive capability. Leading indicators, on the other hand, are conditions, events or measures that precede an adverse event and can predict the arrival of events. Therefore, it is essential to identify leading indicators in safety-critical systems to provide early warnings before adverse events happen.

In this study, first, a systematic approach with mixed techniques, including factor analysis, correlation analysis, and structural equation modeling, is developed to identify leading indicators in each of the three industry partners, two tanker organizations and one container organization, and the common leading indicators in three organizations. Second, a generalizability model of unbalanced design with missing data is developed, to estimate and test the generalizability of the identified leading indicators. That is, whether the leading indicators can be used in other organizations. Third, using the identified generalizable leading indicators, predictive models are developed, combining with fuzzy logic, to predict the probability that there is a potential adverse event, to predict the safety quality level, and to predict the number of adverse events.

With the contributions in this research, efforts on identifying leading indicators can be saved so that more efforts can be concentrated on the management of leading indicators and the prediction of safety performance to provide early warnings.