This study focuses on providing a framework of risk assessment to promote safety and enhance mobility on freeways and expressways. Multi-level Safety Performance Functions (SPFs) were developed at the aggregate level using historical crash data and the corresponding exposure and risk factors to identify and rank sites with promise (hot spots). Additionally, SPFs were developed at the disaggregate level utilizing real-time weather data collected from meteorological stations located at the freeway section as well as traffic flow parameters collected from different detection systems such as Automatic Vehicle Identification (AVI) and Remote Traffic Microwave Sensors (RTMS). These disaggregate SPFs can identify real-time risks due to turbulent traffic conditions and their interactions with other risk factors.

In this study, there were two main datasets that were obtained from two different regions; 78-miles on the expressway network in Orlando, Florida, and a 20-mile mountainous Interstate roadway-section west of Denver, Colorado. These datasets comprise historical crash data, roadway geometrical characteristics, aggregate weather and traffic parameters as well as real-time weather and traffic data.

At the aggregate level, Bayesian hierarchical models with spatial and random effects were compared to Poisson models to examine the safety effects of roadway geometrics on crash occurrence along freeway sections that feature mountainous terrain and adverse weather. At the disaggregate level; a main framework of a proactive safety management system using traffic data collected from AVI and RTMS, real-time weather and geometrical characteristics was provided. Different statistical techniques were implemented, these techniques ranged from classical frequentist classification approaches to explain the relationship between an event (crash) occurring at a given time and a set of risk factors in real time, Bayesian statistics with updating approach to update beliefs about the behavior of the parameter with prior knowledge in order to achieve more reliable estimation, to a relatively recent and promising Machine Learning technique (Stochastic Gradient Boosting) to calibrate several models utilizing different datasets collected from mixed detection systems as well as real-time meteorological stations.

The results from this study suggest that both levels of analyses are important, the aggregate level helps in providing good understanding of different safety problems, and developing policies and countermeasures to reduce the number of crashes in total. At the disaggregate level, real-time safety functions help toward more proactive traffic management system that will not only enhance the performance of the high speed facilities and the whole traffic network but also provide safer mobility for people and goods. In general, the proposed multi-level analyses are useful in providing roadway authorities with detailed information on where countermeasures must be implemented and when resources should be devoted. The study also proves that traffic data collected from different detection systems could be a useful asset that should be utilized appropriately not only to alleviate traffic congestion but also to mitigate increased safety risks. The overall proposed framework can maximize the benefit of the existing archived data for freeways/expressways authorities as well as for road users.