Crash frequency analysis is a crucial tool to investigate traffic safety problems. With the objective of revealing hazardous factors which would affect crash occurrence, crash frequency analysis has been undertaken at the macroscopic and microscopic levels. At the macroscopic level, crashes from a spatial aggregation (such as traffic analysis zone or county) are considered to quantify the impacts of socioeconomic and demographic characteristics, transportation demand and network attributes so as to provide countermeasures from a planning perspective. On the other hand, the microscopic crashes on a segment or intersection are analyzed to identify the influence of geometric design, lighting and traffic flow characteristics with the objective of offering engineering solutions (such as installing sidewalk and bike lane, adding lighting). Although numerous traffic safety studies have been conducted, still there are critical limitations at both levels. In this dissertation, several methodologies have been proposed to alleviate several limitations in the macro- and micro-level safety research. Then, an innovative method has been suggested to analyze crashes at the two levels, simultaneously.

At the macro-level, the viability of dual-state models (i.e., zero-inflated and hurdle models) were explored for traffic analysis zone based pedestrian and bicycle crash analysis. Then, the modifiable areal unit problem for macro-level crash analysis was discussed. In this study, a comparative analysis was conducted to determine the optimal zonal system for macroscopic crash modeling considering census tracts (CTs), traffic analysis zones (TAZs), and a newly developed traffic-related zone system labeled traffic analysis districts (TADs). Based on the modeling results, it is recommended to adopt TADs for transportation safety planning.

After determining the optimal traffic safety analysis zonal system, further analysis was conducted for non-motorist crashes (pedestrian and bicycle crashes). This study contributed to the literature on pedestrian and bicyclist safety by building on the conventional count regression models to explore exogenous factors affecting pedestrian and bicyclist crashes at the macroscopic level. To accommodate for the potentially different impact of exogenous factors we converted the non-motorist crash counts as the product of total crash counts and proportion of non-motorist crashes and formulated a joint model of the negative binomial (NB) model and the logit model to deal with the two parts, respectively.

At the microscopic level, crash modeling analysis was conducted for road facilities. This study, first, explored the potential macro-level effects which are always excluded or omitted in the previous studies.

In addition to the separated analysis at either the macro- or micro-level, an integrated approach has been proposed to examine traffic safety problems at the two levels, simultaneously. This study proposed a Bayesian integrated spatial crash frequency model, which linked the crash counts of macro- and micro-levels based on the spatial interaction.