Econometric crash frequency models are a major analytical tool employed for examining the critical factors influencing crash occurrence. However, there are several methodological challenges associated with existing models suggesting a continual need to develop advanced econometric framework to address these gaps. The current dissertation contributes towards addressing the methodological challenges in crash frequency analysis for analyzing multiple crash frequency variables for the same study unit by proposing advanced econometric approaches. The first part of the dissertation contributes to safety literature by conducting a comparison exercise between the two major streams of multivariate approaches - (1) simulation-based approach and (2) analytical closed form approach - for analyzing the crash counts considering different crash types. In the second part of the dissertation, we propose an alternative and mathematically simpler approach for analyzing multiple crash frequency variables for the same study unit by recasting a multivariate distributional problem as a repeated measures univariate problem. The recasting allows us to estimate parsimonious model systems thus improving parameter estimation efficiency. The third part of the dissertation contributes to burgeoning econometric and safety literature by developing a joint modeling approach that can accommodate for several dependent variables within a parsimonious structure. By recasting the analysis levels for dependent variables, the proposed approach allows for flexible consideration of crashes by type and severity within a single framework. The final part of the dissertation contributes to literature on crash frequency analysis by accommodating population heterogeneity in the impact of exogenous variables. The empirical analysis in this dissertation is based on traffic analysis zone (TAZ) level crash count data for both motorized and non-motorized crashes from Central Florida for the year 2016.