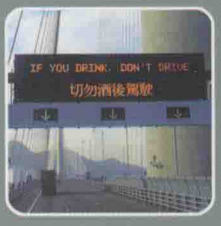

道路交通安全综合评价理论与方法

BAYESIAN APPROACH TO ROAD SAFETY ANALYSES

裴欣 著

北京交通大学出版社
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内 容 简 介

本书在对现有道路交通安全评估研究进行综述分析的基础上，建立了基于完全贝叶斯方法的道路交通安全综合评价理论与方法。其核心——道路事故风险与伤亡程度双层综合评价模型，用以发掘各影响因素与道路安全的关联性，进行特定条件下交通安全状况的评估与事故风险预测；该模型架构简洁、结构灵活，模型求解可运用基于马尔科夫链蒙特卡洛仿真的完全贝叶斯方法。本书将这一综合评价模型分别应用于信号灯交叉口和道路路段，研究道路设计要素、危险暴露量和车速在路口和路段交通安全分析中的作用，验证了模型的适用性与有效性。

本书可供从事交通安全相关研究的研究者参考，也可供对交通安全、交通工程、统计分析等相关专业感兴趣的人士参阅。

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·北京·

前　言

道路交通安全是关系到人类健康与发展的全球性问题。目前，全世界每年约有130万人死于道路交通事故，其中90%来自发展中国家，每年交通事故还造成五千万人受伤，并造成约5200亿美元的经济损失，给个人、家庭和社会带来沉重影响。世界卫生组织预计到2030年，交通事故将成为世界第五大死因。2011年5月11日，联合国启动实施《2011—2020道路交通安全十年行动计划》，呼吁世界各国政府建立更安全的路网，挽救更多人的生命。在我国，虽然近年道路交通事故呈下降趋势，但随着经济社会发展和城镇化、机动化进程的不断加快，影响道路交通安全的因素仍然很多，有些还未得到有效解决，我国仍处于道路交通事故的高发期，道路交通事故死亡人数总量仍然很大，万车死亡率相比其他国家仍处于较高水平，交通安全问题仍然非常严峻。因此，对于道路事故特征及发生机理的研究具有重要的社会和经济意义。

建立事故预测模型，进行道路安全综合评价是交通安全研究与分析的重要方法。传统的最大似然估计法在较为复杂问题的建模与分析方面有其不足，需要研究新的方法来解决新的问题。本书在对现有安全评估研究进行综述分析的基础上，建立了基于完全贝叶斯推论方法的道路事故风险与伤亡程度双层综合评价模型，并通过模型在路段和路口交通安全综合评价中的实际应用验证了综合评价模型的适用性与有效性。

本书的编写得到了很多支持。衷心感谢香港大学的黄仕进教授对作者研究工作的悉心指导，诚挚感谢香港大学的施能艺博士给予非常具有启发性的意见与建议，同时感谢清华大学的张毅教授、姚丹亚教授以及智能交通综合实验室的同仁们给予的帮助和支持。特别地，感谢秦晓教授、黄合来教授、Dr. Kangwon Shin与Prof. Rune Elvik对作者研究课题的有益建议。本书的部分研究数据由香港特区政府及宇航卫星科技有限公司提供，在此致谢。

本书的出版还得到了香港特区政府RGC基金项目（No. HKU7176/07E）、中国博士后基金项目（No. 2012M510461）、国家自然科学基金项目（No. 61021063）、国家重点基础研究发展计划（973计划）项目（No. 2012M510461）以及国家高技术研究发展计划（863计划）项目（No. 2011AA110400）的支持，在此一

并表示感谢。

本书所提出的理论框架与方法架构简洁，形式灵活，可根据具体问题设计模型结构，尝试在道路交通安全综合评价中进行更广泛的应用。真诚欢迎各位专家和同行就交通安全综合评价的理论与方法进行讨论，推进道路交通事故的研究工作，共同致力于改善道路安全。

编　者

2013 年 1 月

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CHAPTER 1

INTRODUCTION

1.1 GENERAL INTRODUCTION

Road safety is a global issue linked to health and development. With more than 1.2 million road deaths and 50 million injuries every year, road traffic injury is now emerging as a serious epidemic across the world. The World Health Organization (WHO) predicts that road crashes will become the fifth leading cause of death worldwide by 2030 (WHO, 2009).

Road crashes not only injure the victims directly, but also affect their families and social networks. It is estimated that there are roughly 100 million families globally suffering from the injury of a family member in a traffic crash. Road fatalities and injuries also result in great loss of property. The annual cost of road traffic injuries worldwide is estimated to be US$520 billion (WHO, 2004). Road safety is thus of great concern for decision makers, governments, local authorities, traffic engineers, and the general public.

Various countries and organizations have made great efforts to improve road safety using a host of strategies. Recently, the United Nations (UN) proposed a global plan for the "Decades of Action for Road Safety 2011-2020", calling on member countries and communities to join the campaign for global road safety. Increasing numbers of researchers are now focusing on road safety issues from

various perspectives, such as health, society, economics, and engineering.

Traditionally, traffic accidents are considered to be random events that are hard to predict and prevent. However, with the more recent influence of the discipline of epidemiology, traffic crashes are gradually being accepted as a type of epidemic that can be analyzed by exploring the relationship between explanatory factors and outcomes. An understanding of the influence of explanatory factors on road safety is thus paramount in attempts to reduce the crash risk.

Descriptive methods are usually preferred for safety analyses. However, with the development of statistical techniques, quantitative predictive analysis is rapidly gaining ascendency, and is now widely used for road safety analysis (National Research Council, 2010). Quantitative predictive models are applied to road safety analyses by evaluating the effects of explanatory factors on safety performance. This allows safety performance functions to be established to assess or predict the safety of a network or individual road entity.

In developing road safety quantitative models, three indicators are generally considered: the length of exposure, the risk of a crash occurrence, and the injury severity level resulting from a crash (Rumar, 2002). This research develops a joint model by integrating predictions of crash occurrence and crash severity into a single framework to investigate the relationship between various explanatory factors and road safety using the Markov Chain Monte Carlo (MCMC) approach full Bayesian method. The proposed model is applied to the safety analysis of signalized intersections and road segments, respectively, in Hong Kong based on an established comprehensive database that incorporates crash data, traffic characteristics, road geometry and operation factors, environmental factors, and temporal distribution.

Hong Kong is a densely developed metropolitan area, with a total population in 2009 of 7 million and 584 000 registered vehicles within an area of just 1104 sq. km (Census and Statistics Department, 2010). Over the past few decades, road safety in Hong Kong has significantly improved, with a promising declining trend in the number of road casualties and mortalities. Hong Kong now has one of the lowest per

capita road fatality rates of all world cities (as shown in Table 1.1). The results of road safety analyses in Hong Kong should thus give traffic safety practitioners a better understanding of the road infrastructure design, enforcement measures, and policy programs that bring about better road safety performance.

Table 1.1 Fatality rate per million of the population in various cities

District	City	Year	Fatality rate
Asia	Bangkok	2008	109
	Singapore	2009	38
	Seoul	2008	48
	Hong Kong	**2009**	**20**
	Osaka	2009	23
Europe	Luxembourg	2008	72
	Greater Manchester	2008	24
	Barcelona	2008	25
	Frankfurt	2008	36
	Greater London	2008	27
	Stockholm	2008	11
North America	Montreal	2009	20
Oceania	Melbourne	2009	37
	Auckland	2009	23

Source: Transport Department (2010) Road Traffic Accident Statistics, 2009. http://www.td.gov.hk/en/road_safety/road_traffic_accident_statistics/index.html (accessed 9 Nov. 2010).

1.2 OBJECTIVES

The aim of the research in this book is to develop a joint probability model in a Bayesian framework for the comprehensive road safety analysis of signalized intersections and road segments, respectively. The specific objectives are as follows.

The objectives of the modeling are

(1) to review the development of road safety analysis methods adopted in past studies;

(2) to establish an integrated modeling framework by incorporating crash occurrence and crash severity models into a joint probability model; and

(3) to introduce a simulation-based MCMC full Bayesian approach for the modeling and inference of the proposed model.

The proposed joint probability model is then applied to conduct a safety analysis of signalized intersections

(1) to establish a comprehensive database involving crash data, traffic volume, geometric design, traffic characteristics, and signal phasing factors at 262 selected signalized intersections in Hong Kong;

(2) to establish two alternative joint probability models in a Bayesian framework and select the most appropriate model based on a goodness-of-fit assessment; and

(3) to explore the different effects of various contributory factors on the crash occurrence at different severity levels, and to reveal the association between crash occurrence and exposure in terms of traffic volume.

The proposed model is further applied to analyze the safety for road segments, with a focus on the roles of speed and exposure. The objectives of this part of the study are

(1) to establish a comprehensive database involving crash data, disaggregated traffic volume and speed data, road geometry and operation factors, weather information and temporal distribution for 112 selected road segments in Hong Kong;

(2) to develop joint probability models with the Bayesian approach considering distance exposure and time exposure; and

(3) to evaluate the effects of average speed and speed dispersion on the crash occurrence and severity with respect to distance and time exposure, respectively, by controlling the effects of various confounding factors.

From a long-term perspective, the proposed predictive model will help to

identify the significant parameters that affect road safety, and should increase our knowledge of the roles of exposure, speed, and other contributory factors in road safety. This information should prove useful in the formulation and design of effective road safety management measures to reduce crashes and casualties, which would be of great social and economic benefit to society.

1.3 BOOK STRUCTURE

Chapter 2 introduces the development of road safety analysis methods. Three important evaluation criteria for road safety performance are presented, together with the corresponding predictive models proposed in the literature. The estimation methods for the statistical models are also discussed in this chapter.

Chapter 3 demonstrates the development of the integrated modeling framework. The derivation and structure of the proposed joint probability models are elaborated, and their notation and formulation are described. The maximum likelihood estimation method and the Bayesian method are introduced in terms of their principles, formulation, inference and assessment, and the choice of the latter estimation method for this research is explained.

In Chapter 4 and Chapter 5, the capability and efficiency of the proposed joint probability models are illustrated by applying them to the safety analysis for signalized intersections and road segments, respectively. A MCMC simulation full Bayesian approach is adopted for the model estimation.

Chapter 4 assesses the effects of various explanatory factors on the crash occurrence and severity, respectively, at signalized intersections. The joint models are then applied to reveal the different effects of the same factor at different crash severity levels, and the results are illustrated and discussed.

Chapter 5 focuses on the role of exposure and speed in road safety analysis. The effect of speed on the crash risk with respect to distance exposure and time exposure is evaluated based on disaggregated crash and speed data. The effects of