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Prediction of Urban Road Congestion Using a Bayesian Network Approach

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Abstract

A reasonable prediction of the possibility of traffic congestion is able to help traffic managers to make efficient decisions to reduce the negative effect of traffic congestion. Previous research has made valuable analyses in this field. However, they rarely consider the dependency and uncertainty of traffic jams. In consideration of the characteristics of traffic congestion from different perspectives, this research proposes a Bayesian Network (BN) analysis approach to predict the possibility of urban traffic congestion. The built-up area of Beijing is taken as the study area of this research. A comprehensive set of variables are utilized to reflect the characteristics of traffic congestion from various viewpoints. The BN method is used to analyze the uncertainty and probability of traffic congestion, and is proved to be fully capable of representing the stochastic nature of traffic congestion. Furthermore, the difference of the congestion probabilities because of applying different urban transport development policies is analyzed in comparison. The study results show that the both road construction and bus system development at the same time can obviously mitigate traffic congestion for the built-up area of Beijing. In the future research, the impact of the comprehensive development of various travel modes on urban traffic congestion needs further studies.

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Keywords: Urban road congestion; Bayesian Network; Certain directional dependence analysis; Clique Tree ; Probabilistic inference

1. Introduction

With the prosperity of economy, the urban traffic demands in China have got unprecedented rapid growths.

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During the period of "Eleventh Five-year Plan" of Chinese government, the total urban travel demand has been increased by about 44.10%, while urban road mileage has been increased by only 26.30%. Because the existing road infrastructures cannot meet the traffic demands, traffic congestion become more and more common in a city of China. Till the end of 2010, the traffic congestion index (TCI) has reached eight for the urban area within the second ring road of Beijing (BTRC, 2011). Facing up to the serious traffic congestion, traffic managers are eager to rationally predict the possibility of traffic congestion for their efficient decision-makings.

Effective and accurate congestion prediction method is an essential part of any successful traffic management system. A geographic information systems (GIS) based methodology could estimate congestion and assess the reliability of road links and such methods use travel time and travel delays to reflect the level of traffic congestion (Pulugurtha et al., 2010). Wang and Wang (2012) establish a traffic flow model based on scale-free networks and random networks, and investigate the relationship between direction-depended heterogeneity and traffic congestion transition. Arnott (2013) proposes a bathtub model to analyze the traffic congestion in downtown area in rush-hour. Previous research has got valuable results. However, they rarely consider the dependency and uncertainty of traffic jams. In consideration of the characteristics of traffic congestion, this research uses the Bayesian Network (BN) method to accurately predict the probability of urban traffic congestion. The remaining part of this paper is organized as follows. In Section 2, the study area, Beijing built-up area, is briefly introduced. After that, the method of BN in this study is described in Section 3. Section 4 compares the traffic congestion probabilities because of applying different urban transport development policies. Finally, this study is concluded in Section 5.

2. Study area and survey data

Traffic congestion is extremely serious in some cities such as Beijing. In this study, the built-up area of Beijing is utilized as the study area. The urban traffic congestion is closely related to a series of issues including urbanization, road network structure, and so on. The description of the utilized variables in this research is given in Table 1. The proportion of severe congestion mileage of road network (Guo et al., 2007) is used to define the severity of the road network congestion. Data corresponding to the variables in the BN are collected from Beijing Statistical Yearbook, Beijing Transportation Research Center and traffic websites. Data complement methods are also used to make up missing data.

Table 1. Description of the variables

Variable	Description	Discrete state description
C	Proportion of severe congestion mileage of road network	0 passage clear；1 congestion
K	Urban land expansion coefficient	0 lack of expansion；1 rapid expansion
L	Density of the road network	0 low；1 high
I	Proportion of urban public transport investment to gross domestic product	0 unreasonable；1 reasonable
O	Growth rate of private car ownership rate	0 low；1 high
R	Proportion of rail trips to public transport trips	0 low；1 high
B	Ten thousand people ownership of buses	0 low；1 medium; 2 high
E	Death rate of ten thousand vehicles	0 low；1 high

3. Methodology

3.1. BN learning

The orders of the variables used in BN method is usually not given in advance. Therefore, it is difficult to give the prior structure of the BN. In this research, a directional dependence analysis (Wang, 2010) is adopted to learn a BN structure. The purpose of this directional dependence analysis is using statistical or information theoretic measures to calculate the conditional independencies between the variables. It can further determine the existence