

# ROAD PAVEMENT CONDITION MODELLING AND PREDICTION USING BAYESIAN NETWORK

Alip Novita Sari<sup>1,a,\*</sup>, Ria A.A. Soemitro<sup>2,b</sup> and Trijoko Wahyu Adi<sup>3,c</sup>

<sup>1,2,3</sup>Civil Engineering Department, Institute Technology of Sepuluh Nopember

Civil Engineering Building 2<sup>nd</sup> floor, ITS Sukolilo Campus, Surabaya 60111, Indonesia

[alipnovitasari@gmail.com](mailto:alipnovitasari@gmail.com), [ria@ce.its.ac.id](mailto:ria@ce.its.ac.id), [tri\\_joko@ce.its.ac.id](mailto:tri_joko@ce.its.ac.id)

**Keywords:** Deterioration, road pavement prediction, Bayesian Network (BN),

## Abstrak

Road deterioration is caused by poor structure, poor drainage, climatic or geological effect and loading. The existing models for condition prediction can be categorized into three main groups, namely deterministic models, probabilistic models and Bayesian models. Among them, one of the most commonly used discrete time stochastic process models is the Markov Chain (MC) model. However, it has limitations that cannot renewed road deterioration factors in real time. This research can minimize the limitation of Markov Chain using prediction model, which is more real time because it is considered by the road damage factors and conditional dependence relationship of the factors.

The architecture design of proposed model using Bayesian Network. The proposed model requires Static Bayesian Network (BN). Static Bayesian Network identifies factors responsible for pavement failure and conditional dependence relationship of the factors. In creating a model, there are two sources of information used namely expert knowledge and historical data.

The purpose of this research is to develop road deterioration model for predicting future road condition in national road network on the national road of Batas Kota Caruban – Batas Kab Nganjuk. The prediction results showed that the road condition in next year is 51 % in a good condition, 44 % in a moderate condition, 3 % in bad condition and only 1 % in a very bad condition. Value road conditions increased by 14 % compared to the previous condition. The prediction result of this model can be used to prepare road maintenance plan. In addition, this model will improve an effective maintenance optimization.

## INTRODUCTION

Over the last several decades due to increasing number of vehicles, a large number of road infrastructures for transport have been built. The sustainable maintenance of these roads has been drawing increasing attention recently because of constrained budget funding and ineffective maintenance. The ineffective maintenance of these roads increases the road deterioration. Road deterioration is caused by poor structure, poor drainage, climatic or geological effect and loading.

Predicting deterioration is a vital component of pavement management systems. The ability of road deterioration models to predict future condition determines the quality of maintenance decision. The existing models for condition prediction can be categorized into three main groups, namely deterministic models, probabilistic models and Bayesian models. Among them, one of the most commonly used discrete time stochastic process models is the Markov Chain (MC) model. However, it has limitations that cannot renewed road deterioration factor in real time. This research can minimize the limitation of Markov Chain using prediction model which is more real time because it is considered by the road damage factors and conditional dependence relationship of the factors.

This paper proposed a model using Bayesian Network (BN) for road pavement condition using Software Genie 2.0. This research will be applied to the

data collected from Batas Kota Caruban – Batas Kab Nganjuk.

## BN THEORY

Bayes' Theorem is a theorem of probability theory originally stated by the Reverend Thomas Bayes. Bayesian networks, also known as Bayesian belief network or belief networks, are a modelling technique for causal relationship based on Bayesian inference. A BN contains two key aspects. The first is a graphical representation of the dependencies between variables. A directed acyclic graph (DAG) is used to represent this. Each variable is represented by a single node within the graph. Direct causal dependencies are represented by a directed arc from the "causing" node to the node that is affected.

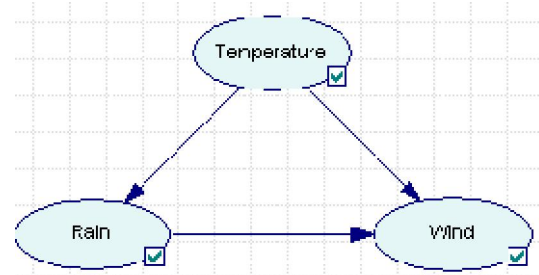


Fig 1. Simple Bayesian Network







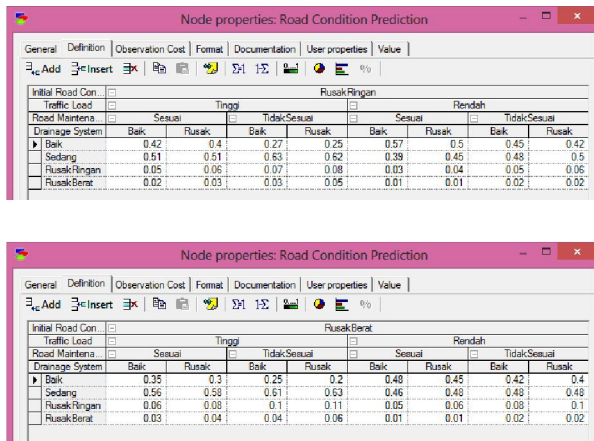


Fig 11. CPT Road condition prediction

### PREDICTION RESULT

After complete the charging of CPT value of each variable, then complete DAG can be displayed with a probability value of each variable represented in the form of a bar chart. Diagram is used as the basis for calculating the probability or prediction of condition.

The road condition prediction in the next year under many factors were generated using Software Genie 2.0. The BN model is supported by Genie, which actually runs the inference algorithm for the condition prediction.

The prediction results showed that the road condition in next year is 51% in a good condition, 44% in a moderate condition, 3% in bad condition and only 1% in a very bad condition. Value road conditions increased by 14% compared to the previous condition this could be due to the maintenance of appropriate measures and quality execution of work in accordance with the standard.

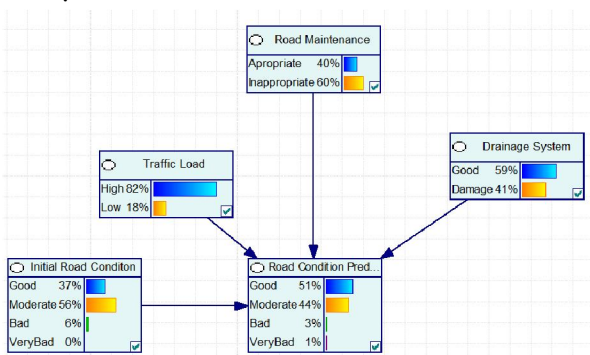


Fig 12. Road Condition Probability

BN has the ability to do the updating. To demonstrate the Bayesian updating ability, some scenarios have been built to demonstrate it.

#### 1. First scenario, set evidence node maintenance

If found evidence of maintenance activities carried out in accordance with the value of the condition, then the value of the good condition of the road for the next year will increase from 37% to 59%.

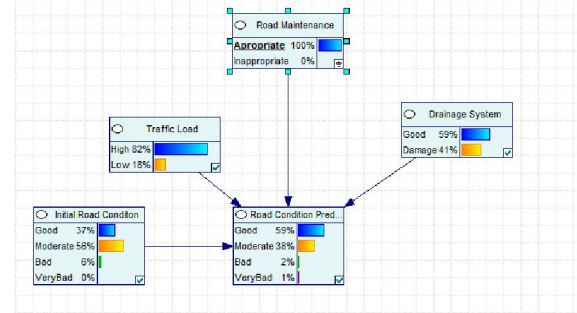


Fig 13. Evidence maintenance

#### 2. Second scenario, set evidence drainage system

If found evidence that good drainage system and drain water functioning well, the value of the condition of the road for the next year will increase from 37% to 54%.

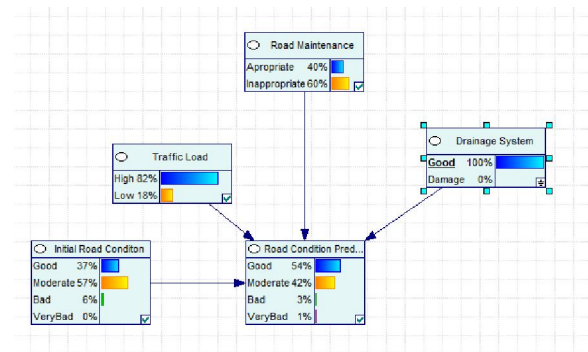
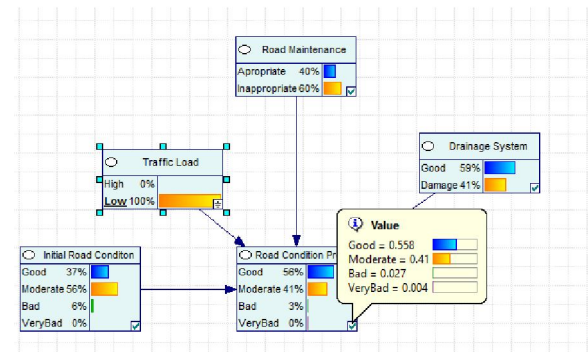


Fig 14. Evidence system drainage

#### 3. Third scenario, set evidence traffic load

If found evidence that traffic load high, the value of the condition for the next year will increase from 37% to 56%.





## CONCLUSIONS

Based on the results of this study the following conclusions are drawn :

1. The variables that very significant on road pavement damage is drainage system, traffic load , and maintenance of roads. The variables has an average value / mean more than 4.
2. From the second questionnaire using correlation matrix shows that all of the variables are connected directly with road conditions.
3. The prediction results showed that the road condition in next year is 51 % in a good condition, 44 % in a moderate condition, 3 % in bad condition and only 1 % in a very bad condition. Value road conditions increased by 14 % compared to the previous condition.
4. Fourth scenarios have been conducted to show the Bayesian updating ability. Variables that most affect the road condition prediction are maintenance variable that shown in the first scenario with a probability value 59 %, increase 29 % from previous year.

5. Method of Bayesian network can be used to predict the uncertainty and can be updated whenever there is new information. The model has the ability to consider multiple deterioration factors jointly.

## REFERENCES

- [1] Arie, Panji. (2008), Influence Factors Analysis That Caused Flexible Pavement Distress. Final Project, Universitas Indonesia, Jakarta
- [2] Asghar, Ali. (2001), Pavement Management System for Canadian Forces Bases. Thesis, University of Ottawa, Ottawa.
- [3] Kock, Matthew. (2008), Weather Forecasting Using Dynamic Bayesian Networks, Department of Computer Science University of Cape Town
- [4] Murphy K. (2002). *Dynamic Bayesian Network: Representation, Inference and Learning*. Disertation, University of California, Berkeley
- [5] Ministry of Public Works and Public Housing. 2011a. Regulation of The Minister of Public Works and Public Housing No. 13/PRT/M/2011 about procedures for maintenance and inspection road infrastructures. Secretary of Ministry of Public Works and Public Housing, Jakarta.