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PROBABILISTIC PREDICTION OF TIME PERFORMANCE IN BUILDING CONSTRUCTION PROJECT USING BAYESIAN BELIEF NETWORKS-MARKOV CHAIN

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ABSTRACT

Time performance is one of the main success criteria of construction project. There are many uncertainty factors that affecting the time performance of building construction projects. However, time performance measurement on the previous research didn't calculate probability the correlation of uncertainty factors.This study aims to predict the probability of project time performance using Bayesian Belief Networks (BBN)-Markov Chain (MC) hybrid. MC is used to represent the dynamic progress of the project and connected the uncertainty factors by BBN. Data is collected by literature study, location survey, questionnaire and interview with expert. Model validation is investigated by applying in a case study of construction projects, building P,Q and R in the city of Surabaya. The results showed that the time performance prediction of the building construction project using the BBN- Markov Chain hybrid was accurately. It can be used measurement method of time performance and provide early warning of time delay in construction project.

Keywords: building construction projects, time performance, probabilistic, Markov Chain, Bayesian Belief Networks.

INTRODUCTION

A success measurement for construction projects used five project success criteria where time performance is the first rank [1]. In the implementation of construction projects, there are several projects that are experiencing delays in the project. Based on research conducted by Odeyinka, 1997 (in [2]), that seven of ten surveyed project experienced delays in implementation. Research that has been carried byAl-Assaf and Heiji [3] of 76 construction projects in Saudi Arabia surveyed 45of them experienced time delays in implementation. While the main cause of time delay in the project implementation was contractors, especially in the preparation of resources and aspects of workplanning/scheduling [4].

To improve the prediction accuracy of the construction projects time, and more realistic, field conditions, this study proposes Bayesian Belief Networks-Markov Chain hybrid in measuring the performance of a project. Bayesian Belief Networks (BBN) is probabilistic graph that combined probability and graph theory to explain the variables that have a high degree of linkages. Models based BBN, also in corporate uncertainty through probability conditional and are a good tool to provide proactive action against the stakeholder [5]. Research relating to the use of Bayesian Belief Networks in the field of construction has been carried by Luu,*et.al* [5],Sahely [6] to diagnose disorders in an aerobic waste water treatment systems, McCabe [7] to diagnose the performance of construction, Bayraktar [8] for the extraction decisions on road maintenance, and Cardenas [9] using BBN approach to control risk of construction projects, while Attoh-Okine [10] using Belief Networks to determine the probability of the factors that affect the cost of highway construction. According to McCabe [7] Belief Networks has a lot of potential in civil engineering applications, including diagnosing and support decision making.

Stochastic process approach contains uncertainty and a collection of random variables corresponding to the time sequence (theHamilton, 1994). One of the stochastic process models is used to explain the phenomenon that the performance of the project time Markov Chain. Markov Chain is a special form of a probability model that is more commonly known as stochastic processes. In the Markov analysis, is probabilistic information can be used to aid decision making. The basic concept of a Markov Chain is a series of events in which the conditional probability future events depend on current events. Studies using the Markov Chain in the field of construction have been carried by Ranjith [11] in predicting damage to the wooden bridge elements, in Australia.

This study aims to calculate the probability prediction of time performance of construction projects that take into account the relationship between the uncertainty factors using BBN-MC, BBN presented causal relationship among a set of uncertainty factors and Markov Chain presented the dynamic process of the progress project over time. Prediction results of performance times in construction project accuratelly could help contractors to estimate projects contingency time and provide early warning of time delays in the construction project.

RESEARCH METHODOLOGY

Probabilistic modeling time performance of the construction project consisted of several steps: Step1.Created a model using Bayesian Belief Networks (BBN) and Markov Chain (MC). Stage Bayesian Belief Networks (BBN). Bayesian Belief Networks is a model to

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represent the uncertainty and probability theory to manage uncertainty. The most basic Bayes equation is [5],[7],[9]:

$$P(Y|X)=\frac{P(X|Y)xP(Y)}{P(X)} \quad (1)$$

P(X)is the probability of X, and P(Y) is the probability of Y, and P(X|Y) is the probability of X when Y is known events have occurred.

BBN describes the causal relationships among variables through the graphical model is a DAG (Directed Acyclic Graph). BBN consists of nodes that represent the variety of the domain, and arcs representing dependency relationships between nodes .Figure-1 shows the structure of a BBN simple, the node at the tail of the arrow is called the parent node, and the node at the head of the arrow is called child nodes. Each node has a probability value in the form of CPT (Conditional Probability Table) which is a quantitative component of Bayesian Belief Networks.

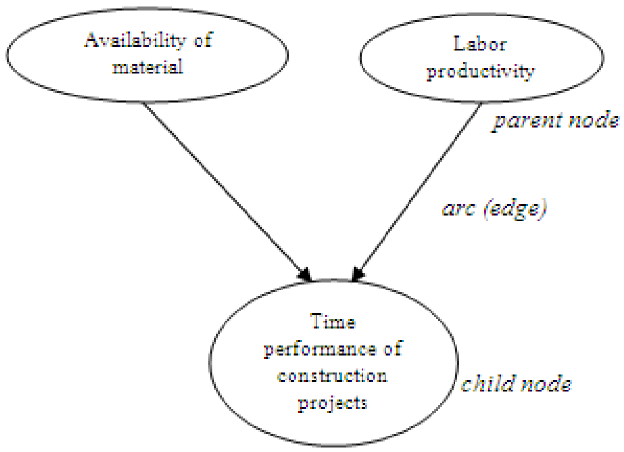

Figure-1.BBN Structure simple of time performance

Stage Bayesian Belief Networks (BBN), namely: a) Determine the factors that affect the performance of a construction project. b) factors through a method of filtering Focus Group Discussion (FGD). c) Obtaining a significant factor in the progress of the performance of a construction project. The most significant factor affecting the time performance of construction projects by the contractor based on the results a literature study, location survey, questionnaire and interview with construction expert namely:1) material prices fluctuation [12-17], fluctuation of materials price in the market that was not unexpected. 2) weather factors, [13-16], [18-20], which affect the implementation, extreme weather such as heavy rain and work flooding, which resulted in flooded job sites. 3) labor availability,[13-14],[20-24],[25-27], [31], labor resource consists of experts, skilled and unskilled labor available in the construction phase. 4) the accuracy of construction method, [5],[15],[20],[23-24],[26,-27],[31],[33] the sequence is a series of activities to build the appropriate contract requirements (drawings, specifications), availability of resources and project environmental conditions. 5) replacement of new labor [28], labor is replaced by new workers due to illness, resignation, so that new workers require adaptation, consequently productivity will decline. 6) delayed of materials delivery, [13-19], [21-24],[26-27],[29-30] ,materials used for construction have been delayed delivery, thus affecting availability of materials. 7) availability of construction materials, [5],[13-14], [18], [20-26],[29-32], basic materials, local and imported available during construction process. 8) availability of construction equipment, [5],[13-14],[18-20], [22-24],[26-27],[29],[32] all tools are used during project activity, either in the form of simple equipment is operated by human power or modern equipment is driven by the engine, available at the project site and when needed. 9) labor productivity, [13],[15-16],[20],[22-24],[27],[31] It is labor performance on every job done on the field. 10) Equipment productivity, [13], [23], [31], output is generated by a simple equipment and modern equipment during operation. d) Calculate the probability of project performance through an inference process of models with elimination variable using BBN. This step using Bayes program.

Stage Markov Chain. Suppose $\{X_t\}$ states Markov Chain with discrete time, and $i_0,i_1,...,i_k$, (k=0,1,2,.....) is a state of the system at any time. The probability of transition phase from state *ij* at time t to state *ik* at time (t_1) is called the one-step transition probabilities, denoted $P_{jk}^{t,t+1}$, where.

$$P_{jk}^{t,\,t+1}=P_r\{X_{t+1}=k|X_t = j\} \quad (2)$$

(Clymer,1990 in [34]).The probability depends on the initial state *j* and *k* as well as the final state depends on the time variable (t).

In general, the n step transition probability is given by:

$$P_{jk}^{(n)} = P_r\{X_{m+n} = k\ |X_m = j\} \quad (3)$$

$m = 0, 1, 2, ...$ and $n = 1, 2,3, ...$

Examples of transition probabilities can be presented in matrix form as follows:

$$P = \textit{initial state(j)} \begin{matrix} & \textit{final state(k)} \\ & \begin{matrix} 1 & 2 \end{matrix} \\ \begin{matrix} 1 \\ 2 \end{matrix} & \begin{bmatrix} P11 & P12 \\ P21 & P22 \end{bmatrix} \end{matrix}$$

The shape of the transition probability matrix can be drawn in the form of the Markov process diagrams in Figure-2.

Stage Markov Chain namely:a) Determining the initial progress probability of construction project time. b) Determining the transition by making a transition probability matrix. c) Determining the probability of permanent condition. d) Determining the percentage or probabilityof the final progress at the construction project time.At this stage using MATLAB program. The incorporation probability of Bayesian Belief Network to

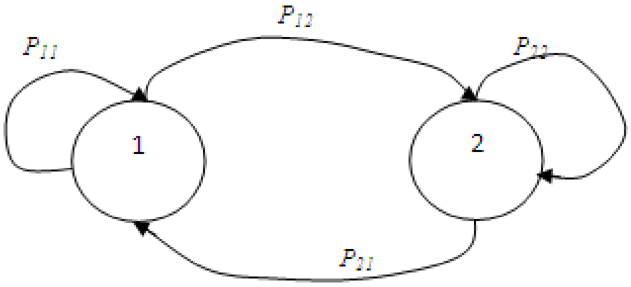

Figure-2. Example of transition probability in Markov process diagram.

the probability of a Markov Chain using the Joint Probability. Step-2. Model Validation, namely 1) To apply the model to some office building of the construction project (case study). 2) The measurement of model accuracy is calculated using statistical formulas Absolute Percentage Error (APE).

$$APE = \left|\frac{yt - \hat{y}t}{yt}\right| x\ 100 \qquad (4)$$

where
$\hat{y}_t$ = prediction value at week-t,
y_t = actual/real value at week-t,
t = prediction period (week).

If the value of APE<30, the accurate prediction models tobe used [12],[35]

3) Discuss the results of the model validation. At this stage, a performance measurement is done by calculating the expected value.

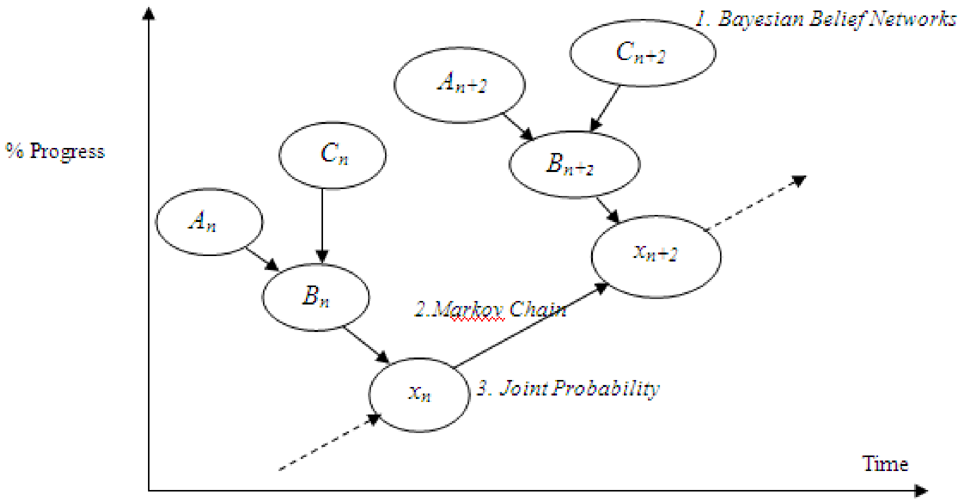

Figure-3. Stage of Bayesian belief networks with Markov Chain Model.

RESULT AND DISCUSSIONS

i. Structure of Bayesian Belief Network Model

The most significant factor affecting the time performance on the implementation of the construction project by the contractor based on the literature review, location survey, interview (expert opinion) and questionnaires [12], namely 1)material prices fluctuation, 2) weather factors, 3) labor availability,4) The accuracy of the construction method, 5) Replacement of new workers, 6) Delay of materials delivery,7) Availability of construction materials, 8) availability of construction equipment,9) labor productivity,10) equipment productivity. Conceptual model based on BBN to predict the probability of performance time is presented in Figure-4. In Figure-4, the performance of the project time is influenced directly by labor productivity factors, construction equipment productivity and availability of construction materials.

The relationship among uncertainty factor is determined by the matrix dependency method [36] through interview with construction expert. Matrix method is used to describe the relationship between the parent nodes and the child nodes. Furthermore, the model parameters are determined that the probability quantitative factors affecting the performance of a construction project with questionnaire, interview, expert opinion, or historical data. In Figure-4 presents a model BBN project to predict the probability of the building P project of time performance.

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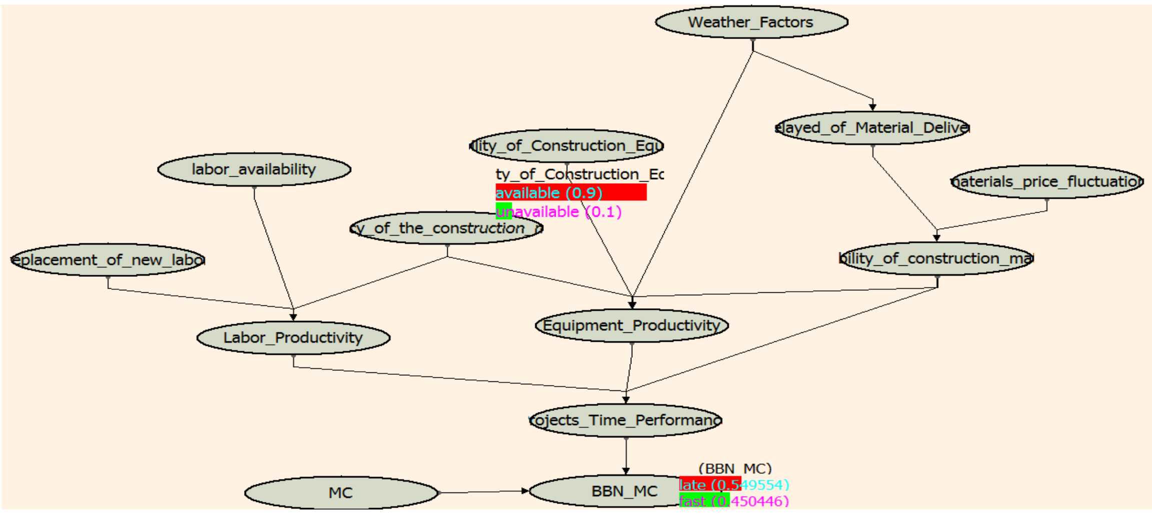

Figure-4. The conceptual BBN-based model for forecasting the probability of Project Time Performance (Building P).

ii. Description of case studies

BBN-MC model validation is done by applying the models in the case of building construction projects P, Q and R in the city of Surabaya, Indonesia. description of the project is presented in Table-1.

Table-1. Description of Building Construction Project.

Description	Project P	Project Q	Project R
Project type	Building project	Building project	Building project
Owner	Government	Government	Government
Project scope	12 floors	12 floors	11 floors plus roof
Period of execution based on contract	26 weeks	27 weeks	16 weeks
The contract value of physical	IDR 52.579.133.000,-	IDR58.580.000.000,-	IDR32.705.654.000,-

Sources: Secondary Data, 2015

iii. Prediction result of project time performance

The model is applied to the building P, Q and R project. Probability values of BBN-MC output for building P are presented in Figure 5 and Expected Value calculation results are presented in Figure-6.

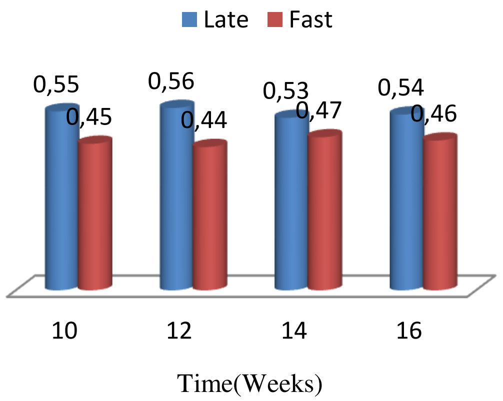

Figure-5. Probability value of BBN-MC Output (Building P).

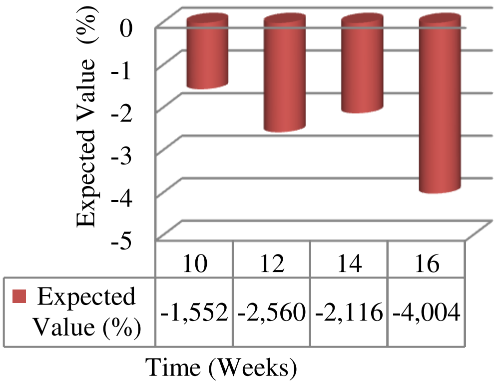

Figure-6. Calculation results of expected value (Building P).

Description
For Expected value=
Sign(-) negatively assumed late
Sign(+) positive assumed fast
Assumed zero on time

From the results obtained and calculated Expected Value project time performance. The result of a performance prediction of the construction project is presented in Figure-7. Figure-7 presents a time performance prediction building P project has been delayed at week 10,so that the BBN-MC model predictions begin in the week.

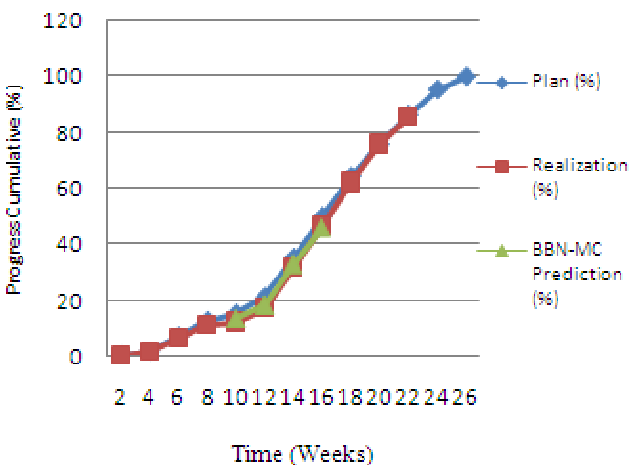

Figure-7. Prediction result of time performance in building P have been presented as "S" graphs.

iv. Model accuracy

The model accuracy is calculated using statistical formulas APE, calculation results were presented in Figure-9, it shows that the value of APE<30, proposed model is accurate.

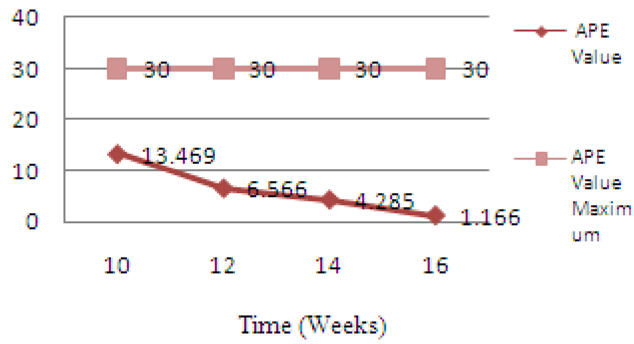

Figure-8. APE calculation results for model validation.

Note

Valid if the value of APE<30

Value of the average APE for three building construction projects are presented in Table-2.

Table-2. Results of the Average APE for Projects of Building P,Q and R.

Time (Weeks)	**Project of building P**	**Project of building Q**	**Project of building R**	***APE* mean**
10	13,469	8,715	2,083	8,089
12	6,566	2,672	0,777	3,338
14	4,285	3,401	2,612	3,433
16	1,166	8,097	0,363	3,209
APE mean	6,372	5,721	1,459	**4,517**

Based on the results of model validation, the BBN-MC models are proposed to measure the performance of a construction project gave good accuracy with APE mean is 4,517.The model can be used as an alternative method of measuring the construction project performance and provide early warning of delays in the project timeline.

Model predictions of BBN-time performance of the proposed MC has strengths and weaknesses in the application of building construction projects were to be the case in this study. The advantages of predictive models BBN-MC is 1) the ability to process the data are limited, 2) developed using expert opinion and historical data, 3) the uncertainty factor that affects the performance time can be added or removed in the model without significantly affecting the rest of the network. 4) provide insight into the relationship between the uncertainty factors that affect the performance time. 5) be able to predict more accurately the performance of time because of the prior two different inputs that prior input from BBN and MC. 6) data input (prior) can be updated at any time in accordance with the conditions in the field. Model predictions of BBN-MC, in addition to having the advantages, it also have weaknesses, namely 1) only predict the performance time gradually over time, 2) in predicting the performance time is not practical because the simulation is done gradually, 3) the prediction of performance time only temporary, not a prediction of the end time construction projects.

CONCLUSIONS

Significant factors that directly affect the progress of construction projec tis based on a model developed using Bayesian Belief Networks from the time performance of construction projects are1) the factor of labor productivity, 2) the factor of construction equipment productivity, 3) the availability of construction materials. BBN-MC models that have been built to predict the performance of a construction project could illustrate the relationship between the uncertainty factors that affect performance construction project time clearly and predict the performance time gradually over time. Based on model validation result, the project time performance prediction gives good accuracy with APE mean is 4,517.Construction time delays in the execution of construction projects could affect the project success because it will give the effect on cost overrun. To minimize time delays in construction project, control methodis necessary for the of construction projects.

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