Evaluation of lead-time procurement in Pupuk Kaltim Inc.
using pure-birth analysis

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Abstract. Industry has an important role in supporting national economy by its contributions to the employment absorption and creating added value of commodities produced. One of the parameters that influence the success of an industry is how the industry evaluates its performance, in particular, the performance of service procurement department. A good industry is an industry which can provide excellent service and well-timed. In the case study, we use pure-birth analysis to evaluate the lead-time procurement in Pupuk Kaltim Inc by collecting the service duration time in each process to be followed in the procurement department and modeling its probability to finish each work at any time. The result shows that the greatest probability of the division to finish their work is around 80 days. Based on the result, we conclude that they have to improve their service performance.

1. Introduction
Economic development is a multi-dimensional process. This process consists not only by transformation of economic structure but also by economic composition [1] Industry is one of the strategic economic activities to increase public revenues and the economic development is indicated by the increase of employment, technology transfer and the increase of foreign exchange.

In practice, many industrial systems consist of multiple units. If one unit fails then others unit will be fail too. It means that failures has statistically correlated and depend on the previous condition. There are three types failure interaction ([2]; [3]; [4]):
1. Type I failure interaction: When a unit fails, other units will immediately fail at a certain probability.
2. Type II failure interaction: The failure of a unit is regarded as an internal shock that increases failure rates of other units.
3. Type III failure interaction: A failure of one unit causes a random amount of damage to the other unit.

Pupuk Kaltim Inc is a State-Owned Enterprises in Indonesia, which was established on December 7th 1977 with the main objectives are to implement and support the policy of the Government in terms of industrial development and national economy, particularly the industrial sector of the fertilizers and chemical industries. The main reason we decide Pupuk Kaltim Inc as our research object is because they are the biggest fertilizer producer to support agriculture sector in Indonesia. As we know,
agriculture is one of main occupations of Indonesian people. Department that most responsible for meeting the needs of the service in any part of Pupuk Kaltim Inc is the service procurement department. One of the most important parameters which can decide the success of the department tasks is duration service procurement itself. In fact, more than 50% procurement in 2015 is out of the targeted time.

The procurement process consists of four stages, that are the determination method and list proposed partner (DUR), clarification of the negotiation, the report of winner tender (LUP), and the last is the manufacture of the letter of agreement (SP). All these stages must always be sequentially, it means that the stage-two could not be done before the stage-one is completed, and so on. One of the most appropriate methods to analyze a case like this is pure birth analysis in Continuous Time Markov Chain (CMTC).

2. Stochastic process
Markov Chain analysis is one of the statistical methods which can be used to estimate the future in probabilistic point of view. The analysis works by using information from the past to obtain the information of the future. Markov Chain is a special form of probabilistic model known as stochastic process [5]. There are two parameters involved in Markov Chain analysis; state and time parameter. Based on the type of the data, the state and time parameters can be discrete or continuous type. Therefore, there are four types of Markov Chain model. In this paper, we built a Markov Chain model with discrete state parameters and continuous time parameters. The model is known as Continuous Time Markov Chain (CTMC). CTMC is a stochastic process having Markov property; conditional distribution of \( X(t+s) \) in the future given by \( X(t) \) in the present and \( X(u) \) from the past, \( u \leq t < s \), is only determined by the present and independent from the past and can be notated as [6]

\[
P(X(t+s) = j | X(t) = i) \]

In other words, CTMC is a stochastic process moving from a state to another that is discrete, however the amount of time spent in each state before move to another state is exponentially distributed. CTMC can be described as a birth and death process, where the process which have states \( \{0, 1, 2, \ldots\} \) can move only from state \( i \) to state \( i+1 \) or to state \( i-1 \). The relationship among the states is shown by figure 1.

![Figure 1. Diagram of Birth Death Process](image)

Where the transition rates are

\[
q_{i,j} = \begin{cases} 
\lambda_i & \text{if } j = i+1 \\
\mu_i & \text{if } j = i-1 \\
0 & \text{others}
\end{cases}
\]

The transition rate \( q_{i,j} \) can be written in matrix generator \( Q \) form as follow

\[
Q = \begin{pmatrix}
q_{0,0} & q_{0,1} & q_{0,2} & \cdots & q_{0,n} \\
q_{1,0} & q_{1,1} & q_{1,2} & \cdots & q_{1,n} \\
q_{2,0} & q_{2,1} & q_{2,2} & \cdots & q_{2,n} \\
\vdots & \vdots & \vdots & \ddots & \vdots \\
q_{n,0} & q_{n,1} & q_{n,2} & \cdots & q_{n,n}
\end{pmatrix} = 
\begin{pmatrix}
-\lambda_0 & \lambda_0 & 0 & \cdots & 0 \\
\mu_1 & -\lambda_1 & \lambda_1 & \cdots & 0 \\
0 & \mu_2 & -\lambda_2 & \cdots & 0 \\
\vdots & \vdots & \vdots & \ddots & \vdots \\
0 & 0 & 0 & \cdots & -\lambda_n
\end{pmatrix}
\]

(1)
From matrix $Q$, we can obtain time-dependent solution of probability in state $n$ by solving the global balance condition

$$\frac{d}{dt} \pi(t) = \pi(t) \cdot Q$$

(2)

Where $\pi(t) = [\pi_0(t) \ \pi_1(t) \ \pi_2(t) \ \cdots]$

3. Analysis and discussion

There are four main processes in the procurement process, namely the determination method and list proposed partner (DUR), clarification of the negotiation, reports of winner tender (LUP), and the last is the manufacture of the letter of agreement (SP). In the DUR process contains a list of vendors who have capability on tender required by the user. In this process involves two to three persons namely Manager Procurement and General Manager, and if the value of services up to more than 50 million, it needs the approval of the Director.

The second process is a negotiation process, this process is a process that most fluctuated than the other processes because there are various problems encountered. This process is carried out by the department of procurement and vendor in order to get the deal price.

The third process is the process LUP or Proposed Statement winner. After getting the price of the winning bidder, the next process is the winner Proposed Statement. This process was signed by the three person on this is the team leader, GM unit, and directors.

The process of the fourth or the last process is the SP or the Letter of Agreement. In this process involves six parties, namely the procurement manager, General Manager of Engineering, Team Lead, User Manager, User Manager and Directors General. Of the four main processes are then distributed according to the number of people who sign it so that the letter obtained 12 processes. All these processes will be built into models of stochastic processes. Construction of this stochastic process models through the following steps, namely formulate postulates that satisfies Poisson and Markov processes, model postulates to the form of differential equations (PD) and the use of partial differential equations theorem for generating functions of transition opportunities, as well as the form and function of a joint moment.

To get a differential equation it is necessary to calculate the average of time duration of the respective data, where the states of the system and the person who is sign the contract are shown in Table 1:

| State | Process | Person in Charge          |
|-------|---------|---------------------------|
| 0     | DUR (List of Business Partner) | Manager of Service Procurement |
| 1     |          | General Manager           |
| 2     |          | Technology and Development Director |
| 3     | Negotiation | Team Leader              |
| 4     | LUP (Report of the Tender’s Winner) | Project General Manager |
| 5     |          | Director                  |
| 6     | SP (Memorandum of Understanding) | Manager of Service Procurement |
| 7     |          | General Manager of Technology |
| 8     |          | Team Leader               |
| 9     |          | User Manager              |
| 10    |          | User General Manager      |
| 11    |          | Director                  |

| Tender (day) | State (day) |
|--------------|-------------|
| 0-1          | 1-2         |
| 2-3          | 3-4         |
| 4-5          | 5-6         |
| 6-7          | 7-8         |
| 8-9          | 9-10        |
| 10-11        | 11-12       |
| State | Process | Differential Equation |
|-------|---------|-----------------------|
| 0     | DUR (List of Business Partner) | \( \pi_0'(t) = -8.11 \pi_0(t) \) |
| 1     | DUR (List of Business Partner) | \( \pi_1'(t) = 8.11 \pi_0(t) - 0.49 \pi_1(t) \) |
| 2     | DUR (List of Business Partner) | \( \pi_2'(t) = 0.49 \pi_1(t) - 0.88 \pi_2(t) \) |
| 3     | Negotiation | \( \pi_3'(t) = 0.88 \pi_3(t) - 0.05 \pi_3(t) \) |
| 4     | LUP (Report of the Tender’s Winner) | \( \pi_4'(t) = 0.05 \pi_3(t) - 0.29 \pi_4(t) \) |
| 5     | LUP (Report of the Tender’s Winner) | \( \pi_5'(t) = 0.29 \pi_4(t) - 0.36 \pi_5(t) \) |
| 6     | LUP (Report of the Tender’s Winner) | \( \pi_6'(t) = 0.36 \pi_5(t) - 0.11 \pi_6(t) \) |
| 7     | SP (Memorandum of Understanding) | \( \pi_7'(t) = 0.11 \pi_6(t) - 0.81 \pi_7(t) \) |
| 8     | SP (Memorandum of Understanding) | \( \pi_8'(t) = 0.81 \pi_7(t) - 8.11 \pi_8(t) \) |
| 9     | SP (Memorandum of Understanding) | \( \pi_9'(t) = 8.11 \pi_8(t) - 0.42 \pi_9(t) \) |
| 10    | SP (Memorandum of Understanding) | \( \pi_{10}'(t) = 0.42 \pi_9(t) - 0.23 \pi_{10}(t) \) |
| 11    | SP (Memorandum of Understanding) | \( \pi_{11}'(t) = 0.23 \pi_{10}(t) - 0.27 \pi_{11}(t) \) |
| 12    | SP (Memorandum of Understanding) | \( \pi_{12}'(t) = 0.27 \pi_{11}(t) \) |

After getting the differential equations, then the next step is calculating the solution. Below are the probability distributions of the tender’s completion in each process.

### 3.1. DUR process
Figure 3. DUR Process in: State 0, State 1, and State 2

From figure 3, we can see that the List Proposed Partner (DUR) is conducted by the procurement manager (state 0), the team leader (state 1), and directors (state 2). In state 1, the greatest probability to complete the work is less than 1 day. Meanwhile, after two days the chances are zero. This occurs because the incoming mail right in the procurement department, after going through the secretary of the letter straight to the procurement manager. In state 1, the biggest probability that the work will be completed is also less than one day. While in state 2 the directors take up to 2 days to complete their works. Based on these results the greatest probability of completion of the work on DUR process is 4 days. This includes ideal because the total days to complete the work in DUR process is less than 10 days, suitable with the company’s target.

3.2. Negotiation process

Figure 4. Negotiation Process
In the negotiation process, based on the result in figure 4, the biggest probability of the completion of the work is about seven days. When passing the seventh day, the probability of the work to be completed is decrease. This does not mean that the work will not be completed when passing the seventh day, but the process of negotiations on the method of appointment is mostly to be completed on the seventh day.

### 3.3. LUP process

![LUP Process: State 4](image)

![LUP Process: State 5](image)

![LUP Process: State 6](image)

**Figure 5.** LUP Process in: State 4, State 5, and State 6

The process of LUP (Report Proposed winner) is conducted by team leader (state 4), project general manager (state 5), and director (state 6). From figure 5, we can see that in the LUP process the probability to complete the work is increase until reach about 15 to 25 days. State 4 is carried out by the team leader where greatest probability to finish the work is in 11th day. Then the next process is carried out by project general manager where the greatest probability to finish the work is 0.8 which is on the 15th day. While in the state 6 the work done by the director where the biggest probability to finish is 0.2 which is on the 20th day. So the total of days required is until about 20th day.

### 3.4. SP process

![SP Process: State 7](image)

![SP Process: State 8](image)
SP process is carried out by six parts: manager of service procurement, general manager of technology, team leader, user manager, user general manager, and directors. On state 7 and 8, the process is undertaken by the manager of service procurement and general manager of technology. From the result shown in figure 6, the biggest probability of the work’s completion of these processes are at 25th day. In state 9, 10, and 11, the greatest probability to finish each work are on 30th, 35th, and 37th day. While in state 12 the largest probability to complete the work is on day 80 that is equal to 1.

4. Conclusion
We have constructed a stochastic model to evaluate the lead time procurement in Pupuk Kaltim Inc. using continuous time Markov chain especially pure birth process. From the analysis, we can conclude that the highest probability to finish the work in DUR process can be reached for about 1 day, in negotiation process is until about seventh day, in LUP process is until about 25th day, and in SP process is until about 80th day. So the total day required by each tender to be finished is about 80 days. Based on government’s policy, it needs 60 days for a tender to be finished in a company.

5. References
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