Performance Measurement Based on Coloured Petri Net Simulation of Scalable Business Processes

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***Abstract*— Business process is also a complex area which receives much attention in recent years especially in increasing productivity and saving cost. Meanwhile, situation at the company allows existing business processes to be enlarged. This paper proposed the performance measurement based on coloured petri net simulation of scalable business processes, which has purpose to compare the performance of scalable business processes. For experiments, this paper uses real-world business processes. Then compare it to some business processes that have been enlarged. The result shows that scalable business processes influence the performance of business process. This paper provides feedback to business process developers for determine appropriate business processes based on the performance through coloured petri net simulation.**

Keywords— simulation; scalability metric; performance measurement; business process; coloured petri net

I. INTRODUCTION

Currently, Business process has widely implemented in many organizations, both small and large organizations. Then, for representing the real business process, business process model also has been well developed for several purposes. The fact, there are many organizations or companies that apply business process model according on their standard operational procedure of organizations [1]. A business process model is established for the company to get profit based on their standard operational procedure of organizations. The need of improving productivity and time eficiency is increasing as technology development makes human life quicker and simpler. Business process is also a complex area which receives much attention in recent years especially in increasing productivity and saving cost [2]. Meanwhile, the situation at the company allows existing business processes to be enlarged. This paper aims to simulate the performance of scalable business process. The scalable business process is the ability of the process or system to handle the growing number of processes or work. for accommodate that growing number is scalability of business process. So, they have the potential process to be enlarged [3]. This paper also focus on measure the performance of scalable business process based on coloured petri net simulation using CPN Tools.

A simulation is the interesting topic for research. Commonly, simulation defines as imitation or emulates the real-world process operation or system over time. Whether done by hand or simulate by computer, simulation concerns the generation of an artificial history of a system and the observation [4]. Type of simulation which is useful when a system's state changes as certain events occur over time is discrete-event simulation. discrete-event simulation is better suited to analyze business and operational processes due to their inherently task-based (discrete) nature. As a result, discrete-event simulation has seen more widespread use throughout industry, as its potential applications are much broader [5]. This paper using CPN Tools for simulate discrete-event simulation of business process. For related work, In [6] authors built a simulation model using CPN Tools from event logs. Then, in [7] authors also simulate the model using CPN for measuring the performance of execution time. In this paper, we explain about measuring the performance of scalable business processes based on CPN simulation.

II. LITERATURE REVIEW

A. Petri Net Models

Petri net is business process modeling that aims to analyze various models in the business processes [8-10]. A Model of petri net has three elements of model, such as transition, place and arc. The transition usually indicates a particular activity (process step or task) that needs to be fire, or a silent step (i.e., t activity) which is used for routing purposes. Place is an element that used to define the pre-conditions transitions and post-conditions transitions. If the precondition is satisfied, a transition can be fired. The result of each firing from transition will be the post-condition. Transitions and places are always connected by directed arcs in such a way that (i) transitions and places have at least one of directed arc and (ii) for each arc, transition can't connected to another transition and then place can't connected to another place. [11]. A formal definition of conventional Petri nets is presented as follows.

A Petri net is a triple (*P, T, F*), where:

- P is a finite set of places.
- T is a finite set of transitions, $P \cup T \neq \emptyset$ and $P \cap T = \emptyset$
- $F \subseteq (P \times T) \cup (T \times P)$ is a set of directed arcs representing flow relations, joining places and transitions together.

Fig. 1 shows the examples of petri net models of sequence model, parallel model and condition model. In sequence model, there is no gateway included. So, flow of activity in sequence model in Fig. 1 is (A-B).

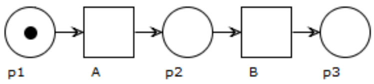

Fig. 1 Examples of Petri Net Sequence Model

B. Similarity Metric

Similarity metric among two business process models has aims to measure the similarity value by calculating the similarity according to behavioral or structural similarity method. Some of business processes that have a high similarity value should be arranged in such a way to increase efficiency [12]. Structural similarity is one of similarity method to measure similarity based on the elements of business process model. In petri net model, two models will compare according to arcs as the relations between these elements, places and transitions. Other similarity method is measuring similarity value based on the intended behavior of process models. It is called behavior similarity metrics. In petri net, the behavior process models are determined by transitions [13].

Label similarity is measured by compare the labels between two models. The equation of behavioral similarity is mentioned in (1).

$$J(A,B) = \frac{|A \cap B|}{|A \cup B|} \quad (1)$$

For Structure similarity, similarity value is measured by compare the similar aspect of petri net models, such as amount of similar place, similar transitions and similar arcs. The equation of structure similarity is shown in (2):

$$J(A,B) = \frac{|A \cap B|}{|A \cup B|} \quad (2)$$

C. Control Flow Complexity (CFC)

Cardoso [14] defines the complexity of model process as the complexity degree to analyze, understand or explain process models. In recent, the research communities of software measurement are using complexity as a challenging topic [15]. One of the approaches of complexity measurement in business process models is Control Flow Complexity that proposed by Cardoso [14]. Control-Flow Complexity (CFC) can be defined as metric for determining and analyzing the complexity degree of business process. Now, for achieve the effective and efficient process management, analysis of complexity degree for model processes has been an important issue to consider in the quest for it, especially for business process management that using process models. Achieve of effective process management must be the aim of the metric of CFC. CFC metric defines the complexity according to the assumptions that the control-flow behavior of a process is affected by construction of splits and joins. Rolon [16] has implemented CFC metric for BPMN models, Mao [17] has implemented CFC for petri net models, and then Anugrah [18] also has implemented CFC metric for business process decomposition. Therefore, equation is developed to calculate the value of complexity for XOR-split, OR-split, and AND-split. The equation is developed as Equation (3), (4) and (5):

- Control-flow Complexity according to XOR-split is CFC value that constructed the CFC value by the sum of the split out from a process model that defined as the XOR-split. For $CFC_{XOR\text{-}split(m)}$ where m is a process model or an activity that will be measured by the control-flow complexity of the XOR-split. For XOR-splits, the control-flow complexity is determined by Equation 3

$$CFC_{XOR-split}(a) = out(a) \quad (3)$$

- Control-flow Complexity according to OR-split is CFC value that constructed by the sum of the split out from a process model that defined as the XOR-split. The CFC for OR-splits is determined by 2^(k-1), where k is the out of the split. It is simply by Equation (4):

$$CFC_{OR-split}(a) = 2^{out(a)-1} \quad (4)$$

- Control-flow Complexity based on AND-split is clear value. The CFC for AND-split is always equal to 1. According to AND-split, it is assumed that all of the out transitions are selected and executed (as the sequence). The equation is simply by (5):

$$CFC_{AND-split}(a) = 1 \quad (5)$$

Therefore, This is done by simply develop the CFC of all the split model constructs and is measured as Equation (6):

$$CFC = \sum CFC_{xor-split}(a) + \sum CFC_{or-split}(a) + \sum CFC_{and-split}(a)$$

(6)

D. Cyclomatic Complexity

McCabe cyclomatic complexity (CC) [19] or can be called by McCabe CC is the famous complexity measurement that used widely for metrics of software. Cyclomatic complexity is corresponding to measuring complexity structure of model process that has been implemented in Web service-based system [20]. For the business process modeled by Petri net, the cyclomatic complexity can be measure as Equation (7):

$$CC = |F| - |P| - |T| + 2 \quad (7)$$

The value of CC determines the complexity of control structure in process model [15]. For the running example, its CC value for fig.1 is 4−3 −2+ 2 = 1 because fig 1 has 4 arcs (flow), 3 places and 2 transitions. Normally, sequence type of petri net has value of CC equal to 1.

III. PROPOSED METHOD

In this paper, we proposed method for measuring scalable business processes before measure the performance. Measuring the scalable business process will get the scalability metric. Scalability metric determines the connectedness and scalable process between two business processes models. If scalability metric between A and B is 0, determine that A and B are not connectedness models and can't scalable. This is important because the extended process business must be related to previous business processes. So, we proposed a equation for measure the scalability metric between two models of business process based on similarity and complexity measure, mentioned in (8):

$$\psi(A,B) = \frac{\sum C(A)}{\sum C(B)} x\ average(simS(A,B), simL(A,B)) \quad (8)$$

Where, measuring scalability has two alternative equation, by using control flow complexity mentioned in (9) or by using cyclometic complexity mentioned in (10). In section IV, this paper compared both complexities.

$$\sum C(A) = CFC(A) x \sum Structure(A) \quad (9)$$

$$\sum C(A) = CC(A) x \sum Structure(A) \quad (10)$$

- $\psi(A,B)$ is scalability metric between A and B.
- $simS(A,B)$ is structural similarity between A and B.
- $simL(A,B)$ is label similarity between A and B
- $\sum C(A)$ adalah multiplication of complexity by $CFC(A)$ or $CC(A)$ and $Strucuctre(A)$, determine the total complexity.
- $CFC(A)$ states control flow complexity of A, seen from amount of AND, XOR and OR gateway that mentioned in Equation (6).
- $CC(A)$ states cyclometic complexity of A, seen from Equation (7).
- $structure(A)$ states amount of petri net element, such as place, arc and transition.

After measuring the scalable business process, followed by measuring the performance of scalable business processes using CPN simulation. One of indicator of performance is time executing of business processess. So, we will compare the time execution of basic business process with scalable business processess.

IV. DISCUSSION

We used case studies to experiment the proposed method, namely the business process of refueling at gas stations. Fig. 1 shows the basic business process of refueling at gas station. Based on the basic business process, the companies expand the scale of business processes into three alternative business processes. Before companies expand seriously, they must understand whether expanding business processes will improve performance or not. Then business process scalability will be measured and performance will be calculated using CPN Tools simulation

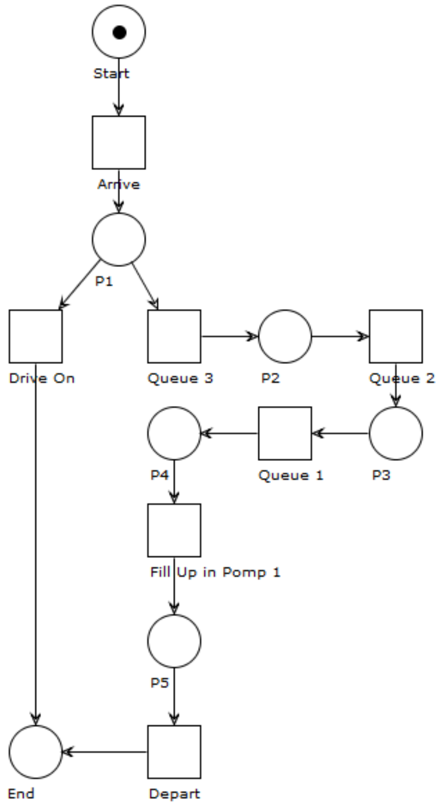

Fig. 2 Model A : Basic Case

Basic business process of refueling at gas station has several basic activities, modeled using petri net in Fig. 1. It is using one pump and has waiting space for three cars. In real world, we assume the filling up a car takes 2 – 5 minutes. So, this is implemented in simulation based on CPN. If 3 cars are waiting, next car drive to other station. Before simulate in CPN, we has scale the basic business process of refueling at gas station become 3 scalable business process. The expanded business processes are shown in Fig. 2, 3, and 4. In Fig. 2, the business process of refueling at gas station has an additional number of pumps. Then, the business process of refueling at gas station in Fig. 3 has an additional number of waiting space for six cars. The last in Fig. 4, the business process of refueling at gas station has different pump. Basic business process uses general pump, but business process in Fig. 4 uses fast pump. So, basic business process of refueling has 3 alternative business processes. We will calculate the scalability value of 3 alternative business processes and compare with basic business process.

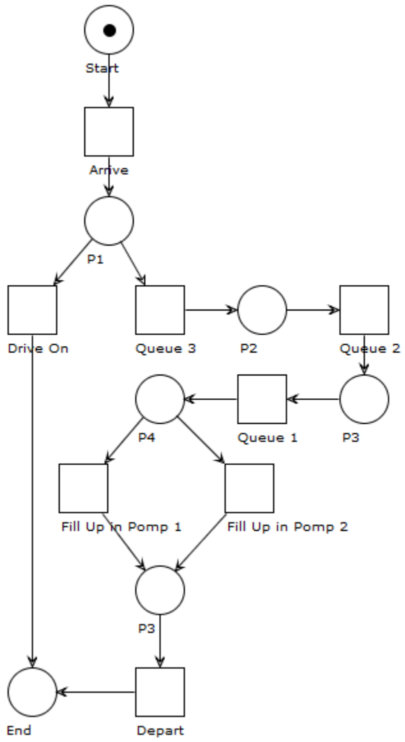

Fig. 3 Model B : Two Pumps

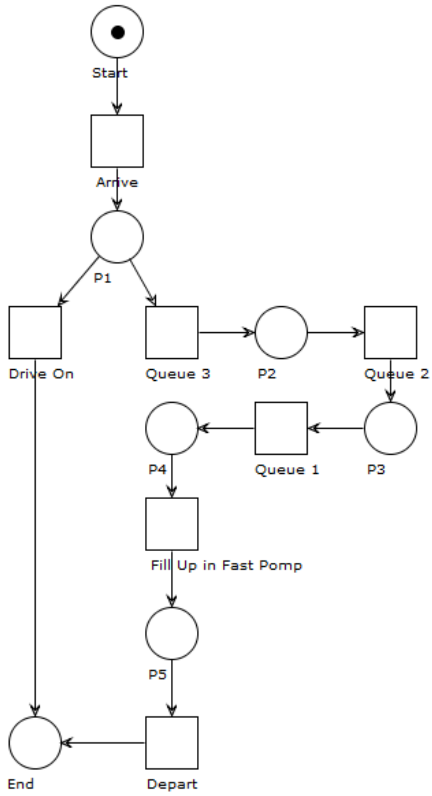

Fig. 4 Model D : Faster Pump

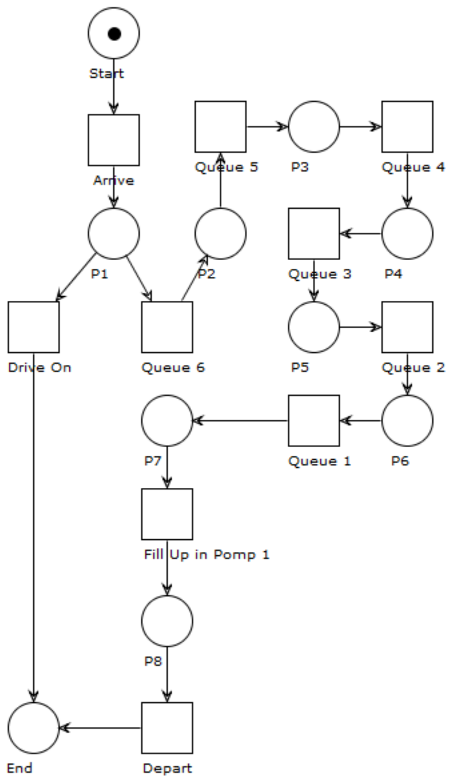

Fig 4. Model C : Six Waiting Spaces

Based on basic case of refueling at gas station and 3 alternative expanded business processes, metric of scalability between business process A and business processes B, C and D measured using scalability metric of CFC and CC.

Table I. Metric of Scalability using CFC

	Model A	Model B	Model C	Model D
Model A	1	0.406452	0.518	0.9

Table II. Metric of Scalability using CC

	Model A	Model B	Model C	Model D
Model A	1	0.406452	0.518	0.9

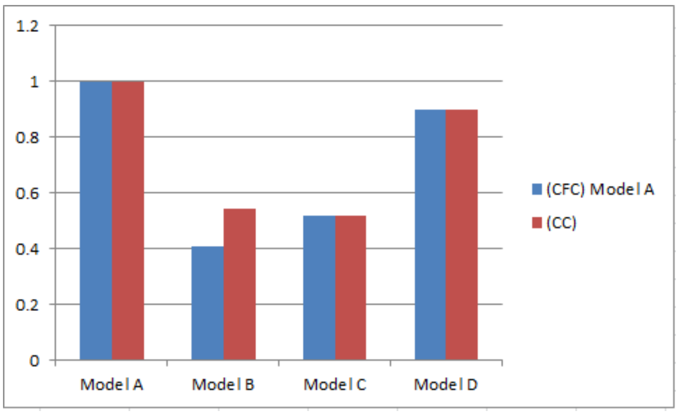

Fig. 5 chart of scalability metrics

Table I shows the result of scalability metric using CFC and Table II using CC. This measurement indicates that between basic case of refueling at gas station and another alternative business process are scalable business processes. It means that there is connectedness for similarity and complexity for each business processes. The lower scalable between model A and alternative business process is between model A and model B. Then model A and model D have high scalable value. So, after measuring the scalable business processes, the experiment is continued with simulating of each business process using CPN Tools simulation.

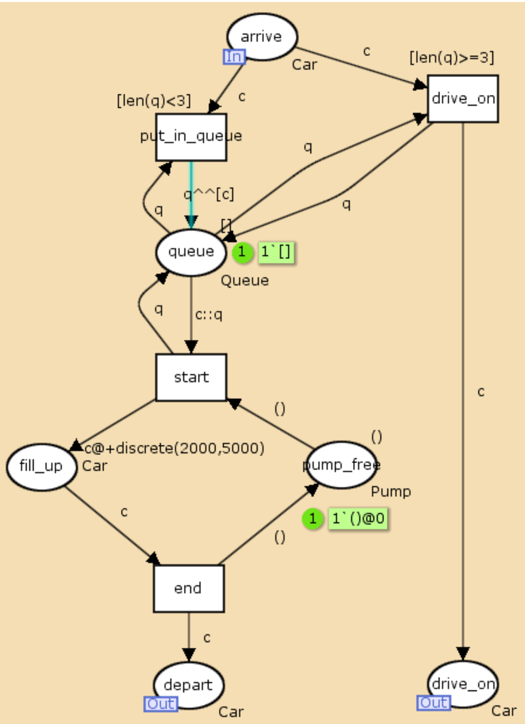

Fig. 6 Simulation using CPN Tools

CPN Tools is using for simulate the business process execution for each business process. Model A (base case), model B (two pumps), model C (six waiting spaces) and model D (faster pomp) are simulating using CPN for measuring the performance of execution time for each business processes. Fig. 6 is example of simulating model. For the scenario of business process, we simulate of refueling 100 cars on basic business process (model A) and simulate on model B (two pumps), model C (six waiting spaces) and model D (faster pomp). We focus on get the average of execution time of refueling process. Average of execution time is automatically determined by CPN simulation.

Table III shows each models of business process has different times in average execution time performance. It is important for company to knowing this value. It is provides feedback to business process developers for determine appropriate business processes based on the execution time through simulation.

Table III. Performance of Execution Time Based on CPN Simulation

Simulation Cases	Avg Execution Time (Minutes)
Base Case	7.354
Two Pumps	3.927
Six Waiting Spaces	10.597
Faster Pump	3.998

Table IV. Comparison between Scalability and Performance of Execution Time

		Base Case	Two Pumps	Six Waiting Space	Faster Pump
S_CC	Base Case	1	0.242121	0.022262	0.01398
S_CFC	Base Case	1	0.242121	0.022262	0.01398
ET	Base Case	7.354	3.927	10.597	3.998

So, from the simulation result, we know that adding a pump significantly will decrease the execution time from 7.3 to 3.9 minutes. Adding more waiting spaces significantly increases the execution time from 7.3 to 10.6 minutes. Then, installing a faster pump significantly decrease the execution time from 7.4 to approach 4.0 minutes.

V. CONCLUSION AND FUTURE WORK

This paper proposed metric of scalability measure based on similarity metric and complexity measure between two business process models. Then, measuring performance based on CPN simulation of scalable business processes. The result shows that scalable business processes influences the execution time. This paper provides feedback to business process developers for determine appropriate business processes based on the execution time through simulation. For the next research, we have to implement the performance of scalable business process based on the several performance parameters, not only in execution time of scalable business process.

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