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Asynchronous agent-based simulation and optimization of parallel business

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Abstract

A Port Container Terminal (PCT) involves complex business processes which are carried out by at least four organizations, namely PCT Operator, Customer, Quarantine and Customs. Each organization produces event log data from the activities. The event log data from the four organizations contain synchronous and asynchronous activities. In this research, the four organizations are represented by four agents. By simulating this log data using agent based simulation, we get the performance of the current business process. The performance indicators gathered are time and cost which are needed to do the activity (task). After the simulation is complete, we found Asynchronous Waiting Time (AWT). AWT is waiting time which happens because the agent in the simulation cannot do the newly assigned task because the agent is still working on the other task. Therefore, we parallelize the task performed by the agent so that the agent can do multiple tasks at a time. After we parallelize the task, we perform an optimization process using Stochastic Multicriteria Adaptability Analysis 2 (SMAA-2). Thus, the optimal amount of task an agent can do simultaneously is analyzed. This study result shows that parallelization can reduce AWT of the current system and the optimization process using SMAA-2 shows the most optimal number of multiple tasks an agent can do simultaneously.

Keywords*: agent based simulation, log data, parallelization, port container, SMAA-2*

1. Introduction

Simulation is widely used to represent how the simulated system works in the real world situation [1]. Therefore, simulation is a powerful tool to evaluate the performance of the system and give insight into the current system which leads to the improvement of the system if it needs some upgrade. From previous studies, Discrete Event Simulation (DES) is used to simulate the business process if the business process is a discrete or synchronous process [2-5]. Beside synchronous business process, there is some organization which utilizes asynchronous business process. Using asynchronous business process, the activity or task inside the organization can be performed more flexibly. DES cannot utilize this asynchronous business process. Instead, the use of Agent Based Simulation (ABS) system proves to be more reliable on simulating asynchronous business process [6].

In our case study, the business process inside the Surabaya Port Container Terminal (PCT) is an asynchronous business process. This is due to the organizational needs to communicate with another party. While the system in Surabaya PCT is already running using a web service system, to improve the business process we need to re-implement the communication process. Each web service system of each organization must be able to communicate with each other since the system will have a crucial role in getting the job of each organization done successfully.

The communication process of the web service is based on the choreography process [7]. The choreography between organizations is different for each system, which means that the choreography needs reconfiguration each time it is about to be implemented in a new environment. The implementation process needs both time and resources available [8]. Thus, the pre-implemented web service system needs to be evaluated before it is implemented as part of the planning stage. Therefore, simulating this asynchronous business process as a part of the planning process is needed.

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In our previous study [6], we simulate the business process using both DES and ABS. DES shows that the current business process has no problem aside from some activity or task that needs a very long time to execute. Therefore, the results of DES only shows which task that needs more time to execute than the others. Meanwhile, ABS gives the same results but with more insight into its communication process. This is due to the characteristics of the agent in ABS which are Autonomous, Proactive, Reactive, and has Social ability [9].

Each agent in ABS can communicate with one another regardless of the task of the target agent is still doing. Thus, ABS gives clarity to the asynchronous communication process of the agents. Because of the asynchronous communication process, ABS shows waiting time which is the product of the communication process called Asynchronous Waiting Time (AWT). AWT made the total waiting time for a task longer since the task cannot be executed until the agent finishes the previous task. By reducing AWT, the cost of the task is different compared to the cost before reducing it. Figure 1 show AWT in details.

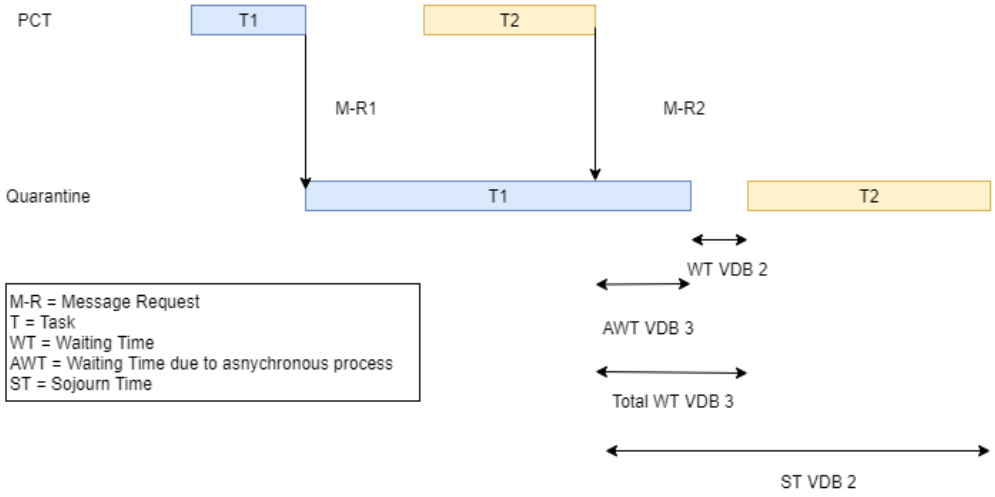

Figure 1. AWT details

Different from the previous researches which did not account the communication process [10-13], in this study we will be focused on reducing AWT using task parallelization and optimizing the number of tasks an agent can do simultaneously. To reduce AWT, we propose parallelization of task for each agent. If an agent can do multiple tasks at once, the total AWT for each task will be reduced. A study on parallelization of the process to reduce the waiting time of the process has been done [14, 15]. In the study, if a task cannot fulfill the assigned deadline, the parallel process can take over the work for the next task. Thus, reducing the waiting time of the task to be executed.

The results of the parallelization are the performance indicator of the system which are time and cost of each task [16, 17]. Based on the parallelization results, we need to know how many parallel tasks that a system needs to produce the most optimal outcome. Since the problem we need to find is the alternative with the most optimal time and cost, we need multicriteria decision making (MCDM) method to solve the problem [18-20]. The MCDM method we used to solve this problem is Stochastic Multicriteria Adaptability Analysis 2 (SMAA-2).

SMAA-2 is an improvement of Stochastic Multicriteria Adaptability Analysis (SMAA). SMAA does not mean to directly rank the alternatives, but to classify the alternatives to more acceptable results or less acceptable one. SMAA-2 give rank to each alternative based on the sets of weight vectors [21, 22]. SMAA-2 has been used by some researchers; such as for evaluating 16 combined heat and power (CHP) units based on efficiency, investment cost, maintenance cost, electricity cost, heat cost, carbon dioxide production, and footprint [23]; for handling dependent uncertainties assessed by experts in a strategic forest planning application, which gives decision recommendation based on the assessments [24].

2. Research Method

The framework is composed by the following steps: (1) gathering log data; (2) agent based simulation; (3) performance evaluation; (4) parallelization; (5) simulation of parallel task; (6) optimization process; (7) the results of the optimized parallel task. Figure 2 shows the research method in detail.

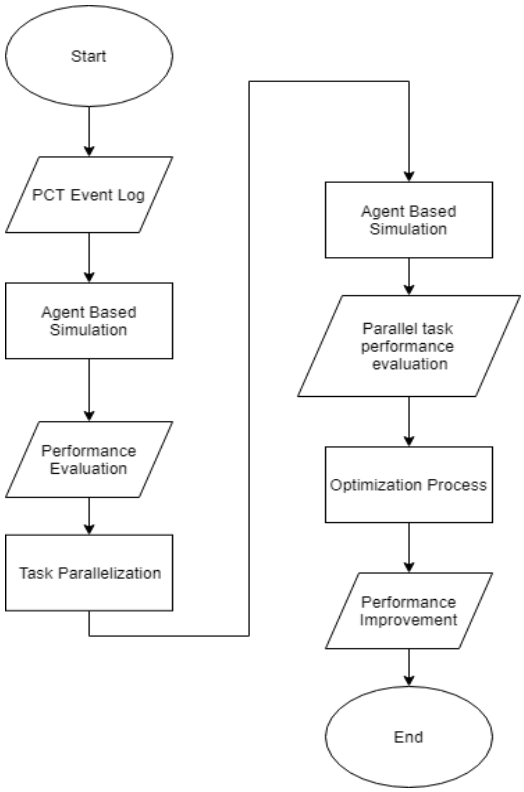

Figure 2. Flowchart of research method

2.1. Simulation

The simulation performed on this study is based on the log data we got from Surabaya PCT Operator in the period of January 2016 to March 2016. Figure 3 shows the structure of the log data.

CONTAINER_NO	Start Time	End Time	Activity	CC_TT_No	HT_No	Ves_ID	NAMA_IMP
TRHU1782109		12/06/2015 17:15:03	Discharge	004	173	AJAI001	CV. CIPTA KARYA MAKMUR
WHLU8040720		12/06/2015 17:45:28	Discharge	003	212	AJAI001	CV. TRI JAYA MAKMUR
TRHU1782109	12/06/2015 17:49:50	02/07/2015	Yard	004	173	AJAI001	CV. CIPTA KARYA MAKMUR
WHLU8040720	12/06/2015 18:09:39	09/07/2015	Yard	003	212	AJAI001	CV. TRI JAYA MAKMUR
WHLU2801550		12/06/2015 20:36:28	Discharge	004	216	AJAI001	
WHLU2801550	12/06/2015 20:52:13	24/07/2015	Yard	004	216	AJAI001	
TRLU8819050		21/06/2015 19:06:29	Discharge	003	208	ALDI003	CV.YUDHA SOLUSI PRATAMA
DFSU1964638		21/06/2015 19:08:04	Discharge	003	208	ALDI003	PT. LAUTAN LUAS TBK
DFSU1964941		21/06/2015 19:14:21	Discharge	003	212	ALDI003	PT. JAKARANA TAMA
DFSU7474140		21/06/2015 19:19:49	Discharge	004	221	ALDI003	PT.GALANGCITRAMITRA MAJUMAPAN
DFSU1965043		21/06/2015 19:32:48	Discharge	004	230	ALDI003	PT. JAKARANA TAMA
CMAU2136921		21/06/2015 19:38:10	Discharge	004	187	ALDI003	PT. WIJAYA INDONESIA MAKMUR BICYCLE INDUSTRIES
TEMU2611128		21/06/2015 19:41:23	Discharge	004	217	ALDI003	PT. JINDAL STAINLESS INDONESIA
TRLU8819050	21/06/2015 19:25:02	02/07/2015	Yard	003	208	ALDI003	CV.YUDHA SOLUSI PRATAMA
DFSU1964638	21/06/2015 19:26:30	06/07/2015	Yard	003	208	ALDI003	PT. LAUTAN LUAS TBK
DFSU7474141	21/06/2015 19:31:53	01/07/2015	Yard	004	221	ALDI004	PT.GALANGCITRAMITRA MAJUMAPAN
DFSU1965043	21/06/2015 19:46:18	30/06/2015	Yard	004	230	ALDI003	PT. JAKARANA TAMA
BSIU3004563		21/06/2015 19:57:03	Discharge	004	173	ALDI003	PT. GUDANG GARAM TBK

Figure 3. Log data structure

From the log data, there are 4 organizations that are involved in the business process. Each organization involved have several task that must be done in the business process. Those organizations involved are:

- Customer
- Surabaya PCT Operator
- Quarantine
- Customs

Since the simulation is done using an agent based simulation, each organization is assigned with an agent. Each assigned agent will do the task of the given organization. For example, an agent which represent PCT Operator will do the task of PCT Operator in real world such as the berthing process of the vessel ship and preparing the container to be transported to the designated place. To build the model, we use the Standard Operating Procedures (SOP) that was used by Surabaya PCT.

2.2. Performance Evaluation

To evaluate the performance of the simulation, we refer to the previous study on evaluating the performance of a discrete event simulation [2]. The performance of the simulation is based on waiting time, execution time, and the cost of each task [15].

a. Waiting time

Waiting time refers to the time each task spent on the ready queue. In this study, AWT is waiting time that occurs because of the asynchronous communication process and it is part of the waiting time of the activity. The longer the waiting time for an activity to be executed, the lower the performance of the system.

b. Execution time

Execution time refers to the time needed for each task to do its process from the start time to its end time. A system with sojourn time equal to its execution time means that the system has good performance.

c. Cost

The cost of each task is based on both waiting time and execution time of the task. While waiting for the execution process, the task already using the available resources. Thus, if the AWT of the task can be reduced, the cost of the task with reduced AWT will be cheaper. The use of resources while in the waiting queue and when the task is executed is different. Therefore, the cost of the task while it is executed will be different from when it is in the waiting queue.

2.3. Task Parallelization

From the previous study, AWT as the waiting time which occurs because of the asynchronous process has been discovered using agent based simulation [6]. To reduce AWT parallelization of the task is needed. By parallelizing task, each agent can do task simultaneously thus reducing the total dwelling time of the container. For this phase, we will parallelize the tasks until there are tasks that have the AWT reduced to zero. Figure 4 shows how AWT affects the execution of tasks.

The task is done by the order of the arrival of tasks. The results of this parallelization process will reduce the AWT of tasks. Figure 5 shows the expected results of the parallel process. With the reduced AWT, the cost of each task will change according to the duration of its total waiting time and execution time. To address this issue, we assume that the cost for each task that we got from the log data is the cost relative to the task sojourn time. To separate the cost of the waiting time and execution time, we have done a curve fitting process on the cost of the tasks. The results of the curve fitting process show that the distribution suitable for the cost of tasks is the Gaussian Distribution. The (1) shows the equation of Gaussian distribution.

$$y = ae^{\left(-\frac{(x-b)^2}{2c^2}\right)} \quad (1)$$

where,

e = 2.71828

x = Random normal variable

a = $1/(c * \sqrt{2\pi})$
c = Standard Deviation

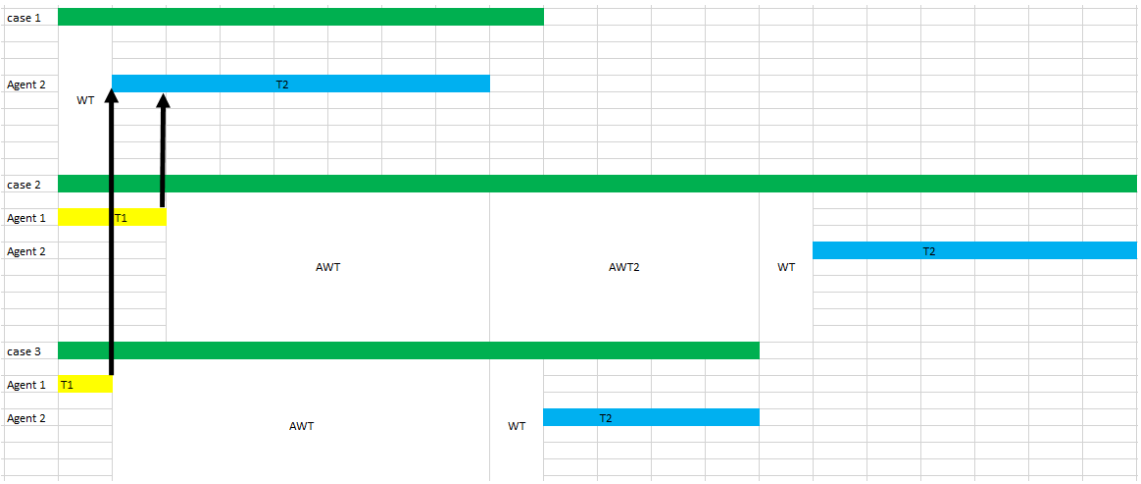

Figure 4. Tasks execution with AWT

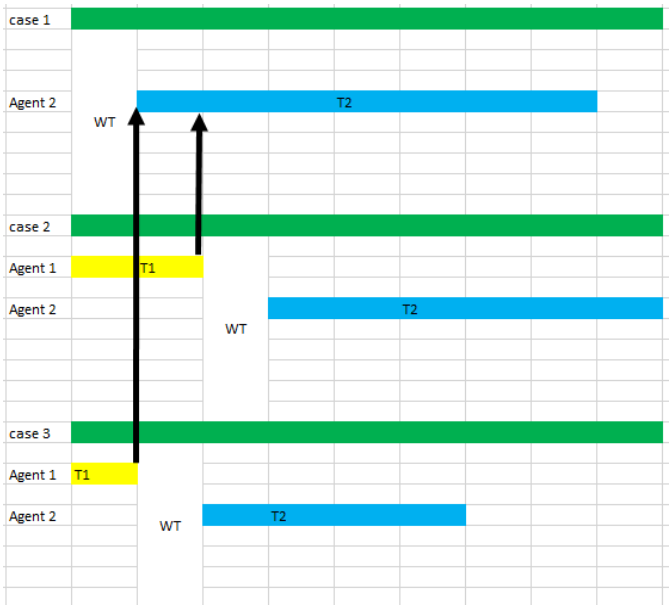

Figure 5. Task with reduced AWT

Therefore, we use Gaussian distribution to determine the cost of the execution of the task (execution cost). But, instead of using the average of the cost, we use the minimal cost of the tasks on the log data. The minimal cost of the tasks is assumed as the cost of the tasks without waiting cost. The (2) shows the modified equation to determine the execution cost of the tasks.

$$C_{ex} = ae^{(-\frac{(x-C_{min})^2}{2c^2})} \quad (2)$$

where,
C_{ex} = execution cost

C_{min} = minimal cost of tasks

Since we have got the execution cost of the tasks, we can calculate the total waiting cost of the tasks. This total waiting cost is caused by both AWT and the task waiting time. Thus, we use (3) to calculate the cost of the tasks after AWT is reduced.

$$C = \left(\frac{W}{W_{Tot}} \times C_w\right) + \left(\frac{W_a}{W_{Tot}} \times C_w\right) + C_{ex} \quad (3)$$

where,

W = Task waiting time
W_a = AWT
W_{Tot} = Total waiting time
C_w = waiting cost
C_{ex} = execution cost

2.4. Parallel Task Optimization

After parallelizing the tasks, we simulate the parallel task with agent based simulation. The performance results will be the input of the optimization process. Since the input parameter is more than one parameter, the optimization method we used is multicriteria decision making (MCDM) method. In this case, we used SMAA-2 as the MCDM method. This method comprised of several steps [25].

The decision problem is represented as a set of m alternatives $\{x_1, x_2, x_3, \dots, x_m\}$ that is evaluated based on n criteria. Then, value function $u(x_i, w)$ is used to represents the decision maker preference with w as the variable for quantifying the decision maker preferences. The decision maker can specify the weights and priority order of the criteria based on Feasible Weight Space (FWS) W. Normally, the weights are non negative and normalized. In (4) define the FWS in n dimension.

$$W = \left\{w \in R^n : w \geq 0 \; and \; \sum_{j=1}^{n} \; w_j = 1\right\} \quad (4)$$

The weight space for 3 criteria is shown in Figure 6. Every corner of the triangle is connected with the maximum value of each criterion {(1,0,0), (0,1,0), (0,0,1)}.

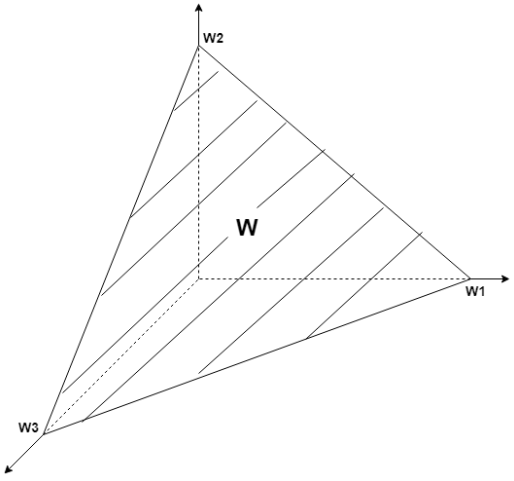

Figure 6. FWS of 3 criteria

Then, stochastic criteria ξ_i and w is mapped into the value function $u(\xi_i, w)$. Based on the value distributions, the rank of each alternative is given based on the number of alternative m with 1 as the best rank to the worst rank m using ranking function on (5).

$$rank\ (i, \xi, w) = 1 + \sum_{k=1}^{m} \; \rho(u(\xi_k, w) > u(\xi_i, w)) \quad (5)$$

Where $\rho(true)$ = 1 and $\rho(false)$ = 0, SMAA-2 is then based on analyzing the stochastic sets of favorable rank weights using (6).

$$W_i^r = \{w \in W: rank\ (i, \xi, w) = r\} \quad (6)$$

The descriptive measure of SMAA-2 is rank acceptability index b_i^r, which measure the different weights which gives alternative x_i rank r. The share of weights gives the alternative an acceptability index for a particular rank. The rank acceptability index is computed using (7).

$$b_i^r = \int_{\xi \in X} \quad f_x(\xi) \int_{W \in W_i^r(\xi)} \quad f_w(w) dw d\xi \quad (7)$$

The best alternatives are the one with the highest acceptability index for the best ranks. The acceptability index is in the range of 0 to 1, where 0 means that the alternative will never get the given rank while 1 means that the alternative will always get the given rank with any weight preference.

3. Results and Discussion

The first step in this research is simulating the log data we got from Surabaya PCT Operator. The log data we used are as shown in Table 1. Using the log data in Table 1, the simulation is performed on the model created. After the simulation process is finished, and then we evaluate the performance of the system. Table 2 shows the performance of the system which is currently running based on the log data we got from Surabaya PCT Operator. Some tasks that were evaluated are *Verification Document Quarantine* (VDQ), *Check Goods Quarantine* (CGQ), *Create Document KH/KT* (CDK), *Verification Document Behandle* (VDB), and *Create Document SPPB* (CDS). The next step is to parallelize the number of tasks an agent can perform simultaneously. Table 3 and Table 4 shows the performance of the simulation with 2 task and 3 task respectively.

Table 1. Log Data

Case_Id	Originator	Activity	Time	Cost	Details
4691694	CUSTOMER	Document_ entry	3/24/2016 20:05	48379.739321638	Dry;Green Line
4691694	TPS	Vessel_ berthing	3/24/2016 22:10	690.90816831999	Dry;Green Line

Table 2. Performance of ABS with 1 Task

Task	Time	Cost (USD)
VDQ	30:57:03	172.3594308
CGQ	5:50:23	383.5689879
CDK	2:15:52	451.6066369
VDB	72:58:15	6.849238501
CDS	14:53:18	2620.039101

Table 3. Performance of ABS with 2 Tasks

Task	Time	Cost (USD)
VDQ	31:50:27	172.3594308
CGQ	4:37:21	402.7124783
CDK	1:47:48	525.2833322
VDB	68:29:09	6.849238501
CDS	11:20:10	3256.18177

Table 4. Performance of ABS with 3 Tasks

Task	Time	Cost (USD)
VDQ	31:50:27	172.3594308
CGQ	2:18:29	408.4938123
CDK	1:46:47	538.7805358
VDB	68:29:00	6.849344971
CDS	11:10:57	3256.76939

From the performance results of the simulation on Table 3 and Table 4, we know that there are some tasks such as VDQ with the same time and cost after we added the number of tasks an agent can perform simultaneously. This means that the activity is no longer has AWT. Thus, giving the agent which perform VDQ 2 parallel task is enough to reduce the AWT of the task. Meanwhile, for the task with longer sojourn time such as CGQ, parallelizing task reduces the sojourn time of the task significantly while increasing the cost of the task.

Since we have evaluated the performance of each task involved in the business process after parallelizing the tasks, we perform the optimization process to determine how many parallel tasks which is the most optimal for the given tasks. Using SMAA-2, the alternatives will be the number of parallel tasks, while the criteria are the time and cost of the tasks. Figure 5 and Figure 6 shows the optimization results using SMAA-2.

Figure 7 shows that for CGQ, using only 1 task is the best approach compared to the parallel counterpart. The use of only 1 task gives 0.82 acceptability index to be firstly

ranked. Thus, it shows the most optimal number of tasks to perform CGQ. Meanwhile, for CDS the most optimal result is when it is performed in 3 tasks simulation. The results of CDS is shown in Figure 8.

Alternative	Rank 1	Rank 2	Rank 3
1 Server	0.82	0.18	0.00
2 Server	0.00	0.18	0.82
3 Server	0.18	0.63	0.18

Figure 7. Optimization results of CGQ

Alternative	Rank 1	Rank 2	Rank 3
1 Server	0.49	0.01	0.50
2 Server	0.00	0.52	0.48
3 Server	0.51	0.47	0.02

Figure 8. Optimization results of CDS

4. Conclusion

On this research, we gathered a log data from Surabaya Port Container Terminal (PCT) Operator for the period of January 2016 to March 2016. The log data is then simulated using agent based simulation model created based on the SOP of Surabaya PCT Operator. By using agent based simulation, we can evaluate the performance of the business process since it gives more insight into the waiting time of the tasks proven by the discovered AWT. This AWT needs to be reduced to give better performance for the business process. To reduce AWT, we parallelize the tasks that can be performed by agents involved in the business process. The result of tasks parallelization is then optimized using SMAA-2 as the multicriteria decision making (MCDM) method.

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