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Optimization of Time and Cost of Multi Organization Business Processes in A Port Container Terminal

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Abstract: Port Container Terminal (PCT) involves multi organizations which are Customer, PCT, Custom, and Quarantine. The business processes of those organizations interact asynchronously from container arrivals to the release of the containers. An organization can be handled by multi agents, which represent the actors involved to perform a sequence of activities (tasks) in the organization. Asynchronous Waiting Time (AWT) occurs when an agent assigns a task to another agent which is still working on another task. The previous study discovered that AWT contributes a significant amount of time. Therefore, this research proposes a method to reduce the AWT by parallelizing the agents of an organization and simulating the parallelized agents using agent based simulation. The simulation results time and cost are then optimized using three methods namely Stochastic Multi-Criteria Adaptability Analysis-2 (SMAA-2), Multi Objective Optimization on the Basis of Ratio Analysis (MOORA), and Complex Proportional Assessment (COPRAS). The three methods achieve the same reduced AWT to 9.4%. From those methods, MOORA achieves the highest accuracy of 80% and the sensitivity coefficient of 7. However, COPRAS results in 78% accuracy with lower sensitivity coefficient of 6. SMAA-2 results in the lowest accuracy of 40% and the highest sensitivity coefficient of 13.

Keywords: Simulation, Agent based simulation, Business process prallelization, SMAA-2, MOORA, COPRAS.

1. Introduction

The business process of Port Container Terminal (PCT) is a complex process involving different organizations with different purposes. In Indonesia, the business process involves 4 organizations. The organizations involved in the process are PCT, Quarantine, Custom, and Customer. These organizations need to work together in order to make the business process run smoothly. Thus, good communications between those organizations are playing a vital part in determining the performance of the business process.

The dwelling time, the duration in which containers are retained in PCT, is regulated by Indonesian constitutional law. The dwelling time of each container must never be over 3 days. Nevertheless, according to the log data gathered from PCT, the time needed to complete the process sometimes take more than 3 days. Therefore, it is basically violating the regulations when the containers are retained for more than the designated time.

Simulation tries to imitate the execution of the real world process [1]. Using simulation, improvement for the current system can be tested for its impact without risking the possibility of a failed system. The results of the previous studies discover that agent based simulation can give insight into the communication process of each agent [2, 3]. The agents inside the simulation represent the organizations involved in the business process. To communicate with each other, every agent needs more time in sending and receiving the message before working on an activity (task). This added waiting time is called Asynchronous Waiting Time (AWT). Another case which adds to AWT is the asynchronous process when an agent is still working

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on another task but the system gave a new task to work on. This can cause a bottleneck that leads to the extended waiting time of the newly assigned task. Since this AWT adds more time to the waiting time of each activity, the dwelling time of each container is also longer. Thus, the performance of the PCT is directly affected by AWT. Aside from the time needed to complete the unloading process, the cost spent for each container can also be used to measure the performance of the PCT [4].

This research aims to reduce the AWT of the current system to improve the performance of PCT. Based on the existing process, AWT contributes much to the total waiting time [5]. Here, we propose parallelization on the agents of the simulation to reduce the workload of each agent. We believe that parallelizing agents can reduce the AWT of the current system since parallelizing have been proven as a method to reduce the workload of another system [6, 7]. After parallelizing the agents, the time and cost required for the parallelized agents are evaluated to determine the performance of the system. The performance of each parallelization is then compared to find the best alternative using optimization methods. Since we use time and cost as the indicator for the performance of the system, we should use Multi Criteria Decision Making (MCDM) methods [8]. The methods we use for the optimizations are Stochastic Multiple-criteria Adaptability Analysis (SMAA-2), Multi Objective Optimization on the Basis of Ratio Analysis (MOORA), and Complex Proportional Assessment (COPRAS). The methods are then compared to each other [9]. The results of the comparison show the best method to use in PCT case.

The main contribution of this research is the method to reduce AWT found on the previous research and find the most suitable optimization method based on the time and cost of each alternative. This research is structured as follows: section 2 presents related theory that support this research, section 3 describes the proposed method for creating the simulation model and parallelize the agents, section 4 shows the results and analysis of the experiment, and Section 5 gives conclusions on the research.

2. Related theory

This section will explain this research related theories.

2.1 Simulation

Simulations have several methods which are generally used. Those methods are discrete event simulation and agent based simulation. Discrete event simulation has been used in several studies [10–12]. While simple, discrete event simulation does not accommodate the communication process we need to simulate the business process of PCT. Therefore, agent based simulation is more suitable to be used as the simulation method.

Agent based simulation uses agents as the representatives of the actors for the system. When creating an agent based simulation, an agent must have several characteristics. Those characteristics are Autonomous, Proactive, Reactive, and Social Ability [13]. Therefore, an agent can adapt to a change in the environment.

Another strong point of agent based simulation is its ability to model the communication process. Nevertheless, several studies involving agent based simulations have not been focused on the time spent for the communication process of the agents involved [14–17]. Thus, the time needed for the communication of the agents has not been studied.

2.2 Agent parallelization

In the case of Port Container Terminal, the asynchronous process of agent based simulation shows an added waiting time called AWT [2]. Generally, tasks with AWT discovered in the previous study are caused when an agent is waiting for the other agent to finish a task and send the message required to do the next task. The example of what causing AWT is depicted in Fig. 1.

Fig. 1 shows the asynchronous communication process which causes AWT. the Y-axis shows the actor of the activity and shows on which case the activities are executed. Meanwhile, The X-axis of the figure shows the time spent for the activities. Green color indicates the case length, while each activity done by different agent is given different color.

Based on Fig. 1, Agent 2 is still working on a task when Agent 1 has already done the task assigned to the agent and send a message for agent 2 to work on the next task. Since agent 2 cannot work on the case yet, the task will have a longer waiting time since it has to wait for the previous task to be completed by agent 2.

A study to reduce the workload of a system have been done [6]. On the previous study, the researchers tried to parallelize the crane and lock used on the port logistic terminal. The best result of the parallelization on the previous research is not the most crane and lock used. Resulting in the need of optimization method to determine the best alternative with the most optimal time and cost.

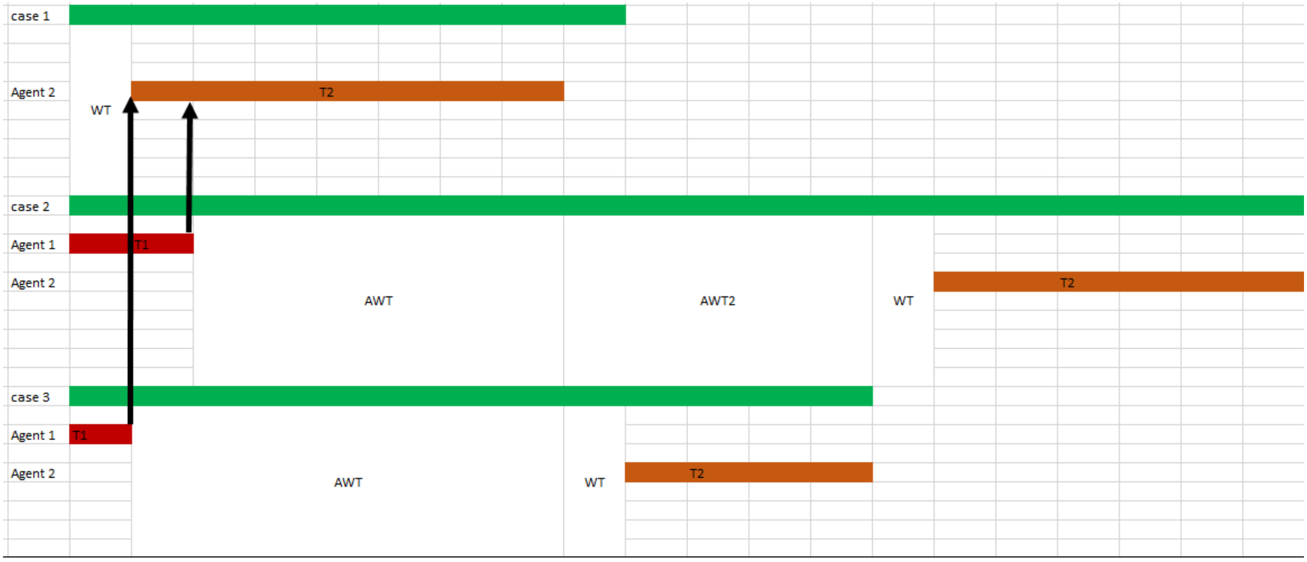


Figure. 1 Example of AWT

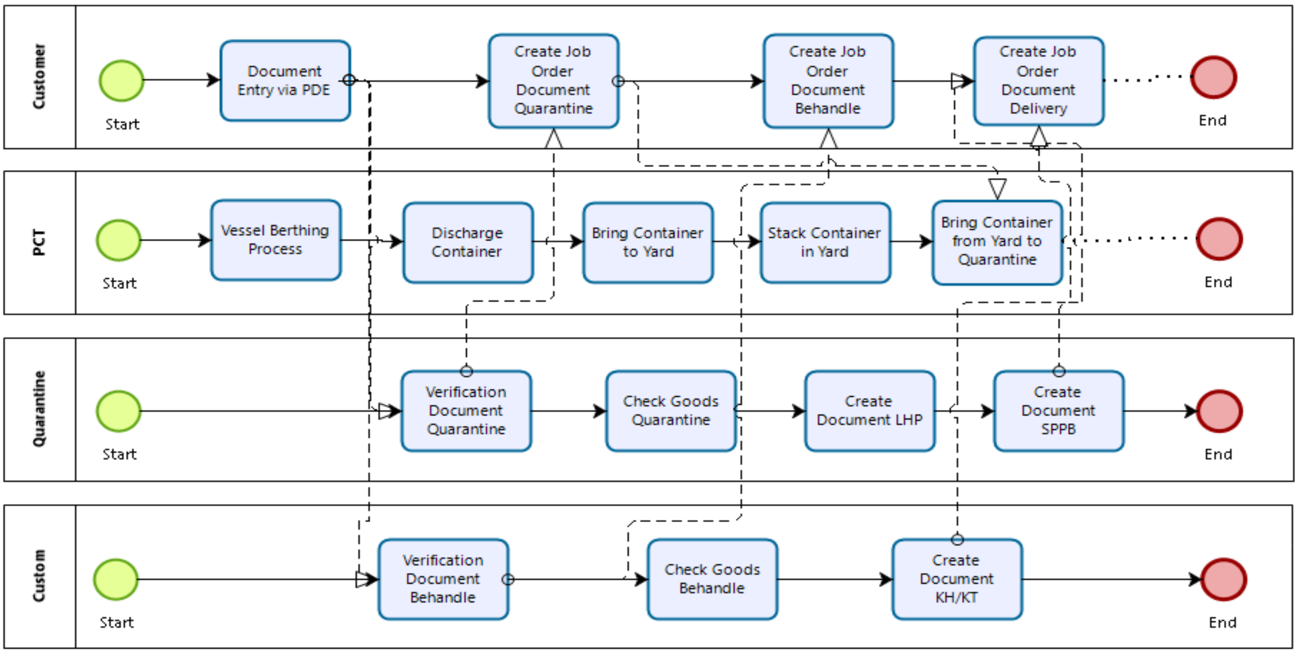


Figure. 2 The SOP of Customer, PCT, Quarantine, and Custom

In Fig. 1, each task is handled by an agent. When tasks are too many and the workload of an agent is too high, we need to parallelize the agents. The benefit of parallelizing the agents is the ability to handle more than one case at a time. The parallel agents can perform a task based on the SOP of the organization the agent represents. The SOP of the organizations in this research is shown in Fig. 2.

Fig. 2 shows that the agent has its respective task based on the organization its represent. The Custom agent has 3 tasks in the SOP to complete a case. A case is a work which needs a sequence of tasks to be handled by 4 or fewer organizations. When performing the task, the agent needs to communicate with another agent. After the completion of a task, Custom agent can send a message which is required for customer agent to perform an activity.

As for the parallelization, for example we parallelized the agent of Custom organization into Custom Agent 1 and Custom Agent 2. Thus, Custom organization can perform 2 cases at a time. Fig. 3 shows how the agent communicate when the agents have been parallelized.

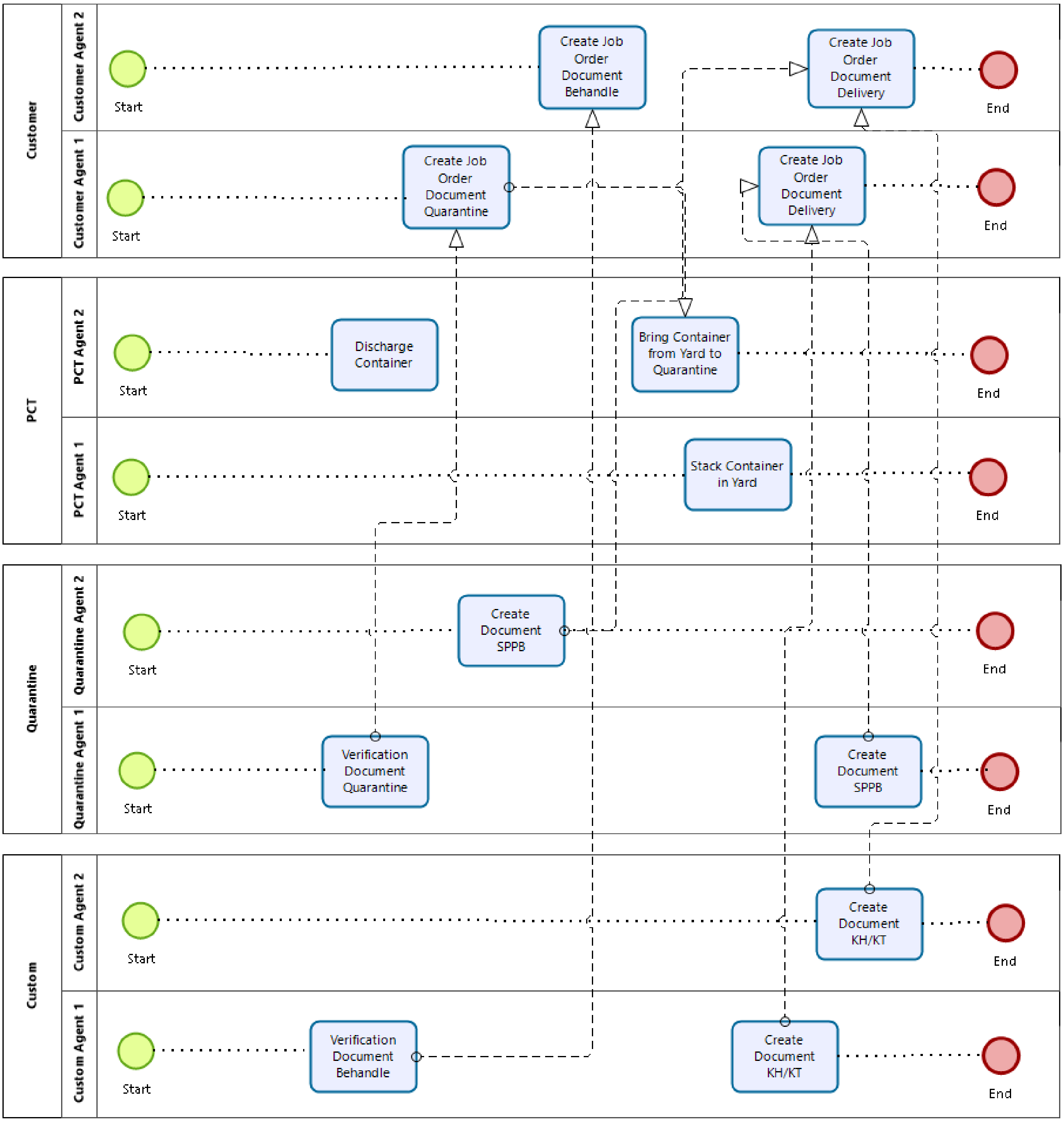


Figure. 3 Communication of parallel agents

Based on Fig. 3, each agent can communicate with another agent of the other organization. The communication of the agents in Fig. 5 is modeled in the form of messages when the simulations are running. The agent of a previous task will send a message for the agent of the next task to start working on the task. When more agents are given to each of the organization, more task can be done at the same time and more messages can be sent and received at the same time. Thus, the AWT of the task can be reduced.

By parallelizing the agents, the reduced AWT affects the cost of the task with the reduced AWT in the log data. We parallelize the agent from no parallel agent for each organization up to 10 parallel agents. To calculate the reduced cost, denote cost C for each case m and task n as the total cost of each task in a case ($C_{11}, C_{12}, \ldots, C_{mn}$) inside the log data. We divide C_{mn} into execution cost (Ce_{mn}) and waiting cost (Cw_{mn}). Instead of using the average of the cost, we use the minimum cost of each task ($\min C_{m1}, \min C_{m2}, \ldots, \min C_{mn}$) in the log data into a Gaussian distribution to determine each task execution cost Ce_{mn}. Therefore, the execution cost Ce_{mn} is calculated using Eq. (1).

$$Ce_{mn} = a_{mn}\, e^{\left(-\frac{(x-\min Ce_{mn})^2}{2\sigma_{mn}^2}\right)} \tag{1}$$

where,

e = 2.71828

x = Random normal variable

a = $1/(\sigma\sqrt{2\pi})$

σ = Cost standard deviation

Since we have Ce_{mn} of each task, we can calculate Cw_{mn} of the task by subtracting C_{mn} with Ce_{mn} as shown in Eq. (2).

$$Cw_{mn} = C_{mn} - Ce_{mn} \tag{2}$$

AWT Wa_{mn} is recognized as the added waiting time apart of the normal waiting time W_{mn}. Thus, we can calculate the reduced waiting cost Cr_{mn} of the tasks. We calculate Cr_{mn} using Eq. (3).

$$Cr_{mn} = \left(\frac{Wt_{mn}}{WT_{mn}} \times Cw_{mn}\right) + \left(\frac{Wa_{mn}}{WT_{mn}} \times Cw_{mn}\right) \tag{3}$$

where,

WT_{mn} = Total Waiting time before parallelization of task mn

Wt_{mn} = Waiting time based on log data of task mn

The total cost Ct_{mn} after parallelization for case m and task n is then calculated using Eq. (4).

$$Ct_{mn} = Cr_{mn} + Ce_{mn} \tag{4}$$

2.3 SMAA-2

Stochastic Multi-Criteria Acceptability Analysis-2 (SMAA-2) is a method developed from Stochastic Multi-Criteria Acceptability Analysis (SMAA). Unlike SMAA, SMAA-2 considers the weight given to each criterion[18]. SMAA-2 has been used on researches, such as evaluating combined heat and power technology[19], and decision support for strategic forest planning with dependent uncertainties [20]. The result of SMAA-2 is an acceptability index with the range from 0 to 1 for each alternative. The steps required to optimize using this method are as follows[21]:

Denote a set of m alternatives $(x_1, x_2, \ldots, x_m)$ which have n criteria. The decision making preference is then mapped into value function $u(x_i, w)$. SMAA-2 initially developed when the decision maker preference is unknown or partially known. Thus, SMAA-2 will show the possibilities of each alternative to place in a certain rank based on Feasible Weight Space (FWS). Weight space W is an FWS which represent the preference of the decision maker. Hence, if we give an exact weight w, SMAA will give a certain rank to each alternative. Fig. 4 depict the weight space for 3 criterion problem.

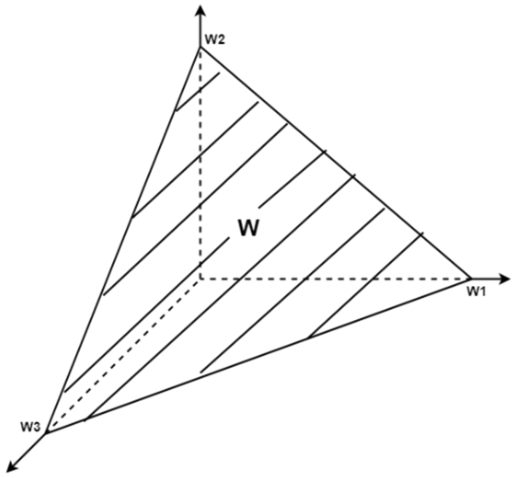


Figure. 4 FWS of 3 criterion problem

Fig. 4 shows the FWS of 3 criterion problem with W1= (1,0,0); W2 (0,1,0); W3= (0,0,1); with the total weight for all criteria cannot be more than 1. Eq. (5) defines the weight space in n dimension.

$$W = \left\{ w \in R^n : w \geq 0 \ and\ \textstyle\sum_{j=1}^{n} w_j = 1 \right\} \tag{5}$$

Each criterion is then mapped into value function $u(x_i, w)$ after the weight w has been determined. We use Eq. (6) to map the value function.

$$u(x_i, w) = \textstyle\sum_{j=1}^{n} u_j(g_j(x_i))w_j \tag{6}$$

where,

g_j = criteria j of alternative x_i

Based on the value function, each alternative will be given rank from the best (=1) to the worst (=m) using Eq. (7).

$$r(i, x, w) = 1 + \sum_{k=1}^{m} \rho(u(x_k, w) > \rho(u(x_i, w)) \tag{7}$$

where,

$\rho(true) = 1$ and $\rho(false) = 0$

Then, each alternative will be calculated using Eq. (8).

$$W_i^r(x) = \{w \in W : rank\ (i, x, w) = r\} \tag{8}$$

Any weight $w \in W_i^r(x)$ results in such values for different alternatives, that alternative x_i obtains rank r . The descriptive measure of SMAA-2 is acceptability index b_i^r which measures the variety of w that gives alternative x_i rank r. The share of all feasible weights will give an alternative a particular rank. Eq. (9) calculate the acceptability index of each alternative.

$$b_i^r = \int_{x \in X} fx(x) \int_{w \in W_i^r(x)} f_w(w) dw dx \tag{9}$$

The best alternative is the one with the highest acceptability for the best ranks. For an alternative with acceptability index of 1 for a particular rank, that alternative will always get the rank even though w is shifted. Vice versa for alternatives with acceptability index of 0.

2.4 MOORA

Multi Objective Optimization on the Basis of Ratio Analysis (MOORA) is a multi-criteria decision making method. Each criteria n should be categorized into beneficial criteria or cost criteria. The research using this method tried to maximize the performance of a machine, minimizing the use of fuel, minimizing the weight of spare parts while maximizing the strength of the spare part [22]. On other researches, MOORA is used to determine a location for a seaport [23], the optimal location for a warehouse [24], determining the multi-criteria problem in welding [25] and optimization for milling process [26]. The total optimization results of the alternative will determine the rank of the alternative. The steps for doing optimization using MOORA is as follows [27]:

1. Determine the objective function is the first step of utilizing this method. The objective function id denoted on Eq. (10).
2.

$$BA = \min \mathrm{Wa} + \min C \tag{10}$$

where,

Wa = Total asynchronous waiting time of all cases after parallelization

C = Total Cost of all cases after parallelization

3. Make decision matrix $m \, x \, n$ containing all the information on the available criteria n in alternative m as shown in Eq. (11).

$$\begin{bmatrix} x_{11} & x_{12} & x_{13} & \cdots & x_{1n} \\ x_{21} & x_{22} & x_{23} & \cdots & x_{2n} \\ x_{31} & x_{32} & x_{33} & \cdots & x_{3n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & x_{m3} & \cdots & x_{mn} \end{bmatrix} \tag{11}$$

4. Split the criteria on the decision matrix into beneficial S_{+i} and cost S_{-i} criteria.
5. Based on the decision matrix in Eq. (11), find the denominator d_j using Eq. (12).

$$d_j = \sqrt{\sum_{i=1}^{m} (x_{ij})^2} \tag{12}$$

where,

d_j = The denominator of criteria j

6. Since we got the denominator of each criterion, the normalized performance of each criterion r_{ij} can be calculated using Eq. (13).

$$r_{ij} = \frac{x_{ij}}{d_j} \tag{13}$$

7. Calculate the normalized performance r_{ij} to weight w_j based on its respective category using Eq. (14) or Eq. (15).

$$S_{+i} = \sum_{j \in \Omega_{max}} w_j r_{ij} \tag{14}$$

$$S_{-i} = \sum_{j \in \Omega_{min}} w_j r_{ij} \tag{15}$$

8. Calculate the optimization value Q_i using Eq. (16)
9.

$$Q_i = S_{+i} - S_{-i} \tag{16}$$

2.5 COPRAS

Complex Proportional Assessment (COPRAS) is an optimization method with complex aggregation compared to SAW or MOORA [27]. This method differentiates the beneficial and cost criteria. this method has been utilized in several studies, namely deciding the best alternative for building refurbishments which has quantitative and qualitative criteria [28], optimizing the blind spot of vehicles [29], material selection [30], and contractor selection [31]. COPRAS has a similar method to MOORA on performing optimization. The steps of COPRAS optimization are as follows:

1. COPRAS perform the same steps as MOORA on step 1 – 3.
2. This method calculates the denominator

using Eq. (17).

$$d_j = \sum_{i=1}^{m} x_{ij} \tag{17}$$

3. The normalized performance of COPRAS is performed using Eq. (13)
4. Perform step 6 of MOORA.
5. Calculate the optimization value Q_i using Eq. (18).

$$Q_i = S_{+i} + \frac{\min(S_{-i})\sum_{i=1}^{m} S_{-i}}{S_{-i}\sum_{i=1}^{m}\frac{\min(S_{-i})}{S_{-i}}} \tag{18}$$

2.6 Comparing MCDM Methods

To find the best method for this research, we used sensitivity analysis and accuracy. Based on previous research [9], several MCDM methods are compared. The MCDM methods are then given different scenarios where the weight of each criterion is changed. The results of all the methods in each scenario are then aggregated. For k alternatives, each alternative which is placed on the first rank gets k points. The alternative placed second gets $k - 1$ points, and so on. The alternative with the highest points is considered as the best alternative.

To perform sensitivity analysis, this research compares the results of a method in a particular scenario when the weights of the criteria of that particular method are equal. Each change of rank of the alternatives adds 1 point to the sensitivity coefficient. The method which has the lowest sensitivity coefficient is considered more stable than that of the higher sensitivity coefficient.

To calculate the accuracy of the methods, this research compares the ranking results of the aggregation process, as performed by the previous research, to the ranking results of each method. If an alternative x is placed on rank k on the aggregate result and alternative x is also placed on rank k by a method, the method got 1 point for the current scenario. The accuracy of the method is then calculated based on the point each method has compared to the total point from all scenarios. The best method is determined based on the accuracy and its sensitivity to weight change.

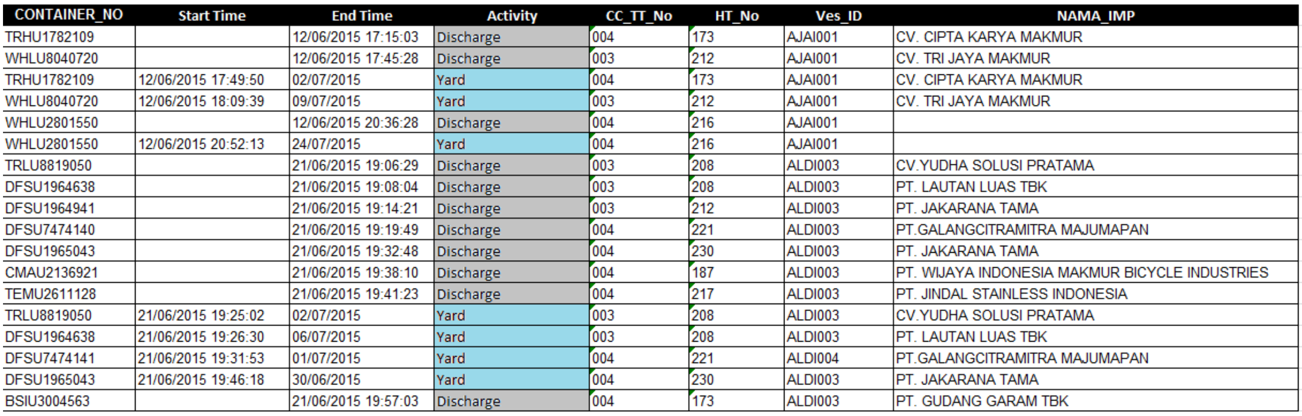
3. Research method

There are three parts of the proposed method. The first step is creating the simulation model, the second step is parallelizing the agents, and the last step is optimizing the time and cost of the parallelization.

3.1 Modeling and running the simulation

To build the simulation model, we refer to the standard operating procedure (SOP) of the PCT. From the SOP we can infer the organizations involved in the business process. The organizations involved are Customer, PCT, Custom, and Quarantine. The SOP also contains the communication process of the organizations. We used Python with SPADE as a tool to build the model. The SOP we used as the reference is as shown in Fig. 2.

Since we can build the model, we need to run the model to get the performance of the system. From the current system, we will tackle 2 scenarios for the implementation of the simulations. First, the scenario when there are not enough agents, resulting in much more waiting time because of the increased AWT since the agent must wait for the completion message from another agent. Second, the scenario when an activity needs 2 or more messages to start. We can run the model using the log data gathered from PCT. Part of the log data gathered is as shown in Fig. 6.



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. 6 Part of log data

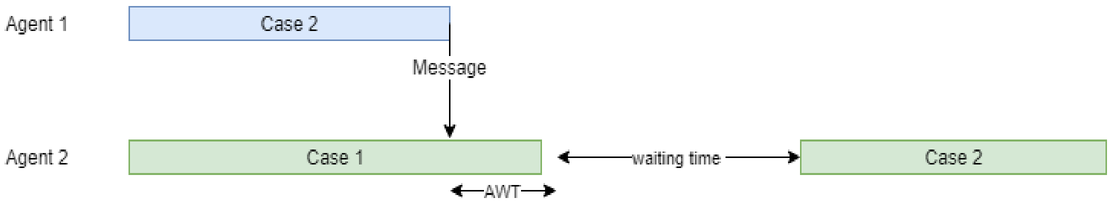


Figure. 7 The first scenario of AWT

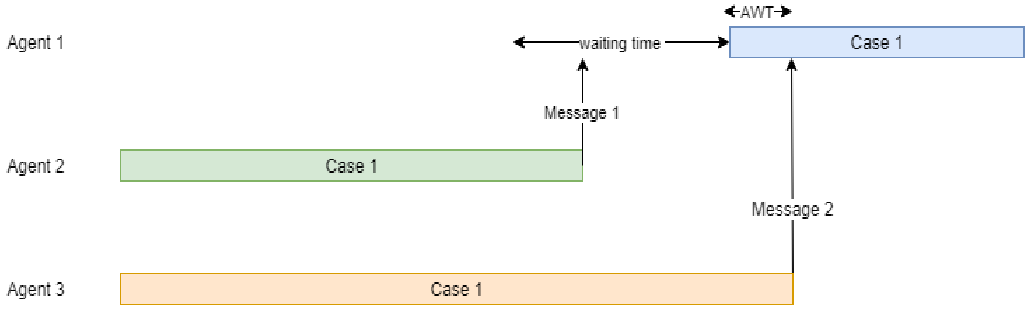


Figure. 8 The second scenario of AWT

The log data contains data from January 2016 with 24,440 records, February 2016 with 23,999 records, and March 2016 with 24,293 records. Each task in a case has a start time, cost, actor and the duration of the execution of the task. Thus, we can infer from the log data the sojourn time, execution time, and waiting time of each task.

3.2 Paralellizing agents

The results of the simulation show how AWT occurred. The first scenario is when an agent has completed a task and send a message to the agent with the next task as depicted in Fig. 7. For the second scenario, an agent needs more than one message to start an activity as depicted in Fig. 8.

Based on Fig. 7, Agent 1 has already done the assigned task and send a message to Agent 2. Meanwhile, Agent 2 is still working on a task from the previous case. Thus, AWT because of this asynchronous process is added to the total waiting time. We calculate the AWT for the affected task using Eq. (19)

$$Wa_{mn} = (Ts_{mn} - W_{mn}) - Te_{mn-1} \qquad (19)$$

where,

Ts_{mn} = Start time of task mn

Te_{mn-1}= End time of the previous task of task mn

Fig. 8 shows how AWT occurred when an agent needs more than one message to execute a task. Agent 1 need two messages to start executing the task of case 1. Meanwhile, only Agent 2 who have done the task assigned and send a message to Agent 1 before the waiting time of the task on case 1 is over. Agent 3 finished working on a task after the waiting time of the task in case 1 is over. Therefore, AWT is added to the task of case 1 and Agent 1 can start working on the case after the AWT is over. To calculate the AWT of the affected task showed in Fig. 6, we use Eq. (20).

$$Wa_{mn} = |Ts_{mn} - Te_{mn-1}| \qquad (20)$$

By parallelizing the agents, the total AWT of the current system can be reduced. Hence, we limit the parallel agent up to 10 parallel agents which represent each organization. Thus, the simulation will cover up to 40 agents working together. Then, we assign a task to each agent which has the shortest time to finish the task that is already given before. After each parallelization, we run the simulation to get the performance of each parallelization. The performance of the parallelization consists of the time and cost required for the simulation.

3.3 Time and cost optimization

SMAA-2, MOORA, and COPRAS need an input of alternatives that will be compared. The number of parallel agents is considered as the alternative for the optimization methods while time and cost of each simulation are the criteria for each alternative.

To optimize using SMAA-2, we use a tool provided [32]. The tool is available online at SMAA.fi/JSMAA. This tool was built using Java as the programming language. The results of SMAA-2 are the acceptability index of 0-1. The highest acceptability index for an alternative in a particular rank means that the alternative is the most suitable ranked for the particular rank.

Since MOORA and COPRAS need the input categorized into beneficial and cost criteria, we split

Table 1. Categorized criteria

Beneficial	**Cost**
-	**Time needed to complete a record**
-	**Cost needed to complete a record**

Table 2. Performance of all agents

No. of Agents	**AWT**	**Cost**
1	**9300469.69**	**65977283.31**
2	**4564010.08**	**67010216.77**
3	**3035485.56**	**66320886.88**
4	**2194768.81**	**67574410.70**
5	**1743519.78**	**65790427.32**
6	**1502409.05**	**64163855.60**
7	**1269282.91**	**64451610.57**
8	**1109564.39**	**64745119.53**
9	**973846.38**	**66812484.07**
10	**870362.55**	**64088425.60**

the criteria of the alternatives. We split the criteria based on the objective function on Eq. (10). The split result is as shown in Table 1.

Since we have only 2 criteria which need to be minimized, both criteria are categorized as Cost criteria. Thus, we have no beneficial criteria for this experiment.

The results of the optimizations are the rank of each alternative based on the optimization value. The higher the optimization value, the alternative will have a higher rank.

4. Result and analysis

Results and analysis section, the results of each MCDM methods and analysis results will be shown.

4.1 Simulation results

From 3 MCDM methods that we used, we evaluate the results based on the sensitivity and accuracy of the methods to the overall results of the optimization. We hypothesize that COPRAS will give the best results on sensitivity analysis since the aggregation step of COPRAS include the worst value of a criterion for all alternatives ($\min(\boldsymbol{S}_{-i})$). Thus, the results of the aggregation will not change much even if the weight of the criteria are changed. Since the accuracy of the methods is based on the aggregate results of all methods, methods which is similar to each other will have the better results. Thus, COPRAS will have the best overall results based on sensitivity and accuracy.

The proposed method has been implemented in programs and evaluated using log data of PCT from January 2016 to March 2016. We simulated 1100 records of log data. The performance result of the simulation for all parallel agents from 1 agent up to 10 agents is shown in Table 2.

From Table 2, only 9.4% of the total AWT left when the simulation is run using 10 agents compared to when the agent is not parallelized. Those data from Table 4 are then optimized using SMAA-2, MOORA, and COPRAS. The results of the optimization are then analyzed by its accuracy and sensitivity.

To calculate the accuracy and sensitivity of each method, we need different scenarios. The scenarios are based on the weight distribution on the criteria. The scenario that is used on this research are w= [0.5,0.5], w= [0.1,0.9], w= [0.3,0.7], w= [0.7,0.3], and w= [0.9,0.1].

4.2 Determining the best MCDM method

The review data were labeled sentiment by the annotator. The sentiments were divided into negative and positive. If there was an adjective within a neutral sentiment, the annotator would classify the sentiment to be negative or positive based on the rating score. The review data were divided into 80% for training and 20% for testing.

From the previous results can be inferred that a change in criteria weight can change the rank of the alternatives. The change in the rank of each method is summarized in Table 3.

From Table 23, each alternative is given different ranks based on the scenarios. From all of the optimization result, simulation using 10 parallel agents gives the most optimal result. Hence, shifting the weight of the criteria change the ranks of the other alternatives. To determine the order of the best alternative, we aggregate the ranking of each alternative in different scenarios. For a number of alternative k, each best alternative got k point, $k-1$ point if the alternative is ranked second, and so on for each scenario.

We can rank the alternatives based on the point each alternative got. Table 4 shows the results of the aggregation.

The ranking results of the alternative are shown in Table 4. Since simulation using 10 agents got 30 points on all the scenarios, the alternative is the best alternative and achieve Rank I on each scenario. Simulation using 8 agents achieve Rank II when w are [0.1,0.9], [0.3,0.7], and [0.9,0.1] while simulation using 9 agents takes Rank II on scenario when w [0.5,0.5] and [0.9,0.1]. the alternatives got Rank II on

Table 3. Summarized results of all methods

Scenario	**Method**	**Rank**									
		I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**
Equal Weight [0.5,0.5]	**SMAA-2**	**10**	**6**	**7**	**8**	**5**	**9**	**3**	**4**	**2**	**1**
	MOORA	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
	COPRAS	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
Cost [0.1,0.9]	**SMAA-2**	**10**	**6**	**7**	**8**	**5**	**1**	**3**	**9**	**2**	**4**
	MOORA	**10**	**8**	**7**	**6**	**9**	**5**	**4**	**3**	**2**	**1**
	COPRAS	**10**	**8**	**7**	**6**	**9**	**5**	**4**	**3**	**2**	**1**
Cost [0.3,0.7]	**SMAA-2**	**10**	**6**	**7**	**8**	**5**	**3**	**9**	**1**	**2**	**4**
	MOORA	**10**	**8**	**7**	**9**	**6**	**5**	**4**	**3**	**2**	**1**
	COPRAS	**10**	**8**	**9**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
AWT [0.7,0.3]	**SMAA-2**	**10**	**6**	**7**	**8**	**5**	**9**	**3**	**4**	**2**	**1**
	MOORA	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
	COPRAS	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
AWT [0.9,0.1]	**SMAA-2**	**10**	**8**	**7**	**6**	**9**	**5**	**4**	**3**	**2**	**1**
	MOORA	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
	COPRAS	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**

Table 4. Rank of alternative based on aggregation results

Scenario	**Rank**									
	I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**
Equal Weight [0.5,0.5]	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
Cost [0.1,0.9]	**10**	**8**	**7**	**6**	**5**	**9**	**3**	**4**	**1**	**2**
Cost [0.3,0.7]	**10**	**8**	**7**	**6**	**9**	**5**	**3**	**4**	**2**	**1**
AWT [0.7,0.3]	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
AWT [0.9,0.1]	**10**	**8**	**9**	**7**	**6**	**5**	**4**	**3**	**2**	**1**

its respective scenario since those alternatives have the highest point compared to the other alternatives on the scenario.

By comparing the results of each method to the results of the aggregate of all methods we can determine the best method to use. The difference in the results will determine the accuracy of the methods. While every change of rank determines the sensitivity of the method. Table 5 shows the comparison of each method results to those of aggregate of all methods.

On Table 5 each method result is compared to the aggregate result on each scenario. SMAA-2 only got 3 points since only alternatives on Rank I, Rank IX, and Rank X have the same results with the aggregate result on scenario with w = [0.5,0.5]. Thus, the total point for SMAA-2 on the scenario is 3/10. The points each method get from Table 5 is used to calculate the accuracy of the method on Table 6.

Table 5. Comparison of each method results to aggregation results

Scenario	Method	Rank										
		I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	
Aggregate results		**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
Equal Weight [0.5,0.5]	**SMAA-2**	**10**	**6**	**7**	**8**	**5**	**9**	**3**	**4**	**2**	**1**	**3/10**
	MOORA	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**10/10**
	COPRAS	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**10/10**
Aggregate results		**10**	**8**	**7**	**6**	**5**	**9**	**3**	**4**	**1**	**2**	
Cost [0.1,0.9]	**SMAA-2**	**10**	**6**	**7**	**8**	**5**	**1**	**3**	**9**	**2**	**4**	**4/10**
	MOORA	**10**	**8**	**7**	**6**	**9**	**5**	**4**	**3**	**2**	**1**	**6/10**
	COPRAS	**10**	**8**	**7**	**6**	**9**	**5**	**4**	**3**	**2**	**1**	**6/10**
Aggregate results		**10**	**8**	**7**	**6**	**9**	**5**	**3**	**4**	**2**	**1**	
Cost [0.3,0.7]	**SMAA-2**	**10**	**6**	**7**	**8**	**5**	**3**	**9**	**1**	**2**	**4**	**3/10**
	MOORA	**10**	**8**	**7**	**9**	**6**	**5**	**4**	**3**	**2**	**1**	**6/10**
	COPRAS	**10**	**8**	**9**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**5/10**
Aggregate results		**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
AWT [0.7,0.3]	**SMAA-2**	**10**	**6**	**7**	**8**	**5**	**9**	**3**	**4**	**2**	**1**	**3/10**
	MOORA	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**10/10**
	COPRAS	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**10/10**
Aggregate results		**10**	**8**	**9**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
AWT [0.9,0.1]	**SMAA-2**	**10**	**8**	**7**	**6**	**9**	**5**	**4**	**3**	**2**	**1**	**7/10**
	MOORA	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**8/10**
	COPRAS	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**8/10**

Table 6. Accuracy calculation

Method	Total Points	Accuracy
SMAA-2	**20/50**	**40%**
MOORA	**40/50**	**80%**
COPRAS	**39/50**	**78%**

Table 7. Sensitivity results

Method	Sensitivity Coefficient				Total
	Cost [0.1,0.9]	**Cost [0.3,0.7]**	**AWT [0.7,0.3]**	**AWT [0.9,0.1]**	
SMAA-2	**3**	**4**	**0**	**6**	**13**
MOORA	**4**	**3**	**0**	**0**	**7**
COPRAS	**4**	**2**	**0**	**0**	**6**

From Table 6, we can infer that MOORA has the best accuracy compared to the other method with 80% accuracy. Meanwhile, COPRAS give an accuracy of 78% compared to the aggregate results. SMAA-2 gives the worst results with 40% accuracy. Since we have calculated the accuracy of each method, we need to calculate the sensitivity to determine the best method. Table 7 contains the sensitivity coefficients of all methods.

The results on Table 7 are based on the results on Table 5. Each method in different scenario is compared to the result of the method when the w = [0.5,0.5]. For example, MOORA in scenario where w = [0.1,0.9] changed the rank of the alternatives on Rank II, Rank III, Rank IV, and Rank V compared to when w = [0.5,0.5]. Thus, the sensitivity coefficient of MOORA on scenario where w = [0.1,0.9] is 4. Based on Table 7, it is clear that the least sensitive method is COPRAS since the method has the least sensitivity coefficient. Method which has the least sensitivity coefficient means that the method is the most stable compared to the other method.

From the accuracy and sensitivity results, MOORA and COPRAS have a trade-off on their accuracy and sensitivity. COPRAS have reduced accuracy, but lower sensitivity. While MOORA have higher accuracy with higher sensitivity. COPRAS have lower sensitivity since the method utilizes $\min(\boldsymbol{S}_{-i})$. Thus, the method is more stable than MOORA which only subtract the value of all positive criteria to negative criteria. SMAA-2 has the worst results on both sensitivity and accuracy since SMAA-2 uses a different approach to rank the alternatives.

5. Conclusion

Agent based simulation reveal an additional waiting time called Asynchronous Waiting Time (AWT) of each task. Based on the existing process, AWT contributes 98% of the total waiting time. Thus, AWT needs to be minimized with consideration of the cost of each task. Thus, we parallelize the agent used in agent based simulation and try to optimize the number of agents. Both AWT and cost is taken into consideration, therefore MCDM methods namely SMAA-2, MOORA, and COPRAS is used. The results show that parallelizing the agents reduced the AWT of the system to 9.4%. Compared to other methods, MOORA gives the best results with 80% accuracy, better than both SMAA-2 and COPRAS. For sensitivity analysis, COPRAS gives better results compared to MOORA and SMAA-2. Further research on the use of the other optimization method can be used to produce more optimized results.

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