Simulation of Agent-Based and Discrete Event for Analyzing Multi Organizational Performance

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Abstract— **Business process simulation is an interesting research for field of business process management and process mining. Through simulation, the parameters in the business process can be changed to determine the optimal simulation performance and evaluating existing business processes to improve performance for future business processes. Simulation in multiple organizations can be used to determine the performance of multiple organizations based on event log recorded on the organization's system. This study proposes simulations on multiple organizations using agent-based simulation and discrete event simulation. The multi-organizational example used in this research is port container terminal. In addition, this study also contributes with the establishment of event log in the future based on the results of forecasting the number of containers. This research proposes how to generate traces and event logs based on forecasting result of container number. This research resulted evaluation of business process performance in multi organization. The results show that the dwelling time in the existing event log and forecasted log exceeds the limit set by the government, which is a maximum of 3 days. Whereas in the event log the average dwelling time is 9.7 days based on agent-based simulations and 5.4 days of dwelling time using discrete-event simulation. Referring to the comparison of the two simulations, it is found that the difference in dwelling time in agent-based simulation and discrete-event simulation is influenced by the presence of asynchronous messages in agent-based simulation, resulting in longer dwelling time.**

Keywords— Asynchronous, Forecasting, Simulation of business process, Agent based simulation, Discrete event simulation,

I. INTRODUCTION

This era, simulation on business processes has an important role in business computing environment for developing distributed applications across various web services [1]. In general, simulation on business processes is a composition between two or more organizations that are applied in web services. Various emerging studies are currently positioning simulation on business processes to form a B2B (business to business) web service or involving organizations in a single service. The real implementation of simulation in business processes is to form a web service to compose two or more business process organizations [2]. Previous studies of asynchronous simulation using agent based simulations is carried out on similar topics [3][4][5]and using discrete event simulation for evaluating determination of organizational performance [6]. Research on simulation is important for multi organizations. It is useful for performing choreographic experiments before simulation is implemented on scalable business processes [7].

Simulation has a certain method for mapping real systems into simulation system. Previous research divides the simulation method into 3 main methods, namely dynamic simulation, discrete-event simulation and agent-based simulation [8]. The determination of the simulation method is influenced by the characteristics of the cases being resolved. Generally, business processes are cases that can be solved by discrete-event simulations because changes in state variables in the event take place discrete. Research on business process simulation using discrete-event method has been conducted by referring to event log to find the process model [9]. This research used port container terminal as a multi organization. In the business process of port container terminal, there is a simulation process involving multi organizations, so that there are several organizations that communicate with each other asynchronously to achieve the objectives of the process. This communication pattern can be handled by agents in agent-based simulations. This is corroborated by previous research to find agent behavior based on extracting event log [10], and conducting agent-based simulations based on agents' communication behavior references obtained from event log to improve business processes [11]. Therefore, the business process of port container terminal has characteristics to apply agent-based simulations referring to asynchronous choreographic communication patterns.

Based on the background that has been described, the researcher proposes to develop an asynchronous agent-based simulation on port container terminal. The main focus of this research is to conduct simulations to evaluate the performance of each activity in multiple organizations. The simulation is not only intended for current event log, but also for future simulation of event log based on the results of forecasting the number of containers. The agent-based simulation results will be compared with discrete event simulations to prove that asynchronous communication patterns affect dwelling time at port container terminal.

II. RELATED WORK

A. Business Process Simulation

Simulation in general can be interpreted as an imitation of the activities of a system, which was made with the aim to observe changes in the characteristics of real systems [12]. Through simulation, the parameters in the business process simulation can be changed to determine the optimal simulation performance before being implemented on a real system, one of which is through a web service. Figure 1 explains the basic flow of why a business process simulation is needed. In general, business processes are formed based on activities that occur in real life (real-world process), these business processes are collected in a system that uses technology to support operations and management, the system is known as a popular information system.

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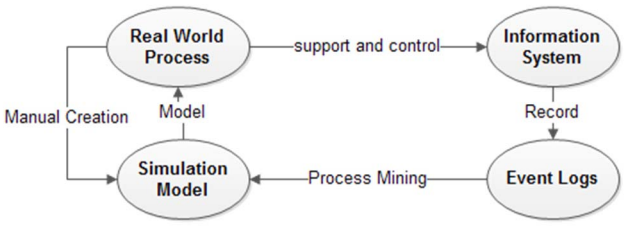

Figure 1. Simulation of Business Process

Through the information system, every activity that runs can be recorded automatically if the information system has a data log recording mechanism. Through these data logs, mining process techniques can develop, namely methods for exploring processes from event log to obtain process models. Process models that are formed from event log are developed to carry out a simulation

B. *Simulation Based Agent and Discrete-Event Simulation*

Agent-based simulation focuses on analyzing business systems involving interactions between agents. Agent-based simulation can be used to represent organizational settings naturally, because it involves businesses who communicate and interact with each other. In particular, it is possible to use ABS to simulate the implementation of business processes, thus generating an event log. In the previous research approach [13] an agent-based simulation framework called AOR was used. This framework provides high level construction such as process models that contain activities and low level construction such as incoming and outgoing messages to facilitate the mapping of business processes [11]. In previous research, business process simulation techniques developed using CPN Tools for discrete event simulation. This simulation is useful for estimating the effects of some redesign, which is able to predict and even predict the effects of changes in business processes when different scenarios are made for simulations [14]. The simulation can be described manually using CPN Tools or automatically through extracting the data log process model. This simulation is able to estimate or estimate the likelihood that would occur if there were changes in business processes. CPN Tools are advanced tools after ProM, because ProM is only able to analyze process models based on existing log data. CPN Tools and ProM are assistive tools that are related to each other in terms of the simulation process.

III. RESEARCH METHOD

This chapter discusses the methodology of studies used in this research. Completely, this chapter describes the event log, pre-processing phase, forecasting, future log generation based on forecasting, simulation using agent-based, and performance assessment as shown in Figure 2.

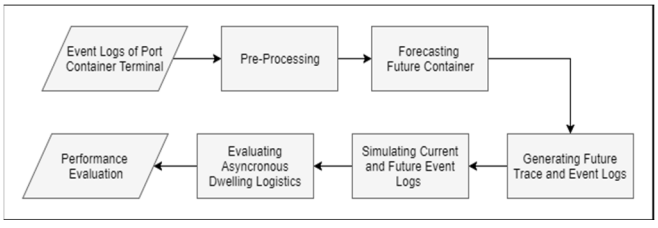

Figure 2. Research Method

A. *Event Log as Dataset*

This section explain the data used for this study. The event log of port container terminal is used for primary data set. Event log in port container terminal represent the recording of business processes occurring in port container terminal at the specified time. This paper limited the time range of event logs used as research data. It is during the January to March range in 2019.

Based on Van der alts [15], event logs have basic attributes such as case id, activity and timestamp. But for the event log in this study, used additional attributes that have not been used in previous research, namely message attributes. Different from the activity attribute that has the originator, the message attribute has sender and receiver. We propose that event logs that have messages contain activities run by different organizations. For example, the organization involved in port container terminal. We limit the issues discussed only specifically for importing goods in the terminal container port, so that the log event available is the log record for importing the goods. Import process of goods on the port container terminal involves the customer, port container terminal (employee of the terminal container port), customs and quarantine. The existence of messages makes communication between organizations important to be realized, because the success of the activity is influenced by the message between organizations. We agree that the number of organizations involved in terminal container ports is 4 organizations. When it simulated using agent-based simulation, the organization changed into 4 agents that communicate with each other. Message is the trigger to run the activity on another agent. If there is no message, then the activity on the other agent cannot run. For discussion of event logs, the attributes used in the research are case id, sender, receiver, activity, message, originator, single timestamp, and cost.

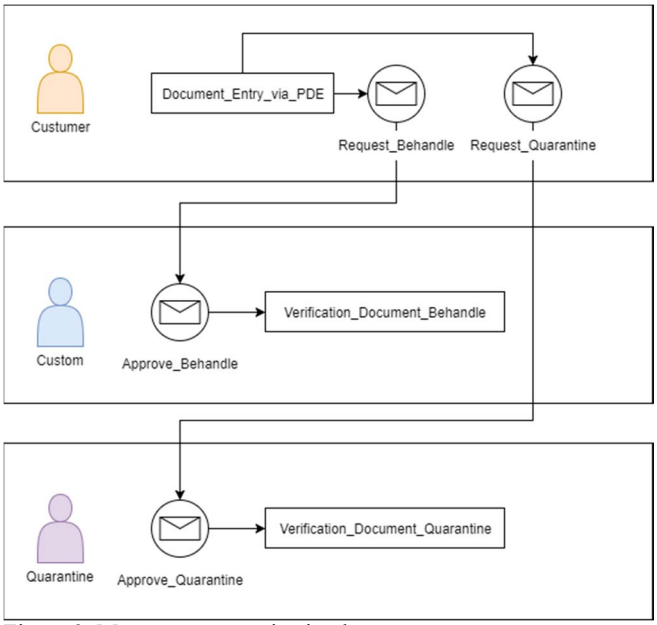

Figure 3. Message communication between agents

Figure 3 shows the exchange of messages between agents. Namely communication between customer agent to quarantine agent and customs agent. The customer sends a message after completing the activity, to trigger customs and quarantine activities. The event log that has been collected is

useful for designing simulations that present the current conditions at the port container terminal. Therefore, data for future event simulations is collected by estimating. First, estimate the number of containers for the coming month. Because the number of containers is the number of cases to log future events, the trace is determined by the normal random method. After we get the resulting log, we simulate the existing event log and the log created with discrete simulations and agent-based simulations.

B. Forecasting

In this phase, forecasting of the number of containers is carried out in the future. Research conducted by previous research [4][5]. It is succeeded in conducting container forecasting and simulating synchronous business processes. In this research, the superior contribution is to do a forecasting of the number of continents in the future, to then form a event log in the future. To forecast the number of containers. Some popular methods for forecasting time series data are used, including: Simple exponential smoothing, double exponential smooting, and moving average.

Simple exponential smooting is a method that uses a constant alpha () between 0 to 1 to determine the weight of the previous data. The more weights (close to 1) assigned to this method, the more weight is given to the most recent data compared to the previous data. The equation for Simple exponential smooting is shown in Equation (1).

$$F_t = \alpha A_{t-1} + (1-\alpha)F_{t-1} \quad (1)$$

F_{t-1} = Forecast result of last period

A_{t-1} = Actual data of last period

Then, double exponential smoothing is a statistical method based on simple exponential smoothing. In double exponentials, there are two commonly used methods. The first method uses only one weight constant, alpha. The second method uses alpha and beta as weight constants. The first is also called brown's exponential smoothing. Double exponential smooting is calculated using Equation (2).

$$\begin{aligned} F_t &= \alpha_t + b_t \\ a_t &= 2A_t - A"_t \\ b_t &= (\frac{\alpha}{1-\alpha})(A_t - A"_t) \\ A_t &= ay_t + (1-\alpha)A_{t-1} \\ A"_t &= aA_t + (1-\alpha)A"_{t-1} \end{aligned} \quad (2)$$

The next method is the moving average. This method is a forecasting technique that calculates the average data of several periods before the target estimate. Calculations using the moving average are shown in Equation (3)

$$MA = \frac{1}{K}(Y_{t-1} + Y_{t-2} + \cdots + Y_{t-K+1}) \quad (3)$$

Forecasting the number of containers is determined using 3 methods. But in the next phase, forecasting results are chosen with the smallest error value. The data used for forecasting is data on the number of containers in January to March 2019, amounting to 90 data. Forecasting is determined only to predict containers in units of days. Obtained container results for the next 30 days, namely April 2019. Based on 90 container data, 60 data are used as traininig data, the remaining 30 are as testing data.

C. Simulation Based Agent and Discrete-Event Simulation

This stage, the activities and communication attributes (sender, message and receiver) have been mapped. Agents involved in the simulation are all organizations involved, namely customers, quarantine, customs and container terminals. The basis of the simulation reference is log data. Not all attribute data in log data is used in agent-based simulations. Attributes in the log data that affect agent-based simulations are activities and messages, to distinguish the two, an ariginator is used in the activity and communication attributes (sender, receiver) in the message. Then in order to calculate the performance evaluation, it takes a sojourn time, waiting time and execution time. Whereas, discrete-event simulation is formed by modeling the container terminal business process without involving agents and messages, so this simulation only focuses on the incident process. Then to carry out agent-based simulations, use the tools for Anylogic 8.0 Personal Learning Edition. This toolkit was chosen because it supports agent-based simulations. In addition, it is also possible to conduct multi-method simulations. Therefore, in later implementation, agent-based simulations can be compared with discrete-event simulations using the same assistive tools. The steps for doing an agent-based simulation are:

a. Create a multi-organization business process model based on the SOP reference.
b. Make agents as organizational representations
c. Configuring messages between agents
d. Configure event log as input data.
e. Prepare the simulation log output.

IV. RESULT AND DISCUSSION

Event Log was tested using a computer with Intel® Core ™ i3 CPU processor specifications M380 @ 2.53 GHz, 4 GB of memory, The operating system used Windows 10 Professional 64-bit and Java was used for programming language and was used Anylogic Personal Learning Edition 8.0 for Agent-based Simulation and discrete-event simulation.

A. Pre-Processing

Pre-processing is done to obtain the value of the sojourn time and execution time for each activity. Sojourn time is the time taken to carry out an activity including the waiting time before the activity is carried out. Sojourn time is the execution time added to the waiting time. To obtain sojoun time, a calculation is done by finding the difference in dates between activities. However, these calculations are still based on expert guidance at port container terminal. Table 1 shows the basis for calculating the sojourn time for each activity and message.

Sojourn time on activity/message is determined based on the difference in the previous activity date. There are also activities that have sojourn time based on intervention by

Activity	SojournTime	AverageST	ST_DEV	ExTime	WaitTime	MIN Sojourn
Document_Entry_via_PDE	6648	7162,957258	2052,277103	5898	750	3603
Request_Behandle	60	89,61290323	29,9975025	38	22	60
Vessel_Berthing_Process	65335	64990,4125	12522,73563	51263	14072	43233
Discharge_Container	387	598,5092742	172,7009066	315	72	300
Bring_Container_to_Yard	1140	1104,708871	348,860568	982	158	600
Stack_Container_in_Yard	746	599,5157258	170,8643815	440	306	300
Approve_Behandle	99840	118141,8387	115346,4038	85408	14432	10980
Verification_Document_Behandle	496	361,9318548	138,0746022	441	55	120
Create_document_SPPB	24780	29968,1371	46418,00623	16328	8452	60
Send_SPPB_Info	68	91,21653226	38,23638658	52	16	60
Create_Job_Order_Document_Delivery	27900	34014,31452	50643,67174	17586	10314	60
Send_Job_Order_Delivery_Info	120	150,353629	29,94478028	119	1	120
Truck_in	172740	123267,5565	332560,8434	119249	53491	540
Dispatch_WQ_Delivery_to_CHE	60	96,96774194	863,7544635	42	18	60
Determine_Container_Type	180	304,016129	2441,721101	120	60	60
Determining_Dry	120	256,1361457	2306,667278	92	28	60
Decide_Task_Before_Lift_Container	120	139,6209677	1498,193003	88	32	60
Lift_on_Container_Truck	120	318,0241935	2733,772438	75	45	60
Truck_Go_To_Gate_Out	2760	4383,798387	9332,013764	2541	219	60
Check_Container_before_Truck_out	60	87,19354839	31,79868059	22	38	60
Truck_Out	120	140,9274194	1500,247381	90	30	60
Document_Entry_via_PDE	5487	7162,957258	2052,277103	4836	651	3603
Request_Behandle	120	89,61290323	29,9975025	86	34	60
Vessel_Berthing_Process	58570	64990,4125	12522,73563	46465	12105	43233

Figure 4. Generated event log based on generated trace (in second)

experts, because these activities are the beginning of the process in certain organizations. For example, the *Vessel_Berthing_Process* activity is the start of an activity in the terminal container port organization, that it is not possible to calculate the difference with the previous activity. Then, based on the results of the sojourn time calculations, obtained sojourn time values for each activity/message. Therefore, it can also be calculated the average sojourn time for each activity / message. A new contribution in this research is to propose methods to establish execution time and waiting time based on the results of the journal time. Determination of execution time and waiting time is done per activity / message refers to the results of the sojourn time of each activity / message.

- Determine the minimum value (MIN) sojourn time activity / message n.
- Determine the standard deviation of the time journal for the activity / message n
- Execution time = normal random (MIN sojourn activity/message time n, standard deviation of sojourn time for activity / message n)
- Waiting time = Sojourn time - execution time

B. *Forecasting Result and Analysis*

Forecasting is carried out to determine the estimated number of containers entering the port container terminal in the future. Based on the event log that has been obtained, one case id represents one container. For example, if in one month 23,000 containers were obtained, it was automatically found that in that month there were 23,000 containers that entered. Referring to the event log, the number of containers obtained in January, February and March 2019. Monthly container data is broken down into container data in a daily time span. The reason is, if monthly forecasting is done, then there are only 3 months as training data. This will certainly make the forecasting results less than optimal. Therefore, data on the number of containers for the 3 months that are available are broken down into data on the number of containers with a daily time span, so that a container data of 92 days is obtained. To do forecasting, the container data for 92 days is divided into 2 parts, 60 container data is used as training data and the rest is used as testing data. Empty number of containers on several dates will certainly affect the mean square error (MSE) and error rate (ER) on the forecasting results.

Table 1. Comparation MSE and RE

Methods	MSE	RE
Moving Average	253946,7	51,16618
Simple Exponential Smoothing	259155	52,92851
Double Exponential Smoothing	428117,2	53,01028

The comparison of MSE and RE for each forecasting method is shown in Table 1. It was found that the moving average method has the lowest MSE and RE values. Low MSE and RE indicate that the results of forecasting the number of containers close to the actual value in accordance with training data. Thus, the results of forecasting using the moving average method are used as a reference to form a trace and form forecasted event log.

C. *Generating Event Log*

Generating event log was performed to form forecasting event log or referred to as forecasted event log to differentiate from existing event log. As discussed in the previous section, forecasting results that are used as references to form event log are forecasting methods that have the lowest MSE and RE values, and have found that the moving average method has the lowest MSE and RE values. Therefore, the results of the moving average forecasting method are used as a reference to form trace and forecasted event log. Forecasted event log is needed to find out the time and cost performance in the future. The steps to generate to form forecasted event log are

- Calculate the forecasted number of containers every day for one month.
- Calculating the frequency of the number of containers per trace in each month.

- Calculate the percentage of frequencies per trace, average containers per day per trace, and standard deviation of containers per day per trace.
- Generating random numbers for the number of containers per trace using the normal distribution by: trace n = NORMINV (RAND (); average container trace n; standart deviation, container trace n).
- If the forecasted container results - the number of containers generated randomly all traces> 0, then the remaining number of containers will be regenerated using the frequency percentage of each trace.
- Number of containers for trace n = percentage of trace n * remaining number of containers in the 5th process.
- Add up the results of each trace in steps 4 and 6. The result of this process is a generated trace.
- Forming the case_id, activity/message, sojourn time, waiting time and execution time attributes to form forecasted event log refers to the generated trace.
- Adding event log for case_id, activity / message, sojourn time, waiting time and execution time refers to the results of the number of containers in the generated trace.

Then, every activity/message on all traces is generated by its sojourn time, by generating random numbers using a normal distribution with the average of sojourn time parameters and standard deviation of sojourn time referring to event log from January to March 2019. The results obtained are sojourn values the time for each activity/message for the generated event log in April 2019. Through sojourn time in the generated event log, execution time and waiting time can also be calculated, in the same way as in Pre-processing. The generated event log can be used to calculate dwelling time in April 2019. The results of the generated event log are shown in Figure 4. Each activity/message already has a complete time attribute for performance evaluation, namely sojourn time, waiting time and execution time.

D. Simulation of Agent Based and Discrete Event

Through the simulation results based on the agent, it is expected that the time and cost performance of each activity will be recognized. Waiting time based on event log available in January to March 2019 and estimated event log in April 2019. The residence time of the approval process carried out by 4 agents (customers, custom, quarantine and port container terminal) based on the time value per activity per agent can be calculated. Therefore, it can be seen that the agent has the longest time performance compared to other agents. The reference for dwelling time calculation is based on the compilation time of ship loading (starting dwelling time) until the truck compilation ends from the area of port container terminal (end dwelling time). Dwelling time is taken at residence time and using agent-based simulation, the value of dwelling time is obtained. The value of dwelling time in January to April 2019. Based on Table 2, the highest stay time in January 2016 was 10.58 days, while the lowest stay time in March 2016 was 8.33 days. The factor that caused the length of stay was asynchronous communication which affected the waiting time for some activities.

Table 2. Dwelling time based on Agent-based simulation (ABS) and Discrete Event Simulation (DES) in days.

Month	ABS	DES
January 2019	10.58	5.79
February 2019	10.21	6.84
March 2019	8.33	4.88
April 2019	9.71	5.83

Figure 5 shows a gantt chart that represents asynchronous communication. Asynchronous communication shows that when ED1 completes an activity, it issues a request message behandle as a trigger for VDB activity.

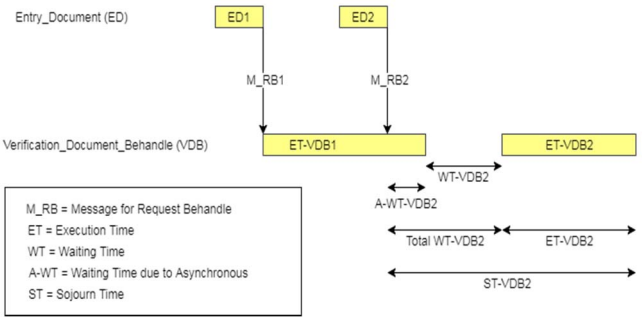

Figure 5. Gantt chart of agent-based simulation

After that, VDB1 starts executing (ET-VDB1). However, in the middle of its journey, VDB1 gets behandle message requests originating from ED2, so that VDB2 does not immediately execute execution, but waits for VDB1 to finish execution to completion. Therefore, this study found is waiting time that comes from asynchronous communication. In Figure 5, waiting time due to asynchronous influence is called A-WT. The total waiting time owned by VDB2 is the sum of normal waiting time (WT) and waiting time due to asynchronous (A-WT).

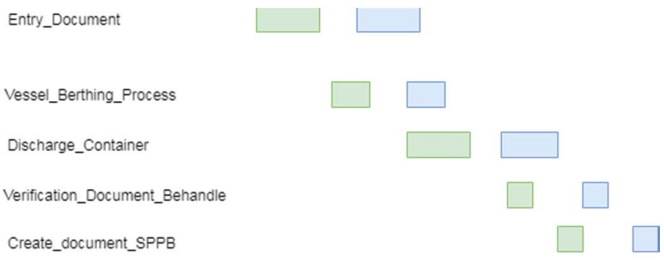

Figure 6. Gantt chart of Discrete event simulation

Meanwhile, the results of dwelling time using discrete-event simulation have lower results because they do not involve messages at the time of simulation, so that each activity undertaken by each agent directly runs without any message interruption. Table 2 shows the dwelling time graph at port container terminal in the range of January to April 2019. The highest dwelling time is in February while the lowest dwelling time is in March 2019. These results provide

evidence that asynchronous messages in agent-based simulations have a significant effect on increasing dwelling time. In Figure 6, the gantt chart shows that synchronous business processes directly execute the process without having to wait for the message as a trigger for the activity, so that all activities in the synchronous business process can be executed sequentially.

V. CONCLUTION

This research produces a method for forming event log through the results of forecasting the number of containers. It was done by generating random distribution normal numbers on each trace to produce generated event log. Generated event log represents event log in the future. Determination of dwelling time is calculated using agent-based simulation and discrete-event simulation on existing event log and forecasted event log. The results show that the dwelling time in the existing event log and forecasted log exceeds the limit set by the government, which is a maximum of 3 days. Whereas in the event log the average dwelling time is 9.7 days based on agent-based simulations and 5.4 days of dwelling time using discrete-event simulation. Referring to the comparison of the two simulations, it is found that the difference in dwelling time in agent-based simulation and discrete-event simulation is influenced by the presence of asynchronous messages in agent-based simulation, resulting in longer dwelling time. Recommendations for improvement are carried out by paralleling customs and quarantine agents. Parallelization is determined based on the presence of an agent that is the arrival of asynchronous messages so that parallelization is expected to reduce waiting times and make an impact to reduce dwelling time.

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