Optimizing Time and Cost Activity based on Discrete Event Simulation with Multi-Objective Optimization Method by Ratio Analysis (MOORA)

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***Abstract*— Medical waste management in a hospital is critical and must be treated properly. Waste management negligence can lead to accumulation of waste, which can trigger new diseases. One of the reasons for the accumulation of waste is insufficient number of resources. Optimization of the number of workers is important, because it will have an impact on the costs incurred and the complete time of the waste treatment. A simulation of medical waste management processes can portray many situations to provide optimal resources. Several existing research utilize Discrete Event Simulation (DES) to simulate waste processes; however, those publications have not determined optimal amount of resources based on cost and time in different rations and identified the effect of difference in the ratio of cost and time to the number of resources. This paper proposes a combination of Discrete Event Simulation (DES) and MOORA to determine amount of resources in different ratio of time and cost. Then, this paper implements two simulations, i.e., a simulation with small amount of incoming waste and a simulation with high amount of incoming waste, to identify the significant between the ratio of cost and time to the number of workers. This study uses a process model of medical waste management of a hospital in East Java to establish the DES. The results of this study indicate that in the case where there is less waste going in, fewer workers will be required than in the case where there is a lot of waste going in. The difference between the balanced ratio and the unbalanced ratio in the case where there is a small amount of incoming waste also does not have a big impact on the resource requirements of workers. In contrast to the case of a lot of incoming waste, the difference in the ratio will be seen significantly in terms of the number of workers needed for each activity.**

Keywords—AnyLogic, Discrete Event Simulation, Medical Waste Management, MOORA Method

I. INTRODUCTION

Medical waste management in a hospital is critical and must be treated properly [1], [2]. Waste management negligence can lead to accumulation of waste, which can trigger new diseases. For example, in COVID-19 pandemic, hazardous medical waste that is not processed properly can be means of potential source of infection [3], [4]. One of the reasons for the accumulation of waste is insufficient number of resources. Optimization of the number of workers is important, because it will have an impact on the costs incurred and the complete time of the waste treatment [5]–[7].

A simulation is widely used to portray several conditions which can happen in the real world. One of simulation technique is Discrete Event Simulation (DES) [8]–[12]. Several research which handled waste management uses DES. Liu [2], utilized DES to simulate several scenarios of medical waste models and compare those scenarios based on several parameters. Huang [8] portrayed several processes by using DES and analyzed in economic, energy and environment sides. Those researches have not determined optimal amount of resources based on cost and time in different rations and identified the effect of difference in the ratio of cost and time to the number of resources.

This research combines Discrete Event Simulation (DES) and MOORA method to determine amount of resources in different ratio of time and cost. MOORA is a widely used in optimization [13]–[17]. Then, this paper implements two simulations, i.e., a simulation with small amount of incoming waste and a simulation with high amount of incoming waste, to identify the significant between the ratio of cost and time to the number of workers.

II. LITERATURE REVIEW

A. Discrete Event Simulation (DES)

Discrete Event Simulation (DES) [9] is a simulation that is used to study systems where the behavior can be represented by discrete events involving building models of systems that consist of several building blocks including processes, entities, and resources. However, in some cases, the system behavior is not just affected by discrete events, continuous events also affect the system behavior as well. First, animation and graphic tools help model understanding. Second, DES is perceived as representative, provides realistic output, and creates confidence in decision making. Third, DES provides statistically valid estimates to the performance of systems [11].

B. AnyLogic

Anylogic is a software that is developed by the AnyLogic Russian Company that has a multi-method simulation tool with an intuitive GUI. It uses Java programming language and allows users to incorporate process modeling, system dynamics and agent-based modeling into a single model [10-11]. It is a software which can be used to do simulations for discrete, continuous, and agent mixed behavior that has been implemented for the business simulation of manufacturing, supply chain, logistics, retail, traffic, and aerospace since 2003.

C. Multi-Objective Optimization on the basis of Ratio Analysis (MOORA)

Multi-Objective Optimization based on Ratio Analysis (MOORA) is a process of concurrently optimizing at least two clashing attributes that are exposed to some limitations [18]. It is a multi-criteria decision-making method that has a high potential for comprehensive evaluation of alternatives in the face of substantial diversity and helpful factor multiplicity [19]. This method was invented in 2004 by Brauers [20].

There are several steps that should be done in MOORA method [20]–[22]:

Step 1: Make decision matrix by using Eq. 1,

$$x = \begin{bmatrix} x_{11} & x_{12} & . & x_{1n} \\ x_{21} & x_{22} & . & x_{2n} \\ . & . & . & . \\ x_{m1} & x_{m2} & . & x_{mn} \end{bmatrix} \quad (1)$$

Step 2: Normalize the decision matrix using Eq. 2.

$$x_{ij}^{*} = \frac{x_{ij}}{\sqrt{\left[\sum_{i=1}^{m} x_{ij}^{2}\right]}\ (j= 1, 2, \ldots, n)} \quad (2)$$

Step 3: Optimize the attributes by using Eq. 3

$$y_i = \sum_{j=1}^{g} x_{ij}^{*} - \sum_{j=g+1}^{n} x_{ij}^{*} \quad (3)$$

If the results are more optimum, weight may be applied to obtain the value of yi, therefore Eq. 3 can be written as Eq. 4.

$$y_i = \sum_{j=1}^{g} w_j x_{ij}^{*} - \sum_{j=g+1}^{n} w_j x_{ij}^{*}\ (j= 1, 2, \ldots, n) \quad (4)$$

III. METHOD

The research method used in this study can be seen in Fig 1.

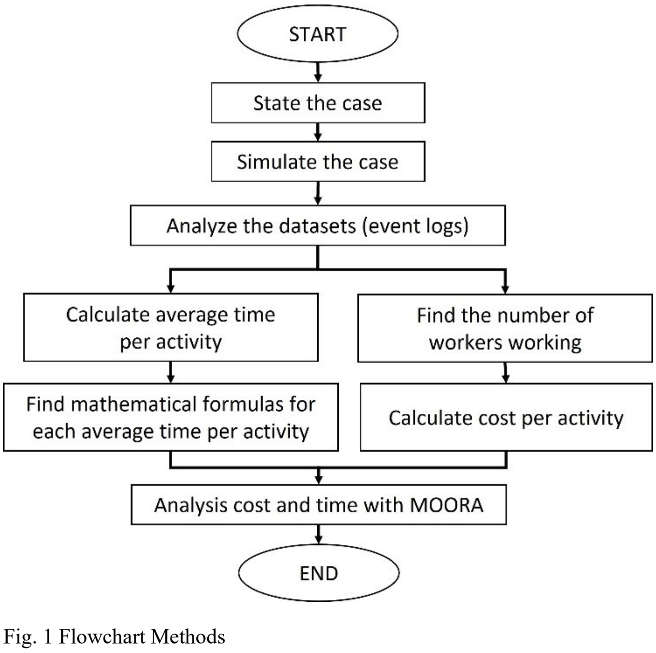

Fig. 1 Flowchart Methods

Based on Fig. 1, the first step that needs to be taken is state the case. State the case is stage of problem definition based on a case study by creating a simulation model like the case study that is made using Anylogic software with discrete events simulation methods.

The second stage is simulating the case. Simulate the case is to do a simulation based on the simulation model that has been made in the previous stage by using the independent variables that have been determined in this study, namely the resource variable in each activity in the model and the amount of waste input that is processed in the model during the simulation. The result of the simulation are event logs that will become a dataset for analysis

The third stage is analyzing the datasets. Analyzing the datasets is the stage where the datasets that have been obtained in the second stage will be analyzed deeply. Analysis of the datasets will be carried out using the SQL Server Management Studio (SSMS) application to be able to analyze the data obtained. The output of the analysis using SSMS is to find the average duration of time per activity carried out for all cases in the process and to analyze the average number of workers working in one day for each activity of the process.

The results of the analysis will be used to find a mathematical formula to determine the continuity between the addition of workers and the duration of time to perform an activity. In addition, it will also be used to calculate operational costs for each activity carried out in the process using Eq. 5.

$$Cost = cost\_per\_hour \times working\_time \times total\_worker \quad (5)$$

By using Eq. 5 the value of each operational cost for each activity in the process will be obtained.

The last step is determining the most efficient operational costs using MOORA method. By using this method, each analysis result that has been obtained will be assessed with the parameters on the MOORA that have been determined and a ranking will be carried out on the results of the MOORA calculation for each number of workers that have been determined for research to obtain the most efficient operational costs possible.

IV. RESULT

A. Material

The case study used for this research is a waste management company. The data used is data from simulation results using Anylogic software in the form of event logs with parameters for each resource. From the event log obtained, the time data for each activity is taken and the average is carried out at that time, then the average activity time will be compared with different resources and other parameters.

Allocated resources are the number of workers allocated to each activity in the process. In this study, resource allocation is set with 13 different amounts of resources to be able to find out the difference to the results in the event log of the allocation of each resource. In addition to this, several other parameters such as the amount of incoming waste and also the processing time for each activity are also taken into account to be able to determine the impact of these parameters on the performance of the process. In this study, two cases will be made for the parameter of the amount of incoming waste, where each case will be made where the amount of incoming waste is not too much and for the other when the incoming waste is too excessive.

B. Time Analysis per Activity

To be able to calculate the average result of the duration of working time for each activity, a SQL Server Management Studio (SSMS) application will be used to process and analyze data from the event log that has been obtained. The use of SSMS in processing and analyzing data is quite effective because SSMS itself can process large data quickly using queries. From the results of the analysis using SSMS, the data obtained on the average duration of work for each activity as shown in TABLE I and TABLE II.

From the calculation of the average duration for each activity, it is known that not all activities have a change in the average time duration for each resource allocation that has been set at the time of performing the simulation. In TABLE I and TABLE II the results shown are only results that indicate a change in the duration of activity in the process.

C. Mathematical Formula Making

To determine this mathematical formula, it takes a data that has a significant and valid change for each data on the average duration of activity for each allocation of the number of resources. If the data has a constant time for each resource allocation, it cannot be determined a mathematical formula for the activity. Therefore, in determining this mathematical formula, only TABLE II data will be used where the data has a significant change in each resource allocation.

To be able to make these mathematical formulas, Microsoft Excel software will be used to visualize the data, and the visualization results will be used for analysis to find trend lines where the trend line will be useful for finding out mathematical formulas from the data.

Data visualization in Fig. 2 is a visualization of the average duration data on the number of resource allocations in the packAshes activity. By getting the data visualization, it is possible to determine the trendline of the data visualization that shows the exponential regression results of the data. From the trendline, it can then be seen the mathematical formula of the trendline and R-square which shows the accuracy of the trendline with the distribution of the data on the visualization. TABLE III contains the results of the determination of the mathematical formula on the data in TABLE II. To get the results of the duration of time using the mathematical formula,

TABLE I. THE AVERAGE DURATION FOR THE FEW INCOMING WASTE CASES

Activity	**Duration (second)**												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**15**	**30**	**50**
packAshes	237	242	239	240	239	239	236	237	237	237	237	237	237
putIWinYellowBin	724	588	614	600	603	605	606	604	603	603	603	603	603
putWasteInRB	301	293	301	309	304	302	305	304	301	301	301	301	301
sendWasteToIncenerator	1085	770	754	791	810	838	838	838	838	838	838	838	838
storeAshesInTPSNRW	1,057,725	198,458	18,186	13,881	12,420	11,896	12,051	13,343	14,508	15,335	15,335	15,335	15,335
storeWasteInTPSRW	15,443	14,611	15,449	15,734	15,889	15,719	15,830	16,183	15,544	15,465	15,465	15,465	15,465

TABLE II. THE AVERAGE DURATION FOR THE HIGH INCOMING WASTE CASES

Activity	**Duration (second)**												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**15**	**30**	**50**
packAshes	3,480	1,952	1,186	778	593	465	410	367	336	303	248	226	238
putIWinYellowBin	2,469	1,361	999	822	717	658	610	596	575	579	602	598	603
putWasteInRB	574	356	299	293	286	298	298	297	298	298	298	297	299
sendWasteToIncenerator	11,809	3,312	1,881	1,477	1,245	1,086	980	906	848	798	716	838	839
storeAshesInTPSNRW	8,934,790	4,453,191	2,740,457	1,867,186	1,368,592	1,034,086	803,056	625,735	482,075	357,820	42,002	15,521	15.650
storeWasteInTPSRW	1,492,262	445,536	73,483	17,234	14,384	11,903	11,974	11,871	12,768	13,855	15,495	15,597	15,476

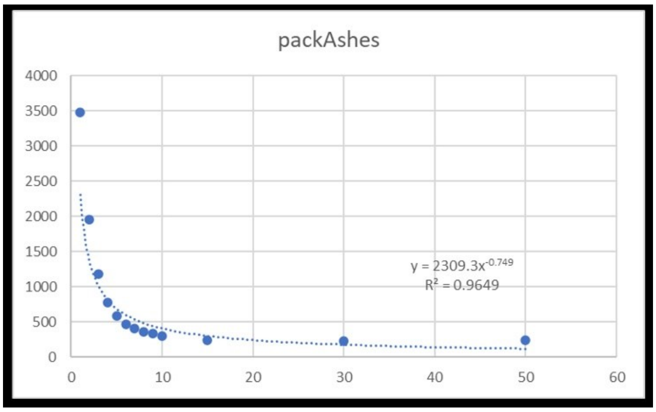

Fig. 2 Visualization of The Average Duration Data for Each Amount of Resource Allocation

TABLE III. MATHEMATICAL FORMULA FOR TIME DURATION

Activity	Formula	R Square
packAshes	$y = 2{,}309.3x^{-0.749}$	$R^2 = 0.9649$
putIWinYellowBin	$y = 1{,}469.8x^{-0.334}$	$R^2 = 0.7642$
putWasteInRB	$y = 391.48x^{-0.11}$	$R^2 = 0.4366$
sendWasteToIncenerator	$y = 4{,}338.3x^{-0.608}$	$R^2 = 0.7861$
storeAshesInTPSNRW	$y = 2E{+}07x^{-1.867}$	$R^2 = 0.9323$
storeWasteInTPSRW	$y = 240{,}886x^{-1.084}$	$R^2 = 0.9167$

it takes a variable x, where the variable x is the number of resources allocated to the activity.

The results of the R-square obtained are results that are less than 0.9 where the results of the R-square indicate that the mathematical formula is still not able to represent the duration of time that is quite appropriate for the results of the experiments that have been carried out. In this study, the formulas that do not represent the duration are found in the putIWinYellowBin, putWasteInRB, and sendWasteTo-Incenerator activities.

D. *Worker* Analysis *Per Activity*

To find out the number of workers needed, an analysis of the event log will be carried out to find out how many workers that work on each activity in the process that shown in TABLE IV and TABLE V.

Calculation of the average number of workers in each activity is done by analyzing the event log with SSMS software. From the results obtained in TABLE IV and TABLE V show the number of workers who actually work for each activity in the process.

E. *Cost Calculation per Activity*

To calculate the cost, Eq. 5 is used, and set cost per hour = 5500 and working time = 8 hours which is the total working time of the workers in the company in one day. The results of the calculations are shown in TABLE VI and TABLE VII.

TABLE IV. THE AVERAGE WORKER FOR THE FEW INCOMING WASTE CASES

Activity	Worker (avg)												
	1	2	3	4	5	6	7	8	9	10	15	30	50
packAshes	1	2	3	4	5	6	7	8	9	10	14	14	14
putIWinYellowBin	1	2	3	4	5	6	7	8	9	9	9	9	9
putWasteInRB	1	2	3	4	4	4	4	4	4	4	4	4	4
sendWasteToIncenerator	1	2	3	4	5	6	7	8	9	10	14	14	14
storeAshesInTPSNRW	1	2	3	4	5	6	7	8	9	10	14	14	14
storeWasteInTPSRW	1	2	3	4	4	4	4	4	4	4	4	4	4

TABLE V. THE AVERAGE WORKER FOR THE HIGH INCOMING WASTE CASES

Activity	Worker (avg)												
	1	2	3	4	5	6	7	8	9	10	15	30	50
packAshes	1	2	3	4	5	6	7	8	9	10	15	30	49
putIWinYellowBin	1	2	3	4	5	6	7	8	9	10	15	30	45
putWasteInRB	1	2	3	4	5	6	7	8	9	10	15	18	18
sendWasteToIncenerator	1	2	3	4	5	6	7	8	9	10	15	30	50
storeAshesInTPSNRW	1	2	3	4	5	6	7	8	9	10	15	30	49
storeWasteInTPSRW	1	2	3	4	5	6	7	8	9	10	15	18	18

TABLE VI. THE COST OF WORKER FOR THE FEW INCOMING WASTE CASES

Activity	Cost (x 1,000 IDR)												
	1	2	3	4	5	6	7	8	9	10	15	30	50
packAshes	44	88	132	176	220	264	308	352	396	440	616	616	616
putIWinYellowBin	44	88	132	176	220	264	308	352	396	396	396	396	396
putWasteInRB	44	88	132	176	176	176	176	176	176	176	176	176	176
sendWasteToIncenerator	44	88	132	176	220	264	308	352	396	440	616	616	616
storeAshesInTPSNRW	44	88	132	176	220	264	308	352	396	440	616	616	616
storeWasteInTPSRW	44	88	132	176	176	176	176	176	176	176	176	176	176

TABLE VII. THE COST OF WORKER FOR THE HIGH INCOMING WASTE CASES

Activity	Cost (x 1,000 IDR)												
	1	2	3	4	5	6	7	8	9	10	15	30	50
packAshes	44	88	132	176	220	264	308	352	396	440	660	1,320	2,156
putIWinYellowBin	44	88	132	176	220	264	308	352	396	440	660	1,320	1,980
putWasteInRB	44	88	132	176	220	264	308	352	396	440	660	792	792
sendWasteToIncenerator	44	88	132	176	220	264	308	352	396	440	660	1,320	2,200
storeAshesInTPSNRW	44	88	132	176	220	264	308	352	396	440	660	1,320	2,156
storeWasteInTPSRW	44	88	132	176	220	264	308	352	396	440	660	792	792

TABLE VIII. MOORA ANALYSIS FOR THE FEW INCOMING WASTE CASES

Activity	∑Resource		
	0.5 : 0.5	0.1 : 0.9	0.9 : 0.1
packAshes	1	1	1
putIWinYellowBin	2	1	2
putWasteInRB	1	1	1
sendWasteToIncenerator	2	1	3
storeAshesInTPSNRW	3	2	3
storeWasteInTPSRW	1	1	2

TABLE IX. MOORA ANALYSIS FOR THE HIGH INCOMING WASTE CASES

Activity	∑Resource		
	0.5 : 0.5	0.1 : 0.9	0.9 : 0.1
packAshes	6	3	15
putIWinYellowBin	5	2	9
putWasteInRB	3	1	5
sendWasteToIncenerator	5	2	10
storeAshesInTPSNRW	8	3	15
storeWasteInTPSRW	4	2	4

F. MOORA Analysis

The analysis using the MOORA method aims to find out how many resources are allocated for each activity, so that the most efficient number of resources is obtained. MOORA analysis performs two criteria, namely time and cost. In this experiment, MOORA analysis is implemented in three settings of the ratio between time and cost, namely 0.5:0.5; 0.1:0.9; and 0.9:0.1, respectively. Determination of the most efficient number of resources will be ranked for each alternative where the highest ranking indicates the most efficient resource results.

TABLE VIII and TABLE IX shown the results of the analysis using the MOORA method for each activity in the process. These results are obtained from the highest-ranking results for each alternative in the MOORA analysis where these results represent the most efficient number of resource allocations for each activity in the process.

V. DISCUSSION

The results of the calculation of the time, there are several activities that produce a constant average value or there is no significant change in each resource allocation. This is because in these activities the number of workers allocated to the activity does not have any effect on the performance of the activity so that the duration of time will always be constant no matter how many workers are allocated to the activity.

The results of the MOORA calculation, as found in TABLE VIII, that in the case where there is only a small amount of incoming waste, then for a balanced ratio to the criteria, the number of workers that can be allocated to the activity, namely the packAshes activity it takes 1 worker, putIWinYellowBin it takes 2 workers, putWasteInRB takes 1 workers, sendWasteToIncenerator requires 2 workers, storeAshesInTPSNRW 3 workers, and storeWasteIn-TPSRW requires 1 worker. For results, if there is an imbalance in the rating ratio, in this case it does not really affect the addition of workers because there is only a difference of one to two workers to optimize it.

Different from the results in the case where there is a lot of incoming waste, it can be seen in TABLE IX in the distribution of a balanced ratio for each criterion it is found that the number of workers that can be allocated to activities in the process, namely in packAshes it takes 6 workers, putIWinYellowBin takes 5 workers, putWasteInRB takes 3 workers, sendWasteToIncenerator requires 5 workers, storeAshesInTPSNRW requires 8 workers, and storeWasteInTPSRW requires 4 workers. In this case, the distribution of an unbalanced ratio for each criterion will result in a significant difference in results where if the ratio to costs is greater it will only require half of the workers at the balanced ratio, and if the ratio to costs is higher, it will require twice as many workers at a balanced ratio.

VI. CONCLUSION

To find optimal resource results in the case study of handling waste in this study, data in the form of event logs is needed which is the result of Discrete Event Simulation (DES) by simulating a process model using AnyLogic software. The event log obtained is then analyzed to obtain the average time duration and number of workers actually working for each activity in the process. The analysis to obtain the optimal number of workers is carried out using the Multi-Objective Optimization Method by Ratio Analysis (MOORA) with the criteria used are the time and cost criteria from the results of the event log analysis.

The results of this study show that in cases where there is little waste entering, only a few workers will be needed to handle activities in the process, namely one to three workers per activity. The results for the difference in ratios for each criterion also do not show much change in the results with balanced ratios. Whereas in cases where there is a lot of incoming waste, the need for resources will also be higher where the average number of resources needed is 5 workers for each activity. For the results on the difference in the ratio for each criterion produces a difference in the number of different resources. At higher cost ratios, the number of workers needed is only half as much as the number required at the balanced ratio. Whereas at a lower cost ratio, the number of workers required is twice the number of workers at a balanced ratio.

For future research, this method will be carried out by adding another case study to test the methods used in this study and other Multi Criteria Decision Making (MCDM) methods such as AHP method will be used to compare the methods used in this case study.

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