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Industrial Area Weighbridge Simulation Model Considering Vehicle Capacity and Destination Using Arena Software

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Abstract. Prolonged waiting times in weighbridge services are deemed essential and negatively influence the quality of weighbridge services. This problem is feasibly overcome by improving weighbridge services using discrete event modeling and simulation of system processes. This research is based on the weighbridge of a company in Gresik. To date, the weighbridge has been hectic serving the weighing of trucks both from within and neighboring companies. In this article, the simulation model represents the weighbridge service process implementing Rockwell Arena software. Process barriers are identified, and resource allocation adjustments are made without disrupting the existing system. An assignment arrangement for each weighbridge is proposed to reduce the average waiting time for all weighbridges through the three proposed improvement models. It was navigated that the weighbridge assignment arrangement could maintain the utility of all weighbridges in a relatively small difference to reduce the average waiting time.

INTRODUCTION

A company generally utilizes distribution in its goods or services from producers to consumers [1, 2]. Besides, the company's distribution facilities and infrastructure also affect whether the goods or services reach consumers. Each truck's load is measured using a weighbridge in the distribution process, especially on land routes. Weighing is intended to prove that the truckload is as it should be distributed. Thus, a weighbridge is thus important as a means of controlling a distribution activity. Therefore, this study aims to determine the quality of service from the object of the study by identifying possible obstacles and adjusting the allocation of resources. According to Marshall and Murphy [3], weighbridges in truck scaling have been increasingly popular because the average log size is smaller, requiring individual scale. The weighbridge is a permanent or portable set of vehicle/truck weighing equipment. To determine the weight of the vehicle and its cargo and monitor the cargo on transport vehicles.

A simulation method involves analyzing the weighbridge service process and developing alternative solutions to reduce problems. The simulation method is deemed essential in solving problems in systems with high complexity [4]. Another consideration in this discipline lies in the selection of simulation software suitable for the research. Arena software has been widely implemented among various simulation software. Several researchers have applied Arena software in various disciplines, including Kamrani, et al. [5], developing a simulation model with Arena to analyse the two adjacent unsignalized T-junctions during rush hours. Another traffic simulation model at signaled intersections was conducted by Tama, et al. [6]. The simulation aims to determine the service time provided by a traffic light at a road junction. The queue of vehicles that occurs can immediately pass through the intersection to reduce the congestion. The input data include data on the time between arrivals, data on the number of queues in the system, data on the plan the object location, and data on the habits or system behaviour. In particular, Iskandar [7] developed simulation models to analyze the queuing service system at weigh stations. Researchers utilize Arena to describe the process of weighing services in loading and unloading activities at the port of the observed object. In this study, the results indicated that the arrival of trucks crossing the weighbridge is greater than the level of service time provided to the queue. In analyzing this queuing service system, the simulation assists the application of theory.

In other cases, a simulation model in the baggage security screening system has been developed by AlKheder, et al. [8]. Neeraj, et al. [9] develop a discrete simulation model of the manufacturing industry. Similarly, Emami, et al. [10] and Liong and Loo [11] have developed an Arena simulation model for unloading loading system in the warehouse. Research on factory layout analysis has been additionally conducted utilizing the Arena simulation model by [12]. Wang, et al. [13] conducted modeling and simulation of emergency services at the emergency

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department of Saint Joseph and Saint Luc Hospital with ARIS and Arena. Previous research using Arena simulation models for facility design was conducted by Greasley [14]. Groenewoud [15] employing arena simulation in analyzing the supply chain system.

Based on previous research, simulation models with Arena are widely used to analyze various case studies with moderate to high system complexity levels. Thus, the Rockwell Arena software was preferred to analyze the problems in this study. In this article, a simulation model with Rockwell Arena software is designed to represent the weighbridge service process. This simulation method is thus appropriately used without disrupting the running system. The objectives of the paper are as follows: (1) To simulate and model the existing conditions of the weighing service process on the object of observation; (2) To identify and analyze the location of potential long queues of transport vehicles, especially at weighbridges with long waiting times; and (3) To navigate the potential improvements in the service process of weighing the object of observation, thereby expecting for more optimal outcome, preventing the long queues at one or several weighbridges.

METHODS

This article focuses on the simulation of a weighbridge service owned by a company in Gresik, East Java, Indonesia. The weighbridge is divided into two factory zones: weighbridge I and III in the first zone, and weighbridges II, IV, and V in the second zone the company's current condition does not have special rules in assigning weighbridges. The truck for the weighing is flexible to choose any weighbridge, arising the problems. There are long queues at particular weighbridges while several other bridges are in loose condition or presenting no queue. These long queues occur as there is no arrangement for trucks entering certain factory areas to weigh certain bridges, creating the utility of each weighbridge to be unbalanced and not optimal.

The task arrangement at each weighbridge is thus expected to overcome the queue problem and optimize each weighbridge. The arrangement is also expected to maintain the utility of all weighbridges with a relatively small difference. Besides, the waiting time for queues, which harms the quality of weighbridge services, is also expected to be reduced. Thus, in this study, the time study method was utilized to obtain the time distribution between the arrivals of transport vehicles. The simulation model is constructed with Arena software that describes the actual system, while the analysis is conducted on various possible conditions. As for the steps in this research, the first step is conducted to collect the required data. The utilized data include time for data between vehicle arrivals, weighing process time, loading-unloading, and travel time between locations. The second step is conducted to process the data into a distribution pattern with the input analyzer in the Arena software. Then, modeling the existing condition of the actual system with Arena software is conducted until verification and validation are conducted in the third step. The fourth step is continued and compared for improvement of scenarios. Furthermore, an in-depth analysis is conducted to navigate the best scenario.

The utilized data include records of truck arrivals for 24 hours (based on company-owned data). Data are also obtained regarding the length of service time at the weighbridge, loading and unloading process time, and vehicle travel time. Regarding the three data, this study utilizes the average time as observed. Observations were made for three days. In addition, the Input Analyzer in the Arena Software is employed to obtain the trucks' arrival time distribution pattern.

RESULTS AND DISCUSSION

Model Development

The existing condition of the service process of all weighbridges is modeled and simulated with Rockwell Arena software. The simulation model is illustrated in Figure 1, along with the model assumptions and elements in the system.

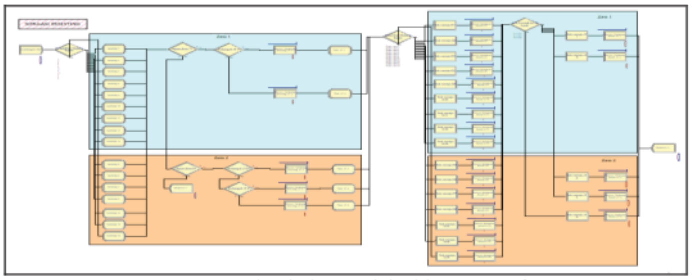

FIGURE 1. A simulation model with Arena Software

Assumptions of the Simulation Model

There are several assumptions in the development of this model. The observed weighbridges are assumed to be in good condition. The human resources are required, assumed to be available, presenting no accidents at work. The service process and the maximum load weight at all weighbridges are assumed to be similar.

The Proposed Model and its Elements

In this model, the vehicle becomes an entity, and data of all vehicles that enter the system are processed and described by one CREATE module to simulate the arrival of transport vehicles into the system. The ASSIGN module assigns specific attribute values to entities such as the vehicle destination and capacity. The weighing process at the weighbridges and the loading-unloading process at the warehouse are simulated with the PROCESS module. As previously discussed, incoming transport vehicles will choose to weigh to one of the selected weighbridges, leading to the destination warehouse destination. Likewise, upon completing the loading and unloading process at the destination warehouse, the transport vehicle is re-weighed at a similar weighbridge. The DECIDE module is utilized to determine the destination of the entity, conducted in accordance with the specific probabilities or conditions.

DELAY module is utilized to suspend the entity at a specific time, where the delay time has been set, and the entity remains in the module for a certain time. In this simulation model, the DELAY module represents the required time for a vehicle to travel from the weighbridge to the warehouse or vice versa. There are two types of DELAY modules, the first is for truck trips from weighbridges to respective warehouses and the second is for the truck travels from the warehouse back to the original weighbridge. Determination of the time in DELAY modules for the system considers the distance and velocity of an entity to produce a route time of the entity movement. The DISPOSE module is set when the vehicle reaches the endpoint where the entity will exit the system. Further explanation for each element of the model is presented as follows.

1. CREATE Module

In the model, there is one arrival vehicle represented by the Create module, named as "Truck Arrival" with the expression of "-0.001 + EXPO (1.99) minutes". The CREATE module functions to create a starting point for generating entity arrivals in the simulation model.

2. PROCESS Module

The PROCESS module is used to model service times at weighbridge and loading-unloading times at warehouses. Table. 1 describes all PROCESS modules. Assuming the equipment is in good condition, workers are always available, and there are no accidents. The capacity per service of each weighbridge in the process module is one because the weighbridge can only serve one truck at a time.

TABLE 1. List of PROCESS Modules

Name	Resources - Capacity	Action	Delay type	Expression
Empty Weighing 1	Resources WB Tool 1 - 1	Seize Delay Release	Constant	3 minutes
Empty Weighing 2	Resources WB Tool 2 - 1	Seize Delay Release	Constant	3 minutes
Empty Weighing 3	Resources WB Tool 3 - 1	Seize Delay Release	Constant	3 minutes
Empty Weighing 4	Resources WB Tool 4 - 1	Seize Delay Release	Constant	3 minutes
Empty Weighing 5	Resources WB Tool 5 - 1	Seize Delay Release	Constant	3 minutes
Weighing 1	Resources WB Tool 1 - 1	Seize Delay Release	Constant	3 minutes
Weighing 2	Resources WB Tool 2 - 1	Seize Delay Release	Constant	3 minutes
Weighing 3	Resources WB Tool 3 - 1	Seize Delay Release	Constant	3 minutes

Name	Resources - Capacity	Action	Delay type	Expression
Weighing 4	Resources WB Tool 4 - 1	Seize Delay Release	Constant	3 minutes
Weighing 5	Resources WB Tool 5 – 1	Seize Delay Release	Constant	3 minutes
Loading-unloading W1	Set Tool W1 – 1, Random	Seize Delay Release	Constant	43 minutes
Loading-unloading W2	Set Tool W2 – 1, Random	Seize Delay Release	Constant	43 minutes
Loading-unloading W3	Set Tool W3 – 1, Random	Seize Delay Release	Constant	43 minutes
Loading-unloading W4	Set Tool W4 – 1, Random	Seize Delay Release	Constant	43 minutes
Loading-unloading W5	Set Tool W5 – 1, Random	Seize Delay Release	Constant	43 minutes
Loading-unloading W6	Set Tool W6 – 1, Random	Seize Delay Release	Constant	43 minutes
Loading-unloading W7	Set Tool W7 – 1, Random	Seize Delay Release	Constant	43 minutes
Loading-unloading W8	Set Tool W8 – 1, Random	Seize Delay Release	Constant	43 minutes
Loading-unloading W9	Set Tool W9 – 1, Random	Seize Delay Release	Constant	43 minutes
Loading-unloading W10	Set Tool W10 – 1, Random	Seize Delay Release	Constant	43 minutes
Loading-unloading W11	Set Tool W11 – 1, Random	Seize Delay Release	Constant	43 minutes
Loading-unloading W12	Set Tool W12 – 1, Random	Seize Delay Release	Constant	43 minutes
Loading-unloading W13	Set Tool W13 – 1, Random	Seize Delay Release	Constant	43 minutes
Loading-unloading W14	Set Tool W14 – 1, Random	Seize Delay Release	Constant	43 minutes
Loading-unloading W15	Set Tool W15 – 1, Random	Seize Delay Release	Constant	43 minutes
Loading-unloading W16	Set Tool W16 – 1, Random	Seize Delay Release	Constant	43 minutes

3. DECIDE Module

In the developed model, the Decide module represents the probability of the transport vehicle's destination location. Previously, the objective data had been collected and processed to predict each visited destination. All the DECIDE modules and their provisions are illustrated in Table 2.

TABLE 2. List of DECIDE Modules

Name	Type	Percentages / Conditions
Destination Warehouse Probability	N-way by Chance	5;3;4;6;9;1;2;23;2;2;0.3;1;2;4;6;28
Destination Zone 1	2 -way by Chance	28
Weigh at WB 1	2 -way by Chance	70
Destination Zone 2	2 -way by Chance	100
Weigh at WB 2	2 -way by Chance	49
Weigh at WB 4	2 -way by Chance	13
Determination of Destination Warehouse	N-way by Condition Attribute (Destination Warehouse)	Destination_warehouse == 1; Destination_warehouse == 2; Destination_warehouse == 3; Destination_warehouse == 4; Destination_warehouse == 5; Destination_warehouse == 6; Destination_warehouse == 7; Destination_warehouse == 8; Destination_warehouse == 9; Destination_warehouse == 10; Destination_warehouse == 11; Destination_warehouse == 12; Destination_warehouse == 13; Destination_warehouse == 14; Destination_warehouse == 15; Destination_warehouse ==16.
Truck Returns to the Weighbridge	N-way by Condition Attribute (Truck WB)	Truck_WB == 1; Truck_WB == 2; Truck_WB == 3; Truck_WB == 4; Truck_WB == 5.

4. DELAY Module

In this case, the DELAY module is utilized to describe a unit of vehicle travel time. Travel time refers to the truck time from the weigh stations to their respective warehouses and vice versa. In this study, all travel times are still assumed to have similar time value.

5. ASSIGN and DISPOSE Module

The ASSIGN module is utilized to add attribute data related to the destination warehouse for each vehicle. In addition, this module also adds attribute data related to the destination weighbridge. The DISPOSE module is utilized as follows: Exit Weigh Bridge 1, Exit Weigh Bridge 2, Exit Weigh Bridge 3, Exit Weigh Bridge 4, and Exit Weigh Bridge 5.

Validation

In this research, the utilized initial replication contains the 20 replications with a simulation time of 30 days. One approach to determine the number of replications includes the trial on the initial replication and calculation on the interval to estimate the population mean value (half-width) based on the replication sample [16]. After the calculation, it was navigated that the required number of repetitions was 18 repetitions. The employed data to test the simulation model validity includes the average queue of trucks and queue waiting time from each weighbridge.

The null hypothesis presents no significant difference between the real conditions and the existing simulation results ($\mu 1 = \mu 2$). The alternative hypothesis contains a significant difference between the real conditions and the existing simulation results ($\mu 1 \neq \mu 2$). The results of the calculation of the hypothesis test for each weighbridge are illustrated in Table 3. The conclusion provides adequate evidence of no significant difference between the existing conditions and the existing simulation results. Based on the conducted statistical tests, it is concluded that the constructed simulation model is valid.

TABLE 3. Hypothesis Test Results

	Average Queuing					Queue Average Waiting Time				
	WB 1	WB 2	WB 3	WB 4	WB 5	WB 1	WB 2	WB 3	WB 4	WB 5
Spt	0.5837	77.87039	0.45733	0.571661	0.576532	10.3596	2721.421	0.286023	0.696044	22.75016
	0.383096	0.029812	0.97788	0.782304	1.695827	0.053	0.000843	1.448835	0.96376	0.066322

Improvement Scenario

Zoning is probable for inconsideration in this improvement scenario because the distance between zone 1 and zone 2 is relatively close. In the first improvement scenario, trucks going to warehouse 6 were initially only served by weighbridge 2, further changed to be served by weighbridge 1 and 3. Shifting was due to the tight queues at weighbridge 2 and the looseness in weighbridge 1 and 3. In addition, another consideration was undertaken because the three weighbridges had the same maximum tonnage weight, which was 70 tons. In addition, trucks going to Warehouse 16 were initially served by weighbridge 5, further altered to be served by weighbridge 4, due to the closeness of the two weighbridges. It is expected that such a scenario provides an option if one of the weighbridges is dense.

In the second improvement scenario, trucks heading to warehouse 5 were initially served by weighbridge 2. The change was made to be served only at weighbridge 3, due to the dense queues at the weighbridges 2. In addition, vehicles heading to warehouse 5 had a short inter-arrival time, thereby predicting to reduce queues at weighbridge 2. On the other hand, trucks heading to warehouse 16 were initially only served by weighbridge 5, further served by weighbridge 4.

In the third improvement scenario, trucks heading to warehouse 7 were initially served by weighbridge 2, further changed to be served by weighbridge 4, due to the dense queues at weighbridge 2 and the closest distance to weighbridge 4. Trucks heading to warehouse 7 had a short time between arrivals, thus changes are predicted to reduce queues at weighbridge 2. Trucks heading to warehouses 14 and 16 at this time can weigh at weighbridge 4 and weighbridge 5. Table 4 illustrates the proposed weighbridge assignment scenario. The selection of the best scenario was undertaken by comparing the average number of queues at each weighbridge. A recap of the average queue at each weighbridge is illustrated in Table 5.

TABLE 4. Improvement scenario

	WB 1	WB 3	WB 2	WB 4	WB 5
Existing	WH1, WH2, WH3, WH4	WH9,WH10,WH11,WH12,WH13	WH5,WH6,WH7, WH8	WH14, WH15	WH16
Scenario 1	WH1, WH2, WH3, WH4, WH6	WH6,WH9,WH10, WH11,WH12,WH13	WH5,WH7,WH8	WH14, WH15, WH16	WH16
Scenario 2	WH 1, WH2, WH3, WH4	WH5,WH9,WH10,WH11,WH12,WH13	WH6,WH7,WH8	WH14, WH15, WH16	WH16
Scenario 3	WH 1, WH2, WH3, WH4	WH9,WH10,WH11,WH12,WH13	WH5, WH6, WH8	WH7,WH14, WH15, WH16	WH14,WH16

TABLE 5. Recapitulation of average queue number

	WB 1 (Truck)	WB 2 (Truck)	WB 3 (Truck)	WB 4 (Truck)	WB 5 (Truck)
Scenario 1	2.44	12,971	1,278	1,222	1,833
Scenario 2	1.33	5,056	1,389	1,278	1,833
Scenario 3	1.33	10,013	0.667	2,056	2,278

In improvement scenario one, the number of queues at weighbridge two is reduced, but the number of queue length exceeds the 10 trucks. In improvement scenario 3, the number of queues for trucks at weighbridge two also decreased, but the number of queues length exceeds the 10 trucks. Whereas at weighbridge 3, the queue indicates fluctuation compared to other weighbridges. Meanwhile, improvement scenario 2 has a relatively greater number of queues. Weighbridge 2 has relatively fewer queues, for less than ten queues. This condition is ideal, and trucks are capable of weighing with less than ten queues of trucks. In addition, the queues for weighbridges 1,3,4, and 5 have been relatively low, thereby preventing the disturbance of the traffic of other vehicles. Therefore, the chosen alternative offers the alternative improvement of scenario 2.

CONCLUSIONS

The service of five weighbridges is simulated with Software Arena for analysis and improvement. Existing conditions are analyzed to navigate specific models and logics. The required data for the model is collected, and its distribution pattern is searched. At the experimental stage, running was conducted, and the number of repetitions was identified. After the model was tested, it was apparent that there were long queues at weighbridge 2. On the other hand, at weighbridge 1, weighbridge 3, weighbridge 4, and weighbridge 5, the queues were relatively short. The three alternative improvement scenarios were developed by setting the weighbridge assignment. Thus, it is expected that the load will be more evenly distributed for each weighbridge. The result of the research indicates that improvement scenario 2 becomes the best scenario. The assignment of the designed scenario improvement 2 succeeded in minimizing the average truck queue at the weighbridge. In addition, scenario improvement 2 also succeeded in equalizing utility levels between weighbridges.

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