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MODELLING OF DISTRIBUTION SYSTEM IN A FACTORY WAREHOUSE USING ARENA

(Pemodelan Sistem Pengedaran Gudang Kilang Menggunakan Arena)

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ABSTRACT

Warehousing represents material storage and physical management processes as well as the methods used by these processes that include all material movement and storage. Distribution system or logistics is a combination of processed functions to manage materials and products from manufacturer to consumer. This research focuses on the study of the warehouse distribution system of a cement factory. The processes involved in this system are modelled using simulation to study the operation in the factory warehouse. Data for building the model were collected through interviews and observation of the whole operation in the warehouse. A computer simulation model is designed, built and run using Arena. Results obtained from the simulation model were analysed to identify the weaknesses of the current system and improvement models were proposed. A total of five improvement simulation models were investigated. The effects of models on customer average waiting times at the various checking points and the model output are analysed. Overall, the best improvement model has succeeded in reducing the average customer waiting time and increased the total customers served in the daily operation of the system very significantly.

Keywords: Arena; simulation; distribution system; cement factory; improvement model

ABSTRAK

Pergudangan merupakan proses penyimpanan bahan dan pengurusan fizikal serta merangkumi kesemua kaedah dalam pengurusan pergerakan dan penyimpanan barangan. Sistem pengedaran atau logistik merupakan gabungan fungsi-fungsi yang diproses mengurus barangan dan hasil daripada pengeluar kepada pengguna. Penyelidikan ini tertumpu kepada kajian sistem pengedaran gudang sebuah kilang simen. Proses yang terlibat dalam sistem pengedaran gudang kajian dimodel menggunakan simulasi untuk mengkaji sistem di gudang kilang tersebut. Data untuk pembangunan model simulasi diperoleh melalui kaedah temu ramah dan pemerhatian ke atas keseluruhan operasi di gudang tersebut. Suatu model simulasi komputer direka bentuk, dibina dan dijalankan menggunakan Arena. Hasil yang diperoleh dari model simulasi dianalisis untuk mengenal pasti permasalahan dalam sistem sedia ada dan model penambahbaikan dicadangkan. Sebanyak lima model simulasi penambahbaikan telah dikaji. Seterusnya dianalisis kesan model penambahbaikan ke atas tempoh masa menunggu pelanggan di pelbagai titik semakan dan output model. Secara keseluruhannya, model penambahbaikan terbaik telah berjaya mengurangkan purata masa menunggu pelanggan serta meningkatkan bilangan pelanggan yang dilayan dalam operasi harian sistem dengan sangat bererti.

Kata kunci: Arena; simulasi; sistem pengedaran; kilang simen; model penambahbaikan

1. Introduction

A warehouse functions as a distribution centre. Receiving and shipping are the interface of a warehouse for incoming and outgoing material flow. Receiving and shipping operations involve, for example, the assignment of trucks to docks and the scheduling of loading and unloading activities (Gu *et al.* 2007). Distribution process involves shipping of goods which requires an efficient system to minimise waiting time which is often the main problem in a distribution system. According to Chorafas (1974), the important factor in the success of an industry is efficiency and economic in the movement of goods. To understand more about warehouse design and control, see Rouwenhorst *et al.* (2000). Liong and Loo (2009) also gave an overview on warehouse operation and a simulation model for the loading and unloading process at a detergent warehouse.

Simulation approach to problem analysis and solution are widely used nowadays, for examples, in manufacturing of goods, material handling, delivery system, business processes, and in transportation. According to Na *et al.* (2009), analysis of port and terminal planning process and container handling system are often done using simulation. Generally, Simulation modelling is a paradigm often used to analyse a complex system. Simulation studies are found to assist in understanding the details of the processes, and the graphical modelling and animation tools in simulation packages like Arena help the management to be involved in the development of the system (Kelton *et al.* 2010; Seila *et al.* 2003).

Simulation is found to be actively used to model supply chain, where Jain and Leong (2005) for example, used simulation to determine how the proposed system can meet deliveries under various conditions; and Terzi and Cavalieri (2004) had reviewed more than 80 papers related to supply chain. Lee *et al.* (2002) stressed that simulation is the preferred way for modelling supply chain due to the stochastic nature of the system. Vieira (2004) has simulated a supply chain using Arena and measure the inventory level and the service quality as the benchmark for determining the quality of the proposed system. Simulation approach is attractive as it provides the flexibility of what-if analysis and evaluating performance of a system under the existing configuration, or under new proposed configurations and procedures (Jain & Leong 2005; Kelton *et al.* 2010). Therefore, simulation study is a good and attractive approach to analyse the distribution system in a warehouse.

In this study, the main problem in the distribution system in a cement factory is the long processing time taken by certain processes involved in the product distribution. Trucks have to queue for their turns for loading of the cement into the truck due to the limited number of loading lines and long loading time. Therefore simulation modelling using Arena (Kelton *et al.* 2010) is used to analyse and improve the distribution system of the company with the hope that it will point to some useful suggestions towards a more effective management of the current resources.

2. Simulation Model

Simulation modelling is a paradigm often used to analyse a complex system. This paradigm represents a simplified system to study the actual system followed by experiments on the system based on certain set of goals (Altiok & Melamed 2007). Simulation is a methodology applied to explain the behaviour of a system using either a mathematical symbolic model (Sokolowski & Banks 2009). According to Alghadafi and Latif (2010), simulation is a concept which involves the building of a model that copies the reality.

In building the simulation model on the computer, the actual system is studied to understand every process involved in the entire system. Data required to build the simulation model has been identified which are

- Truck arrival time
- Truck interarrival time
- Time duration of order checking and truck weighing process
- Time duration of loading process

- Time duration of truck weighing process
- Time duration of order recheck process
- Time duration of order correction process

2.1. *Assumptions*

Assumptions made in the building of the simulation model are:
(1) The amount of workforce involve in the simulation is fixed.
(2) The production of cement is continuous at all time at the same rate to ensure the stock is sufficient to fulfil the demand.
(3) The distribution system in the warehouse is smooth at all time.
(4) The time take by the truck to move from one location to another location for the next process is short and insignificant.

2.2. *Mechanism*

In terms of loading discipline, trucks that arrive at the warehouse area to get the cement are required to queue for their turn. The serving mechanism for the cement bag and jumbo size cement pack is a single queue with multiple servers since there are two lines available for loading respective products. Upon arrival, incoming trucks for 50kg bag and bulk cement products will queue in a line heading towards two servers as shown in Figure 1. For the jumbo size bag of cement product, it is a single queue with a single server mechanism. The queuing system in this study has been identified to be the first in first out (FIFO) queuing discipline with priority given according to the arrival time where trucks that arrived earlier would be served first.

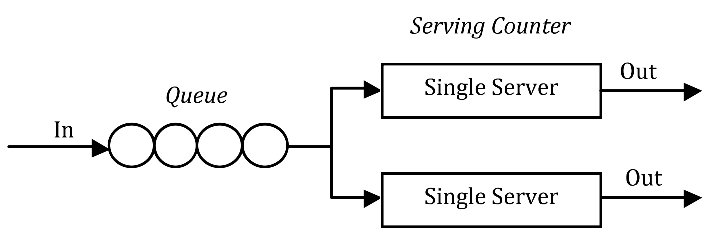

Figure 1: Single queue with multiple servers' mechanism

2.3. *Arena Model*

Figure 2 shows the processes involved in the distribution of cement of three different products namely the 50kg bag, jumbo bag and bulk cement and the workflow of the entire system.

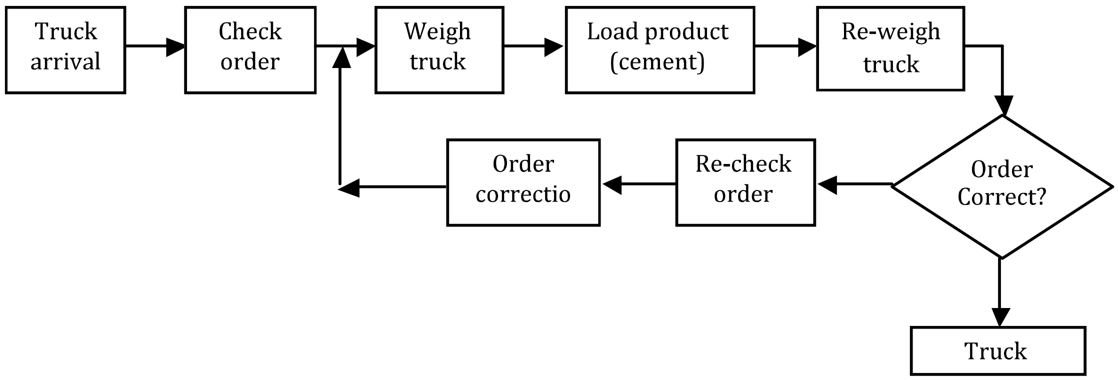

Figure 2: Distribution system workflow in the warehouse

Figures 3 and 4 show the main simulation model and the sub model respectively whereby the processes involved in the system as shown in Figure 2 are arranged in a more detailed workflow using the Arena 12.0 simulation package (ArenaSimulation 2009; Kelton *et al.* 2010).

The animation for the simulation model as shown in Figure 5 is built within the Arena model for a better and clearer understanding of the workflow of system.

3. Results

Distribution expression for the processes involved in the warehouse that are used in the building of the model as shown in Table 1 are obtained using input analyzer, a ready built-in tool within the Arena package. Times for all processes are measured in the minute unit inclusive of the interarrival time of the trucks. The amount of cement loading into the truck is measured in metric tonne unit.

The completed simulation model was run with 500 replications in this study. Upon arrival of the trucks, they are divided according to their product order, namely 50kg cement bag, jumbo cement bag and bulk cement, for the loading process.

Tables 2 and 3 show the results obtained from the generated report with some important aspects from the entire system identified being emphasised such as the following with entity refers to the trucks:

(1) Waiting time duration in the system per entity
(1) Serving time duration in the system per entity
(2) Overall time duration in the system per entity
(3) Number of incoming and outgoing entity in the system

Table 1: Data probability distribution equations

Name		Distribution	Expression
	50 kg cement bag	Exponential	0.999 + EXPO(11.7)
Interarrival time	Jumbo cement bag	Gamma	2 + GAMM(81.2, 1.3)
	Bulk cement	Exponential	0.999 + EXPO(17.8)
	50 kg cement bag	Weibull	5.5 + WEIB(14.6, 1.53)
Loading process	Jumbo cement bag	Beta	17 + 23 * BETA(0.422, 0.476)
	Bulk cement	Beta	9.5 + 10 * BETA(1.03, 0.684)

To be continued...

...Continuation

Total cement loading	50 kg cement bag	Beta	3 + 42 * BETA(2.8, 4.22)
	Jumbo cement bag	Beta	14 + 17 * BETA(1.35, 0.521)
	Bulk cement	Weibull	11 + WEIB(13.8, 1.69)
Order checking and truck weighing process		Uniform	UNIF(3.75, 4.25)
Re-weighing truck process		Uniform	UNIF(1.75, 2.25)
Order re-checking process		Uniform	UNIF(4.5, 5.5)
Order correction process		Uniform	UNIF(4.5, 5.5)

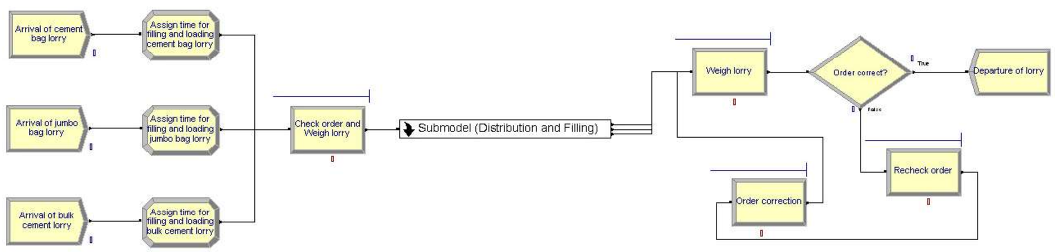

Figure 3: Main model of the distribution system in the cement factory warehouse

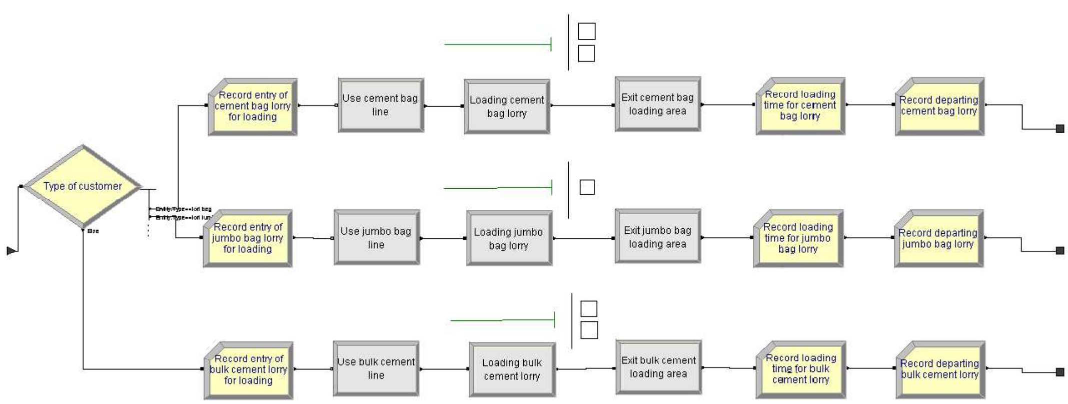

Figure 4: Sub model of the distribution system in the cement factory warehouse

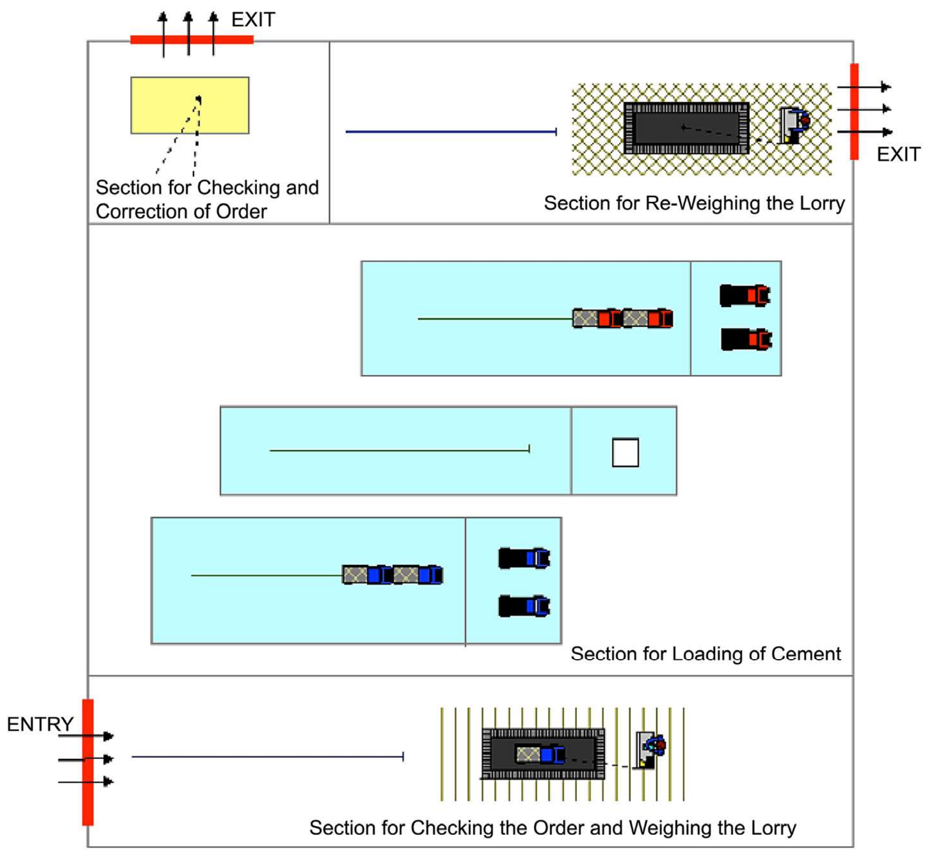

Figure 5: Animation of the simulation model

Table 2: Maximum and minimum time duration for original simulation model

Process		Waiting time duration (minute)		Serving time duration (minute)		Overall time duration (minute)	
		Min	Max	Min	Max	Min	Max
Loading process	50kg cement bag	0.76	50.01	16.03	21.77	16.80	71.78
	Jumbo cement bag	0.00	16.68	19.81	35.78	19.81	52.46
	Bulk cement	0.00	5.22	14.12	16.81	14.12	22.03
Order checking and truck weighing process		0.73	6.50	3.96	4.03	4.74	10.51
Truck re-weighing process		0.07	0.44	1.96	2.04	2.07	2.46
Order re-checking process		0.00	1.83	0.00	5.48	0.00	6.91
Order correction process		0.00	0.32	0.00	5.46	0.00	5.51

As shown in Table 2, the range for waiting time duration for loading process is rather high with minimum value of 7.76 minutes and maximum value of 50.09 minutes that might be caused by the serving time that differs according to the amount of cement ordered. At the same time, the high demand for 50kg cement bag contributes to the long queue due to the turnover rate is lower for product loading compared with the truck arrival rate in the loading area. Hence, the service becomes slow and loading area turns congested with trucks waiting to be served.

Table 3: Average time duration for original simulation model

Process		Average waiting time duration (minutes)	Average serving time duration (minutes)	Average overall time duration (minutes)	No of Trucks	
					In	Out
Trucks	50kg cement bag	10.90	24.83	35.73	76	74
	Jumbo cement bag	5.49	34.30	39.79	9	9
	Bulk cement	3.51	21.68	25.19	51	50
Order checking and truck weighing process		2.17	4.00	6.17	136	136
Loading process	50kg cement bag	8.62	18.60	27.22	76	74
	Jumbo cement bag	2.72	28.03	30.74	9	9
	Bulk cement	0.94	15.44	16.38	51	50
Truck re-weighing process		0.27	2.00	2.27	135	135
Order re-checking process		0.03	4.69	4.72	2	2
Order correction process		0.00	4.69	4.69	2	2

From Table 3, referring to number of incoming and outgoing trucks from the system gives the value of 76 (incoming) and 74 (outgoing) for 50kg cement bag while bulk cement has 51 (incoming) and 50 (outgoing) trucks. This shows three 50kg cement bag trucks and one bulk cement truck did not manage to get out from the system at the end of the simulation time and they were all stuck in the loading process. This means the loading process has hiccups in the operation of the distribution system.

Generally, the waiting time per entity for loading process is longer than the rest of the processes as shown in Table 3. This could be due to the more complicated and time consuming process especially for the 50kg cement bag that requires manpower to arrange the cement bags that are dropped onto the conveyor belt that connects to the cement warehouse. The cement in the warehouse is filled and packed using the machines on the spot when required during the loading process which is being controlled by a button in the loading area before being transferred to the conveyor belt. Therefore, the movement of the cement bags also depends on the operating machines in this process. Aside from that, labour used in the arrangement of the cement bag needs to rest once in a while and the changing of shifts between staff also waste some time which causes this process to not able to operate smoothly and continuously. Overall, the major problem of the entire system occurs in the loading process of the products especially for the 50kg cement bag that causes congestion in the loading area. For the other processes, the range and average waiting times are very small and insignificant. In other words, these other processes are operating smoothly.

The number of entity which is the incoming and outgoing trucks is used as measurement in calculating the authenticity of the original simulation model built. Table 4 shows the error percentage for each of the processes involved in the system, with comparison between result from the simulation model and the actual data for the distribution system. The error percentages for order rechecking and order correction process are high because the frequency for both of the processes is very low as well as the use of probability in the decide module of the simulation model.

Table 4: Percentage of error for the processes in the simulation model

Process		**No of trucks**		**Actual data**	**Percentage of error (%)**
		In	Out		
Trucks	50kg cement bag	76	74	81	8.64
	Jumbo cement bag	9	9	9	0
	Bulk cement	51	50	53	5.66
Order checking and truck weighing process		136	136	142	4.23
Loading process	50kg cement bag	76	74	81	8.65
	Jumbo cement bag	9	9	9	0
	Bulk cement	51	50	53	5.66
Truck re-weighing process		135	135	143	5.59
Order re-checking process		2	2	1	100
Order correction process		2	2	1	100

4. Improvement Simulation Model

The improvement simulation model is built after the result obtained from the original model is analysed. Improvement is implemented by doing some modification on the original model in order to solve the problem that occurs in the system. Among some of the suggestions considered in this study are:

- Truck arrival time is scheduled in advance by the management.
- Adding number of resources in the system such as additional serving line.
- Serving time duration is fixed and standardised.

Using those suggestions, five improvement models are built by combining some of the suggestions to study the effect of the modification on the original model, as well as to obtain the best improvement model. The characteristics of the five improvement models are summarised as follows:

(1) Improvement model 1 (IM1)
   (i) Additional of one serving resource in the loading process
   (ii) Expression of serving time duration for loading process changed to TRIA(5.5, 10, 30)

(2) Improvement model 2 (IM2)
- (i) Interarrival time of truck is fixed to 15 minutes
- (ii) Expression of serving time duration for loading process changed to TRIA(5.5, 10, 30)

(3) Improvement model 3 (IM3)
- (i) Interarrival time of truck is fixed to 10 minutes
- (ii) Additional of one serving resource in the loading process
- (iii) Expression of serving time duration for loading process changed to TRIA(5.5, 10, 30)

(4) Improvement model 4 (IM4)
- (i) Interarrival time of truck is changed to UNIF(5,10)
- (ii) Additional of one serving resource in the loading process
- (iii) Expression of serving time duration for loading process changed to TRIA(5.5, 10, 30)

(5) Improvement model 5 (IM5)
- (i) Interarrival time of truck is changed to UNIF(5,10)
- (ii) Additional of one serving resources in the loading process
- (iii) Expression of serving time duration for loading process changed to TRIA(5.5, 10, 30)
- (iv) Operation time cut to 9 hours per day

Table 5: Comparison of average waiting time among all improvement models

Process		Average waiting time duration (minutes)					
		IM1	**IM2**	**IM3**	**IM4**	**IM5**	**Original**
Trucks	50kg cement bag	2.62	0.91	1.27	2.55	2.66	10.90
	Jumbo cement bag	5.49	4.89	5.45	6.28	6.10	5.49
	Bulk cement	3.50	2.81	3.44	4.28	4.44	3.51
Order checking and truck weighing process		2.17	1.14	1.46	1.46	2.47	2.17
Loading process	50kg cement bag	0.25	0.00	0.00	0.27	0.26	8.62
	Jumbo cement bag	2.75	2.79	2.79	2.50	2.20	2.72
	Bulk cement	0.93	0.98	0.89	0.58	0.57	0.94
Truck re-weighing process		0.29	0.23	0.31	0.40	0.40	0.27
Order re-checking process		0.01	0.01	0.01	0.03	0.02	0.03
Order correction process		0.00	0.00	0.00	0.00	0.00	0.00

Table 6: Comparison of number of outgoing trucks among all improvement models

Process		**Number of outgoing trucks (unit)**					
		IM1	**IM2**	**IM3**	**IM4**	**IM5**	**Original**
Trucks	50kg cement bag	74	63	94	125	69	74
	Jumbo cement bag	9	10	9	9	6	9
	Bulk cement	52	51	51	51	29	50
Order checking and truck weighing process		136	125	157	189	107	136
Loading process	50kg cement bag	74	63	94	125	70	74
	Jumbo cement bag	9	10	9	9	5	9
	Bulk cement	52	51	51	51	29	50
Truck re-weighing process		137	126	157	188	106	135
Order re-checking process		2	2	3	3	2	2
Order correction process		2	2	3	3	2	2

Since the problem of the system has been identified to occur from the loading system, the aspect of waiting time for each truck is emphasised in the systems during loading process in all improvement models. Comparison of all the improvement models are given in Tables 5 and 6 in terms of average waiting time duration and number of outgoing trucks (i.e. the final output), respectively.

Overall, IM4 has been chosen as the best improvement simulation model among all improvement suggestions implemented on the original simulation model. The arrival time for the trucks can be scheduled by the management based on the interarrival time that has been used in IM4, which is UNIF(5, 10). The arrival time suggested for trucks is 7.5 minutes with allowance of 2.5 minutes error for trucks to arrive earlier or later than scheduled as long they arrive within the range of 5 to 10 minutes that has been scheduled. Loading area for 50kg cement bag area should also be added to three lines to increase the truck turnover rate in the loading process hence decrease the trucks waiting time in the queue. Among other factors, the serving time could also be decreased with the labour shift changing being done efficiently without long delays. Rest time for these labour forces should also be reduced to a more sensible duration so that the processes can operate more smoothly.

During the operation of IM4 simulation, 185 trucks were served with 125 trucks for 50kg cement bag, 9 trucks for jumbo cement bag and 51 trucks for bulk cement. Compared to the original simulation model, IM4 shows improvement of 28.11% in the total number of 50kg cement bag trucks served in a day of operation from 74 to 125 whereas the average waiting time duration for every trucks is reduced from 8.62 minutes to 0.27 minutes, or about 96% reduction computationally, and without showing any negative impact on the rest of the processes in the system. Hence, theoretically, improvement suggestions in IM4 are proven to be effective in making the current system better. However, practically, human factor may have an effect on the average waiting time of the system. Also, undeniably, adding another resource of 50kg cement bag would increase expenditure cost of the company. Even though so, the workers and the management would get satisfaction from the improved quality in serving the trucks aside from the happy and satisfied customers for the efficient service. The cost of this could be considered as a profitable investment in long term. The proving of the benefits of this suggestion from the monetary or the many other aspects could be studied and valued through further studies.

5. Conclusions

This study has been conducted to understand the distribution system in the warehouse of a cement factory in details and then simulation modelling is done using Arena. A complete model was run and analysed to identify the problem that occurs in the actual current system at the warehouse. Suggestions for improvement were implemented on the original simulation model to observe the effect of those changes. Before the implementation of the suggestions, the original model is verified and validated to ensure that the model runs as expected and represents the actual system correctly.

With the improvement suggestions implemented on the model, five improvement models were built and compared to identify the best one among them all. Comparison shows that improvement model IM4 is the best and it is compared with the original model to show the improvement areas, especially from the aspects of average waiting time and number of outgoing trucks. The suggested improvement model can be applied in the warehouse of the studied cement factory for a better quality of operation in the warehouse. However, the management has to consider other factors involved in implementing those suggestions such as the cost to modify the current changes.

The operation of the distribution in the warehouse is the focus in this study. Further study on the operations of the distribution system is suggested to be done especially on the loading process since this is the main problem in this study. The other processes can be developed in a more detailed manner considering other factors that have been ignored such as cement production machines failure situation. The scheduling for arrival time of the trucks could also be done following certain patterns. The cement production has been modelled as part of the simulation model generally and further study could also be done on the production system in this cement factory. With this, the production and distribution systems can be combined and simulated on the same model to give a clearer picture of the operations in the cement factory.

References

Alghadafi E. M. & Latif M. 2010. Simulation of a Libyan Cement Factory. *Proceedings of the World Congress on Engineering 2010*, pp. 2292-2296.

Altiok T. & Melamed B. 2007. *Simulation Modelling and Analysis with Arena.* Amsterdam: Elsevier Inc.

ArenaSimulation. 2012. Arena Simulation Software. Rockwell Automation, Inc. http://www.arenasimulation.com (2 November 2012).

Chorafas D. N. 1974. *Warehousing: Planning, Organising and Controlling the Storage and Distribution of Goods*. London: Macmillan.

Gu J., Goetschalckx M. & McGinnis L. F. 2007. Research on warehouse operation: A comprehensive review. *European Journal of Operational Research* **177**: 1-21.

Jain S. & Leong S. 2005. Stress testing a supply chain using simulation. Proceedings of the 2005 Winter Simulation Conference, pp. 1650-1657.

Kelton W. D., Sadowski R. P. & Swets N. B. 2010. *Simulation with Arena*. 5th Ed. New York: McGraw-Hill.
Lee Y. H., Cho M. K., Kim S. J. & Kim Y. B. 2002. Supply chain simulation with discrete-continuous combined modeling. *Computers and Industrial Engineering* **43**: 375-392.
Liong C.-Y. & Loo C. S. E. 2009. A simulation study of warehouse loading and unloading systems using Arena. *Journal of Quality Measurement and Analysis* **5**(2): 45-56.
Na U. J., Chaudhuri S. R. & Shinozuka M. 2009. Simulation-based seismic loss estimation of seaport transportation system. *Reliability Engineering and System Safety* **94**(3): 722-731.
Rouwenhorst B., Reuter B., Stockrahm V., Houtum G. J. V., Mantel R. J. & Zijm W. H. M. 2000. Warehouse design and control: Framework and literature review. *European Journal of Operational Research* **122**: 515-533.
Seila A. F., Ceric V. & Tadikamalla P. 2003. *Applied Simulation Modeling*. Belmont: Thomson Learning Inc.
Sokolowski J. A. & Banks C. M. 2009. *Principles of Modeling and Simulation: A Multidisciplinary Approach.* Hoboken, NJ: John Wiley & Sons.
Terzia S. & Cavalier S. 2004. Simulation in the supply chain context: a survey. *Computers in Industry* **53**: 3-16.
Vieira G. E. 2004. Ideas for modelling and simulation of suppy chains with Arena. Proceedings of the 2004 Winter Simulation Conference, pp. 1418-1427.

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