SIMULATION MODEL OF A PACKAGING PROCESS

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ABSTRACT

As a flexible technique, simulation is one of the most powerful tools to analyze the systems, specially the complex ones. In this study, a simulation model of the packaging process at Echlin Company, an automotive parts manufacturer in Connecticut, is built using the well-known simulation software, ARENAÊ . Necessary data and information are taken from an earlier study on the same company. Six experiments were conducted with the simulation model to test the performance of the process under several conditions. Several performance statistics are collected and results are analyzed. Reliability and validity of the model is shown comparing the model results to the actual results from the process.

Key words: *Simulation Modeling, Packaging Process, ARENAÊ Computer Simulation Software.*

INTRODUCTION

Echlin Manufacturing is one of the leading automotive part manufacturers in Connecticut. They have a warehouse, located in Brandford, Connecticut, to store the products manufactured in other divisions. The packaging line, known as Department 185, is the place where most of the packaging activities are done. The line currently has problems with the utilization rate and workload of the servers.

The main purpose of this study is to introduce a modeling approach to packaging processes in general and construct a valid simulation model for further studies. For this purpose, the packaging activities in Department 185 will be modeled and utilization of the servers will be analyzed using the ARENAÊ Simulation Software (Version 5.0, Rockwell Software Inc., 2000). Due to the limitations on visiting the warehouse and observing the process personally, data and information from a former research[1] studying the same facility are used. Using this information and data, a simulation model is constructed and utilization of the servers is analyzed under several considerations. Then, the model is experimented and the process stability is examined under different simulation runs.

1. The Packaging Process

Warehouse operations often include a step where finished products must be packed into shipping cartons. This step is highly important when the product is fragile, as in the case of computers, electronic devices and fresh farm products. Many defects may occur during the transportation, forcing the producer to rework on such defective products. Packaging process becomes an even more important issue for the high volume productions where large numbers of packages must be rapidly processed. Especially for the fresh farm products, the speed of packaging is very important due to the time sensitive nature of such products. Hence, many researches studying the food packaging process have been done in the literature. Some of these researches study the management[2], production planning[3,4], scheduling[5] and process control[6] issues for the food packaging facilities, while some researches[7,8] address the packaging cost and revenue considerations of the packaging process. Compared to the food packaging process, packaging of the automotive parts has received very little attention from researchers.

2. Simulation Modeling

The packaging process investigated in this study is modeled and analyzed using the discrete event simulation method. In the literature, simulation usually refers to the use of a computer model to investigate the behavior

[1] Said Ali Alhinai, *Determining the Utilization of Indirect Labor Serving a Packaging Line at Echlin Using ARENA Simulation Technology*, Unpublished Research Project, University of New Haven, June 29, 1996.

[2] Constance L. Falk and Daniel S. Tilley, "Packing Facility Management: Stochastic Dominance Analysis of Cost Allocation and Revenue Distribution Rules", *Agribusiness*, Volume 6, Issue 4, July 1990, pp.355-369.

[3] Stokes, Sturdivant, Ziari, Rister and Mccarl, "Meat Packing Plant Production Planning: Application of Mixed Integer Goal Programming", *Agribusiness*, Volume 14, Issue 3, 1998, pp.171-181.

[4] Millera, Leung, Azhar and Sargent, "Fuzzy Production Planning Model for Fresh Tomato Packing", *International Journal Of Production Economics*, Volume 53, Number 3, 1997, pp.227-238.

[5] A. G. Lagodimos, A. Charalambopoulos and A. Kavgalaki, "Computer-aided Packing Shop Scheduling in a Manufacturing Plant", *International Journal of Production Economics*, Volume 46, 1996, pp. 621-630.

[6] Nigel P. Grigg and Lesley Walls, "The Use of Statistical Process Control in Food Packing: Preliminary Findings and Future Research Agenda", *British Food Journal*, Volume 101, Number 10, 1999, pp.763-784.

[7] Steven T. Buccola and Abdelbagi Subaei, "Optimal Market Pools for Agricultural Cooperatives", *American Journal of Agricultural Economics*, Volume 67, 1985, pp.70-80.

[8] Pinhas Zusman, "Group Choice in an Agricultural Marketing Co-operative", *Canadian Economics Association*, Volume 15, 1982, pp.220-234.

of a system (a set of interacting components). In order to construct a simulation model, the system is seen as consisting of a number of entities (e.g. products, people) which have a number of attributes (e.g. product type, age). An entity may consume work in the form of people or a machine termed a resource. The amount and timing of resource availability may be specified by the model user. Entities may wait in a queue if a resource is not available when required. Besides many queuing systems, simulation is the most appropriate modeling approach for analyzing dynamic, interactive and complicated systems[9].

Simulation modeling usually includes both the process of building a model and the conducting of experiments on that model[10]. An experiment consists of running the simulation for a time period for a specified number of replications in order to understand the behavior of the model and to evaluate the effect of different input levels on specified performance measures.

The majority of simulation software implements a model using the discrete-event method[11]. This method uses a list of several types of future events in time order that are kept on what is known as the simulation calendar. As the simulation executes, simulation calendar simply picks the next event from the top of calendar closest to the current simulation time. This event changes the system status according to its type and may generate further events. The timing of these events are calculated and then placed on the calendar in time order. The simulation continues to pick events from the calendar until there are no events left or the simulation has reached its defined end time. The technique is able to handle future event timings based on statistical distributions and many events occurring at one time.

3. Description of the Packaging Line

The packaging area at Echlin, divided into four sub-areas, consists of 33 benches and two autobagers. Three of the sub-areas contain eight benches and one contains nine benches. There are two material handlers serving in each sub-area. These handlers are responsible for setting up and preparing the benches for the packers.

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[9] M. Pidd, *Tools for Thinking: Modeling in Management Science*, (NewYork:Wiley, 1996).

[10] Andrew Greasley and Stuart Barlow, "Using Simulation Modelling for BPR: Resource Allocation in a Police Custody Process", *International Journal of Operations & Production Management*. Volume 18, Issue 9/10, p. 978.

[11] A. M. Law and W. D. Kelton, *Simulation Modeling and Analysis*, 2nd ed., (NewYork: McGraw-Hill, 1991).

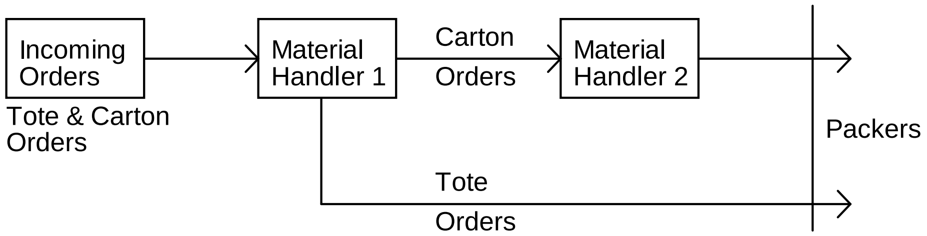
Primarily, there are two types of orders to be served in the process. The first is the orders requiring corrugated cartons and the second is the orders requiring totes. These orders will be referred as carton orders and tote orders, respectively, in this study. Each order consists of serving either dumped or stacked parts. With this information, an order falls in one of the following categories:

- Tote order with dumped parts
- Tote order with stacked parts
- Carton order with dumped parts
- Carton order with stacked parts

All orders arrive the system at the beginning of the day and they are processed the same day. When an order is ready to be processed, material handler # 1 checks the order to see if all required components are available. If some components are missing, order is put aside. If the order is complete, then the material handler # 1 processes the order according to its type. After the material handler # 1 processes an order, carton orders are passed to the material handler # 2, while tote orders are directly passed to the packers. Material handler # 2 performs some additional activities (i.e., making the cartons) to process the carton orders, and then the carton orders are passed to the packers. Figure 1 shows the entity flow in this process.

Figure 1:

Process Flow Diagram



Each order requires a list of activities to be performed by the material handlers. Some of the activities are common for all orders. Hence, some activities depend on the type of the order. All the required activities to serve an order can be listed as follows:

Table 1:

Jobs and Assignments to the Material Handlers

Type of Activity	**Responsible Unit**
Common activities (for all orders)	Material Handler # 1
Processing dumped parts (for orders with dumped parts)	Material Handler # 1
Processing stacked parts (for orders with stacked parts)	Material Handler # 1
Making the totes (for tote orders)	Material Handler # 1
Disposing the trash (for all orders)	Material Handler # 1
Making the cartons (for carton orders)	Material Handler # 2

As it can be seen from the Table 1, material handler # 1 carries the most of the work-load. Material handler # 1 processes all types of orders and performs additional jobs as well. These additional jobs are: processing dumped parts, processing stacked parts, making the totes and disposing the trash. On the other hand, material handler # 2 processes only the carton orders, which are 80% of the total orders, and does not perform any additional jobs.

4. Data Collection

Due to the inability to visit the department 158, necessary data for modeling is taken from an earlier study[12]. This data is assumed correct and some modifications are made to fit in the modeling approach used in this study. Following important statistics are collected on the process.

Table 2:

Important Statistics on the Process

Statistic	**Value**
Average numbers of orders per day	32.25
Average number of totes per order	19
Average number of cartons per order	19
% of orders requiring cartons	80% of total orders
% of orders requiring totes	20% of total orders
% of orders requiring dumped parts	33.4% of total orders
% of orders requiring stacked parts	66.6% of total orders

[12] Alhinai, *Determining the Utilization...*

As previously noted, every incoming order requires some tasks to be completed. These are; (1) the common tasks, which are the same for all order types and (2) the additional tasks, which vary according to the order type. Therefore, each order requires different number of tasks to be completed. Necessary number of activities for each order type is listed below.

Table 3:
Necessary Activities Associated with Each Order Type

	Necessary Number of Activities for Each Order Type					
Order Types / **Activities**	**Common Tasks**	**Serving Dumped Parts**	**Serving Stacked Parts**	**Making Totes**	**Making Cartons**	**Disposing Trash**
Tote Order with Dumped Parts	1	1.5	-	19	-	3
Tote Order with Stacked Parts	1	-	3	19	-	3
Carton Order with Dumped Parts	1	1.5	-	-	19	3
Carton Order with Stacked Parts	1	-	3	-	19	3

The service times for each activity are given in Table 4.

Table 4:
Service Times for Each Activity

Activities	**Service Times (in minutes)**
Common tasks	12.250
Serving dumped parts	0.250
Serving stacked parts	0.600
Making the totes	0.109
Making the cartons	0.327
Disposing the trash	0.200

As an order comes into the packaging line, it automatically creates the necessary tasks mentioned above. If an order is taken from the queue into service, self-contained tasks will be performed immediately. Remaining tasks do not have to be processed immediately. Material handler # 1 processes them during the day.

5. Modifications Prior to the Modeling

5.a.Assumptions

Following assumptions are made in this study:

- All orders coming to the system are considered complete (i.e., all required components are available) as an order arrives to the packaging line.
- Only the utilization of the material handlers # 1 and # are analyzed in this study. Utilization of the packers is not studied and the servers are limited to the material handlers # 1 and # 2.
- Data and the other information gathered from the previous study are assumed correct.

5.b. Modifications

To be able to use the data from the actual system in the simulation model, some modification and transformations are made. Even if the main objective of the simulation model is to reflect the characteristics of the actual process, software limitation and complex situations in the actual system forces the analysts to simplify the process for modeling purposes.

5.b.i.Entity Definitions

In the actual process, there is only one kind of entity entering the system: orders of different type. As shown in Table 3, each order requires different activities to be performed. Some of these activities are performed along with the order while the other activities are left to be performed later during the day. To be able to reflect this situation in the simulation model, entities entering the system are broken into two main categories. The first category includes the orders with self-contained tasks, and the second category includes the miscellaneous jobs, which consist of additional activities that are part of the order but are left to be processed later. Table 5 shows the categorization of the entities.

Table 5:

Entity Categorization

		Corresponding Numbers of Activities					
Order Types	**Categories**	**Common Tasks**	**Serving Dumped Parts**	**Serving Stacked Parts**	**Making the Totes**	**Making the Cartons**	**Disposing Trash**
Tote Order	Orders	1	1	-	15.2 (*)	-	1

with Dumped Parts	Misc. Jobs	-	0.5	-	3.8 (**)	-	2
Tote Order with Stacked Parts	Orders Misc. Jobs	1 -	- -	1 2	15.2 3.8	- -	1 2
Carton Order with Dumped Parts	Orders Misc. Jobs	1 -	1 0.5	- -	- -	19 -	1 2
Carton Order with Stacked Parts	Orders Misc. Jobs	1 -	- -	1 2	- -	19 -	1 2

Notes: (*) 80% of the total number of totes (19*0.8 = 15.2)
(**) 20% of the total number of totes (19*0.2 = 3.8)

From the Table 5, it can be seen that miscellaneous jobs include:

1. Serving additional dumped parts (0.5 times)
2. Serving additional stacked parts (2 times)
3. Making additional totes (3.8 times)
4. Additional trash disposals (2 times)

It can also be noted that some of the miscellaneous jobs is not necessary for some order types. For example, orders with stacked parts do not require serving dumped parts and vice versa. Serving the stacked parts is considers only the orders with stacked parts.

5.b.ii. Entity Arrivals

As noted earlier, all orders arrive to the system once at the beginning of the day. It means that there is no inter-arrival time pattern in the system. The only consideration for the entity arrivals is the number of incoming orders per day. According to the data, the number of incoming orders per day is normally distributed with an average of 32 orders per day and standard deviation of 4 orders per day. Integrating this situation with the simulation model is generally an easy task using ARENAÊ . Batch arrival option can easily handle this kind of situation. Unfortunately, trial version of ARENAÊ allows maximum of 100 active entities in the system at any instant. Creating all orders and the corresponding miscellaneous jobs at the beginning of the run would exceed this limitation and cause the simulation to halt. This problem required a different approach to entity arrival pattern in the model. Following approach is used in the simulation model to overcome this problem.

<u>Automatic Order Creation Mechanism:</u>

In the actual process, orders are created at the beginning, which means that there will always be at least one order waiting in the material handler # 1 queue. A valid simulation model should reflect this situation. A mechanism, instantly providing another order for every completed order (until the desired number of orders for the day is reached), would reflect this situation. After the desired number of orders for the day is reached, automatic order creation mechanism deactivates itself and no new orders are created.

5.b.iii. Servers and Service Times

There are two servers of interest: (1) the material handler # 1 and (2) the material handler # 2. Material handler # 1 processes all orders and miscellaneous jobs. Material handler # 2 only makes cartons for the orders requiring cartons. Servers work 8 hours per day and are available all the time except when they are on a break. Standard break schedule is a ten-minute break every two hours and a thirty-minute lunch break at 12:00 noon.

According to the entity definitions given in Table 5, service times for the servers can be computed as follows:

<u>Material Handler # 1 Service Times:</u>

Orders:

1. Tote Orders with Dumped Parts = 14.36 minutes
   (common activities + disposing trash once + serving dumped parts once + making 80% of totes = 12.25 + 0.2 + 0.25 + 15.2*0.109 = 14.36 minutes)
2. Tote Orders with Stacked Parts = 14.71 minutes
   (common activities + disposing trash once + serving stacked parts once + making 80% of totes = 12.25 + 0.2 + 0.60 + 15.2*0.109 = 14.71 minutes)
3. Carton Orders with Dumped Parts = 12.70 minutes
   (common activities + disposing trash once + serving dumped parts once = 12.25 + 0.2 + 0.25 = 12.70 minutes)

4. Carton Orders with Stacked Parts = 13.05 minutes
   (common activities + disposing trash once + serving stacked parts once = 12.25 + 0.2 + 0.6 = 13.05 minutes)

Miscellaneous Jobs:

1. Additional dumped parts = 0.5*0.25 = 0.125 minutes total (1 job is created in the model)
2. Additional stacked parts = 0.60 minutes each (2 jobs are created in the model)
3. Making additional totes = 3.8*0.109 = 0.4142 minutes total (1 job is created in the model)
4. Additional trash disposals = 0.20 minutes each (2 jobs is created in the model)

<u>Material Handler # 2 Service Times:</u>
Making cartons for carton orders = 19*0.327 = 6.213 minutes.

6. The Model

After the packaging process is described in detail, the data is collected, and necessary modifications are made, a simulation model to analyze the actual process now can be built. The first step in building a simulation model is problem formulation.

6.a. Problem Formulation

To formulate the packaging process under investigation into a simulation model, several input parameters such as entities and entity attributes, servers, service times and queue ranking disciplines need to be defined. As described earlier in greater detail, there are two types of orders (entities) entering the system:

1. Tote orders (with 33.4% dumped, 66.6% stacked parts) 80% of total orders
2. Carton orders (with 33.4% dumped, 66.6% stacked parts) 20% of total orders

Each order requires the following miscellaneous jobs:

1. Processing Additional Dumped Parts
2. Processing Additional Stacked Parts
3. Making Additional Totes
4. Additional Trash Disposals

There are two servers; material handler # 1 and # 2. The material handler # 1 first serves all orders and miscellaneous jobs. Tote orders leave the system after being served by the material handler # 1 while carton orders are passed to the material handler # 2 and then leave the system.

Service times for the entities are as follows:

Tote orders with dumped parts	= 14.36 minutes
Tote order with stacked parts	= 14.71 minutes
Carton order with dumped parts	= 12.70 minutes
Carton order with stacked parts	= 13.05 minutes
Additional dumped parts	= 0.25 minutes
Additional stacked parts	= 0.60 minutes
Additional totes	= 0.4142 minutes
Additional trash disposals	= 0.20 minutes
Material handler # 2 service time	= 6.213 minutes

The following probability distributions are used for the material handler # 1 queue ranking discipline. Entities with low priority values are served first.

Entities	Priority Distribution, Value, (% of Time)
Orders	Discrete, 1(70%), 5(30%)
Additional Dumped Parts	Discrete, 1(20%), 2(30%), 3(20%), 4(20%), 5(10%)
Additional Stacked Parts	Discrete, 1(15%), 2(15%), 3(40%), 4(15%), 5(15%)
Additional Tote	Discrete, 1(15%), 2(15%), 3(15%), 4(40%), 5(15%)
Trash Disposals	Discrete, 4(25%), 5(75%)

6.b.Conceptual Model

Before a computer model of the process is coded, a conceptual model, visually describing how the entities flow through the system and interact with each other, needs to be constructed. Conceptual model also visualizes how the actual process is seen by the computer model, hence enables the model user to validate the model[13]. Figure 2 provides a block

[13] Law and Kelton, *Simulation Modeling...*

diagram of the model visually describing the entity flow throughout the system and Figure 3 provides the flowchart of the process depicting how the actual process is coded into a computer program.

Figure 2:
Block Diagram of the Model

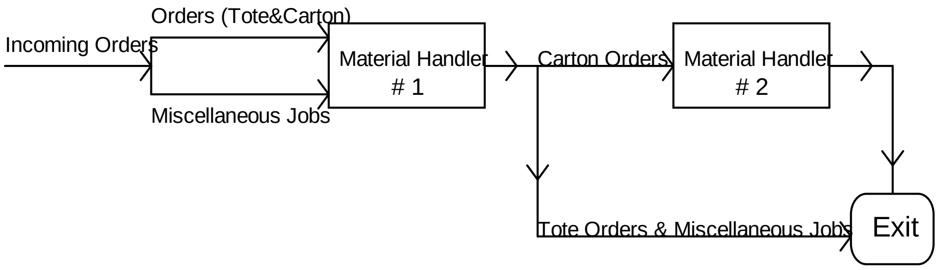
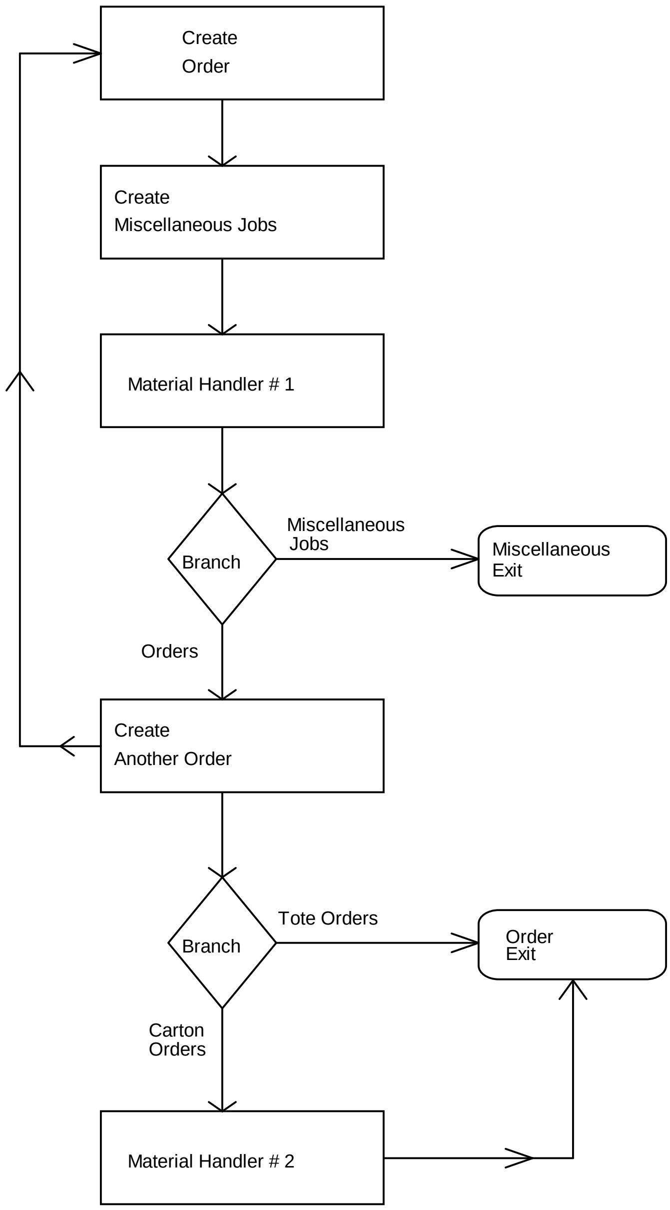


Figure 3:
Flowchart of the Process



6.c. Computer Model

ARENAÊ automatically writes the SIMAN codes for the model. It has powerful and user-friendly dialog boxes that enable users to easily build computer models. In the model, following important ARENAÊ blocks are used to transfer the model algorithm into SIMAN Language:

- Use "create" block to create incoming orders.
- Use "duplicate" block to create miscellaneous jobs corresponding to order types.
- Use "assign" block to assign attributes, service times and priorities to the entities.
- Use "server" block to define server schedules and server states.
- Use "branch" block to direct the entities to the appropriate stations.
- Use "variables" block to define service times for the orders and duplicate quantities for the miscellaneous jobs.

In addition to its ease of use, ARENAÊ also includes several powerful built-in tools such as watch and trace options for the model verification purposes. Combined with the animation capabilities of ARENAÊ , these tools enable users to trace the active entities in the system and to watch the changes on the system state during the simulation run. In this study several pilot runs, using animated objects, and trace and watch options are executed for verification of the computer model. In addition, an experiment using the real data from the actual process is conducted in the next section. Results from this experiment agree with the actual results.

6. Model Analysis and Experiments

Six different experiments (runs), each with five replicates, were conducted with the computer model. The first five runs are to test the model stability under the different run lengths. The last run is to collect statistics on the process using the real data (i.e., verification run). These six run specifications are as follows:

Run 1: 27 orders per day, constant service times, simulation runs for 1 day.
Run 2: 27 orders per day, constant service times, simulation runs for 2 days.
Run 3: 27 orders per day, constant service times, simulation runs for 3 days.
Run 4: 27 orders per day, constant service times, simulation runs for 4 days.

Run 5: 27 orders per day, constant service times, simulation runs for 5 days.

Run 6: # of orders per day is Normally distributed with an average of 32 orders and standard deviation of 4 orders, constant service times, simulation runs for 1 day.

7. Simulation Results

Table 6 summarizes the results obtained from the six runs explained above. Run averages show the average of five replications conducted for each run.

Table 6:

Summary of Results

Collected Statistics	**Run Averages**					
	Run 1	**Run 2**	**Run 3**	**Run 4**	**Run 5**	**Run 6**
Carton Orders Flow Time (minutes)	221.95	224.89	236.72	243.20	244.31	238.88
Tote Order Flow Time (minutes)	261.10	275.29	253.51	241.35	246.78	282.49
Additional Dumped Parts Flow Time (minutes)	216.64	221.86	230.77	223.36	231.62	235.35
Additional Stacked Parts Flow Time (minutes)	217.60	222.25	226.12	234.57	234.32	236.72
Additional Tote Flow Time (minutes)	261.10	270.07	253.51	241.35	243.58	266.26
Trash Disposal Flow Time (minutes)	235.44	241.38	248.40	252.27	254.58	246.29
# of Incoming Orders	27	54	81	108	135	30
# of Total Orders Served	27	54	81	108	135	29
# of Total Miscellaneous Jobs Served	107	220	330	441	552	114
# of Carton Orders Served	23	44	65	87	108	25
# of Tote Orders Served	4	10	16	21	27	4
# of Additional Dumped Parts Served	9	17	26	34	43	10
# of Additional Stacked Parts Served	36	74	110	149	184	40
# of Additional Totes Made	8	21	32	43	55	8

# of Additional Trash Disposals	54	108	162	216	270	57
Material Handler # 1 BUSY (%)	81.87	82.58	82.58	82.68	82.71	89.58
Material Handler # 1 IDLE (%)	7.71	7.00	7.00	6.90	6.87	0.00
Material Handler # 1 ON-BREAK(%)	10.42	10.42	10.42	10.42	10.42	10.42
Material Handler # 2 BUSY (%)	29.34	27.81	27.72	27.62	27.45	32.00
Material Handler # 2 IDLE (%)	60.24	61.77	61.86	61.96	62.13	57.58
Material Handler # 2 ON-BREAK(%)	10.42	10.42	10.42	10.42	10.42	10.42

As can be seen from the Table 6, simulation results for the utilization of the material handlers are almost uniform and do not significantly vary between the runs. This result shows the stability and reliability of the model, even it was run for only one day.

For the current process flow (i.e., Run 6), it is obvious that the material handler # 1 is over-utilized (89% busy) while the material handler # 2 is under-utilized (32% busy). Work-load is not evenly distributed between the material handlers. Modification of the process flow is necessary to balance the utilization of the material handlers.

With constant service times and actual order arrivals (i.e., normally distributed with mean = 32 and standard deviation = 4), the material handler # 1 can not process all incoming orders. Results from the Run 6 shows that the maximum number of orders processed by the material handler # 1 is 30 orders per day. If there are more than 30 orders in a day, material handler # 1 will have to work at its maximum available capacity and there will still be some unfinished jobs at the end of the day.

CONCLUSION

The main purpose of this study was to build a stable simulation model that is able to collect reliable statistics on this packaging process. A computer simulation model using ARENAÊ simulation software is built and the model stability is verified for achieving this goal. Simulation results clearly indicate that the actual process has problems balancing the work-load over the servers. Simulation modeling is clearly a powerful tool for analyzing the dynamic and complicated systems. Once a valid and reliable simulation model of the system is built, it is then very easy to perform what-if analysis and try several scenarios on this system.