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ORIGINAL ARTICLE

# Simulation modeling of a manufacturing process using Tecnomatix plant simulation software

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**ABSTRACT** – Industries are under constant pressure to fulfil the high demands of customer orders. Thus, there is a need to model and predict the throughput to avoid any chances of failure to meet the demands. Process simulation is applied to study and analyze the system which can provide a framework for predicting and optimizing the process based on mathematical models. This work presents the implementation of simulation tools in the real production planning framework to increase the number of throughput. The procedure starts with input data collection and data fitting,and then continues with simulation model building, model validation, identification of the number throughput, and develope improvement strategies.The result showed, through a number of replications and experiments, possible improvements were proposed for a specific problem raised in this case study.

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*Data fitting;*
*Model validation;*
*Prediction;*
*Simulation Modeling;*
*Throughput*

## INTRODUCTION

Simulation is when the processes or systems are studied using mathematical models, running it for specific variables of input until the required output is achieved during a specific period of study. This needs simulation experiments for different scenarios and the changes are observed for a defined assumption in order to get the optimum output [1][2][3]. A simulation model can be represented as shown in Figure 1, where the input variables ($x_1$, $x_2$, … $X_n$) are iterated for optimum output designated by $y_1$, $y_2$,… $y_m$ , which are functions of the inputs. In order to get the optimum value of the output, different search methods are used by feedback mechanism, where the new input is experimented/tested for possible output to be compared with set value [4] [5][6][7][8].

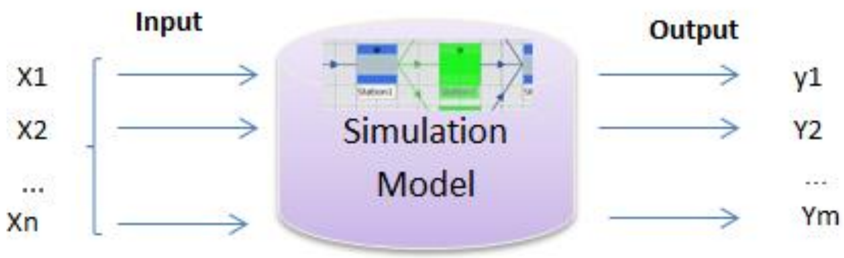


Figure 1: basic simulation model

The data in this case study was taken from a leading global manufacturer of advanced magnetic materials and related products, located at Pekan, Pahang. These products are widely used in industrial production and automotive applications. The product range includes permanent magnets, advanced semi-finished materials and parts, cores and inductive components for the electronics, magnets and magnet assemblies for use in a wide variety of fields and industries spanning watch-making and medical technology, renewable energies, shipbuilding, automotive and aviation. The product variety ranged from common mode choke, transformers up to inductors. There are various processes involved in the factory, including winding, pre-cut, stripping, tinning, looping, soldering , potting, mechanical and electrical inspection, and visual inspections. Based on the visual observations, the inspection and packeging worksatations are the most congested and with high number of work-in-process products..It is necessary for the company to improve the efficiency of the existing inspection and packaging areas in order to improve the number of throughputs. This work aims to analyze the existing inspection and packaging areas to avoid the observed problems. A simulation modeling of the reel and inspection and packaging will take place for a possible output so that it fulfills the exceeding demand from the customers.

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## CASE STUDY

In simulation modeling, understanding the nature of the problem and system dynamics is the most important step for the appropriate management of the problem to be solved. Thus, the production system for this case is on a specific areas of packaging and quality control activities during the production of tape and reel products, which is packed on the standardized size of tape as shown in Figure 2. The problem in the company was that due to the high demand of the tape and reel the company was unable to meet the demand of the customer. Therefore, there was a possibility of slipping or delayed. Hence, there was a need to improve the efficiency of the existing inspection and packaging areas in terms number of throughput. The main operations are inspection and packaging. Currently, the units from the assembly line are transported to the QA area for sampling inspection. The units being put in the rack should wait for inspection. After that the units are moved to the sampling inspection for mechanical and electrical inspections, followed by the visual inspection. After the inspection has been completed and if no reject parts are found, the booking parts in the system is done by using SAP software. The packaging is performed using the tape and reel packaging machine, followed by carton packaging before it is transported to the logistics operations, as shown in Figure 3.

a) b)

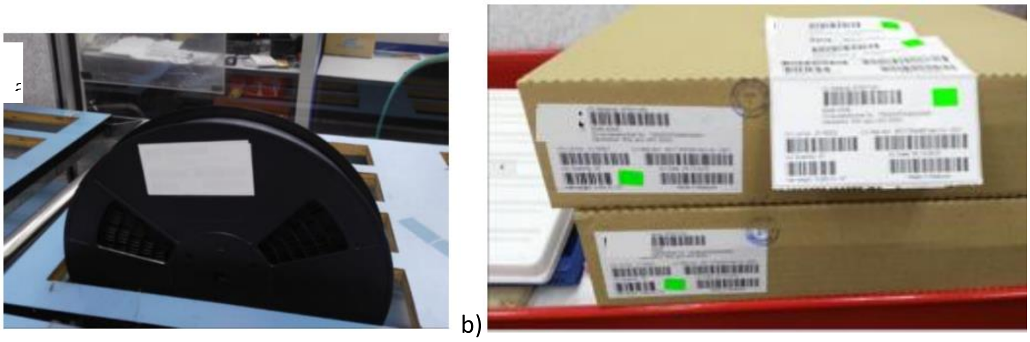

Figure 2: a) Tape and Reel Product b) carton packaging

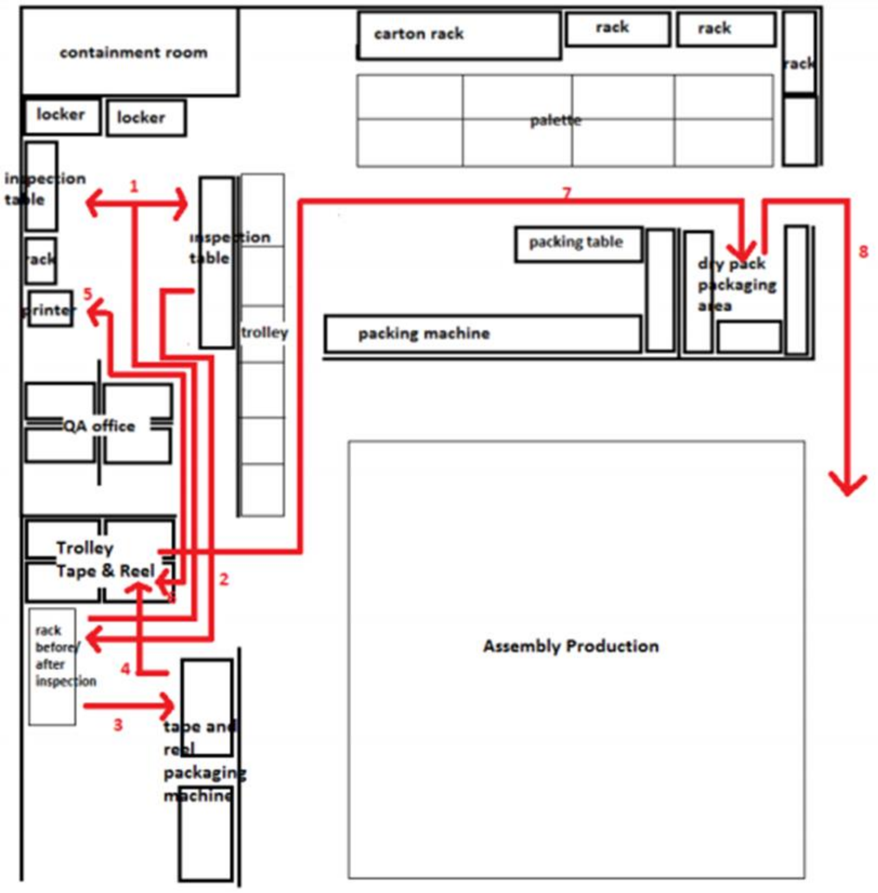


Figure 3: Quality Assurance layout/ area including inspection and packaging area.

## INDPUT DATA COLLECTION AND DATA FITTING

One of the the important steps in simulation modeling process is data collection and interpretation of it. The structure of the process is outlined and the data for the six stations is as shown in Table 1. The product models are designated as A, B,C, and D. The data was collected for the mechanical sampling inspection, electrical sampling inspection and packaging process stations. It includes the Inter-arrival times, processing times and system total times. The data fitting and goodness-of-fit test was performed using the Tecnomatix Plant simulation software [9]. Based on the data fitting results, the summary of modeling data (distributions) is shown on Table 2.

Table 1: The data collection for each station in the case study

| Time | Model | interarrival time | Arrival Time (min) | Inspection Time | | | |
|---|---|---|---|---|---|---|---|
| | | | | Electrical Setup time | Total Electrical Inspection Time (min) | Total Mechanical Inspection Time (min) | Visual Inspection Time (min) |
| 8.00 - 9.00 (0-60min) | A | 0 | 5 | 5 | 23 | 11 | 5 |
| | B | 15 | 20 | 4 | 25 | 11 | 6 |
| | C | 14 | 34 | 4 | 22 | 12 | 5 |
| | D | 5 | 39 | 4 | 26 | 12 | 7 |
| 9.00-10.00 (60min-120min) | B | 41 | 80 | 6 | 27 | 11 | 6 |
| | D | 18 | 98 | 5 | 23 | 12 | 7 |
| | A | 14 | 112 | 4 | 28 | 11 | 5 |
| 10.00-11.00 (120min-180 min) | B | 22 | 134 | 5 | 23 | 11 | 6 |
| | C | 18 | 152 | 5 | 28 | 12 | 5 |
| | D | 19 | 171 | 5 | 25 | 12 | 7 |
| | C | 7 | 178 | 5 | 26 | 12 | 5 |
| 11.00-12.00 (180-240 min) | A | 14 | 192 | 6 | 23 | 11 | 5 |
| | D | 30 | 222 | 6 | 26 | 12 | 7 |
| 12.00-1.00 (240-300 min) | B | 29 | 251 | 4 | 29 | 11 | 6 |
| | A | 12 | 263 | 4 | 24 | 11 | 5 |
| | C | 23 | 286 | 6 | 27 | 12 | 5 |
| | B | 7 | 293 | 6 | 21 | 11 | 6 |
| 2.00-3.00 (300-360min) | D | 47 | 340 | 4 | 30 | 12 | 7 |
| | A | 13 | 353 | 6 | 25 | 11 | 5 |
| 3.00-4.00 (360-420min) | C | 36 | 389 | 5 | 28 | 12 | 5 |
| | B | 11 | 400 | 5 | 28 | 11 | 6 |
| | A | 11 | 411 | 6 | 23 | 11 | 5 |
| 4.00-5.00 (420-480min) | D | 22 | 433 | 6 | 29 | 12 | 7 |
| | C | 16 | 449 | 6 | 24 | 12 | 5 |
| | D | 19 | 468 | 6 | 25 | 12 | 7 |
| | B | 11 | 479 | 5 | 24 | 11 | 6 |
| 5.00-6.00 (480-540min) | A | 9 | 488 | 5 | 30 | 11 | 5 |
| | C | 24 | 512 | 5 | 27 | 12 | 5 |
| | B | 24 | 536 | 4 | 28 | 11 | 6 |
| | A | 2 | 538 | 5 | 28 | 11 | 5 |

| Time | Model | Total Inspection Time | setup time tape reel packaging | Tape and reel packaging time (min) | Book in System (SAP) (min) | Packaging Time (min) | | | Total Time |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Delivery Time | Carton Packaging Time | Carton Quality Inspection | |
| 8.00 - 9.00 (0-60min) | A | 39 | 3 | 20 | 6 | 0.81 | 5 | 4 | 77.81 |
| | B | 42 | 3 | 25 | 6 | 0.79 | 5 | 5 | 86.79 |
| | C | 39 | 3 | 23 | 6 | 0.93 | 5 | 3 | 79.93 |
| | D | 45 | 3 | 22 | 6 | 0.8 | 5 | 4 | 85.8 |
| 9.00-10.00 (60min-120min) | B | 44 | 3 | 25 | 6 | 0.88 | 5 | 5 | 88.88 |
| | D | 42 | 3 | 22 | 6 | 0.8 | 5 | 4 | 82.8 |
| | A | 44 | 3 | 20 | 6 | 0.83 | 5 | 4 | 82.83 |
| 10.00-11.00 (120min-180 min) | B | 40 | 3 | 25 | 6 | 0.77 | 5 | 5 | 84.77 |
| | C | 45 | 3 | 23 | 6 | 0.99 | 5 | 3 | 85.99 |
| | D | 44 | 3 | 22 | 6 | 0.8 | 5 | 4 | 84.8 |
| | C | 43 | 3 | 23 | 6 | 0.93 | 5 | 3 | 83.93 |
| 11.00-12.00 (180-240 min) | A | 39 | 3 | 20 | 6 | 0.83 | 5 | 4 | 77.83 |
| | D | 45 | 3 | 22 | 6 | 0.85 | 5 | 4 | 85.85 |
| 12.00-1.00 (240-300 min) | B | 46 | 3 | 25 | 6 | 0.76 | 5 | 5 | 90.76 |
| | A | 40 | 3 | 20 | 6 | 0.83 | 5 | 4 | 78.83 |
| | C | 44 | 3 | 23 | 6 | 0.93 | 5 | 3 | 84.93 |
| | B | 38 | 3 | 25 | 6 | 0.78 | 5 | 5 | 82.78 |
| 2.00-3.00 (300-360min) | D | 49 | 3 | 22 | 6 | 0.82 | 5 | 4 | 89.82 |
| | A | 41 | 3 | 20 | 6 | 0.83 | 5 | 4 | 79.83 |
| 3.00-4.00 (360-420min) | C | 45 | 3 | 23 | 6 | 0.94 | 5 | 3 | 85.94 |
| | B | 45 | 3 | 25 | 6 | 0.78 | 5 | 5 | 89.78 |
| | A | 39 | 3 | 20 | 6 | 0.83 | 5 | 4 | 77.83 |
| 4.00-5.00 (420-480min) | D | 48 | 3 | 22 | 6 | 0.8 | 5 | 4 | 88.8 |
| | C | 41 | 3 | 23 | 6 | 0.97 | 5 | 3 | 81.97 |
| | D | 44 | 3 | 22 | 6 | 0.82 | 5 | 4 | 84.82 |
| | B | 41 | 3 | 25 | 6 | 0.78 | 5 | 5 | 85.78 |
| 5.00-6.00 (480-540min) | A | 46 | 3 | 20 | 6 | 0.83 | 5 | 4 | 84.83 |
| | C | 44 | 3 | 23 | 6 | 0.92 | 5 | 3 | 84.92 |
| | B | 45 | 3 | 25 | 6 | 0.89 | 5 | 5 | 89.89 |
| | A | 44 | 3 | 20 | 6 | 0.83 | 5 | 4 | 82.83 |

Table 2: The summary of the data fitting for the detail data from table 1

| Type of Test | Inspection Test | Distribution | Mean | Standard Deviation | α | β |
|---|---|---|---|---|---|---|
| Electrical Inspection Test | Hi Pot Voltage Test | Erlang | 7.7 | 1.1 | - | - |
| | Inductance Test | Erlang | 1.1 | 1.5 | - | - |
| | RCU Test | Erlang | 7.6 | 1.1 | - | - |
| Mechanical Inspection Test | Pin Length Checking | Weibull | - | - | 5 | 3.3 |
| | Width Casing Checking | Lognorm | 2.7 | 0.8 | - | - |
| | Length Casing Checking | Lognorm | 2.7 | 0.8 | - | - |
| | Height Casing Checking | Weibull | - | - | 5 | 3.3 |
| Visual Inspection | - | Erlang | 5.8 | 0.8 | - | - |
| Packaging | - | Lognorm | 9.9 | 0.66 | - | - |
| Carton Quality | - | Gamma | - | - | 32 | 0.1 |

## THE SIMULATION MODEL

The statistical fitting distributions for the respective workstations were used in the model using the Tecnomatix Plant Simulation software, which represents (mimics) the actual process as shown in Figure 4-6. The workstations are Mechanical inspection, electrical, cartoon Packaging and overall inspection and packaging process of the existing system.

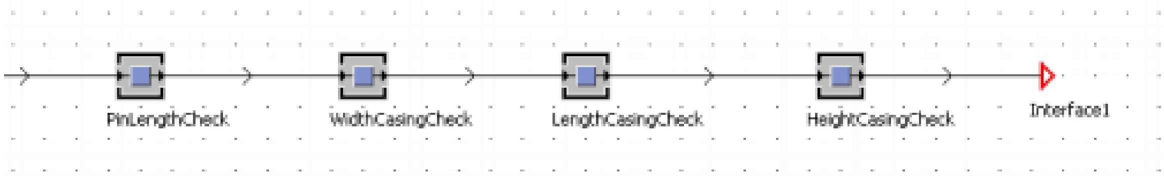


Figure 4: The Mechanical inspection existing substation

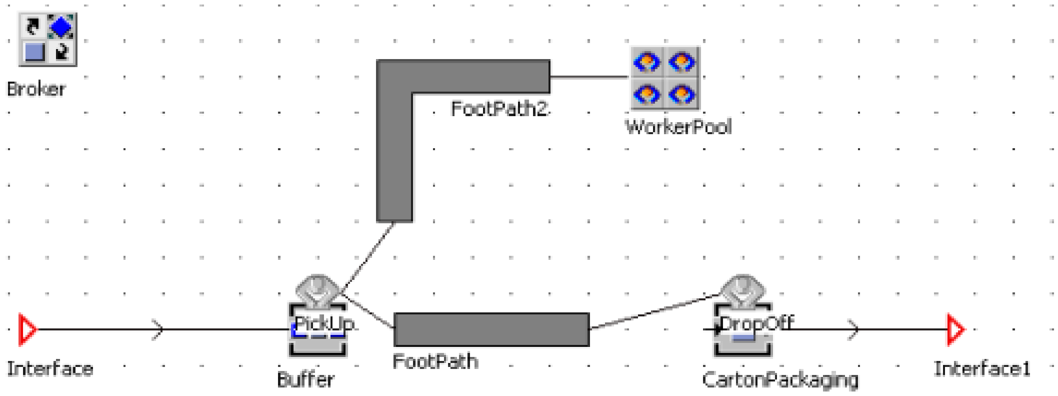


Figure 5: Cartoon Packaging of Existing substation

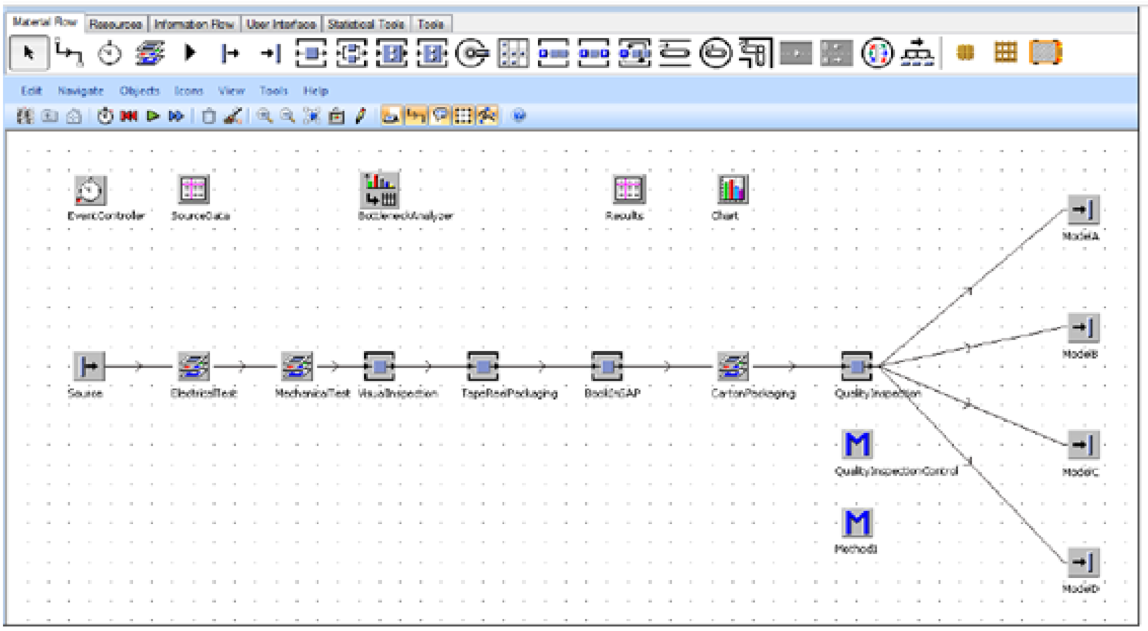

Figure 6: Existing model of the Inspection and packaging process

## IMPROVED MODEL DEVELOPMENT

For an efficient production operation, all stations should be loaded with equal amount of work. Existing throughput shall be improved in order to increase the total number of throughput, throughput per hour, throughput per day. Therefore, several improvement scenarios have been introduced in order to improve the whole system, which includes adding the inspection workstation (1 mechanical Inspection Test and 1 electrical Inspection Test) and increasing/decreasing the buffer size. The simulation test is done for 30 days. Figures 7–9 show the improved models of each processes.

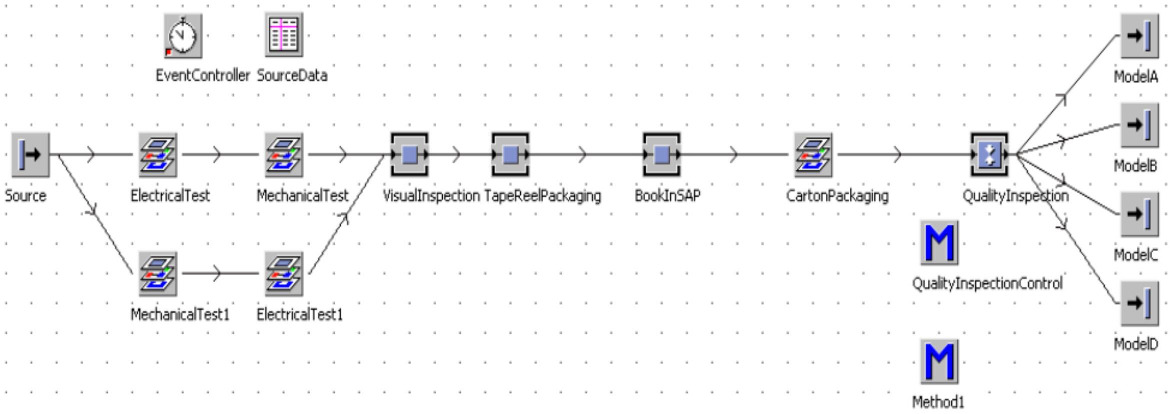


Figure 7: Improved main system

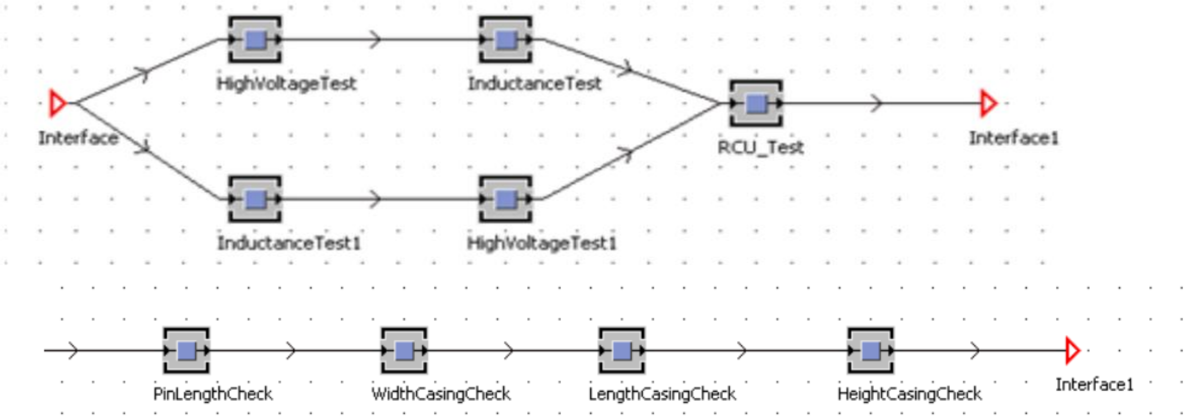


Figure 8: Improved electrical and mechanical stations framework

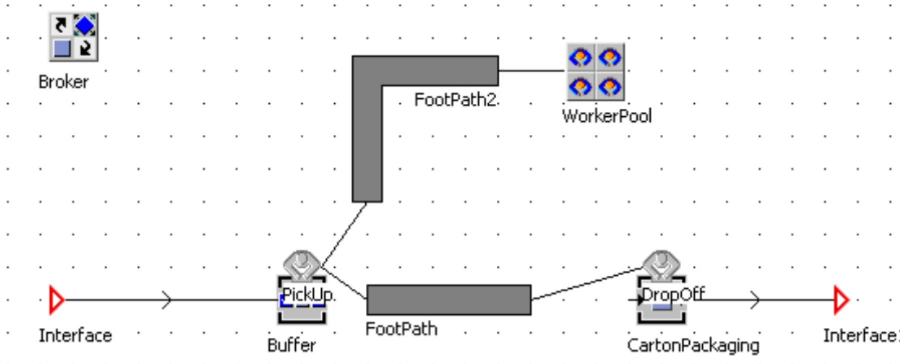


Figure 9: Cartoon packaging improved substation

## MODEL VALIDATION AND VERIFICATION

Comparison of processes was made by introducing and increaseing the number of workstation. The existing model was verified by checking programming code, tracing and checking the output. Moreover, validation is done by comparing the real quantity of products that can be produced with the simulation results at 0.05 significance level. The objective of the simulations was to compare the performance of existing processe and improve it. Performance measures are throughput rate which is in terms of throughput per day, throughput hour and total throughput. The improved systems in terms of adding the inspection workstation (1 mechanical Inspection Test and 1 electrical Inspection Test) resulted in an improved throughput which can fulfill the customers' demands.

The existing system simulation outputs were verified with actual throughput based on the production log book in the factory and it was found to be similar. After sevel replications and experiments, the improved results were compared with the existing system for each model products . For example, the output of model A was increased from 78.54 to 98.14 parts peday. The overall results was validated and agreed with actual production and production managers' recommendation, as shown in Table 3.

Table 3: Throughput Rate Comparison of the System for different Models of the product

| Model | The existing System | | | The Improved system | | |
|---|---|---|---|---|---|---|
| | Total Throughput | Throughput per hour | Throughput per day | Total Throughput | Throughput per hour | Throughput per day |
| ModelA | 2342 | 3.3 | 78.54 | 2927 | 4.09 | 98.14 |
| ModelB | 1871 | 2.74 | 61.93 | 2123 | 3.06 | 70.39 |
| ModelC | 1206 | 1.99 | 40.25 | 1431 | 2.24 | 47.79 |
| ModelD | 607 | 1.47 | 20.25 | 714 | 1.56 | 23.68 |

## CONCLUSION

The simulation modeling was performed based on the the company's existing data and after several experiments, improvement was proposed. According to the simulation results, the addition of inspection workstation (1 mechanical Inspection Test and 1 electrical Inspection Test).would result in the improved thoughput. The increase in percentage throughput rate for all models can be summarized as Model A (24.98 %), Model B (13.47 %), Model C (18.66 %) and Model D (17.63%). Therefore, it can be concluded that several improvements can be introduced in order to improve the whole existing system in relation to other workstations.

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