Processing Time and Throughput Analysis, Man/Machine Utilization and Bottleneck Removal in the Hard Disk Drive Component Manufacturing Process using Process Simulation

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Processing Time and Throughput Analysis, Man/Machine Utilization and Bottleneck Removal in the Hard Disk Drive Component Manufacturing Process using Process Simulation

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Due to the continued expansion of the hard disk drive industry. The company; therefore, needs to improve its production process in order to enhance productivity and meet customer demand. In order to conduct an analysis and develop guidelines for improvement, the researcher developed a computer simulation model based on the Arena Program in order to simulate the actual production process and study the root causes of any problems found – and then propose guidelines for improvement.

Keywords : Computer Simulation, Processing Time, Throughput, Bottleneck, Hard Disk Drive

1 INTRODUCTION

Due to the continued expansion of the hard disk drive industry, those upstream companies producing and assembling hard disk drive components need to improve their production processes in order to gain a competitive edge over domestic and international rivals, and respond to the growing market demand. The hard disk drive (HDD) component manufacturing company in this study produces products comprising actuator assemblies for HDD, membrane switches, and optical fiber components. Its recent total production output has increased due to growing market demand. The study data, obtained in April 2011, shows that Product A accounted for 70% of total production, in increase from a production rate of 6,134 pieces per shift (10.33 hours) in March 2011, to 6,200 pieces per shift. This resulted in a need to improve the production processes so as to meet the delivery deadlines. The preliminary evaluation indicated that the two main problems, which could be immediately noticed from the production processes, were associated with bottlenecks and non-value added activities (NVA). The seven non value-added activities included defects, over production, unnecessary inventory, unnecessary processing, unnecessary movements, unnecessary transportation, and waiting [(1)]. A bottleneck is the point in a process that limits the output of an entire system, where there is the most work-in-progress [(2)].

A simulation is a tool employed to measure effectiveness and to improve a production process prior to the modification of actual production. Created by Rockwell Software Inc., the Arena program in particular has been widely used due to its ability to simulate a complex production, and to compare the operational performance of a system, including bottlenecks and processing times. The processing time is the total production time, starting from the work pieces (products, orders etc.) being transferred into the process through to being transferred out of the process [(3)]. Throughput is the number of customers per hour or the number of work pieces produced over a given period [(4)]. Utilization means the utilization of resources, representing the average amount of time related to the performance of certain resources employed in a system [(5)]. The program is used to model resource management so that it is suitable for an actual production process, covering manpower, machines and costs, and can be used to predict the product outcomes created by a daily production design - without affecting the actual

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production process. As a result, this simulation program has widely been used for both production and service processes; for instance, the program was used in a conducted by Rose [6] to simulate complex systems in the hydraulic tube production process, the aim being to reduce costs within those production systems related to machinery. The model simulation in that study was conducted using a quality index focused mainly in costs, in order to measure operational performance of the machines and to identify the appropriate machine maintenance and management regimes.

A model that is able to undertake a variety of comparisons is useful when attempting to improve a production system. Research conducted by [7] created a simulation using Arena to ascertain the appropriate cycle time for the production of a wafer fab in the semiconductor manufacturing industry. The research simulated four system types using two factors and two levels in order to conduct a comparison based on the principles contained within the Design of Experiment approach. The first factor was the service process which was assessed on two levels, these being FIFO (First In First Out) and CR (Critical Ratio). The other factor was the bottleneck loading, which was also assessed on two levels, these being a 80% loading and a 95% loading. The results showed that the 80% loading and the 95% loading were suitable for use with the FIFO system due to the minimum lead time.

Similarly, research conducted by [8] proposed three different types of model using factors obtained from an analysis, one that affected a reduction in the production lead time as the key measurement of effectiveness of an electronic components assembly system. These factors were the production time, the number of work pieces produced and bottlenecks.

In addition, another study by [9], related to the electronics industry, incorporated a model into the electronics assembly process by simulating the attachment of interconnections to the substrate plates of a robot, so as to establish optimum accuracy in the placement stage and reduce the number of defects. As compared to the actual system, the test model produced an accuracy value of 95%, so could be used as a prototype within a systems modification.

The prediction of future systems performance can be assisted through the use of such a simulated model. Study [10] developed a model to improve the bare circuit board manufacturing process, which required a switch of the operation from a manpower to a machine based system, in order to estimate the optimum machine production quantity for the system. The results showed that machines with multiple-operations were able to significantly reduce the costs of employment and training.

As a result, this research study was focused on an analysis of the hard disk drive component production and assembly processes, using the Arena program to simulate a production system and thus identify bottlenecks, manpower and machine effectiveness, the number of work pieces produced and processing times, the aim being to develop improvement guidelines.

2 RESEARCH METHODOLOGY

The researchers divided the analysis into three main steps, the details of which are as follows:

2.1 Data Collection for Model Development

The researchers conducted a simulation for only a part of the Product A component assembly process during the morning shift (10.33 hours, rest periods not included). The three main production processes are:

1. Arm and Coil assembly process – comprised of six workstations.
2. Arm and Coil bonding process using epoxy – comprised of nine workstations.
3. Damper installation process - comprised of three workstations.

The product characteristics are shown in Fig. 1.

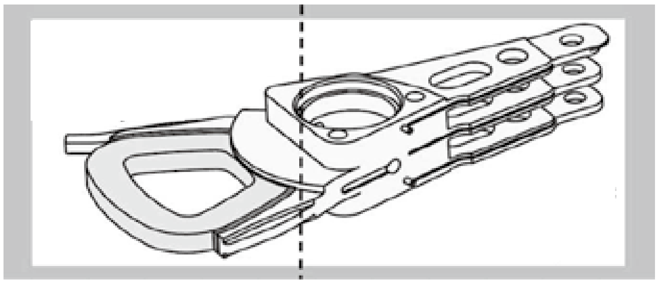


Figure 1: Product A

Data related to the processing time at each station was collected ten times by timing the production of one work piece - from the work piece being transferred to the station to it being transferred out of the station, and including transportation by carriage between stations, as shown in Table 1. From the data collected at each station, the most appropriate data collection times could be ascertained using a range taken from the station with the widest range – this being the eleventh station (range of 1.30), the station that transports items from one station to the next. Work that had the widest range could generate the most time periods to record, meaning that other sub-work activities had a higher confidence range and a lower error. This principle, of identifying the number of times to record, was based on a confidence level of 95% and an acceptable error rate of ±5%.

Table 1: Processing Times at each Workstation using Ten Timings

Process	Work station	Processing Time (Sec)											
		1	2	3	4	5	6	7	8	9	10	Average	Range
Assembly of Arm/Coil	1	5.32	5.92	5.97	6.17	6.21	6.15	6.21	5.32	5.42	6.22	5.89	0.90
	2	6.21	5.51	5.91	6.21	5.31	6.20	6.22	6.20	5.91	6.17	5.99	0.90
	3	5.62	6.22	5.40	6.02	6.12	6.10	5.71	5.40	6.12	6.22	5.89	0.82
	4	5.97	6.03	5.50	6.10	5.90	6.01	6.10	5.99	5.31	5.82	5.87	0.79
	5	5.41	6.21	6.12	5.90	6.20	6.21	6.01	5.99	5.50	6.21	5.98	0.80
	6	5.52	5.32	5.98	6.15	6.30	6.01	6.30	5.60	6.23	6.20	5.96	0.98
Bonding	7	5.91	5.92	5.32	6.30	5.81	6.20	6.22	5.32	6.31	5.72	5.90	0.99
	8	5.49	5.32	5.50	5.50	5.43	5.42	5.43	5.47	5.55	5.45	5.45	0.24
	9	Constant 47 minutes											
	10	4.68	4.95	5.07	5.28	5.24	4.87	4.91	5.27	5.16	5.34	5.08	0.67
	11	11.06	11.19	11.72	11.16	11.06	11.37	10.53	10.42	10.58	11.31	11.04	**1.30**
	12	Constant 47 minutes											
	13	5.23	5.25	5.40	5.59	5.26	4.98	5.16	5.28	5.39	5.27	5.28	0.61
	14	5.98	5.60	5.72	5.20	6.16	5.23	6.31	5.41	6.02	6.01	5.76	1.11
Damper	15	5.46	5.54	5.60	5.90	5.76	5.63	5.57	6.45	5.32	5.89	5.71	1.13
	16	5.32	5.92	5.97	6.17	6.21	6.15	6.21	5.32	5.42	6.22	5.89	0.90
	17	6.21	5.51	5.91	6.21	5.32	6.20	6.22	6.20	5.91	6.17	5.99	0.90
	18	5.62	6.22	5.40	6.02	6.12	6.10	5.71	5.40	6.12	6.22	5.89	0.82

The formula used for identifying the number of times required (n) is as follows:[11]

$$n = \left[\frac{\frac{k}{s}\sqrt{n'\sum X_i^2 - (\sum X_i)^2}}{\sum X_i}\right]^2$$

Where n′ = the number of times used for timing (ten times)

k = confidence factor (3)

k = 1: a confidence level of 68.3%

k = 2: a confidence level of 95.5%

k = 3: a confidence level of 99.7%

s: = the acceptable error rate, being 0.05

Σx_i - the sum of the total data, being 110.40

$(\Sigma x_i)^2$ = Sum of the total data with the exponent of 2, being)110.40^2(

Σx_i^2 = Sum of the total data with the exponent of 2, being 1220.37

Substituted

$$n = \left[\frac{\frac{3}{0.05}\sqrt{10(1220.37)-(110.40)^2}}{(110.40)}\right]^2$$

$$n = 5$$

Therefore, the number of timings required was five, and there was no need for further timings to be taken as data collection had already been conducted ten times.

2.2 Model Development

This section describes the creation of the model using the Arena program. The details of the stages in this study production process can be broken down into three steps as follows:

2.2.1 Input Analysis

Creating a model requires the feeding of input data into a modeling system, so as to analyze a given process [5].For example, if a study is to be conducted on a production system, the input data will be the processing times for each workstation. This input data is referred to as the distributed data, thus any analysis of the input data is critical in order to obtain the most accurate outcomes.

Analysis of input data can be conducted using an Input Analyzer. The first workstation; for instance, has a distribution of data that can be expressed using the distribution equation: 4.6 + 0.82 * BETA(1.42, 1.02)

Distribution Summary
Distribution: Beta
Expression: 4.6 + 0.82 * BETA(1.42, 1.02)
Square Error: 0.004211

Figure 2: Distribution using an Input Analyzer

2.2.2 Modeling the Product A Component Assembly Process

The current Product A production process is shown in Figure 3, and can be described as follows: raw materials are transferred in at a certain time, this being every 5.89 seconds. Prior to the raw materials being fed into the system, a conformity inspection is carried out. If there are any defects in the raw materials used, these will be eliminated immediately. Non-defects will be transferred to the assembly process, which is where coordination between manpower and machinery takes place. After this, another conformity inspection will be carried out. If any work pieces do not pass the standards set, they will undergo a correction process, after which conforming work pieces will be transferred to the bonding process - which uses epoxy, and the curing process. After this, yet another conformity inspection is carried out and any defects corrected. Non-defects will be transferred to the damper installation process when a final conformity inspection will be carried out. This represents the end of the entire operation.

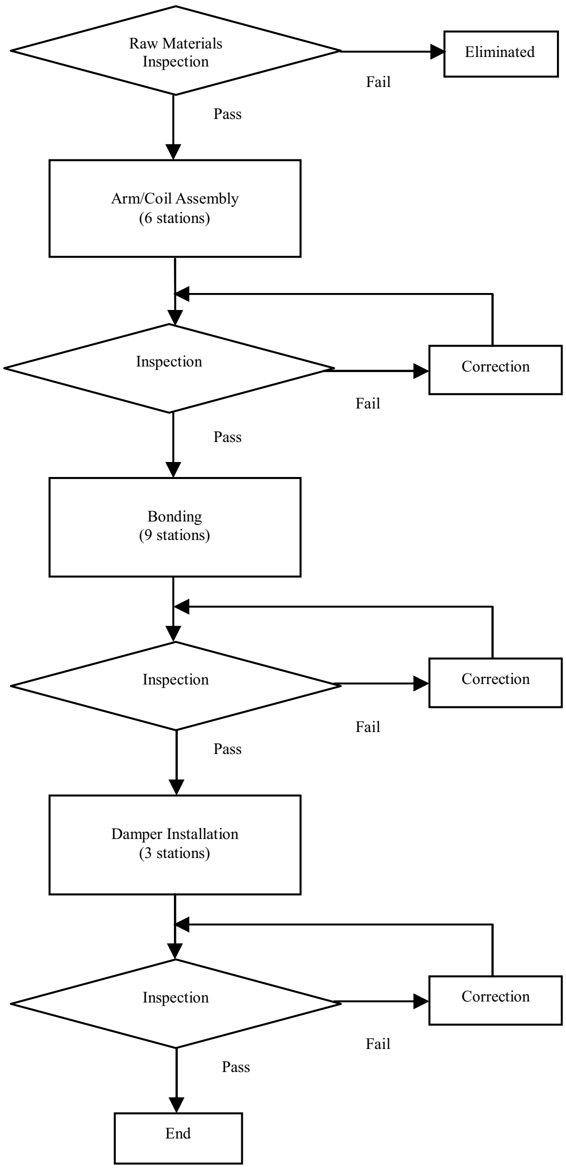
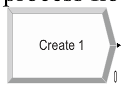


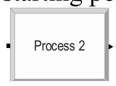
Figure 3: The Process Flowchart for Product A

2.2.3 Flowchart Modules

The following Flowchart Modules are shown in the process flow diagram:

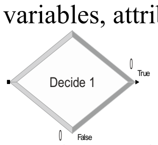


A Create module is a module used as the starting point of the simulation system.

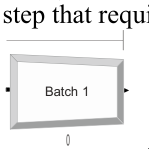


A Process module is one which is the key to a model's development.

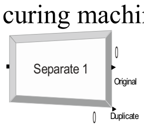
An Assign module is one used to assign variables, attributes and entity types.



A Decide module is used for a process step that requires a decision within the system.

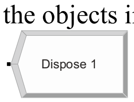


A Batch module is one that combines all interested objects, such as transferring objects into a curing machine.



A Separate module is a module that separates combined objects, such as transferring out objects from a curing machine.

A Record module is a module that gathers statistical data in the model, such as collecting data on the objects imported into this module.



A Dispose module is the final module used in the model.

From the production process shown in Figure 3, a simulation model was developed as shown in Figure 4. The details of the model are explained in Table 2.

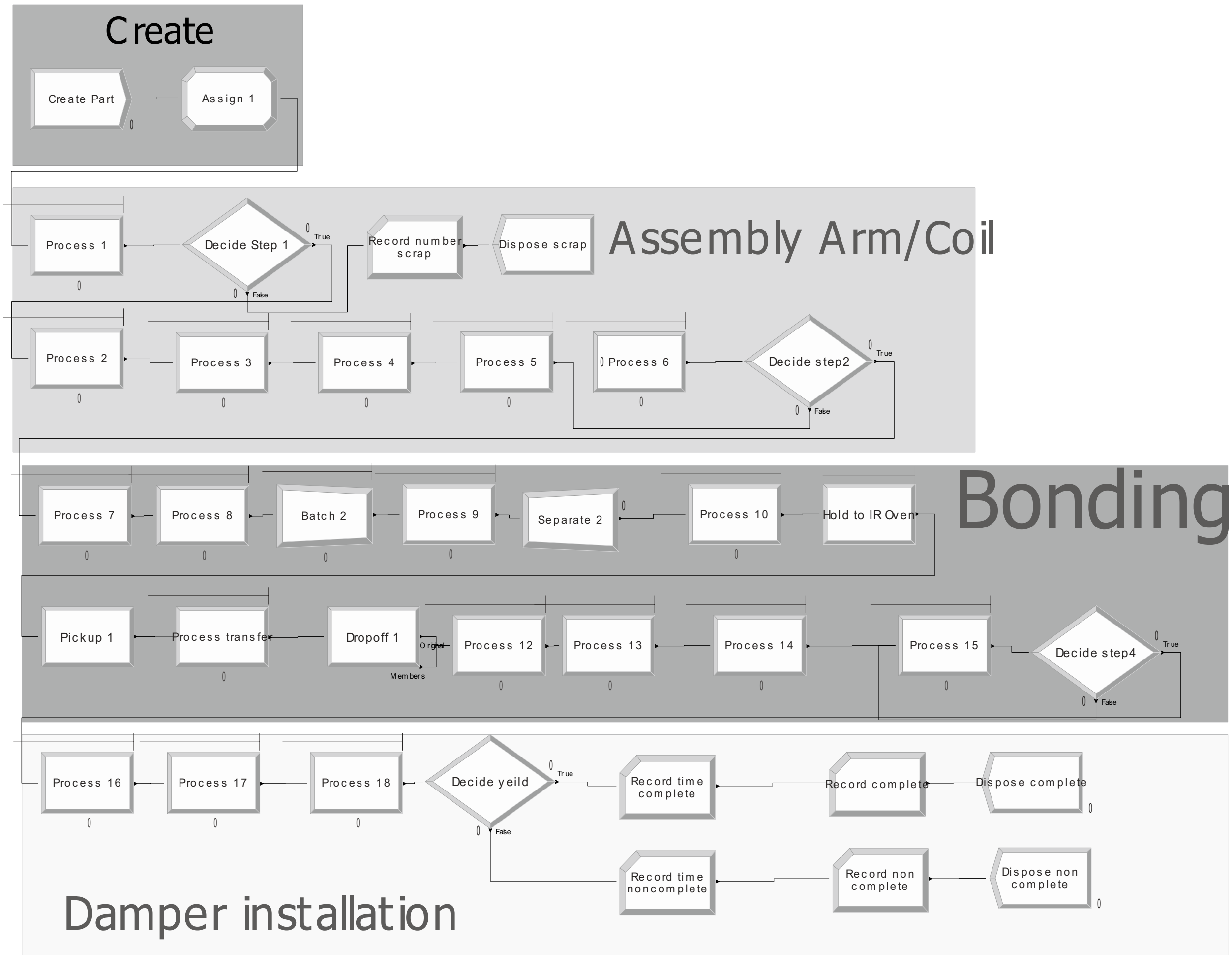


Figure 4: Production Simulation Model using Arena

Table 2: The Data for each Workstation in the Simulation Model

Process	Workstation	Entity Types	No. of (Manpower/Machines)	Average Processing Time (Seconds)	Activity
Arm and Coil Assembly Process	1	Man	1	5.87	NVA
	2	Man	1	5.97	VA
	3	Man	1	5.88	VA
	4	Man	1	5.86	VA
	5	Man	1	5.96	VA
	6	Man	1	5.96	NVA
Bonding Process	7	Man	1	5.90	NVA
	8	Man	1	5.44	VA
	9	Machine	1	47 min. (Constant)	VA
	10	Man	1	5.07	VA
	11	Man	1	12.81	NVA
	12	Machine	1	47 min. (Constant)	VA
	13	Man	1	5.27	NVA
	14	Man	1	5.76	NVA
	15	Man	1	5.70	NVA
Damper Installation Process	16	Man	1	5.87	VA
	17	Man	1	5.96	VA
	18	Man	1	5.88	NVA

2.3 Model Validation

A model validation was then conducted using the Testing Hypothesis (t-test), in order to ensure whether the average processing time within the actual production system and the average time obtained from the simulation model showed any significant differences - to a confidence level of 95%.

$H_0 : \mu_{actual} = \mu_{simulation}$
$H_1 : \mu_{actual} \neq \mu_{simulation}$

Where μ_{actual} is the average processing time for each workstation based on the actual timings.

$\mu_{simulation}$ is the average processing time of each workstation obtained from the simulation model.

The t-test results are shown in Table 3. H_0 is satisfied when the P-value is higher than 0.05. From Table 3, it can be concluded that the processing time of the actual production process and the processing time obtained from the model were not significantly different. Therefore, the model can replace the actual system.

Table 3: t-test Results of Comparison between the Actual System and the Model

Workstation	μ_{actual}	$\mu_{simulation}$	P-value
1	5.89	5.87	0.93
2	5.98	5.97	0.90
3	5.89	5.88	0.95
4	5.87	5.86	0.91
5	5.97	5.96	0.94
6	5.96	5.96	0.99
7	5.90	5.90	0.98
8	5.45	5.44	0.85
9	47 Min. (Constant)		
10	5.07	5.07	0.97
11	12.88	12.81	0.92
12	47 Min. (Constant)		
13	5.28	5.27	0.99
14	5.76	5.76	0.99
15	5.71	5.71	1.00
16	5.89	5.87	0.86
17	5.98	5.96	0.87
18	5.89	5.88	0.96

3 RESULTS AND DISCUSSION

The index used in the analysis of the production process included the processing time for each workstation and the utilization or performance of manpower and machinery - representing an average ratio of resource performance as compared to the total for the system as a whole, bottleneck points and the total product output of each workstation at a certain throughput time. The details of this are as follows:

3. 1Processing Time and Throughput Analysis

The average production time per one work piece is 158.77 minutes. The NVA time includes the inspection processes and the transfer of work pieces, which together account for 68.4 minutes, or 43% of the total processing time. However, idle time occurs during the inspection steps within the transfer between the three processes, including the transportation of materials during the internal process. The results of a throughput analysis, based on a simulation carried out over one day, generated a total of 6,195 work pieces over 10.33 hours.

$$\text{Throughput} = \frac{6{,}195\ pieces}{10.33\ hours} = 600 \text{ pieces/hour}$$

Guideline for improvement 1: A reduction in the production time may be achieved by focusing on non-value added activities using the E-C-R-S principle, where: E (Eliminate) is an elimination of steps or operational methods, C (Combine) is a combination of steps, R (Rearrange) is the rearrangement of working steps in accordance with their priority, and S (Simply) represents simplification of the steps or operational methods [(11)]. Using the principle of E in the process, the machine curing process can be reduced by one cycle. Reducing the curing process to one cycle will result in a reduction in production times of 47 minutes and an increase in throughput.

3.2 Man/Machine Utilization and Bottlenecks

The results of an analysis of manpower/machinery utilization and bottlenecks are shown in Table 4.

Table 4: System Utilization and Bottlenecks

Process	Work Station	Entity Type	Utilization (%)	Work In Process (WIP)
Arm and Coil Assembly Process	1	1 Man	99.81	1.089
	2	1 Man	100.00	0.141
	3	1 Man	98.70	0.153
	4	1 Man	98.24	0.107
	5	1 Man	100.00	5.641
	6	1 Man	99.95	2.749
Bonding Process	7	1 Man	98.70	0.236
	8	1 Man	91.34	0.003
	9	1 Machine	94.52	0
	10	1 Man	85.12	0
	11	1 Man	0.58	178.440
	12	1 Machine	94.58	94.473
	13	1 Man	87.97	65.065
	14	1 Man	96.36	14.425
	15	1 Man	96.09	0.718
Damper Installation Process	16	1 Man	98.41	2.910
	17	1 Man	100.00	27.854
	18	1 Man	98.56	0.141

From Table 4, the average utilization of resources (manpower/machinery) is 100%, while 0.58% represents the minimum – reflecting the range of difference in terms of utilization. An improvement at every step would therefore generate a more uniform utilization. Work In Process (WIP) is work in the process that has not yet been completed and is used as an indicator of bottlenecks in the system [12]. As shown in Table 4, a bottleneck occurs at the eleventh workstation - a transfer point of one lot of 360 work pieces to a curing machine located at the twelfth station, and this causes subsequent bottlenecks at the twelfth station, where it take 47 minutes to complete the curing process, and at the thirteenth station, which is the arm inspection point for the work pieces before being transferred to the fourteenth station.

Guideline for improvement 2: Line balancing should be conducted in order to reduce the bottleneck problem and to enhance the utilization of resources - by scheduling a standard processing time for each station and using Takt Time to establish a similar pace at all the stations [12]; for example.

Whereby:

$$\text{Takt Time} = \frac{\text{amount of available work}}{\text{customer demand during that time period}}$$

Guideline for improvement 3: The size of the transfer batch should be reduced in order to reduce the bottleneck problem. A transfer batch is the quantity of work pieces flowing from one machine to the next [2] - located at the eleventh station where a batch of 360 pieces has to be completed before transferring to the next step. This batch should be reduced to one-third of the original batch size, or 120 pieces, so as to shorten the waiting time and thus reduce WIP and prevent the entire transfer batch from being rejected due to damage.

4 CONCLUSION

An Arena program computer simulation of the production and assembly processes for Product A can effectively simulate the actual production system, and thus enable further analyses to be carried out in support of improvement guidelines development. . However, a constraint of the simulation is the model outcomes. In this study, the model developer created alternatives to the system, and as a result, the outcomes obtained from the model development tended to be estimates not those outcomes that would indicate the most effective alternatives to the actual system.

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