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Huang, Yanhui. ***Applying Simulation Approach to Streamline Hospital Operations***

Abstract

Simulation Modeling is a tool for manufacturing operations to determine the optimized process layout, inventory level, human resource management, equipment and maintenance scheduling to achieve high utilization. The benefits of simulation study projects include cost reduction, inventory control, productivity improvement and high resource utilization.

In this study, the simulation approach was used in the improve of the Cleaning room efficiency for ABC Stomatological Hospital. The study results showed that the new operation parameter combination would increase the operation efficiency.

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Chapter I: Introduction

A health care provider, hereafter referred to as ABC Stomatological Hospital to protect the confidentiality of the information provided was established in 1994. Based in Guangdong Province, China, the company provides stomatological services throughout south mainland China. At the end of 2016, ABC Stomatological Hospital had eight branches more than thousands of employees.

Background of the Project

ABC Stomatological Hospital provide multiple operations each day. After the operations/surgery, the Tool-sets will be sent to a Cleaning room. The Cleaning room will perform a series sanitation processes the clean each Tool-Set and then send the tools back to the correspondence operation/surgical room.

The key performance measurements for the Cleaning room operation include number of Tool-sets cleaned each day (how many of them could not be cleaned), the utilization of cleaning staff, the utilization of each equipment and the waiting time of each Tool-sets.

Statement of the Problem

ABC Stomatological Hospital experienced a high number of late deliveries, unbalanced equipment loads, and low equipment and staff utilizations in its' Cleaning room operation. This affected the hospital's option and profits.

Purpose of the Study

The purpose of the study was to use simulation methodologies to improve the Cleaning room of ABC Stomatological Hospital operation efficiency and increase the hospital's profits. ABC Stomatological Hospital used a demand driving scheduling process in which the Tool-sets required based on the patients' demand. After receiving the Tool-sets, the Cleaning room combined the Tool-sets and put them through a series sanitation processes. Staff were assigned based on the total number of Tool-sets waiting to be cleaned at each station, i.e. a staff assignment could change during the day depends on the queue status at each station. If there were Tool-sets that could not be cleaned, they will be sent to an outside cleaning agent to get cleaned. However, the cost of cleaning Tool-sets with the outsourcing the cleaning services is very high. This study used a simulation approach to solve scheduling issues, so the capacity of Cleaning room resources. could be optimized.

Definition of Terms

The project team and the researcher agreed the definitions of the following terms at the beginning of this project:

Cleaning room. The room where the operation/surgery Tool-sets were cleaned after been used.

Simulation methodology. Model the real systems through computer software.

(Borshchey & Filippoy, 2004)

Tool-Set. The operation/surgery tools used in the ABC Stomatological Hospital to provide healthcare services to its patients. Different Tool-sets contain different numbers of surgery tools.

Z1.4 sampling plan. The acceptance sampling plan standard published by the ANSI that emphasizes on verifying the accuracy of a population data set based on sampling.

Assumptions of the Study

Several assumptions were made throughout this study to find the optimized resource combination. First, ABC Stomatological Hospital created a project team and provided sufficient resources to support the project. The four team members represented hospital functions include scheduling, operation and accounting.

Secondly, the operation data used within this study was accurate and up to date. Six-months' operation records was used to optimize the Cleaning room operation.

Thirdly, this study assumed that the patient that served by the hospital would remain at the same level; therefore, the optimized resource scheduling combination could be used to improve the Cleaning room efficiency.

Methodology

The objective of this study was to use simulation modeling to determine the optimized operation resource combination for the Cleaning room of the ABC Stomatological Hospital. This objective was accomplished by using the design of experiment in the validated simulation model. Multiple combinations of cleaning resources were used in the simulation model. The outcomes of each model were compared before moving to the next level. Operational Goals were prioritized to evaluate the different experiment combination.

The following is the list of project objectives:

(ranked by priority from high to low):

1. Complete as much Tool-sets as possible. The goal is to complete 100% of the cleaning job, the closer the better.
2. Find the total number of staff (and their starting time and assignment), number of steamers and number of UV Dryers that will result the highest utilization.
3. The goal of average utilization of staff members is 90%, the closer the better.
4. The goal of average utilization of Standard steamers is 100% and,
5. The goal of average utilization of UV Dryers is 100% as well, the closer the better.

6. Reduce the number of underfilled steamer and UV Dryer (due to long waiting time).

Limitations of the Study

This research project focused on utilizing available resources currently owned by ABC Stomatological Hospital. Options such as increased resource capacity (buying new steamers or adding more operators) were excluded. Second, the data used in this research only reflected the historical operational records ABC Stomatological Hospital. Hence, the proposed specific solutions from this research may not generalize to other businesses.

Summary

This chapter addressed the background of the research project including the problems ABC Stomatological Hospital faced, the purpose of the study and objectives of the research. It also defined important terms and the limitations of the study.

The next chapter explores the literature related to the simulation modeling approach. The simulation model validation as well as apply the design of experiment in simulation modeling to determine the optimized operation combinations.

Chapter II: Literature Review

The Tool-sets Cleaning room of ABC Stomatological Hospital experienced operational efficiency problems, which has led to uncompleted work, outsourcing jobs and high operational cost. The hospital wanted to utilize the simulation modeling approach to find the optimized operation resource combination to eliminate/reduce the above problems.

This literature review analyzed simulation modeling and the reason for using it in this project. It also reviewed simulation model validation and the benefit of using design of experiment methods to improve ABC Stomatological Hospital's operational efficiency.

Simulation Modeling

According to Kelton, Sadowski and Zupick (2014), computer simulation is the approach of using computer simulation software to model the real-life has advantage of dealing with complicated operation (Kelton, Sadowski & Zupick, 2010). In addition, the simulation modeling approach also gives the flexibility to the researchers to use the design of experiment tool with the software model to perform the "what-if" analysis (Kelton, 2012). With the computer hardware and software development, the computer simulation gets more and more popular, industries started to use simulation modeling as a tool to improve their operation efficiency, reduce the operation cost as well as improve the resources utilizations.

Simulation Modeling Process

The process of developing a simulation model and perform the design of experiment analysis is a systematic approach (Banks, Carson, Nelson, & Nicol, 2005) which could involve the following steps:

1. Problem Identification

In this step, researcher or project teams need to first evaluate the existing system and determine which problem to target for the simulation study (Adner & Levinthal, 2001). After that, the project objective and scope need to be defined. The objectives of the project should include the performance measures of the outcome, both quantitative and qualitative. In addition, the objective measures need to be prioritized in order to help the researcher or project team to develop the simulation study outcome evaluation criteria (Cayirci, 2013).

At the end of this stage, the researcher or project team need to also briefly determine the time frame of the simulation modeling study.

2. Data Collection and Evaluation

   In this step, the system operation data will be collected. Input variables such as job arrival rate, probability of event occurring, process time and transportation related information will be determined (Davidovitch,. Parush & Shtub, 2008). The critical part of this step is that the data need to come from the real operation data to ensure the simulation model reflect the actual operation.

3. Base Model Development

   Base model development starts with process mapping. A detailed flow chart of the real process will then translate to the model which recognized by simulation software. During this translation process, detailed parameters that required by simulation software need to be programmed, links that connecting different processes need to be built and the input and output of the simulation model need to be defined as well (Kelton, Sadowski & Zupick, 2010).

Documentations such as assumptions, input variable details and entity status changes need to be documented at this stage for future model verification and audit.

4. Base Model Verification

   Before using the base model for process improvement, the simulation outcome of the base model needs to be verified with the real operation system for verification and validation (Rossetti, 2010). Comparing the outcomes with real condition parameters of the real system with statistical hypothesis tests as well as using experts to exam the base model outcomes are often used at this stage (Borshchev & Filippov, 2004). During the verification process, technics such as product tracking, acceptance range evaluation, sensitivity analysis with probability distribution changing to constant and animation observations are often employed.

5. Use Base Model to Perform Process Improvement Study – Design of Experiment

   After the based model is been development and verified, the next step is to use the design of experiment approach to find the solution. In general, a set of response variables, the output of the simulation model is of interest (Banks, Carson, Nelson & Nicol, 2005). Operational parameters, the input of the simulation model, can be changed by the researcher or project team. Other than that, the research or the project team needs to also decide the appropriate simulation starting conditions, the length of the model warmup period and the number of replications of each run as well as the output data collection periods (Sterman, Repenning & Kofman, 1997).

After each simulation, the outcomes will be compared with the previous model's outcome with the same types of tests mentioned in Step 4. If the new combination of the input operation is better than the previous model, the new model will stay in the study and the previous model will be "knocked" out, versa vise (Lant & Mezias, 1990).

The following figure shows an example of the comparation.

Parameters	Model n		Model n+1		Difference	
	Parameter Setting	Utilization	Parameter Setting	Utilization	Parameter Setting	Test Result
Parameter 1						
Parameter 2						
Parameter 3						
Parameter 4						
Parameter 5						
Parameter 6						
Parameter 7						
Parameter 8						
Parameter 9						
	Decision	Move with n+1				
		Stay with n				

Figure 1. Sample comparison table of simulation study.

This step will be repeated until the ideal situation is reached of the project objectives are met (Struijk, 2014). The results of each model should be recorded to track the process improvement status.

6. Make Recommendations and Trail Run

   The solutions find in the simulation study will then be presented to the organization for implementation. If possible, a trail run should be conducted to check if the solution from the simulation study is effective (Sokolowski & Banks, 2009).

7. Project Closing and Continues Improvement.

   After the project is completed, the research or project team should reevaluate the system and seeking for opportunities to continually improve the process. The continuous improvement cycle should never stop.

8. The above process is summarized in the following flow chart.

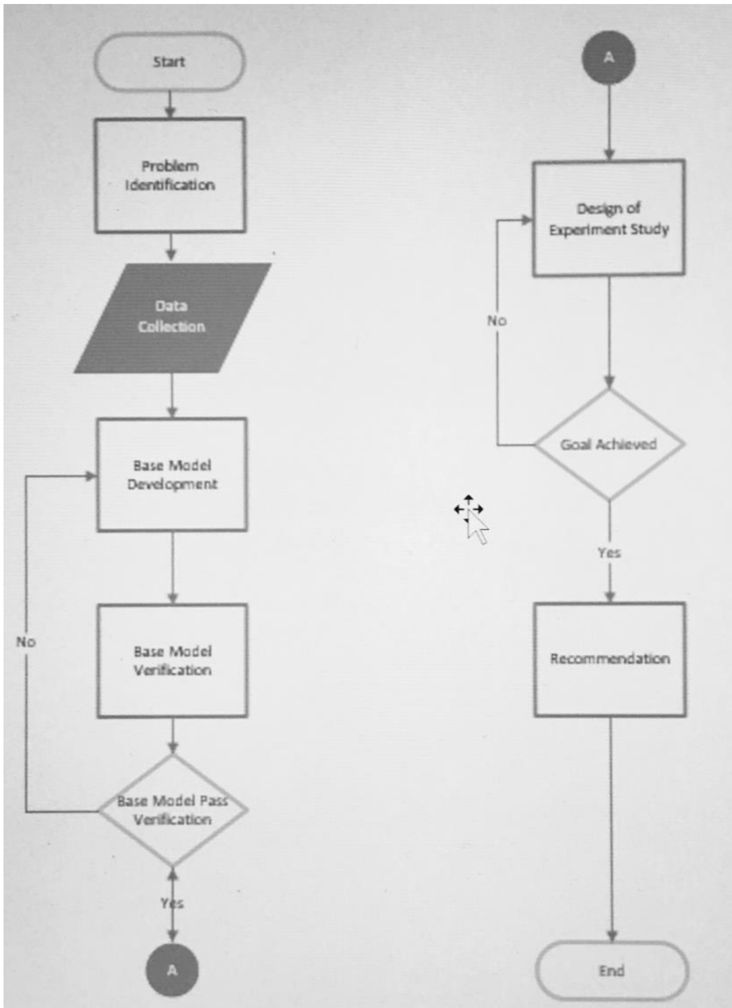

Figure 2. Simulation model project process.

Summary

This chapter covered the simulation modeling approach for process improvement. The approach is often used to reduce costs, increase operational efficiency and improve staff and other resources planning. The use of Design of Experiment in the simulation study can help the organization determine the best operational variable combination, which leads to improved profit. Given the operational challenge ABC Stomatological Hospital faced, this research intended to use the above approach to help the hospital find a way to better utilize its resources and improve the operational efficiency.

The next chapter will look at the methodology associated with simulation modeling. It will go over the methods employed to help the Cleaning room of ABC Stomatological Hospital find their best operational strategy. The data collection and procedures used in the research will also be covered.

Chapter III: Methodology

The Cleaning room of ABC Stomatological Hospital experienced a high number of late deliveries, unbalanced workloads, and increased unfilled cleaning equipment. This reduced the organization's profits. The objective of this study was to use simulation methodologies to provide a planning tool that resulted in lower cost of operation. Arena software was used in the analyze and improve phases in this study. In this research, the objective was to minimize the cost deviation in each operation cycle.

Data Collection

The tools cleaning records were collected for the year of 2016. The records included time the tools arrive to the Cleaning room, waiting time to get into the clean steamer, the total number of pieces of tools in each steamer, waiting time to get into the dryer, the total pieces of tools in each dryer and the time the Tool-sets are ready to send back to the surgery room. Table 1 shows an example of this type of record.

Table 1

Sample Tool-sets Cleaning Record

ID	Process Parameter
Time Arrive	8:05am
Time Enter the Steamer	8:50am
Total Number of Pieces in the Steamer	325
Time Enter the Dryer	10:52am
Total Number of Pieces in the Dryer	652
Time Completed	12:06pm
Memo	

Data Verification

The accuracy of the cleaning records was checked before this data was analyzed. US Z1.4 sampling plan – single sampling plan was used to determine the sample size. In the first step, Sample Size Code Letter was determined from the Z1.4 standard shown in Figure 3.

ANSI/ASQC Z1.4 ISO 2859 Table

Table 1 - Sample size code letters (see 10.1 and 10.2)

Lot size		Special inspection levels				General inspection levels		
		S-1	S-2	S-3	S-4	I	II	III
2 to	8	A	A	A	A	A	A	B
9 to	15	A	A	A	A	A	B	C
16 to	25	A	A	B	B	B	C	D
26 to	50	A	B	B	C	C	D	E
51 to	90	B	B	C	C	C	E	F
91 to	150	B	B	C	D	D	F	G
151 to	280	B	C	D	E	E	G	H
281 to	500	B	C	D	E	F	H	J
501 to	1 200	C	C	E	F	G	J	K
1 201 to	3 200	C	D	E	G	H	K	L
3 201 to	10 000	C	D	F	G	J	L	M
10 001 to	35 000	C	D	F	H	K	M	N
35 001 to	150 000	D	E	G	J	L	N	P
150 001 to	500 000	D	E	G	J	M	P	Q
500 001 and over		D	E	H	K	N	Q	R

Figure 3. Sample size code Z1.4 standard.

Secondly, the total number of samples that needed to be checked was identified from the Z1.4 Master Table shown in Figure 4. If the verification results show the data accuracy met the standard, a 100% double check of the records had to be done to ensure all the errors in the data set were corrected before any data analysis was conducted.

Table 2-A — Single sampling plans for normal inspection (Master table)

Sample size code letter	Sample size	Acceptance quality limit, AQL, in percent nonconforming items and nonconformities per 100 items (normal inspection)																									
		0,010	0,015	0,025	0,040	0,065	0,10	0,15	0,25	0,40	0,65	1,0	1,5	2,5	4,0	6,5	10	15	25	40	65	100	150	250	400	650	1 000
		Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re
A	2	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	0 1	↓	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	30 31
B	3	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	30 31	44 45
C	5	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	30 31	44 45	↑
D	8	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	30 31	44 45	↑	↑
E	13	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	30 31	44 45	↑	↑	↑
F	20	↓	↓	↓	↓	↓	↓	↓	↓	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑	↑	↑	↑	↑	↑
G	32	↓	↓	↓	↓	↓	↓	↓	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑	↑	↑	↑	↑	↑	↑
H	50	↓	↓	↓	↓	↓	↓	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑	↑	↑	↑	↑	↑	↑	↑
J	80	↓	↓	↓	↓	↓	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑	↑	↑	↑	↑	↑	↑	↑	↑
K	125	↓	↓	↓	↓	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
L	200	↓	↓	↓	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
M	315	↓	↓	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
N	500	↓	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
P	800	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
Q	1 250	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
R	2 000	↑	↑	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑

↓ = Use the first sampling plan below the arrow. If sample size equals, or exceeds, lot size, carry out 100 % inspection.

↑ = Use the first sampling plan above the arrow.

Ac = Acceptance number

Re = Rejection number

Figure 4. Sample master Z1.4 table.

Process Analysis – Process Mapping

The tool cleaning process is divided to the following steps:

1. Quick Water Wash

   The majority of Tool-sets (90%) received by the Cleaning room will need Quick Water Wash. The facility has enough sinks for this process.

2. Steamer Sanitation

   Tools will then be put into a big container. Each container has the capacity of holding average of 300 pieces of tools. Each Steamer can hold up to two containers.

3. Packaging

   After completing the sanitation process, the tools will then be packed as Tool-Set. This process is done by the staff. The packed surgery Tool-sets will then put on the cart.

4. UV Dryer

   The packed Tool-sets will then be put in a UV Dryer. Each UV Dryer has the capacity of holding 3 carts.

5. The tools completed the UV Dryer process will then send back to the operation room.
6. The other 10% Tool-sets must be processed by the “Deep Cleaning” process before going to the Steamer. After the tools are “Deep Cleaned”, they will join the regular steamer process.

Figure 5 is the Flow Chart for the cleaning process.

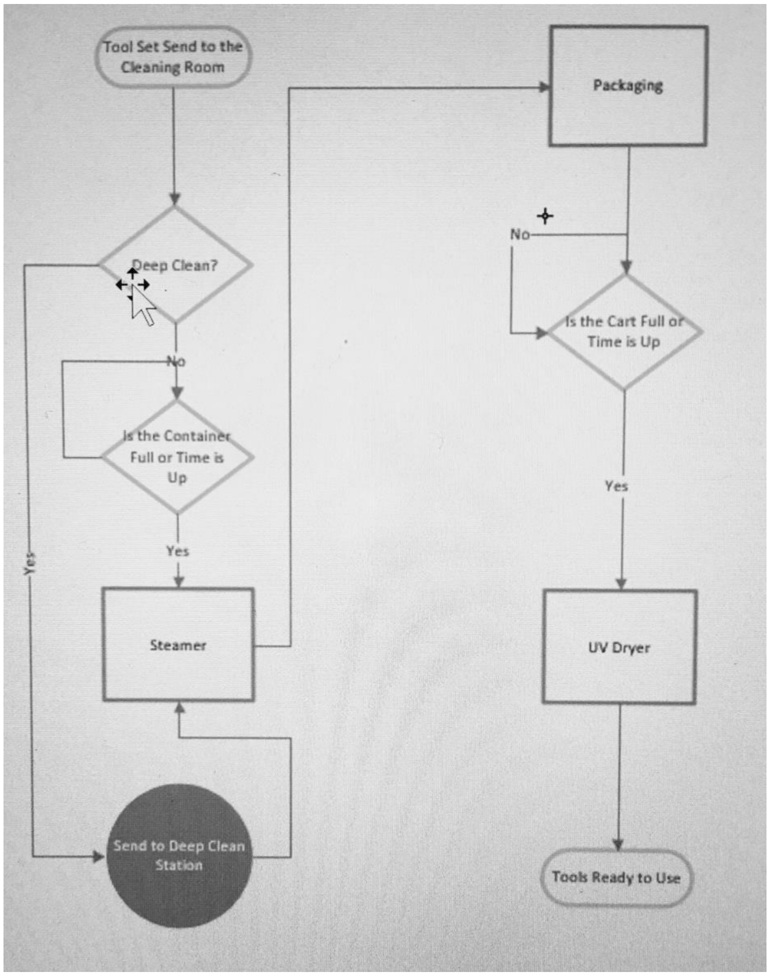

Figure 5. Cleaning room process flow chart.

Operation Policies

The hospital established several operation policies for the Cleaning room.

1. The Tool-sets need to be washed, steamed and dried together all the time.
2. If a container is waiting to be filled for too long (greater than 25 minutes), it will be put into the steamer no matter how many pieces of tools are in the container (this may result under filled containers or only one container of tools to be steamed by a standard steamer).
3. If a cart is waiting to be filled for too long (greater than 45 minutes), it will be put into the UV Dryer no matter how many pieces of tools are in the container. This

means UV Dryer may process under filled carts or only one or two carts in some cases.

Simulation Model Programming – Transfer the Process to Simulation Model

The process shows in Figure 5 needs to be translated to the simulation modeling, so the simulation study can be performed. The following approaches are used to modeling each steps of the cleaning process.

1. Tool-sets sent to the Cleaning room

   The create entity block is used for tool arrivals (Figure 6). The time interval is defined by exponential distribution and the maximum arrival

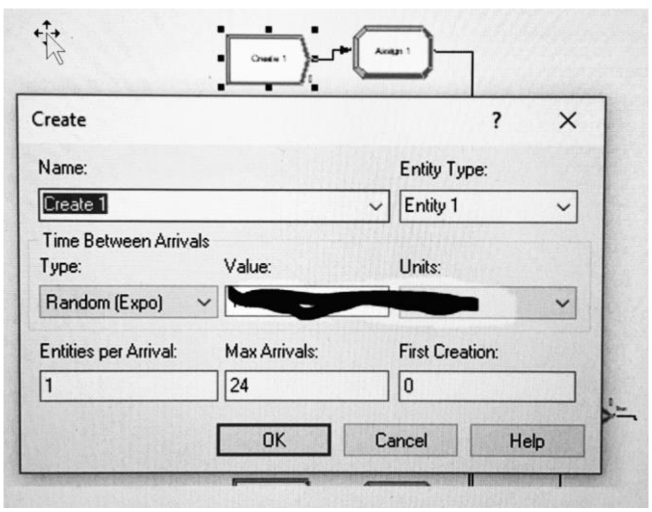

Figure 6. Workpieces arrive simulation block.

2. Steamer Process

   Steamer process is divided to the following sub processes.

   1) Group Tool-sets to Container

      Batch block (Figure 7) is used to group Tool-sets together, the signal of sending batch to container is triggered by either the total number of tools or the waiting time (to accommodate the hospital operation policy).

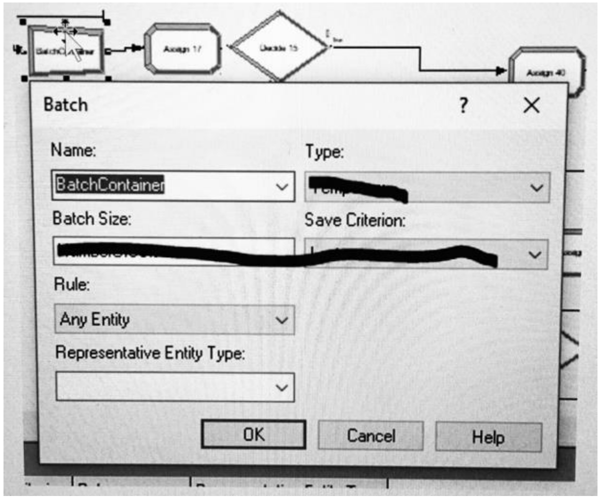

Figure 7. Steamer container group process logic.

2) Group Containers to Steamer

Another batch block is used to group containers to steamer, if there two containers are ready or if the time is up, the container(s) will then be released to the steamer to start the steam snatiation process (Figure 8).

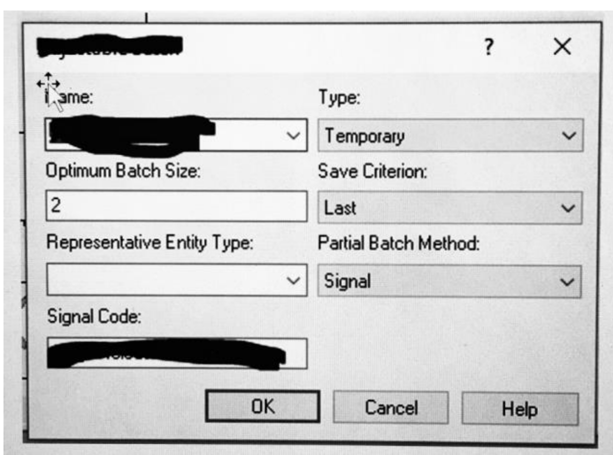

Figure 8. Steamer group process logic.

3) Steamer Process

A series of process blocks are used to simulate the steamer set up and steaming process. Resources (operator and steamer) are seized by these process block and their utilization are collected by the software (Figure 9)

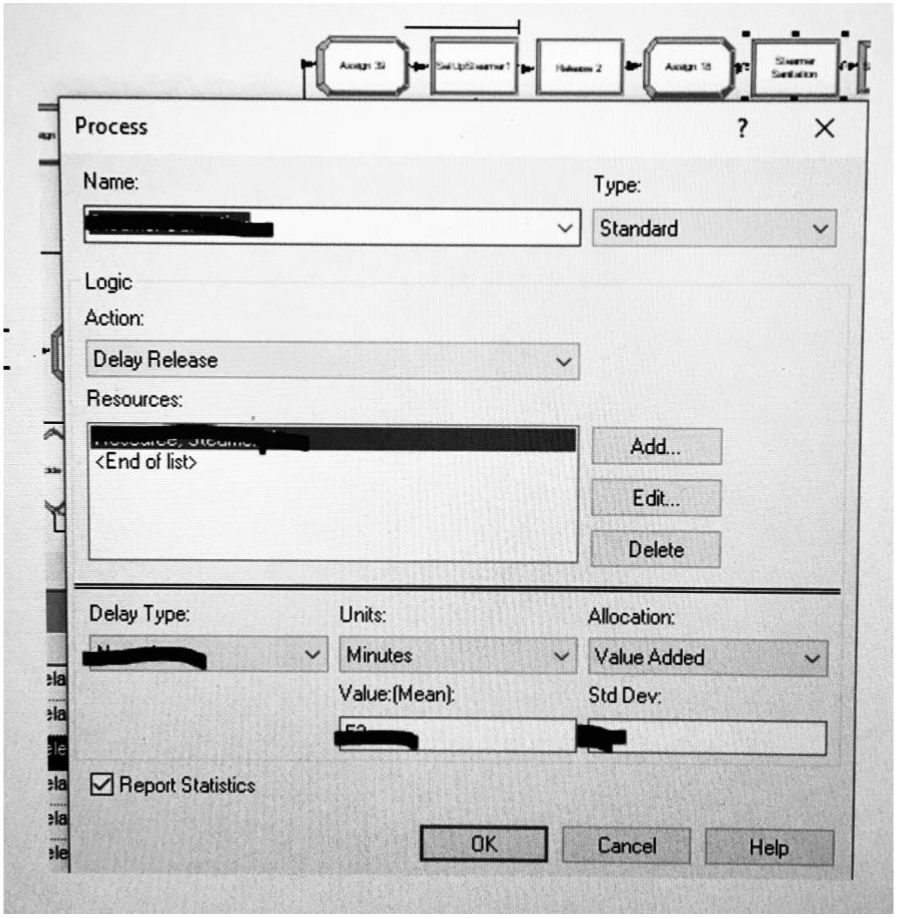

Figure 9. Steamer process logic.

3. After the Tool-sets come out from steamer, the Tool-sets will be separated by Separate blocks, so they can be packaged.

4. Packaging Process

   Process block is used to simulate the packaging process. The utilization of packaging staff is collected by the process model.

5. UV-Dryer Process

   UV-Dryer process is divided to the following sub-processes:

   1) Group Tool-sets to Cart

Batch block (Figure 10) is used to group Tool-sets together, the signal of sending batch to cart is triggered by either the total number of tools or the waiting time (to accommodate the hospital operation policy).

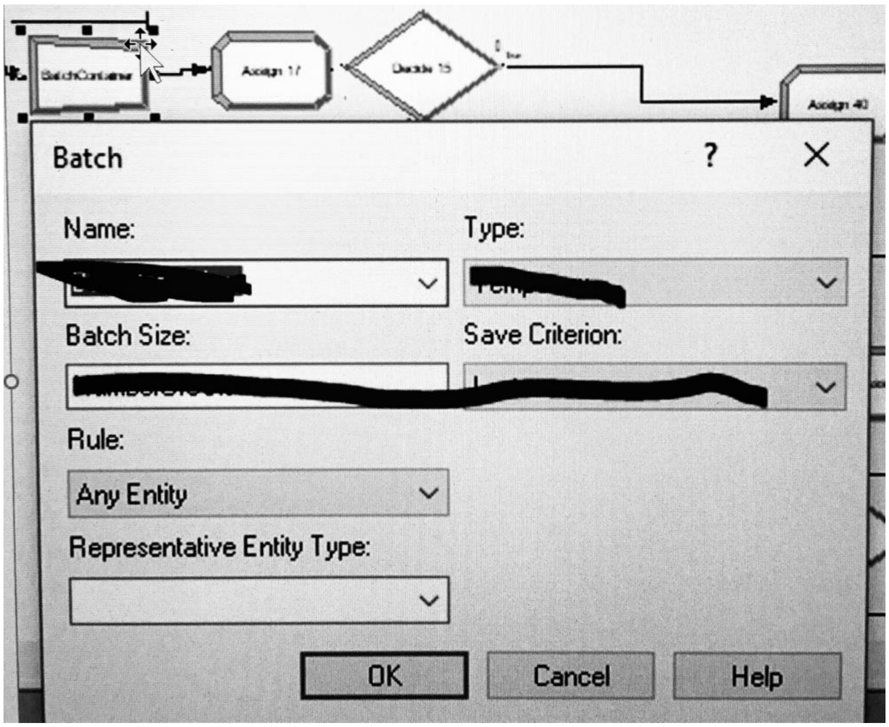

Figure 10. UV-Dryer cart group process logic.

2) Group Containers to UV-Dryer

Another batch block is used to group carts to UV-Dryer, if there three carts are ready or if the time is up, the cart(s) will then be released to the steamer to start the dry process (Figure 11).

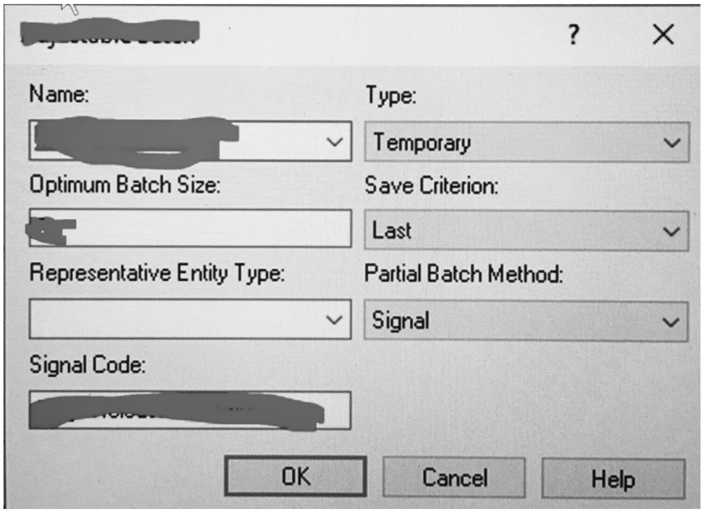

Figure 11. UV-Dryer group process logic.

3) Dry Process

As shown in Figure 12, a series of process blocks are used to simulate the steamer set up and UV-Dryer process. Resources (operator and UV-Dryer) are seized by these process block and their utilization are collected by the software.’=

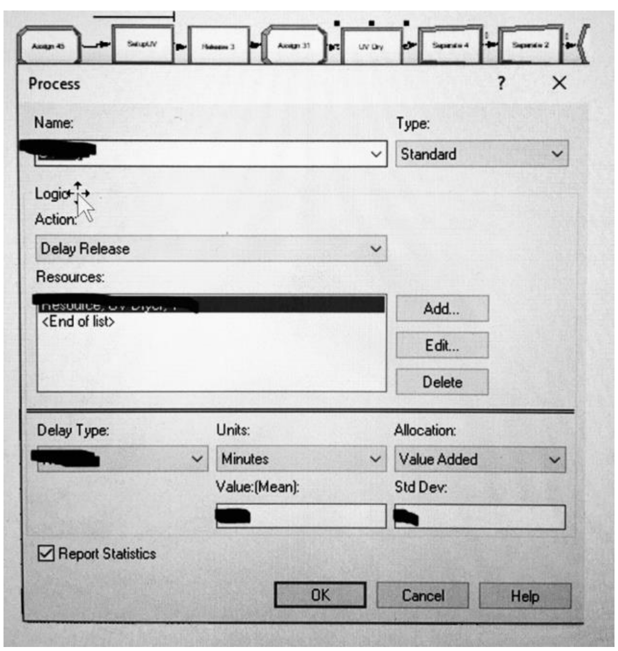

Figure 12. UV-Dryer process logic.

6. Simulation Study and Results Validation

The simulation model run was set up to run with 20,000 replicants, the process parameters were collected by the software. Figure 13 shows sample statistics collected by the software. These results were then validated by the actual operation outcome.

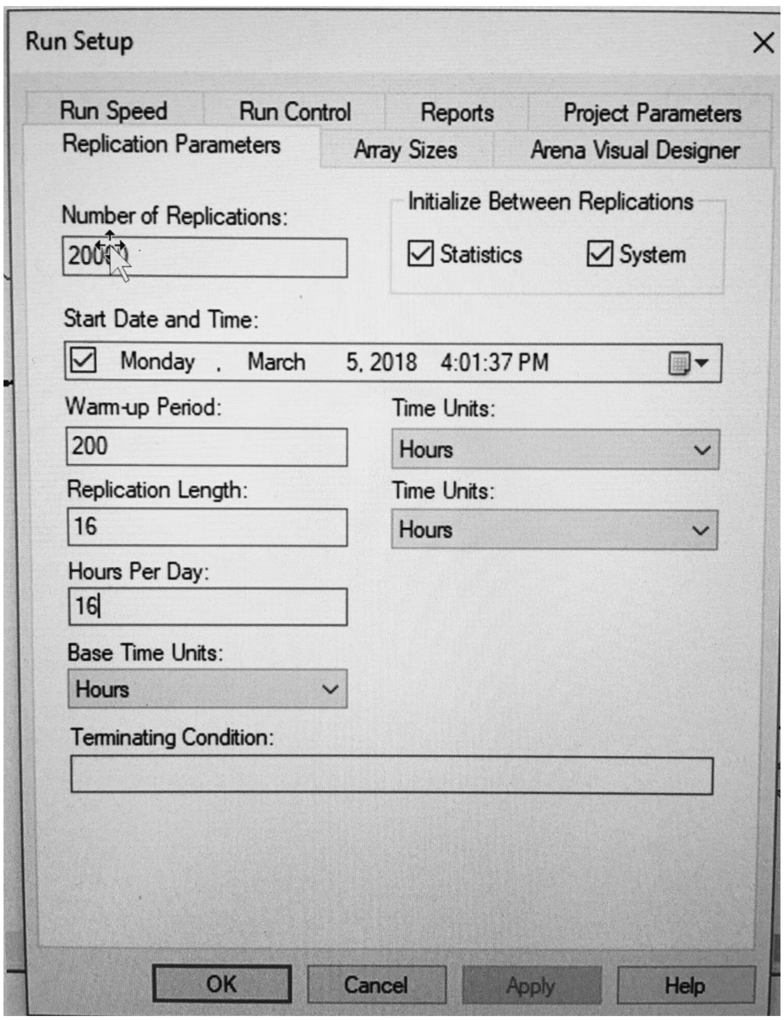

Figure 13. Simulation run setup.

7. Using the Validated Model for Process Improvement

After the model successfully passing the validation process, it was then used for the "What-if" analysis, operation parameters such as shift scheduling, amount of equipment and number of operators at each station are modified and keyed in to the simulation model, outcomes from the simulation model were evaluated to check if the process is improved until the optimized level are reached.

Summary

This chapter covered the research methodology for evaluating the key performance parameters of the ABC Stomatological Hospital. Process mapping was used to study the Cleaning room process.

Next, this chapter covered how to use the process mapping outcome to establish the simulation model. The simulation model based on the process mapping outcome was built and run with 20,000 replicates. The outcomes of the replicates were then verified with the actual process data. cation was done based on one month of operational data. After successfully passing the validation, the model was then used for design of experiment analysis to determine the optimized the combination of the process resources.

The next chapter will review the results of this study. The simulation model outcome will be discussed in detail in the next chapter as well.

Chapter IV: Results

The Cleaning room of ABC Stomatological Hospital experienced a high number of delayed jobs as well as the low efficiency in terms of equipment and staff utilizations. This has increased the hospital's operation costs and reduced their patient satisfaction level. The goal of this study was to use simulation modeling to provide a better process operation resource combination to increase the efficiency of the operation.

Results of Data Verification

There were total of 6 months records collected for this study. According to Z1.4 standard Sample Size Code Letter table showed in Chapter III Figure 5, the sampling plan letter code was letter N. The total number of samples needs to be checked with letter code N was 500 based on Z1.4 Master Table showed in Figure 6 in Chapter III. The master table also indicated that the acceptance level of this verification should be 1 which meant if there was less than or equal to 1 error in 500 samples, the data set would be considered as accurate. The researcher selected 500 randomly data set and verified the accuracy of them. The result showed that all of them were correct. It was concluded that the data set was considered accurate.

Simulation Model

Arena software (from Rockwell Automation) was used to build the simulation model. Seventy-five blocks were used in the model (Figure 14). According to the actual Cleaning room operation situation, the model is set to run 16 hours per day with two shifts and seven days for each week. In order to get reasonable results, the model has set up to run with 20,000 replicants with 200 replicants warm-up period.

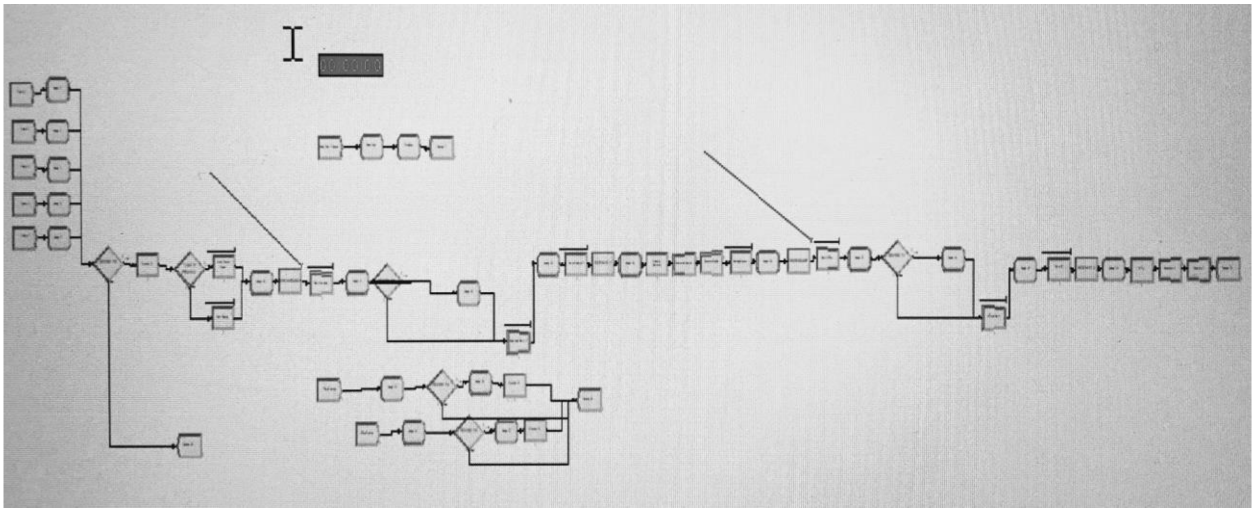

Figure 14. Arena simulation model for the cleaning room process.

Results of the Base Model and Model Validation

Based on the request from the ABC Stomatological Hospital, the following operation parameters were included in the model.

1. Number of Staff

   This parameter represents how many operators work in the Tool-sets Cleaning room.

2. Staff Specialization

   This parameter shows if the staff are assigned to specific work station. At the time of the study, there was no specialization assigned to the staff, which means these staff are cross-trained and will work on the station that has the largest amount job waiting.

3. Staff Utilization

   Staff Utilization measures the percent of time during the working hours the staffs were busy. This parameter was not collected when the study is performed.

4. Utilization of the Steamer

   This parameter measures the percent of time the Steamer was busy during the Cleaning room operation period.

5. Utilization of the UV-Dryer

   This parameter measures the percent of time the UV-Dryer was busy during the Cleaning room operation period.

6. Unfinished Tool-sets

   This parameter records the numbers of tools sets that sent to the Cleaning room but could not been cleaned in the same day. This may result a delay of the hospital operation.

7. Number of Unfilled Steamer

   This parameter measures the number of steamers that were not fully filled (with less than two container or unfilled container).

8. Number of Unfilled UV-Dryer

   This parameter measures the number of UV-Dryer that were not fully filled (with less than three cart(s) or unfilled cart(s)).

The following table shows the results of the base model outputs and the comparison to the actual operation measurements. The differences (in percentage) was calculated in column 3. The ABC Stomatological Hospital approved the results of the base model and believe it represents the actual operation situation.

Table 2

Summary of Base Model Evaluation

Parameters	Base Model	Real Operation	Differences in Percentage
Staff Utilization	39.78%	Not available	
Steamer Utilization	37.56%	39.50%	5.2%
UV-Dryer Utilization	75.66%	78.00%	3.08%
Tool-sets Receipt	352	360	
Tool-sets Cleaned	314	312	

Design of Experiment Study

The ABC Stomatological Hospital set up the following goal for this project (ranked by priority from high to low):

1. Complete as much Tool-sets as possible. The goal is to complete 100% of the cleaning job, the closer the better.
2. Find the total number of staff (and their starting time and assignment), number of steamers and number of UV Dryers that will result the highest utilization.
3. The goal of average utilization of staff members is 90%, the closer the better.
4. The goal of average utilization of Standard steamers is 100% and,
5. The goal of average utilization of UV Dryers is 100% as well, the closer the better.
6. Reduce the number of underfilled steamer and UV Dryer (due to long waiting time).

After discussing with the ABC Stomatological Hospital, the project team decided to use 10% as the general threshold to evaluate the outcome of the new operation parameters combination. The output of each model needs to be evaluated by both the project team and the management team of ABC Stomatological Hospital before been considered as an “improved” operation.

Seventeen rounds of new models were studied in the project until the optimized operation status was reached. The following table shows the comparison between the model seventeen outcomes and the actual operation results.

Table 3

Summary of Final Model

Parameters	Model Seventeen	Real Operation	Differences in Percentage
Staff Utilization	80.25%	Not available	
Steamer Utilization	74.92%	39.50%	5.2%
UV-Dryer Utilization	90.23%	78.00%	3.08%
Tool-sets Receipt	352	360	
Tool-sets Cleaned	352	312	

The following is the summary of the project goals:

1. Complete as much Tool-sets as possible. The goal is to complete 100% of the cleaning job, the closer the better.

   This goal is achieved. Based on the seventeen-model outcome, all the tools were cleaned on the same day.

2. Find the total number of staff (and their starting time and assignment), number of steamers and number of UV Dryers that will result the highest utilization.

   The combination of staff (and the staff specialization), number of steamers and number of UV-Dryers were determined.

3. The goal of average utilization of staff members is 90%, the closer the better.

   The staff member’s utilization is 80%.

4. The goal of average utilization of steamers is 100%.

   The average utilization of steamer is 75%.

5. The goal of average utilization of UV Dryers is 100% as well, the closer the better.

   The average utilization of UV-Dryer is 90%.

6. Reduce the number of underfilled steamer and UV Dryer (due to long waiting time).

   The unfilled steamer is 12 and unfilled UV-Dryer is 8.

Summary

This chapter began by showing the results of data verification. It showed that the data used in this research was accurate. The chapter also went over the results of the base model results. The results of the base model also validated with the actual operation data. Project goals were determined by the ABC Stomatological Hospital. The design of experiment was then used to find the optimized operation parameter combination. After seventeens round simulation study, the research team believed that it reached the optimized level with the current operation process. Due to the conflict of project goals, not all of them could be achieved. The next chapter will draw conclusions from the study and make recommendations. The opportunities for future research will also be discussed in the next chapter.

Chapter V: Discussion

In this study, simulation approach was used in the project of improving the resource efficiency of the Cleaning room of ABC Stomatological Hospital.

Chapter I introduced the background of ABC Stomatological Hospital and the challenges of late completion, low efficiency and underfilled equipment they were facing. ABC was unable to effectively plan for staff scheduling. The goal of this study was to use simulation methodology to help ABC Stomatological Hospital find the best resource combinations. This chapter also covered the assumptions of the study.

Chapter II was a literature review of simulation modeling approach, design of experiment and process mapping. The chapter covered simulation software and why it could help an organization reduce costs and improve operational efficiency.

Chapter III covered the methodology for this study regarding collection and analysis of historical data, built the simulation model for ABC Stomatological Hospital. Six months' operation records were collected for this study. These records were verified by Z1.4 Standard for accuracy. Simulation modeling, base model validation and design of experiment performed to determine the key process performance parameters. Chapter III concluded with the discussion of the limitations of the study.

In Chapter IV, the results of data verification, process simulation model, simulation model verification and the design of experiment output were presented. The final model output was used as ABC Stomatological Hospital scheduling tool.

This chapter draws conclusions from this research project followed by recommendations that are made for ABC Stomatological Hospital. Opportunities for future research will be discussed at the end.

Limitations

This study was limited to the Cleaning room of the ABC Stomatological Hospital operation records so the detailed Tool-sets probability factor could not be identified. The second limitation of this research was the project goals set by the hospital contains items that are conflict, for instance, in order to increase the equipment utilization, the model needs to limit the number of equipment, the result of this constrain might affect the waiting time of the Tool-sets, the project team needs to weight different goals to determine the priority to evaluate if the proposed experiment achieve the goals.

Conclusions

The literature review demonstrated that simulation study could provide help an organization improve its operation efficiency. It showed that organizations can benefit from successful simulation projects.

A goal of this study was to find an operation parameter combination that ABC Stomatological Hospital could use to improve the performance of its Tool-sets Cleaning room efficiency. This goal was accomplished through simulation study.

The findings in this study correlate to the literature review. For ABC Stomatological Hospital, there would be a significant operation efficiency improvement of its Cleaning room with the use of simulation modeling tool.

Recommendations

Based from the results of this study, the following recommendations are being made for the Cleaning room of the ABC Stomatological Hospital. First, the hospital should start using the new scheduling tool from this research project. This new tool will help the company increase the operation efficiency.

Next, it is being recommended that ABC Stomatological Hospital to assign staff members to special station. The number of staff assigned to each station is based on the utilizations from the simulation study. The key criteria of this assignment are to reduce the waiting times of each station so the Cleaning room can process more Tool-sets.

Third, ABC Stomatological Hospital should reduce the number of equipment (number of steamer and number of UV-Dryer). A better staff plan at the bottleneck station will reduce the cleaning tools waiting time and increase the utilization of the equipment resources. This will reduce the needs of total amount of equipment.

Finally, a future recommendation would be for ABC Stomatological Hospital to continually use simulation approach to search for additional opportunities to keep increasing the Cleaning room operation efficiency.

Opportunities for Future Research

In the research project, ABC Stomatological Hospital used simulation modeling as a tool to determine the best operation parameter combination. The results of the pilot test showed that this could increase the efficiency of the Cleaning room operation of ABC Stomatological Hospital significantly.

A future study might be conducted to evaluate ABC Stomatological Hospital's other business practices. The literature review indicated that the competition of the hospital service market is getting stronger. ABC Stomatological Hospital should perform a strengths, weakness, opportunities and threats (SWOT) analysis and reevaluate their business model to determine if they need to change their strategic plan to become a leader in the field. Simulation modeling model could be used in this type of evaluation. The external factors that impact the operational costs could be used in building the simulation model. The output of the simulation model would help the management team figure out what business model will bring the most financial benefit to the company.

Another research opportunity could be the deeper evaluation of the design of experiment outputs. Future researchers may use simulation modeling sensitivity analysis to evaluate different what-if combinations in the simulation modeling outputs. However, in order to perform this type of evaluations, more powerful simulation software will be needed for this type of analysis.

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Appendix: Sample Arena Simulation Output

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