# REPORT OF BIG PROJECT

LAB WORK OF COMPUTER SIMULATION

*MAKESPAN ANALYSIS APPROACH AT BOLU KIDANG SLEMAN YOGYAKARTA*


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# Chapter I. INTRODUCTION

## 5.1 Background of Problem

Production is the main activity in a company which involves many variables. Production is defined as the activity of processing objects (raw material) into different objects (final product) with increasing value. The increase of value may vary depending on customer demand and production process. Based the customer’s perspective, the price of a particular product will have an appropriate as its value while from production process the value is increased with certain value. But, in the production process the profit obtained from the increased value may vary depending on the production variables. The variables considered in production includes make span, number of machines, capacity of machines, raw material lead time, raw material quantity, number of operator, working time, maintenance, inventory, etc. Bad considerations of these variables may cause big loss in a company.

Bolu Kidang, is a company in Yogyakarta which produces various type of cakes. Bolu Kidang has many demand for various type of *bolu* everyday but the production is not scheduled. Unscheduled production may cause big loss in company which results with profit decrease. Because of varying type of *bolu* produced by the company there are various type of production process that must be followed by the materials in order to be a finished *bolu*. However, the number of machine, capacity and operator is limited which forces the product to be produced one type at a particular time.

Production of every *bolu* in Bolu Kidang has various production route and process time depending on what type of *bolu* to make. Because of the various type of *bolu* to produce, the company doesn’t has valid data about makespan and average inventory. In the production process the data becomes hard to collect because of uncertain number of operators in the company.

## 1.2 Problem Formulation

The problem formulations in this research are as follows:

1. How can the company minimize makespan?
2. What problems in the system that occurs and may affect makespan?
3. How to overcome the problems in the system which can be applied by Bolu Kidang to maintain optimum makespan?

## 1.3 Problem Constraints

Constraints of this research are as follows:

1. The research is done only in Bolu Kidang.
2. Production is done 6 days consecutively from Monday to Saturday.
3. The research only focus on 3 types of *bolu*.

## 1.4 Research Objectives

The objective of this research are as follows:

1. To find how to minimize makespan in Bolu Kidang.
2. To find the problems that may affrct makespan in Bolu Kidang.
3. To find what can be done by Bolu Kidang in order to maintain optimum makespan.

## 1.5 Research Benefits

### 1.5.1 For Researchers

1. Knowing how the production process occurs in the Bolu Kidang
2. Knowing the form of simulation models using software flexsim 6.
3. Knowing the simulation results that have been on the way.
4. Knowing that the solution should be to produce something optimal results at the end of observation.

1.5.2 For Company

1. The result can decrease production cost of the company
2. The company will determine the appropriate method to minimize makespan in production
3. The company will be able to improve the quality of services and maintenance that met customer satisfaction.

## 1.6 Systematics Writing

Systematics in the writing of a report on research in the Bolu Kidang are:

a. CHAPTER I, INTRODUCTION

Contains a description of the object of research. And also about the background of the problem, formulation of the problem, the object of study, as well as the benefits to the investigator and the object of research.

b. CHAPTER II, LITERATURE REVIEW

Contains deductive study and inductive study, theoretical review about jobshop simulation and makespan with valid reference, there are previous research also that become our basic research.

c. CHAPTER III, RESEARCH METHODOLOGY

Contains the translation of research into real technical and the retrieval of data for research and data collection methods, both primary and secondary. And a flow chart of the study.

d. CHAPTER IV, DATA COLLECTION AND PROCESS

Contains data collected, though based on the data model. In this chapter is explained about the company's profile with existing processes and also contains the data needed to make the model. On the other hand, the data also contain the process for establishing a model.

e. CHAPTER V, DISCUSSION

Includes findings and analysis of simulation result. Findings is obtained from the simulation and these finding will be analysed in order to find optimum result.

f. CHAPTER V, CONCLUSION

Contains the conclusions of the research problem formulation for the object.

# Chapter II. LITERATURE REVIEW

## 2.1 Deductive Study

In a company, usually there is a production process in there; production process is a job that involves human labour or machinery to produce a good or service. One of kind of production process is Job Shop. In this study, the researcher will explain about Job Shop and Makespan. According to Phanden (2015) Job Shop is how to set of “n” type of product to be processed in set of “m” machines in order to optimize and minimize waste in production process.

In Job Shop production, not all of product will through the same machine or step from begin until finish product. The machines are not identical and performing different operations (Sharma & Jain, 2014). There are several characteristics in Job Shop, which are Disproportionate Manufacturing Cycle Time; Large Work-In-Progress; Limited Functions of Production Planning and Control (Chandra, 2011). These three characteristics of job shop in last sentence of this paragraph are having relation with makespan, as the researcher will explain later.

Makespan always be present in all of company that has the production process in it. Job shop scheduling deals with allocation of parts to various machines with the objective of minimizing the makespan (Phanden & Jain, 2015). Seemslike in job shop, makespan is proceesing time “j” of job “n” through to be processed by machines “m” (Tavakkoli-Moghaddam & Daneshmand-Mehr, 2005).

There are several ways to solve the job shop problem with the objective to minimize makespan in production, one of the way is with simulation model. In this simulation model, all of aspect in production process such as each machines, operator, processing time, machine capacity, storage, etc; are included in this simulation model, after simulation done with a predetermined time, we can see that result from analyzing summary report and state report (Chandra, 2011). Simulation based on general algorithm can slove job shop scheduling in order to solve the makespan problem (Phanden & Jain, 2015). So, we can easily know how to solve job shop problem in order to minimize makespan using computer simulation model then generate the report.

## 2.2 Inductive Study

According to Phanden & Jain (2015), in their research about makespan assessment for flexible process plans, job scheduling is affecting the makespan of production. In the research simulation based on Genetic Algorithm (GA) is used because it provides meaningful understanding of real phenomenon of a system nature. GA in this work is represented by a bit (gene) of a chromosome is formed by a process plan number of a part-type where each bit is in fixed order is representing the process plan of a particular part type. At the beginning of simulation, each gene of chromosomes is initialized randomly from flexible process plans of a part type. As result of research, GA proves as a promising evolutionary technique to solve job shop scheduling.

Similarly, Nawara & Hassanein (2013) has been able to prove that job shop scheduling problems can be solved by using Arena simulation software. Arena is used because it is a well-known simulation program and production engineers are familiar with it. The simulation in this study is used to find minimum makespan of four different products which must follow a particular sequence for each product where there are 4 process to finish with only 1 machine available for each process ($n = 4$, $m = 4$). Result of this study is are reasonable optimum solutions for minimizing maksepan.

In accordance with the preceding studies, Tavakkoli-Moghaddam & Daneshmand-Mehr (2005), define scheduling and sequencing of jobs on machines as problem basic and significant problem in production process and it can be solved with several method such as branch and bound, cutting plane, heuristics models, etc. in the study the simulation is based on Visual SLAM, a simulation language. The result of study is evidence that simulation with Visual SLAM is an efficient tool for solving job shop problem of minimizing makespan.

For instance, the previous research has proved that various methods are able to minimize makespan in job shop. This study will be able to give evidence regarding to minimizing makespan by using Flexsim simulation software.

# Chapter III. RESEARCH METODOLOGY

## 3.1 Research Object

The object of research in this research is a cake production company named Bolu Kidang located on Palagan Tentara Pelajar Street no. 118. The researcher focuses on only 3 variants of cake production in the company which are bold topping, cheese topping, and chocolate topping. Because of varying demand and also varying available operators, Bolu Kidang sometimes aren't able to fulfil their demand which causes unsatisfied customer. With a jobshop production process which is unscheduled is one of the reasons that researched decided to help in overcoming the unscheduled production process by minimizing the production makespan.

## 3.2 Data Collection Method

### 3.2.1 Primary

The primary data collected in this research will be data regarding to the production process flow, quantity, capacity and time, weekly demand and available operators. The qualitative data collected includes the production process flow while production quantity, capacity, processing time, weekly demand and available operators are included in quantitative data.

### 3.2.2 Secondary

The data collected from literature are included into secondary data of research. The data are not directly collected by the researchers but are collected by other persons. The literature study used are related to jobshop, makespan, and simulation.

### 3.3 Flow Chart Diagram (about research methodology)

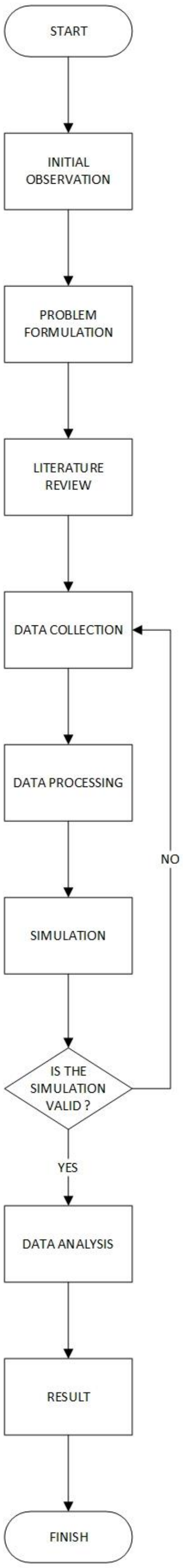


Figure 1. Research Flowchart Diagram

The flow of this research are as follows:

1. Start

   The researcher will begin this research about Job Shop simulation.

2. Initial Observation

   The researcher start to look for and observe a company that have Job Shop production process as the object of research.

3. Problem Formulation

   After observation is done, the researcher is start to define the problem from that Job Shop production process.

4. Literature Review

   After define the problem, the researcher try to looking for theory or statement to strengthen this research. The data are not directly collected by the researchers but are collected by other persons.

5. Data Collection

   The data that should be collected in this research is related to production process flow, quantity and capacity, processing time, weekly demand and available operators.

6. Data Processing

   The data processing is done by process the data that collected from Job Shop in a company in order to make the model in software and make the expert fit.

7. Simulation

   Make the model like in the Job Shop production process and run it in order to analyse the production process.

8. Validation

   Used to determine whether the data and simulation is able to represent the real production process

9. Data Analysis

   After the simulation model is done, the researcher can analyse the data from generate report in simulation software.

10. Result

    Result is the main conclusion of data analysis and try to make suggestion for next research.

11. Finish

The researcher has done make research about Job Shop production process simulation.

# Chapter IV. DATA COLLECTION AND PROCESS

## 4.1 Data Collection

### 4.1.3 Company Profile (vision, mission, etc)

Bolu Kidang is one of cake shop in Yogyakarta, this cake shop established on 1996, begin with the founder (Bambang) that has hobby to make a cake, then from it the founder try to make many variant of cake based on *bolu*. Now, Bolu Kidang which located on Palagan Tentara Pelajar Street no. 118 Yogyakarta become successful cake shop because that delicious cake. The vision of Bolu Kidang is "become successful cake shop in Yogyakarta". To realize the vision of this cake shop, mission are needed, there are:

1. Develop cake taste
2. Develop cake variant
3. Expansion cake shop, open new branch.

### 4.1.4 Description of Production Process

First, put all raw materials such as eggs, flour, baking powder, sugar, etc. into a basin. Then mix all ingredients in a basin until all raw materials is mixed well. Second, separate the dough into 3 basin, that 3 basin will added by coloring extract, the three coloring extract are yellow, chocolate, and green. Then become 3 cake layer variant, there are chocolate-yellow blending, green-yellow blending, and chocolate-green blending.

Third, after adding color in dough is finish, then put the three dough in oven that already heated before, wait for prescribed time, remove the cake from oven, then the employee start to cut the cake into 3 cake with different cake layer. After that, If the cake will not be added toppings, it will directly move to packaging with box. If the cake will add toppings, there are two kind of topping, which are chocolate and cheese. But before move to adding topping process, the cake should be chilled first, and then add cream on the cake. After give cream on cake, then give chocolate or cheese toppings on that cake. After adding toppings is finish, the cake will move to packaging with box, after all process is done, all finish cake will store in storage.

4.1.5 Production Process Flowchart

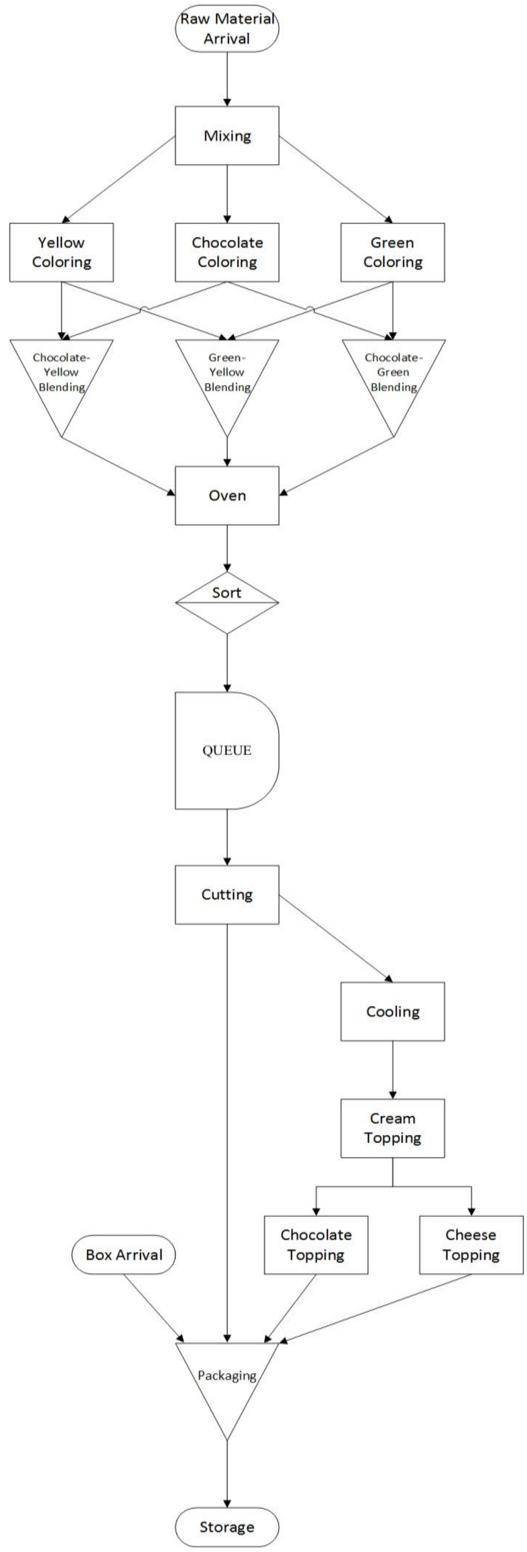


Figure 2.Production Process Flowchart

4.1.6 Data (based on your research)

1. Historical Data

Table 1. Weekly Demand Historical Data

| Period | Weekly Demand (pcs) |
|---|---|
| 1 | 352 |
| 2 | 362 |
| 3 | 359 |
| 4 | 358 |
| 5 | 359 |
| 6 | 351 |
| 7 | 359 |
| 8 | 358 |
| 9 | 354 |
| 10 | 352 |
| 11 | 354 |
| 12 | 359 |
| 13 | 356 |
| 14 | 352 |
| 15 | 355 |
| 16 | 359 |
| 17 | 354 |
| 18 | 362 |
| 19 | 365 |
| 20 | 357 |
| 21 | 356 |
| 22 | 365 |
| 23 | 346 |
| 24 | 356 |
| 25 | 357 |
| 26 | 356 |
| 27 | 361 |
| 28 | 356 |
| 29 | 356 |
| 30 | 358 |

2. Production Process Data

In the production process we assume that all raw material are ready to mix with quantity 1 group (64 pieces) of raw material is available in a day. The raw material will be mixed and later on be divided to 3 coloured pieces and blended where in the blending process the 2 coloured which leave maximum 30 item to process further and if there are coloured products which is unavailable to process it will be considered as thrash at the end of the day. The blended materials will be placed in the oven but the oven must process the materials in batch of maximum 30 item in order to reduce electricity cost. After the oven process the material will be given topping for particular colours of product. But before given topping every semi-finished cake will be cut into 5 pieces and if they are the bold variant it will directly be packaged while the variants with topping will be cooled, given topping and be packaged. The packaging uses box where one box is used for only one product per box and the available box quantity in a day is only 180 boxes. After packaging the products are ready to be distributed to customers. The production is done from 5 a.m. up to 12 a.m for 6 days from Monday to Saturday.

3. Time Process Data

Table 2. Fixed Time Processing Data

| Object | Type | Time (Minute) |
|---|---|---|
| Oven | Setup | 15 |
| Oven | Setup | 25 |

Table 3. Mixing Time Process Data

| No | Mixing (minute) |
|---|---|
| 1 | 25 |
| 2 | 33 |
| 3 | 25 |
| 4 | 30 |
| 5 | 32 |
| 6 | 34 |
| 7 | 29 |
| 8 | 31 |
| 9 | 27 |
| 10 | 26 |
| 11 | 31 |
| 12 | 25 |
| 13 | 28 |
| 14 | 28 |
| 15 | 31 |
| 16 | 33 |

| No | Mixing (minute) |
|---|---|
| 17 | 27 |
| 18 | 25 |
| 19 | 30 |
| 20 | 33 |
| 21 | 29 |
| 22 | 25 |
| 23 | 30 |
| 24 | 30 |
| 25 | 25 |
| 26 | 29 |
| 27 | 33 |
| 28 | 31 |
| 29 | 27 |
| 30 | 32 |

Table 4. Coloring Time Process Data

| No | Coloring (second) | Coloring (minute) |
|---|---|---|
| 1 | 12 | 0.2 |
| 2 | 8 | 0.133333333 |
| 3 | 22 | 0.366666667 |
| 4 | 9 | 0.15 |
| 5 | 29 | 0.483333333 |
| 6 | 22 | 0.366666667 |
| 7 | 17 | 0.283333333 |
| 8 | 7 | 0.116666667 |
| 9 | 27 | 0.45 |
| 10 | 18 | 0.3 |
| 11 | 22 | 0.366666667 |
| 12 | 27 | 0.45 |
| 13 | 10 | 0.166666667 |
| 14 | 21 | 0.35 |
| 15 | 18 | 0.3 |
| 16 | 19 | 0.316666667 |
| 17 | 9 | 0.15 |
| 18 | 17 | 0.283333333 |
| 19 | 27 | 0.45 |
| 20 | 22 | 0.366666667 |
| 21 | 26 | 0.433333333 |
| 22 | 18 | 0.3 |
| 23 | 19 | 0.316666667 |
| 24 | 8 | 0.133333333 |

| No | Coloring (second) | Coloring (minute) |
|---|---|---|
| 25 | 25 | 0.416666667 |
| 26 | 29 | 0.483333333 |
| 27 | 20 | 0.333333333 |
| 28 | 8 | 0.133333333 |
| 29 | 8 | 0.133333333 |
| 30 | 23 | 0.383333333 |

Table 5. Blending Time Process Data

| No | Blending (second) | Blending (minute) |
|---|---|---|
| 1 | 71 | 1.183333333 |
| 2 | 78 | 1.3 |
| 3 | 62 | 1.033333333 |
| 4 | 84 | 1.4 |
| 5 | 73 | 1.216666667 |
| 6 | 46 | 0.766666667 |
| 7 | 74 | 1.233333333 |
| 8 | 78 | 1.3 |
| 9 | 75 | 1.25 |
| 10 | 67 | 1.116666667 |
| 11 | 45 | 0.75 |
| 12 | 74 | 1.233333333 |
| 13 | 97 | 1.616666667 |
| 14 | 91 | 1.516666667 |
| 15 | 84 | 1.4 |
| 16 | 87 | 1.45 |
| 17 | 99 | 1.65 |
| 18 | 76 | 1.266666667 |
| 19 | 98 | 1.633333333 |
| 20 | 72 | 1.2 |
| 21 | 83 | 1.383333333 |
| 22 | 86 | 1.433333333 |
| 23 | 83 | 1.383333333 |
| 24 | 40 | 0.666666667 |
| 25 | 64 | 1.066666667 |
| 26 | 48 | 0.8 |
| 27 | 95 | 1.583333333 |
| 28 | 90 | 1.5 |
| 29 | 60 | 1 |
| 30 | 41 | 0.683333333 |

Table 6. Cooling Time Process Data

| No | Cooling (minute) |
|---|---|
| 1 | 4 |
| 2 | 3 |
| 3 | 5 |
| 4 | 5 |
| 5 | 5 |
| 6 | 5 |
| 7 | 5 |
| 8 | 5 |
| 9 | 4 |
| 10 | 3 |
| 11 | 5 |
| 12 | 4 |
| 13 | 4 |
| 14 | 5 |
| 15 | 4 |
| 16 | 3 |
| 17 | 5 |
| 18 | 5 |
| 19 | 5 |
| 20 | 5 |
| 21 | 5 |
| 22 | 3 |
| 23 | 4 |
| 24 | 3 |
| 25 | 5 |
| 26 | 5 |
| 27 | 4 |
| 28 | 4 |
| 29 | 5 |
| 30 | 5 |

Table 7. Cream Topping Time Process Data

| No | Cream Topping (second) | Cream Topping (minute) |
|---|---|---|
| 1 | 79 | 1.316666667 |
| 2 | 75 | 1.25 |
| 3 | 61 | 1.016666667 |
| 4 | 36 | 0.6 |
| 5 | 57 | 0.95 |
| 6 | 79 | 1.316666667 |

| No | Cream Topping (second) | Cream Topping (minute) |
|---|---|---|
| 7 | 71 | 1.183333333 |
| 8 | 77 | 1.283333333 |
| 9 | 93 | 1.55 |
| 10 | 89 | 1.483333333 |
| 11 | 93 | 1.55 |
| 12 | 74 | 1.233333333 |
| 13 | 92 | 1.533333333 |
| 14 | 98 | 1.633333333 |
| 15 | 91 | 1.516666667 |
| 16 | 56 | 0.933333333 |
| 17 | 58 | 0.966666667 |
| 18 | 72 | 1.2 |
| 19 | 90 | 1.5 |
| 20 | 75 | 1.25 |
| 21 | 45 | 0.75 |
| 22 | 54 | 0.9 |
| 23 | 93 | 1.55 |
| 24 | 47 | 0.783333333 |
| 25 | 35 | 0.583333333 |
| 26 | 67 | 1.116666667 |
| 27 | 80 | 1.333333333 |
| 28 | 66 | 1.1 |
| 29 | 79 | 1.316666667 |
| 30 | 81 | 1.35 |

Table 8. Chocolate/Cheese Topping Time Process Data

| No | Chocolate/Cheese Topping (minute) |
|---|---|
| 1 | 2 |
| 2 | 1 |
| 3 | 2 |
| 4 | 2 |
| 5 | 2 |
| 6 | 2 |
| 7 | 1 |
| 8 | 2 |
| 9 | 1 |
| 10 | 1 |
| 11 | 1 |
| 12 | 2 |
| 13 | 2 |
| 14 | 1 |

| No | Chocolate/Cheese Topping (minute) |
|---|---|
| 15 | 1 |
| 16 | 1 |
| 17 | 1 |
| 18 | 1 |
| 19 | 2 |
| 20 | 1 |
| 21 | 2 |
| 22 | 2 |
| 23 | 1 |
| 24 | 2 |
| 25 | 2 |
| 26 | 2 |
| 27 | 1 |
| 28 | 2 |
| 29 | 2 |
| 30 | 2 |

Table 9. Packaging Time Process Data

| No | Packaging (minute) |
|---|---|
| 1 | 4 |
| 2 | 2 |
| 3 | 2 |
| 4 | 2 |
| 5 | 4 |
| 6 | 4 |
| 7 | 4 |
| 8 | 4 |
| 9 | 3 |
| 10 | 4 |
| 11 | 3 |
| 12 | 2 |
| 13 | 2 |
| 14 | 4 |
| 15 | 4 |
| 16 | 3 |
| 17 | 4 |
| 18 | 5 |
| 19 | 2 |
| 20 | 4 |
| 21 | 2 |
| 22 | 2 |

| No | Packaging (minute) |
|---|---|
| 23 | 3 |
| 24 | 5 |
| 25 | 3 |
| 26 | 5 |
| 27 | 5 |
| 28 | 5 |
| 29 | 3 |
| 30 | 2 |

4. Time Transfer Data

   In fact the factory is very small, so time transfer is nearly less than 1 second.

5. Location Capacity Data

Table 10. Location Capacity Data

| Location | Capacity |
|---|---|
| mixing | 60 |
| coloring | 20 |
| blending | 1 |
| oven | 30 |
| queue | 30 |
| cutting | 1 |
| cooling | 180 |
| cream topping | 6 |
| chocolate/cheese topping | 6 |
| packaging | 1 |

6. Material Handling Data

   In fact the production space is very low and the item is not fragile, so it is better to assume that there is no loading and unloading in the production process.

7. Arrival Data

   All of the raw material arrives in one group (64 pieces) for a day. Boxes also arrives daily with 180 pieces in a day.

8. Resources Data

   In reality there are many raw material needed to create a cake. But because of restricted data from the company the researcher assume that the raw material is in one group (64 pieces) and can be directly mixed. The boxes in this company is ready to use and doesn't need further process to be used as a packaging media.

9. Network Node Data

   The network node data are as follows:

Table 11. Network Node Data Table

| Object | Connected Objects |
|---|---|
| Operator1 | Raw Material Source, Mixing Machine |
| Operator2 | Coloring Machines ,Blending Machines, Oven |
| Operator3 | Jobshop Queue, Cutting Machine, Cooling Machine, Topping Machines (Cream, Cheese, and Chocolate) |
| Operator4 | Box Arrival, Packaging Machine, Storage |

10. Downtimes Data

    Since the production time from 5 a.m. to 12 a.m. on Monday to Saturday, so the nonproductive time are downtimes.

11. Global Variable Data

    There is no global variable data in this research.

12. Expertfit Data

Data-Summary Table

| Data Characteristic | Value |
|---|---|
| Source file | <edited> |
| Observation type | Real valued |
| Number of observations | 30 |
| Minimum observation | 25 |
| Maximum observation | 34 |
| Mean | 29.13333 |
| Median | 29.50000 |
| Variance | 8.46437 |
| Coefficient of variation | 0.09986 |
| Skewness | -0.09640 |

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Figure 3. Data Summary of Mixing Processing Time

Automated-Fitting Results

Relative Evaluation of Candidate Models

| Model | Relative Score | Parameters | |
|---|---|---|---|
| 1 - Erlang(E) | 84.68 | Location | 0.00699 |
| | | Scale | 0.30027 |
| | | Shape | 97 |
| 2 - Beta | 82.26 | Lower endpoint | 23.65567 |
| | | Upper endpoint | 34.08772 |
| | | Shape #1 | 1.30911 |
| | | Shape #2 | 1.14949 |
| 3 - Johnson SB | 82.26 | Lower endpoint | 23.35194 |
| | | Upper endpoint | 34.22558 |
| | | Shape #1 | -0.14813 |
| | | Shape #2 | 0.71453 |

32 models are defined with scores between 0.81 and 84.68

Absolute Evaluation of Model 1 - Erlang(E)

Evaluation: Good

Suggestion: Additional evaluations using Comparisons Tab might be informative. See Help for more information.

Additional Information about Model 1 - Erlang(E)

"Error" in the model mean relative to the sample mean -3.5527e-15 = 0.00%

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Figure 4. Automated-fitting Results of Mixing Processing Time

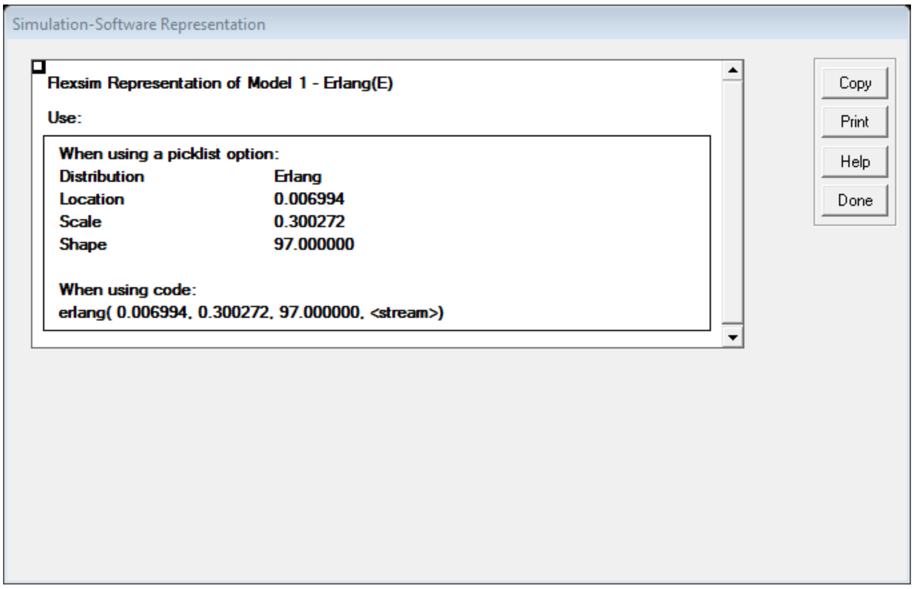
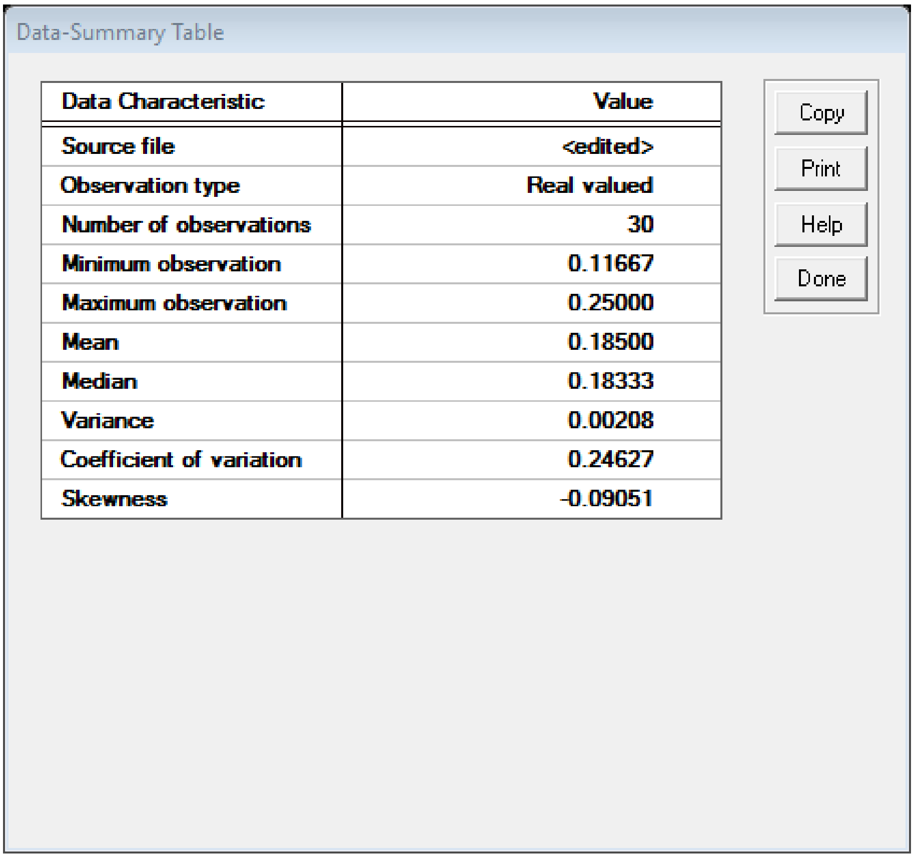
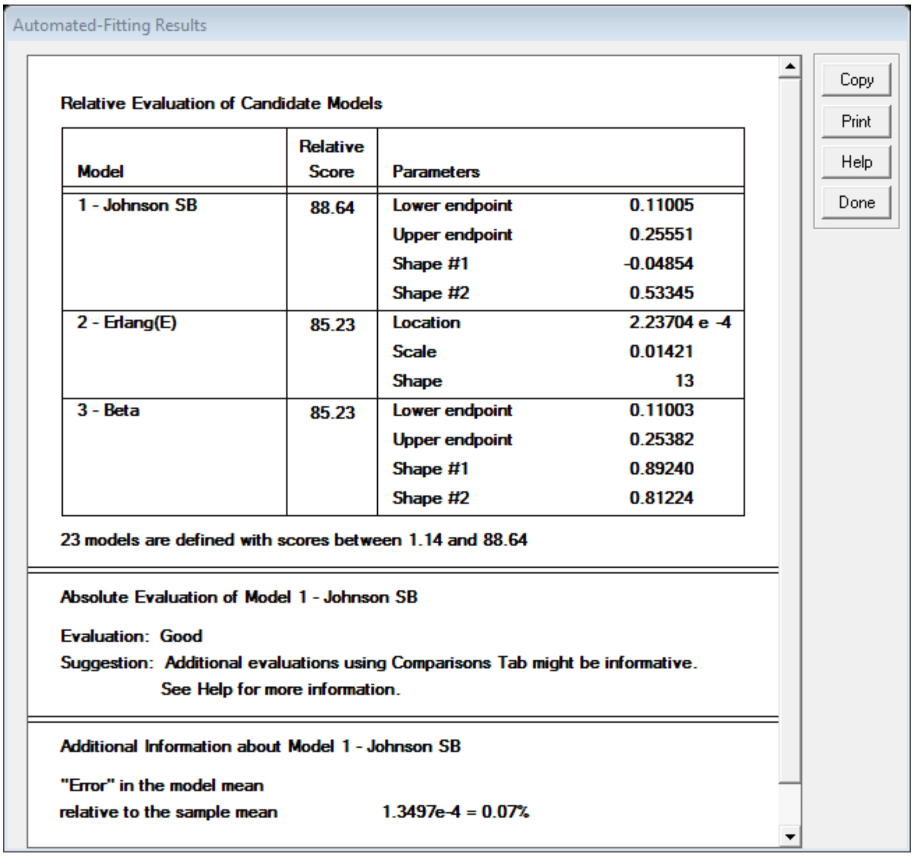



Figure 5. Simulation-software Representation of Mixing Processing Time




| Data Characteristic | Value |
|---|---|
| Source file | <edited> |
| Observation type | Real valued |
| Number of observations | 30 |
| Minimum observation | 0.11667 |
| Maximum observation | 0.25000 |
| Mean | 0.18500 |
| Median | 0.18333 |
| Variance | 0.00208 |
| Coefficient of variation | 0.24627 |
| Skewness | -0.09051 |

Figure 6. Data Summary of Coloring Machine


Automated-Fitting Results

Relative Evaluation of Candidate Models

| Model | Relative Score | Parameters | |
|---|---|---|---|
| 1 - Johnson SB | 88.64 | Lower endpoint | 0.11005 |
| | | Upper endpoint | 0.25551 |
| | | Shape #1 | -0.04854 |
| | | Shape #2 | 0.53345 |
| 2 - Erlang(E) | 85.23 | Location | 2.23704 e -4 |
| | | Scale | 0.01421 |
| | | Shape | 13 |
| 3 - Beta | 85.23 | Lower endpoint | 0.11003 |
| | | Upper endpoint | 0.25382 |
| | | Shape #1 | 0.89240 |
| | | Shape #2 | 0.81224 |

23 models are defined with scores between 1.14 and 88.64

Absolute Evaluation of Model 1 - Johnson SB

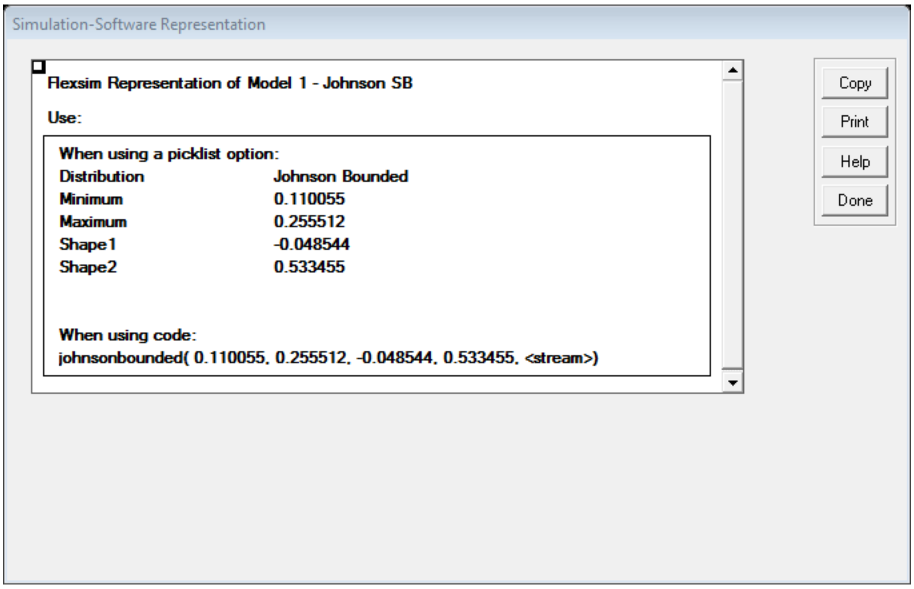
Evaluation: Good
Suggestion: Additional evaluations using Comparisons Tab might be informative.
See Help for more information.

Additional Information about Model 1 - Johnson SB

"Error" in the model mean
relative to the sample mean 1.3497e-4 = 0.07%



Figure 7. Automated-fiting of Coloring Machine


Simulation-Software Representation

Flexsim Representation of Model 1 - Johnson SB

Use:

When using a picklist option:

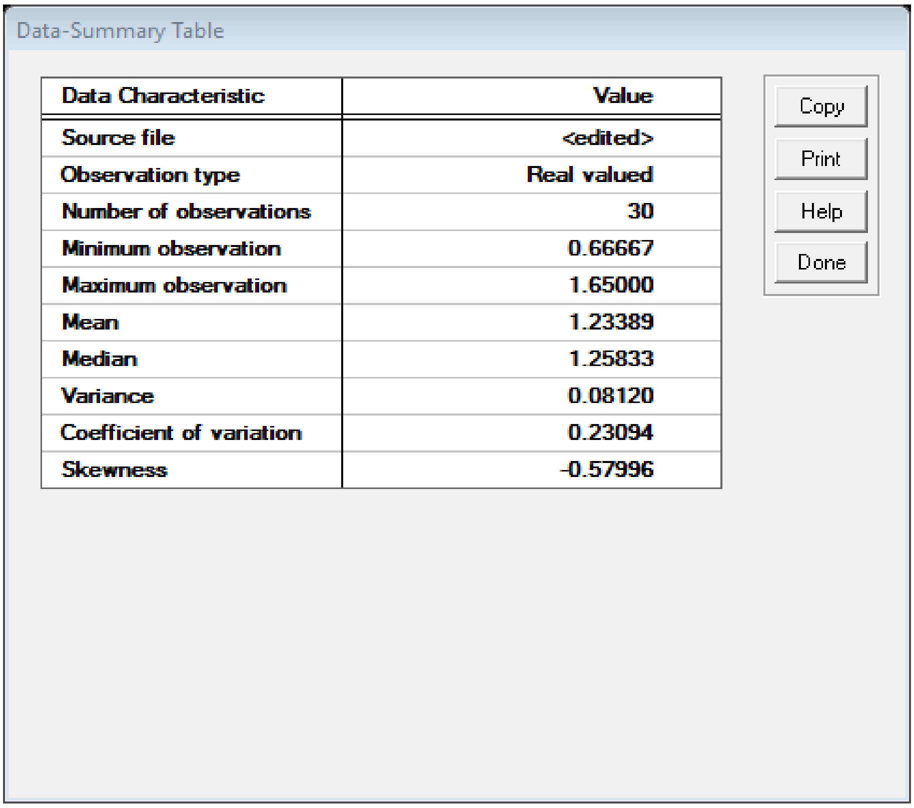
| | |
|---|---|
| Distribution | Johnson Bounded |
| Minimum | 0.110055 |
| Maximum | 0.255512 |
| Shape1 | -0.048544 |
| Shape2 | 0.533455 |

When using code:

```
johnsonbounded( 0.110055, 0.255512, -0.048544, 0.533455, <stream>)
```



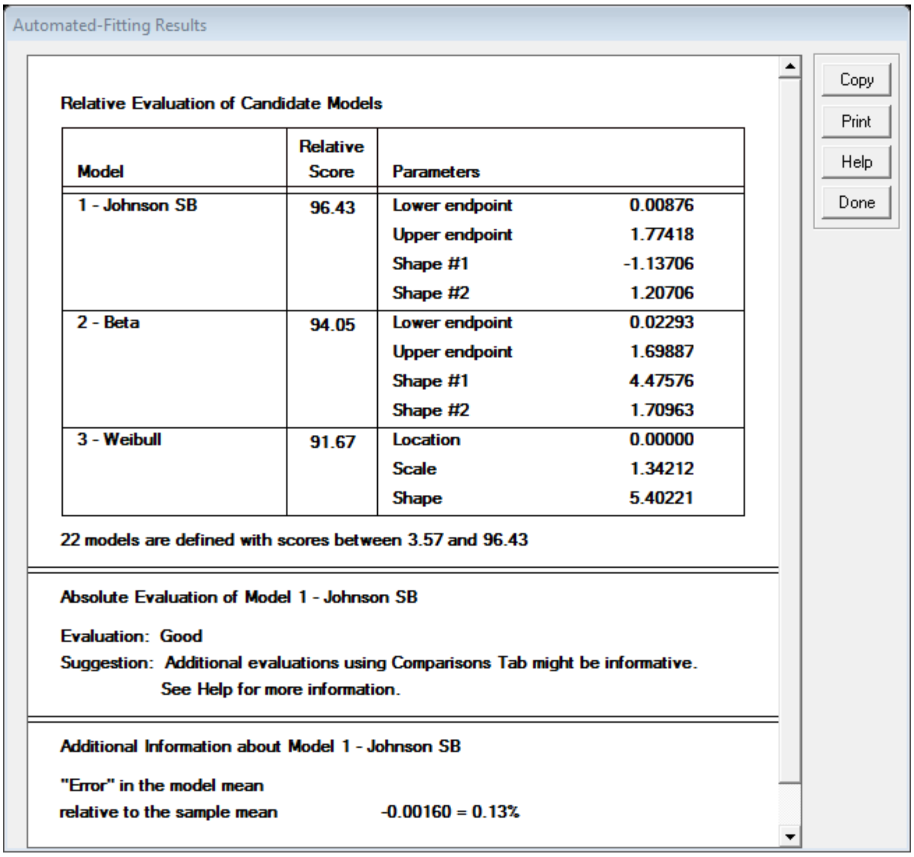
Figure 8. Simulation-software Representation of Coloring Machine


Data-Summary Table

| Data Characteristic | Value |
|---|---|
| Source file | <edited> |
| Observation type | Real valued |
| Number of observations | 30 |
| Minimum observation | 0.66667 |
| Maximum observation | 1.65000 |
| Mean | 1.23389 |
| Median | 1.25833 |
| Variance | 0.08120 |
| Coefficient of variation | 0.23094 |
| Skewness | -0.57996 |



Figure 9. Data Summary of Blending Machine


Automated-Fitting Results

Relative Evaluation of Candidate Models

| Model | Relative Score | Parameters | |
|---|---|---|---|
| 1 - Johnson SB | 96.43 | Lower endpoint | 0.00876 |
| | | Upper endpoint | 1.77418 |
| | | Shape #1 | -1.13706 |
| | | Shape #2 | 1.20706 |
| 2 - Beta | 94.05 | Lower endpoint | 0.02293 |
| | | Upper endpoint | 1.69887 |
| | | Shape #1 | 4.47576 |
| | | Shape #2 | 1.70963 |
| 3 - Weibull | 91.67 | Location | 0.00000 |
| | | Scale | 1.34212 |
| | | Shape | 5.40221 |

22 models are defined with scores between 3.57 and 96.43

Absolute Evaluation of Model 1 - Johnson SB

Evaluation: Good

Suggestion: Additional evaluations using Comparisons Tab might be informative.
See Help for more information.

Additional Information about Model 1 - Johnson SB

"Error" in the model mean
relative to the sample mean -0.00160 = 0.13%



Figure 10. Automated-fiting of Blending Machine

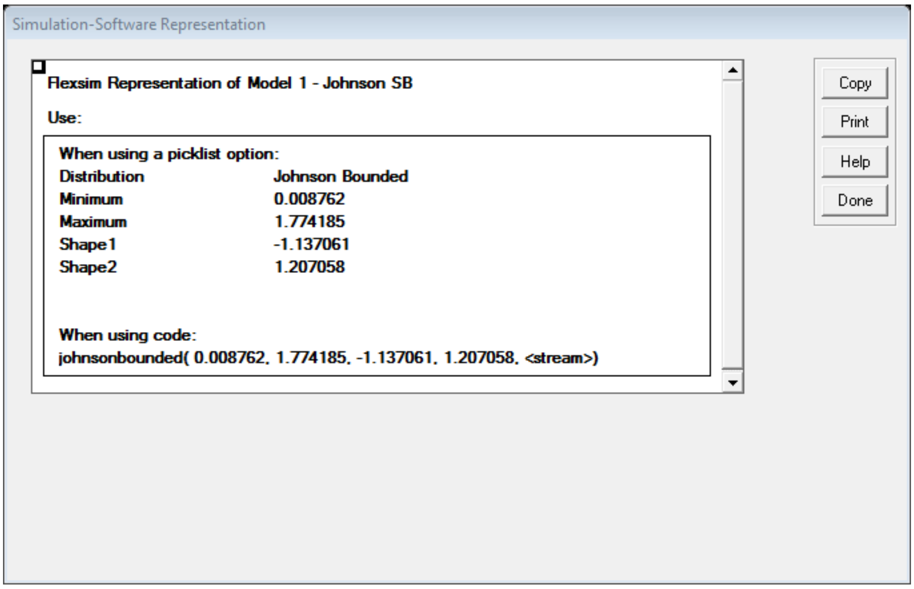
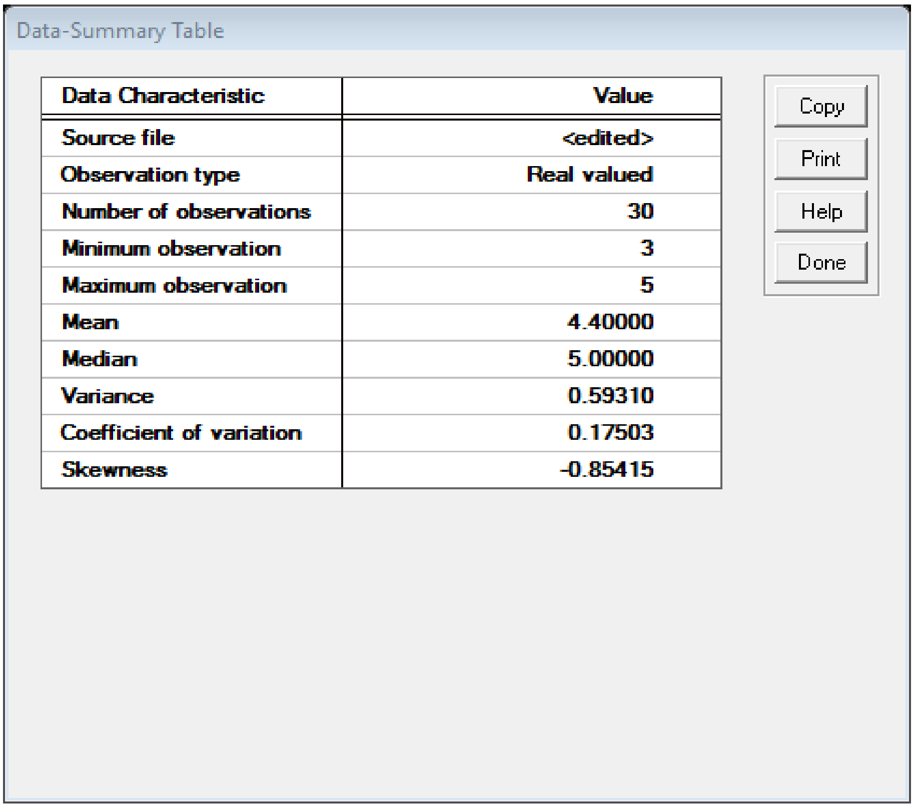
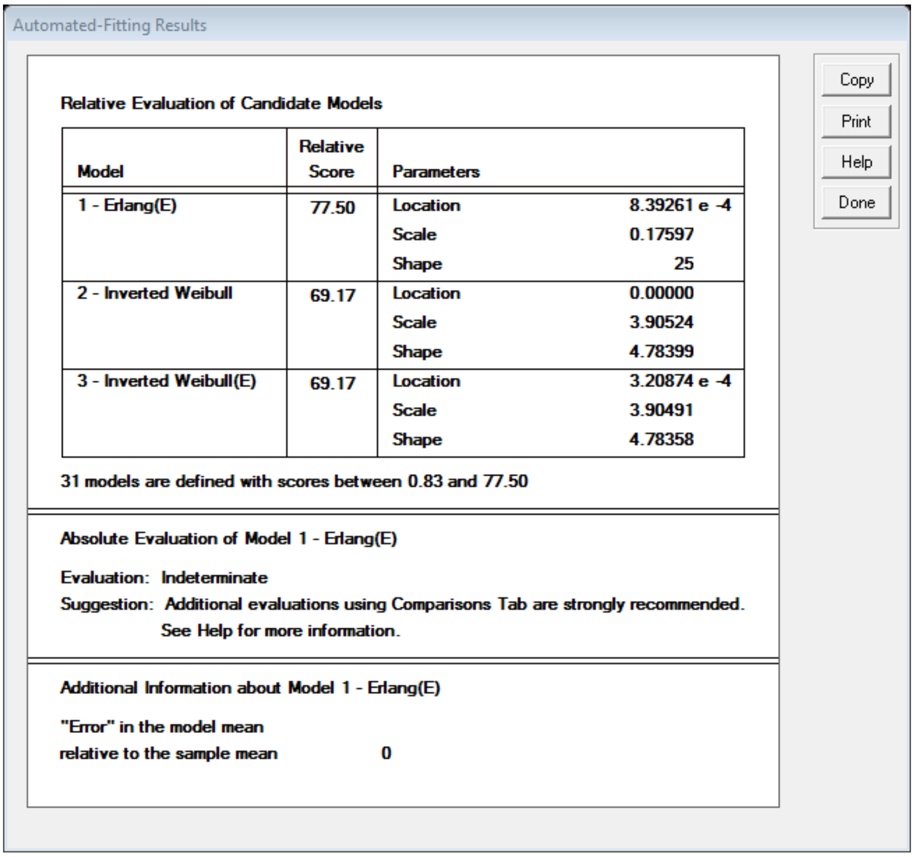



Figure 11. Simulation-software Representation of Blending Machine




| Data Characteristic | Value |
|---|---|
| Source file | <edited> |
| Observation type | Real valued |
| Number of observations | 30 |
| Minimum observation | 3 |
| Maximum observation | 5 |
| Mean | 4.40000 |
| Median | 5.00000 |
| Variance | 0.59310 |
| Coefficient of variation | 0.17503 |
| Skewness | -0.85415 |

Figure 12. Data Summary of Cooling Machine


Automated-Fitting Results

Relative Evaluation of Candidate Models

| Model | Relative Score | Parameters | |
|---|---|---|---|
| 1 - Erlang(E) | 77.50 | Location | 8.39261 e -4 |
| | | Scale | 0.17597 |
| | | Shape | 25 |
| 2 - Inverted Weibull | 69.17 | Location | 0.00000 |
| | | Scale | 3.90524 |
| | | Shape | 4.78399 |
| 3 - Inverted Weibull(E) | 69.17 | Location | 3.20874 e -4 |
| | | Scale | 3.90491 |
| | | Shape | 4.78358 |

31 models are defined with scores between 0.83 and 77.50

Absolute Evaluation of Model 1 - Erlang(E)

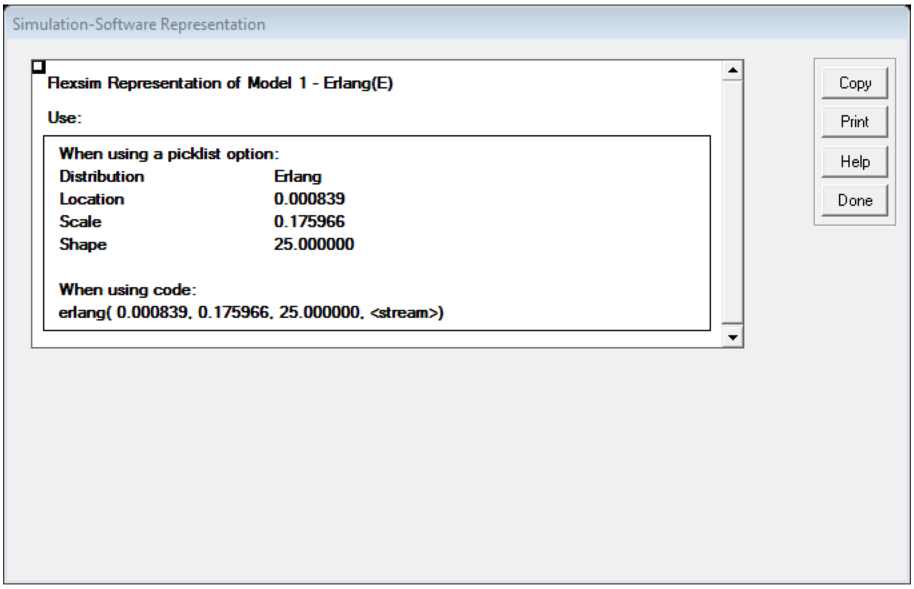
Evaluation: Indeterminate
Suggestion: Additional evaluations using Comparisons Tab are strongly recommended.
See Help for more information.

Additional Information about Model 1 - Erlang(E)

"Error" in the model mean
relative to the sample mean 0



Figure 13. Automated-fiting of Cooling Machine


Simulation-Software Representation

Flexsim Representation of Model 1 - Erlang(E)

Use:

When using a picklist option:

| | |
|---|---|
| Distribution | Erlang |
| Location | 0.000839 |
| Scale | 0.175966 |
| Shape | 25.000000 |

When using code:
erlang( 0.000839, 0.175966, 25.000000, <stream>)



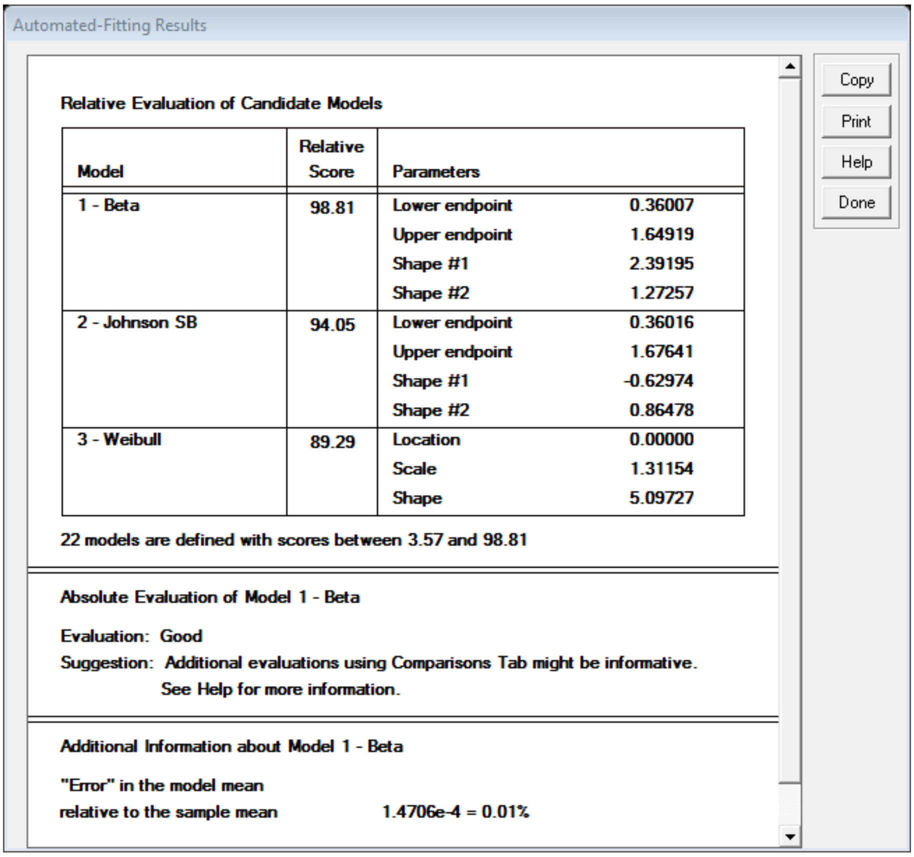
Figure 14. Simulation-software Representation of Cooling Machine

Data-Summary Table

| Data Characteristic | Value |
|---|---|
| Source file | <edited> |
| Observation type | Real valued |
| Number of observations | 30 |
| Minimum observation | 0.58333 |
| Maximum observation | 1.63333 |
| Mean | 1.20167 |
| Median | 1.25000 |
| Variance | 0.08539 |
| Coefficient of variation | 0.24318 |
| Skewness | -0.54559 |

Copy
Print
Help
Done

Figure 15. Data Summary of Cream Topping Machine


Automated-Fitting Results

Relative Evaluation of Candidate Models

| Model | Relative Score | Parameters | |
|---|---|---|---|
| 1 - Beta | 98.81 | Lower endpoint | 0.36007 |
| | | Upper endpoint | 1.64919 |
| | | Shape #1 | 2.39195 |
| | | Shape #2 | 1.27257 |
| 2 - Johnson SB | 94.05 | Lower endpoint | 0.36016 |
| | | Upper endpoint | 1.67641 |
| | | Shape #1 | -0.62974 |
| | | Shape #2 | 0.86478 |
| 3 - Weibull | 89.29 | Location | 0.00000 |
| | | Scale | 1.31154 |
| | | Shape | 5.09727 |

22 models are defined with scores between 3.57 and 98.81

Absolute Evaluation of Model 1 - Beta

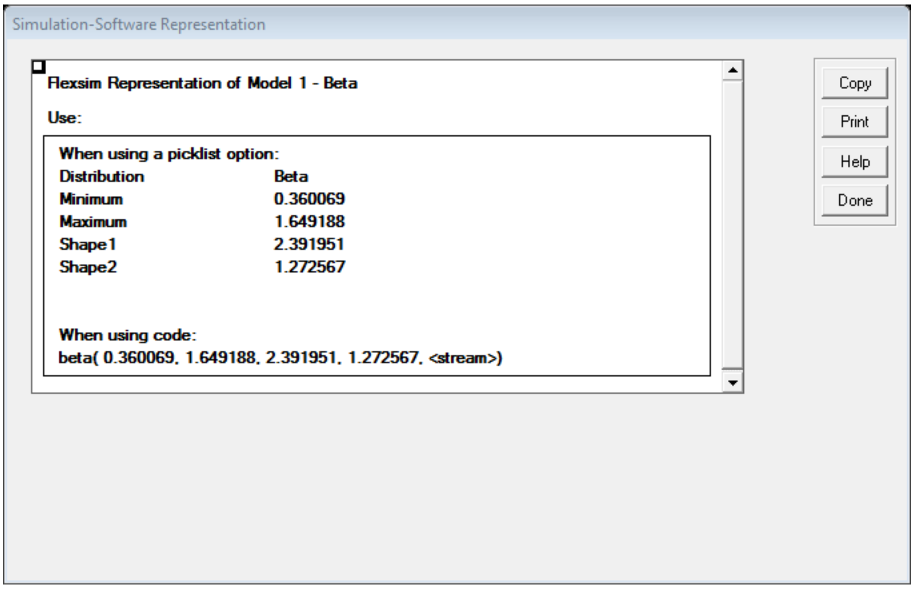
Evaluation: Good
Suggestion: Additional evaluations using Comparisons Tab might be informative.
See Help for more information.

Additional Information about Model 1 - Beta

"Error" in the model mean
relative to the sample mean 1.4706e-4 = 0.01%



Figure 16. Automated-fiting of Cream Topping Machine


Simulation-Software Representation

Flexsim Representation of Model 1 - Beta

Use:

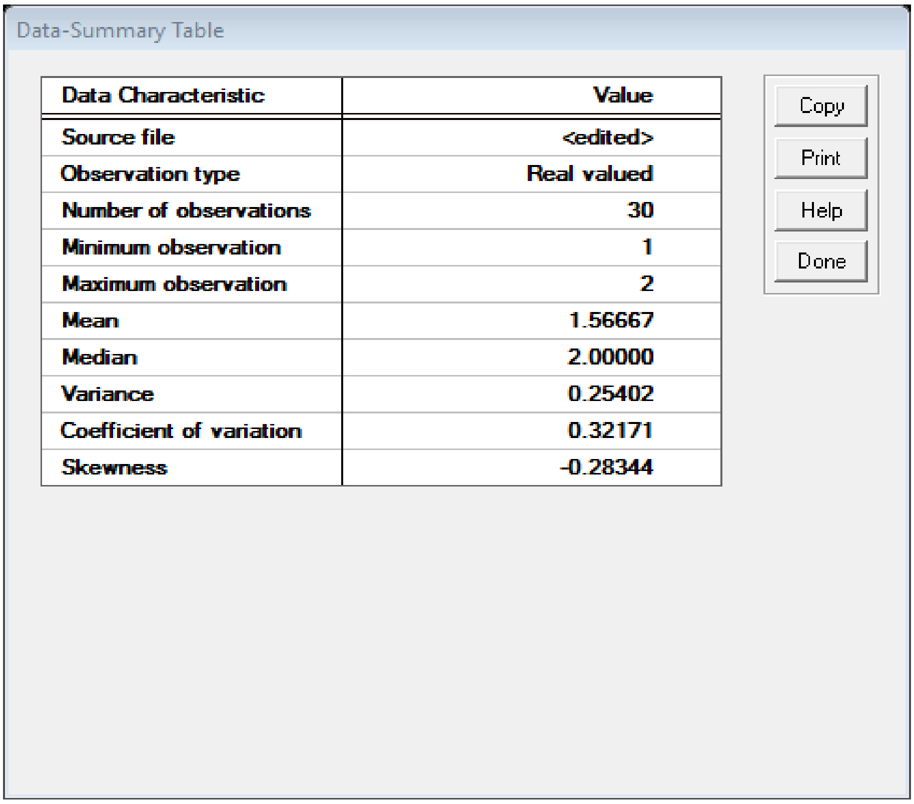
When using a picklist option:

| | |
|---|---|
| Distribution | Beta |
| Minimum | 0.360069 |
| Maximum | 1.649188 |
| Shape1 | 2.391951 |
| Shape2 | 1.272567 |

When using code:
beta( 0.360069, 1.649188, 2.391951, 1.272567, <stream>)



Figure 17. Simulation-software Representation of Cream Topping Machine

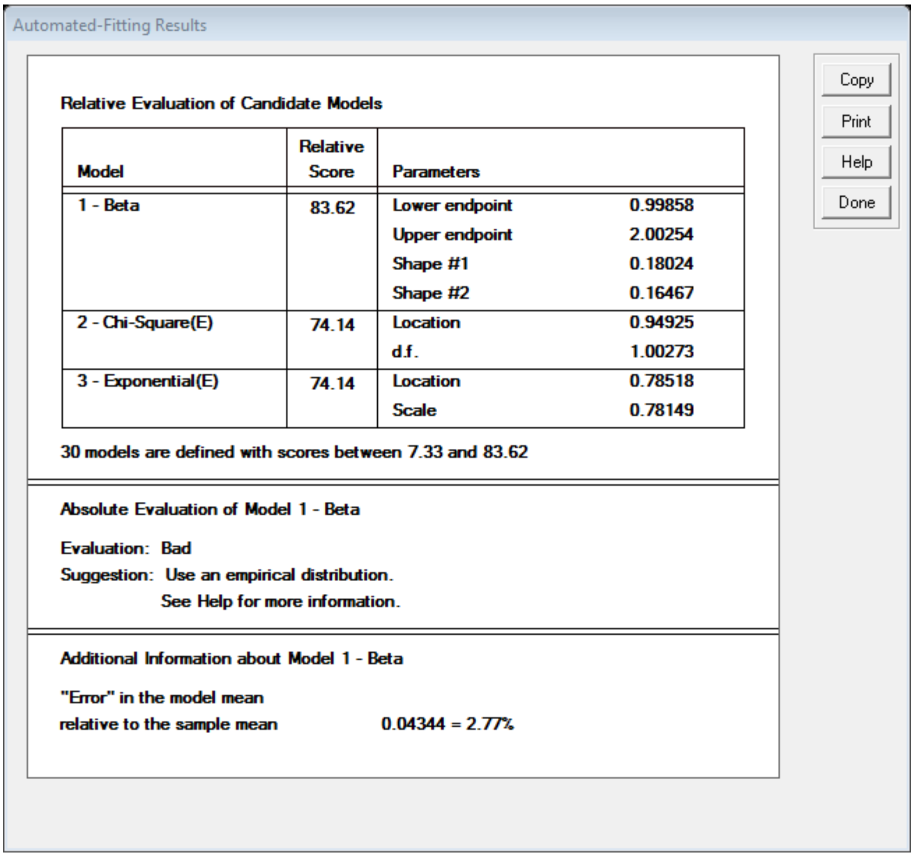


Data-Summary Table

| Data Characteristic | Value |
|---|---|
| Source file | <edited> |
| Observation type | Real valued |
| Number of observations | 30 |
| Minimum observation | 1 |
| Maximum observation | 2 |
| Mean | 1.56667 |
| Median | 2.00000 |
| Variance | 0.25402 |
| Coefficient of variation | 0.32171 |
| Skewness | -0.28344 |



Figure 18. Data Summary of Chocolate/Cheese Topping Machine



Automated-Fitting Results

Relative Evaluation of Candidate Models

| Model | Relative Score | Parameters | |
|---|---|---|---|
| 1 - Beta | 83.62 | Lower endpoint | 0.99858 |
| | | Upper endpoint | 2.00254 |
| | | Shape #1 | 0.18024 |
| | | Shape #2 | 0.16467 |
| 2 - Chi-Square(E) | 74.14 | Location | 0.94925 |
| | | d.f. | 1.00273 |
| 3 - Exponential(E) | 74.14 | Location | 0.78518 |
| | | Scale | 0.78149 |

30 models are defined with scores between 7.33 and 83.62

Absolute Evaluation of Model 1 - Beta

Evaluation: Bad
Suggestion: Use an empirical distribution.
See Help for more information.

Additional Information about Model 1 - Beta

"Error" in the model mean
relative to the sample mean 0.04344 = 2.77%



Figure 19. Automated-fiting of Chocolate/Cheese Topping Machine

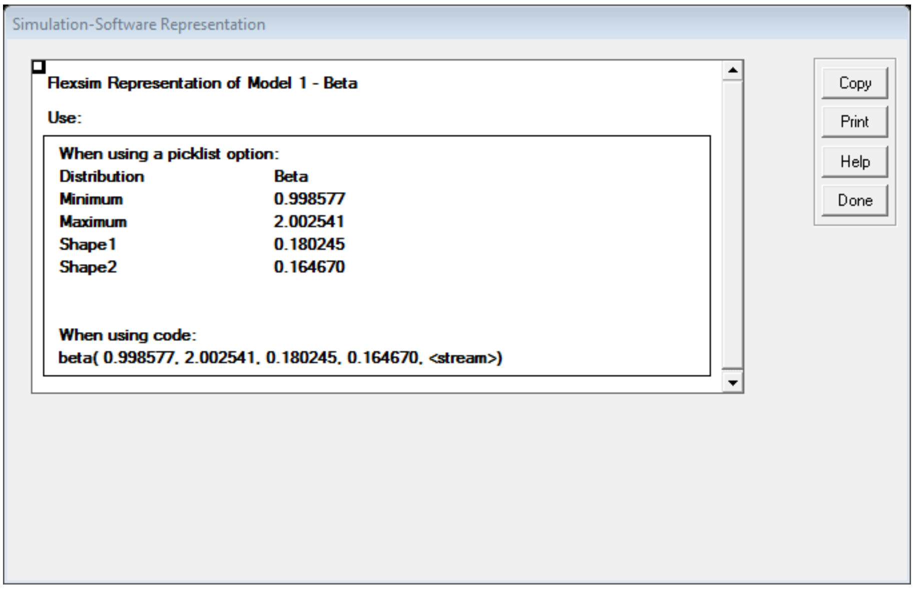
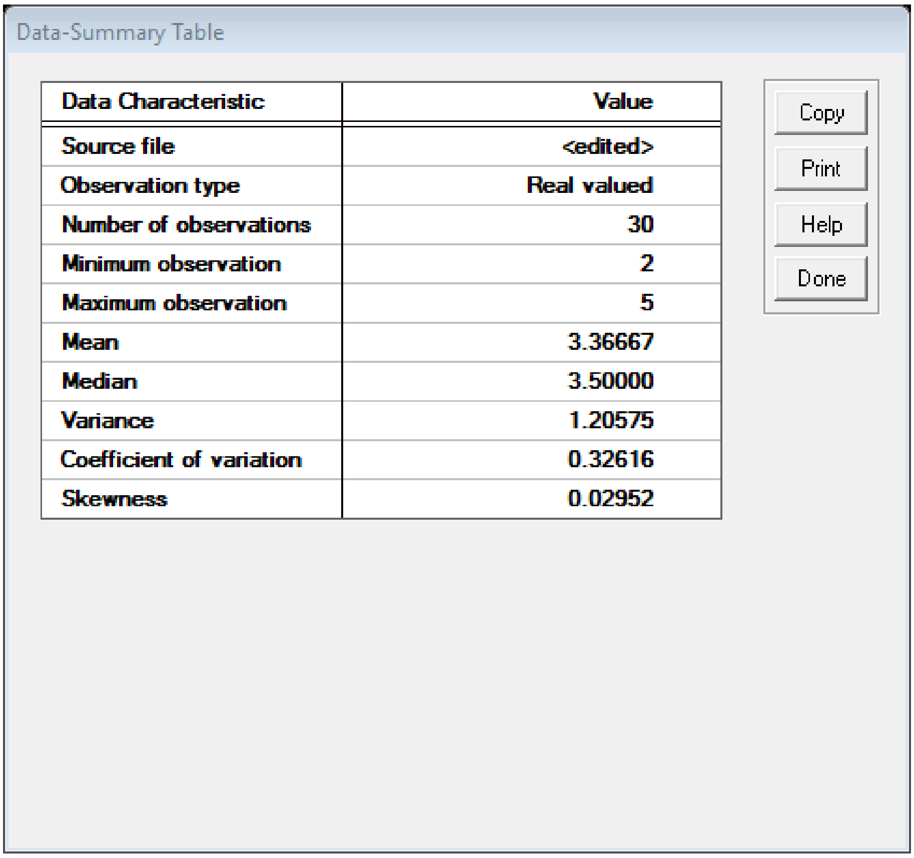



Figure 20. Simulation-software Representation of Chocolate/Cheese Topping Machine


Data-Summary Table

| Data Characteristic | Value |
|---|---|
| Source file | <edited> |
| Observation type | Real valued |
| Number of observations | 30 |
| Minimum observation | 2 |
| Maximum observation | 5 |
| Mean | 3.36667 |
| Median | 3.50000 |
| Variance | 1.20575 |
| Coefficient of variation | 0.32616 |
| Skewness | 0.02952 |



Figure 21. Data Summary of Packaging Machine

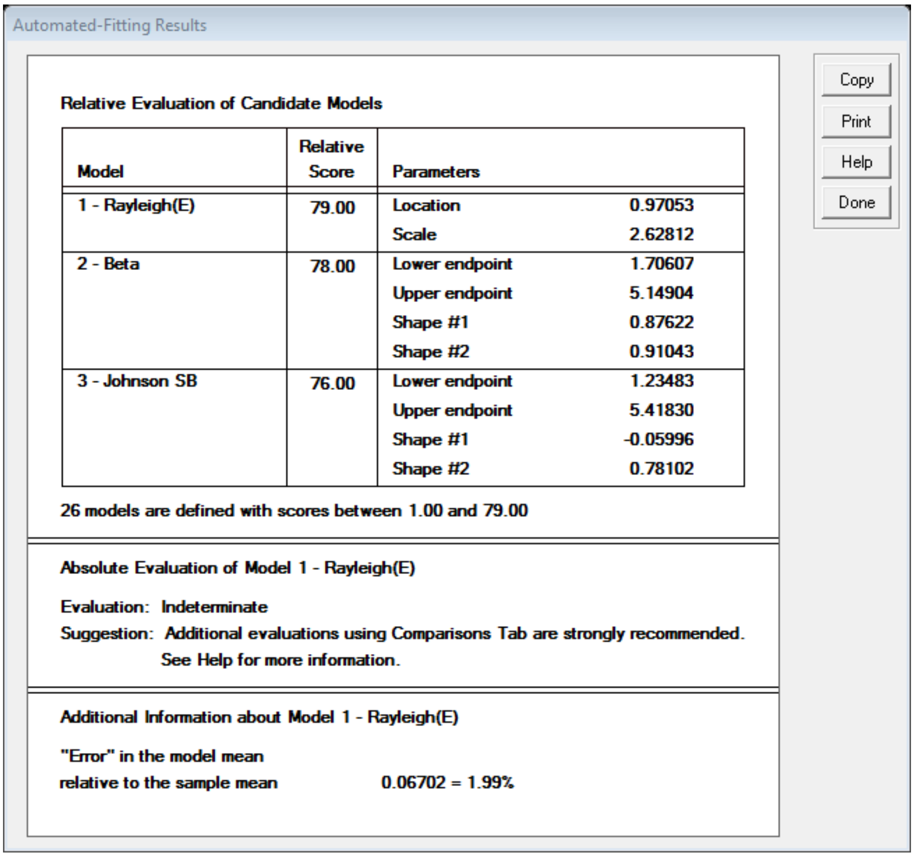



Figure 22. Automated-fiting of Packaging Machine

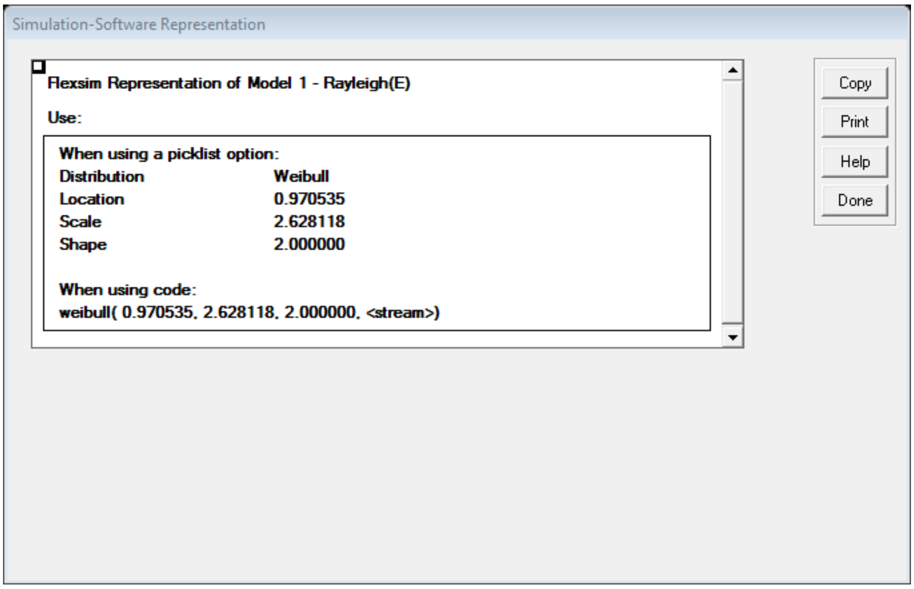



Figure 23. Simulation-software Representation of Packaging Machine

13. Global Table Data

Table 12. Routing (Global Table Data)

| | Column 1 | Column 2 | Column 3 | Column 4 | Column 5 |
|---|---|---|---|---|---|
| Row 1 | 1 | 2 | 3 | 5 | 6 |
| Row 2 | 1 | 2 | 3 | 4 | 6 |
| Row 3 | 1 | 6 | 0 | 0 | 0 |

## 4.2 Data Process

### 4.2.1 Step in Flexsim

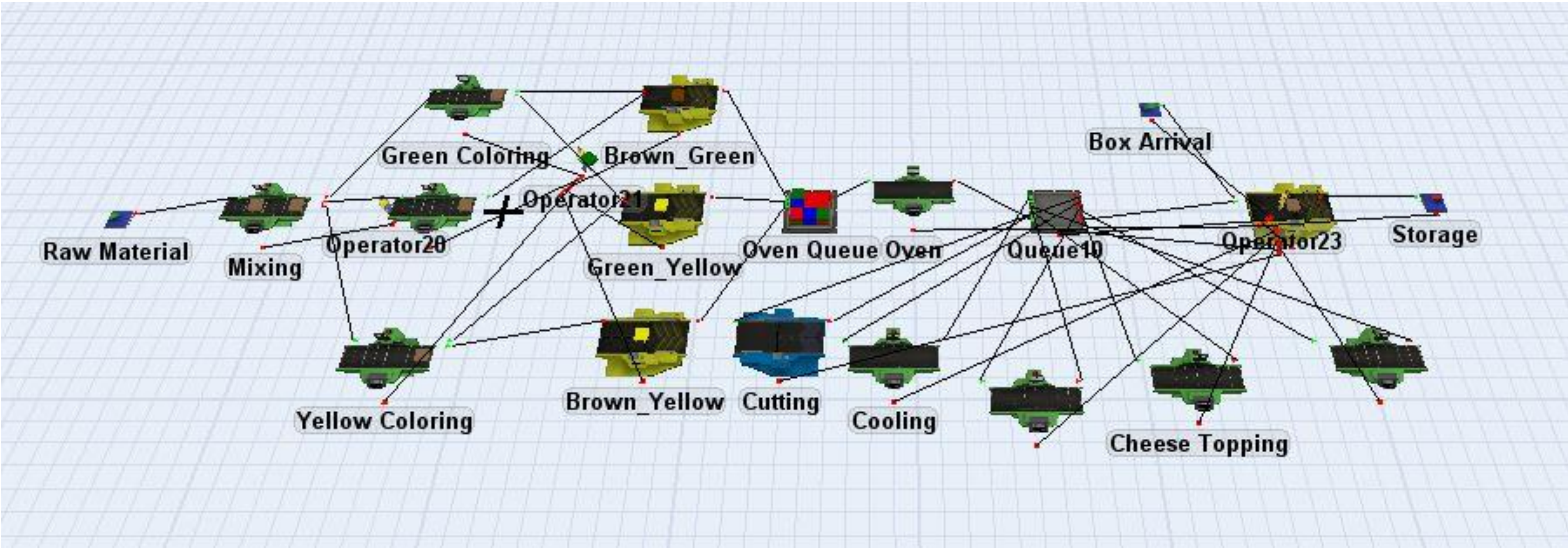



Figure 24. Running Model

The steps in Flexsim are as follows:

1. Build model

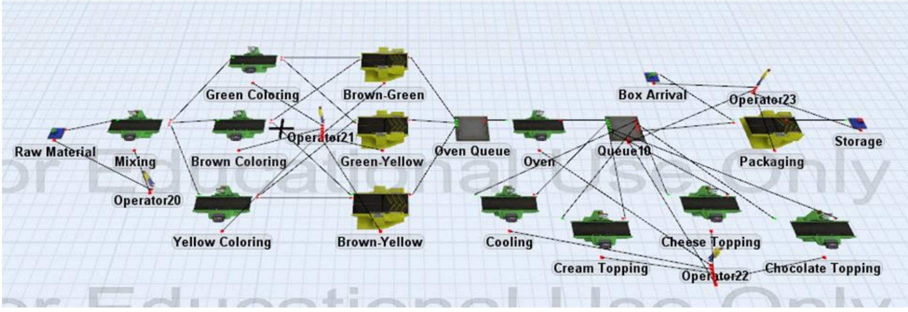



Figure 25. The Simulation Model

Develop a model as shown in the figure above. Use A connection for connecting objects and S connection for connecting task executor with object

2. Edit source properties

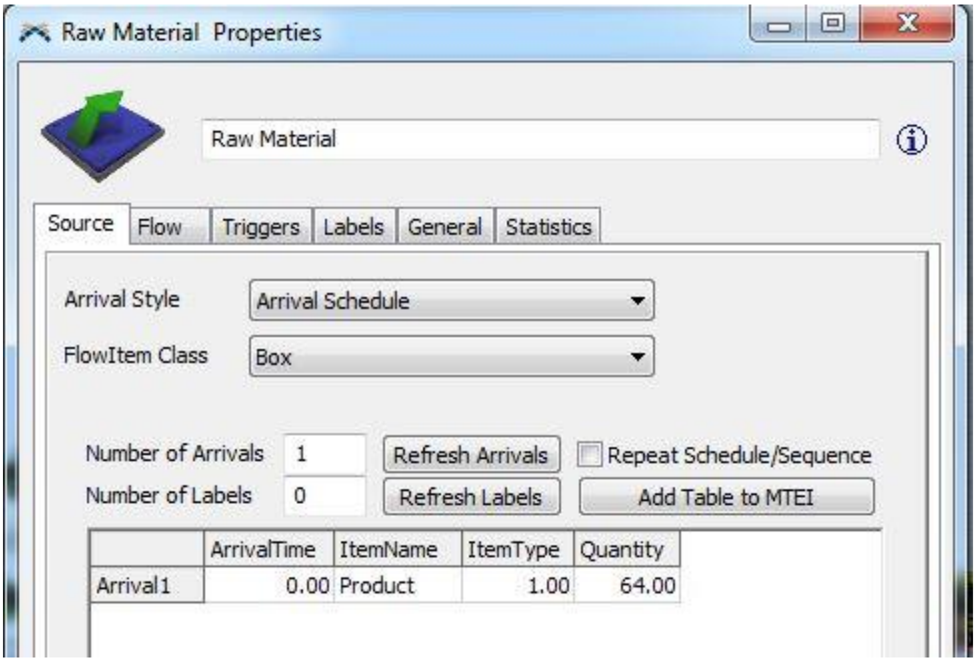



Figure 26. Raw Material Properties Source Tab

Change the arrival style to arrival schedule with quantity 64. This is for one time simulation.

3. Edit mixing properties

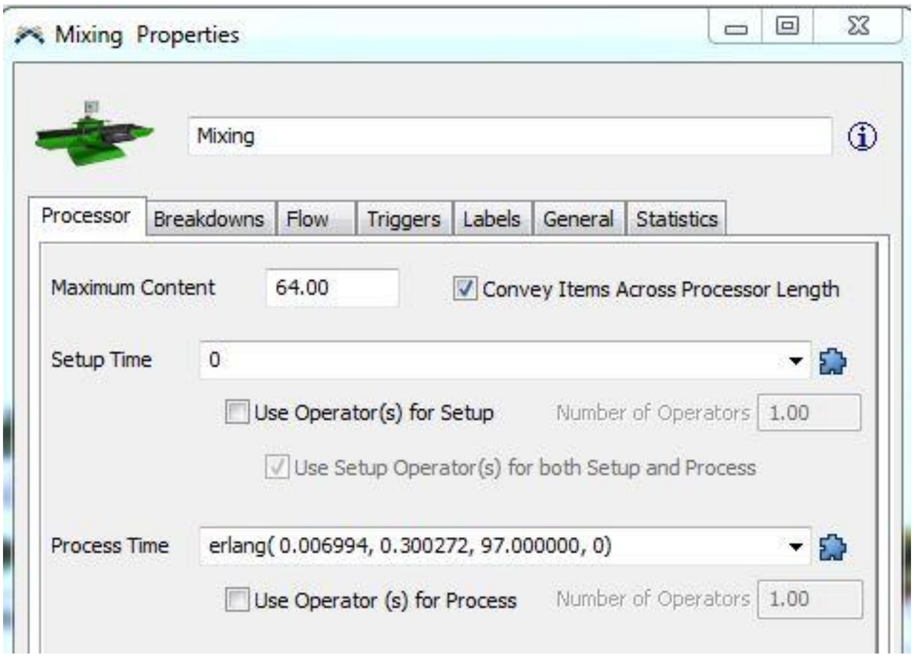



Figure 27. Mixing Properties Processor Tab

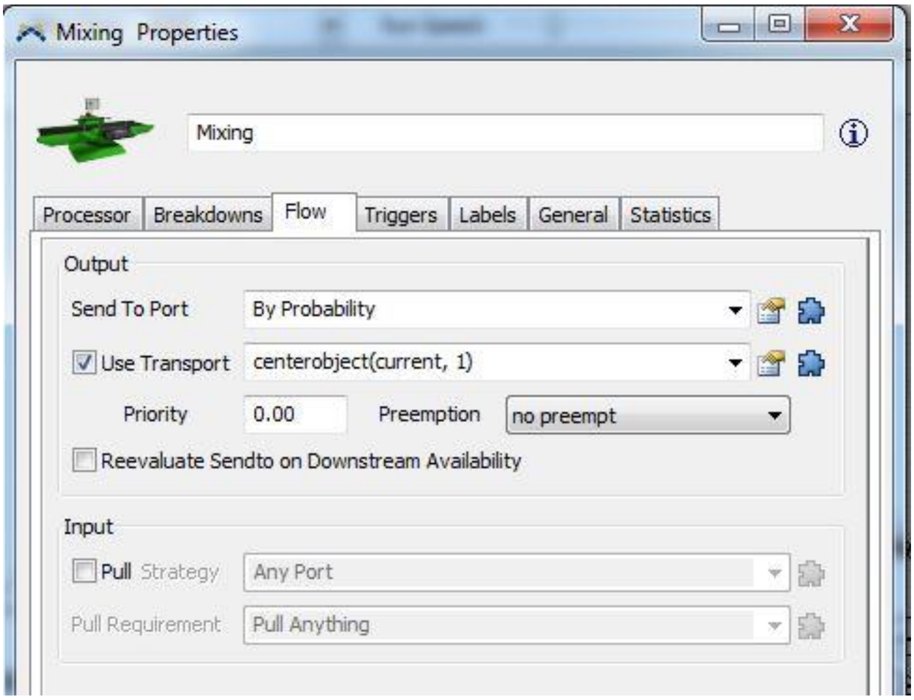



Figure 28. Mixing Properties Flow Tab

Edit the processing time of mixing machine to match the result obtained from Expertfit and set the capacity to 64 because this is batch work. In the flow tab change the output to be based on probability with around 33.3% for each output (remember there are only 3 outputs). Check on use transport for every object in model

4. Edit properties of each coloring machine

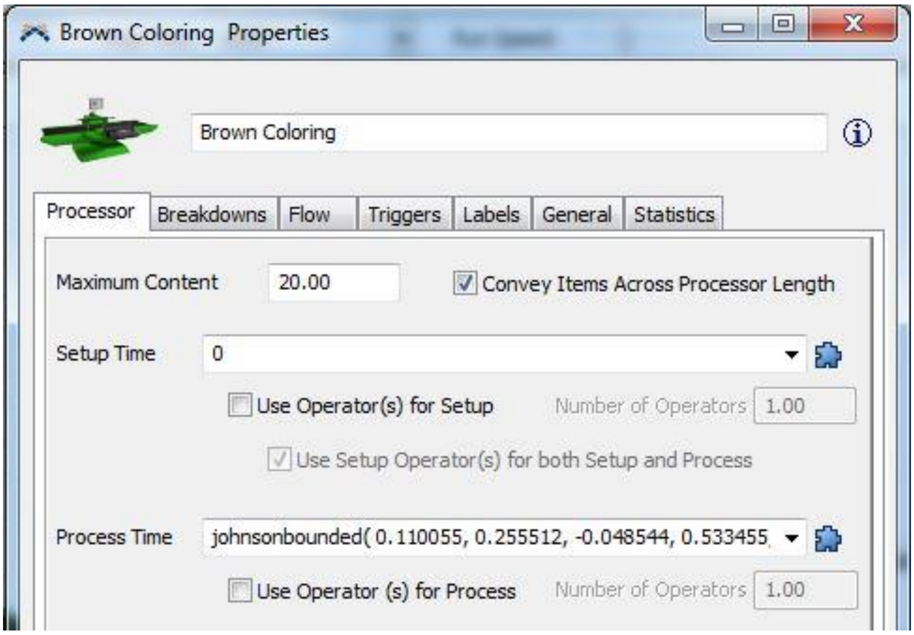



Figure 29. Processor Tab for Coloring Machines

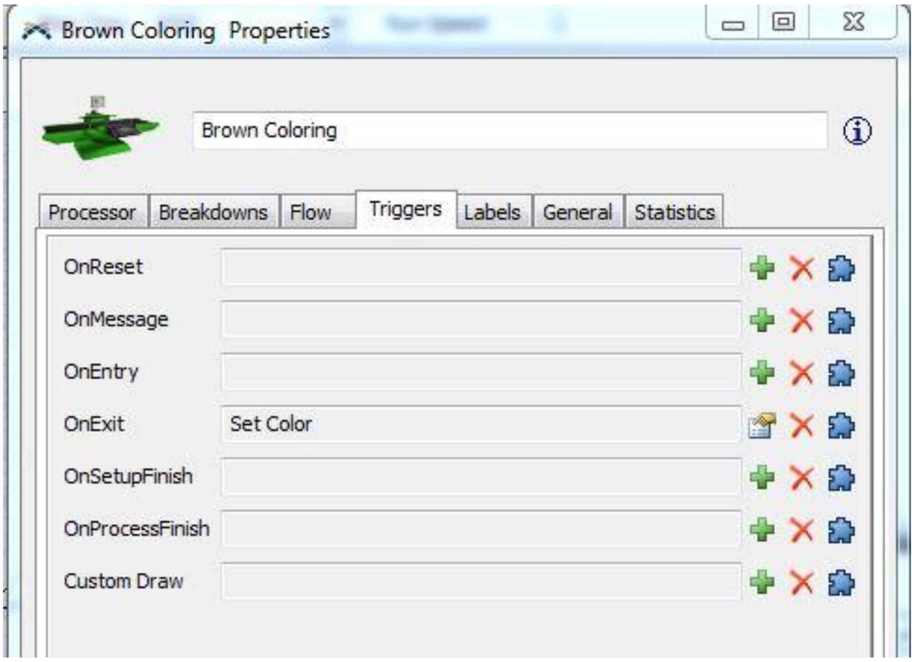



Figure 30. Trigger Tab for Coloring Machines

Match the processing time of each coloring machines to the result obtained from Expertfit and set capacity to 20 because the end result will total 60 pieces from 3 coloring mahcines. In the trigger tab set color for each coloring machines result by adding Set Color property OnExit for each coloring machines with the corresponding color.

5. Edit blending machine properties

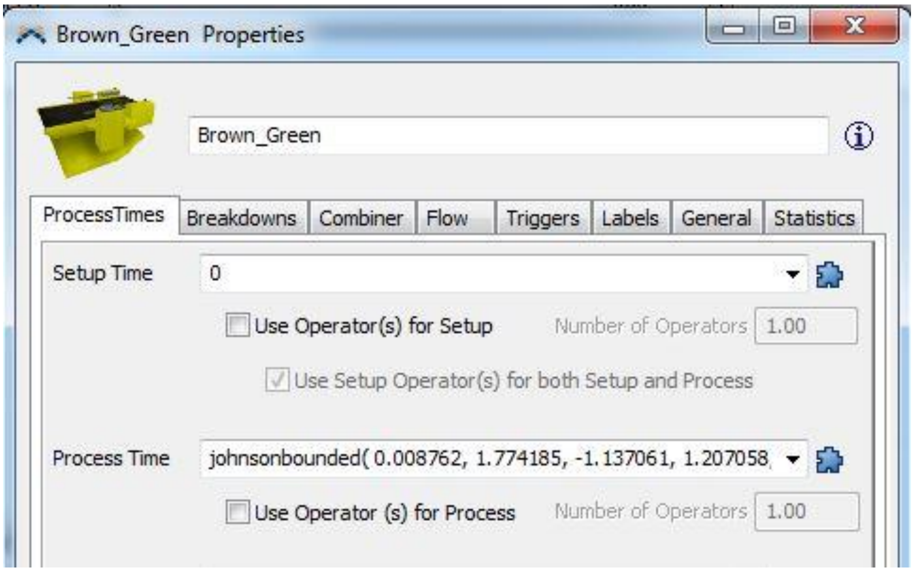



Figure 31. ProcessTimes Tab for Blending Machines

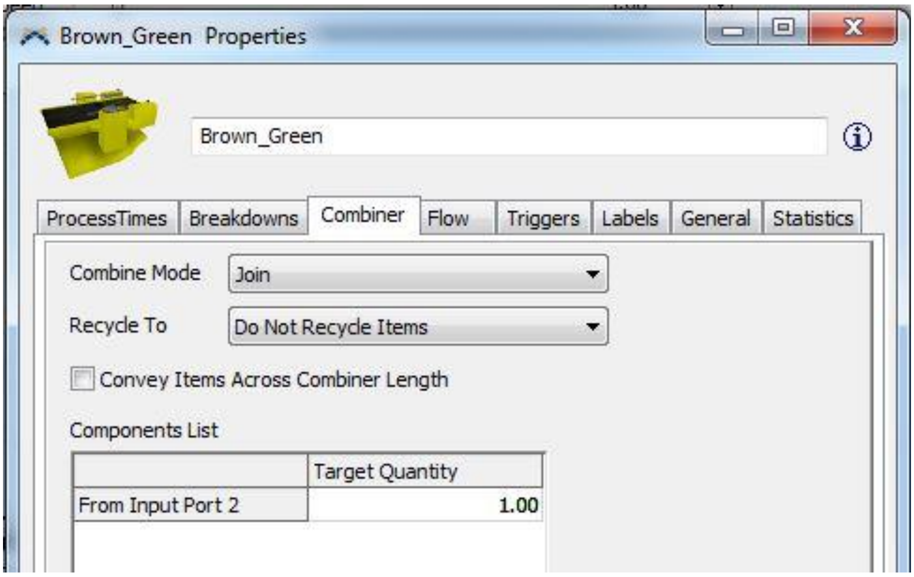



Figure 32. Combiner Tab for Blending Machines

Match the processing time of each blending machines to the result obtained from Expertfit and in combiner tab ensure that the machines combine mode are Join. Also in the triggers tab, set OnExit to set item type respectively at 1, 2, and 3 for brown-green, green-yellow, and brown-yellow blending machines respectively.

6. Do batching for oven

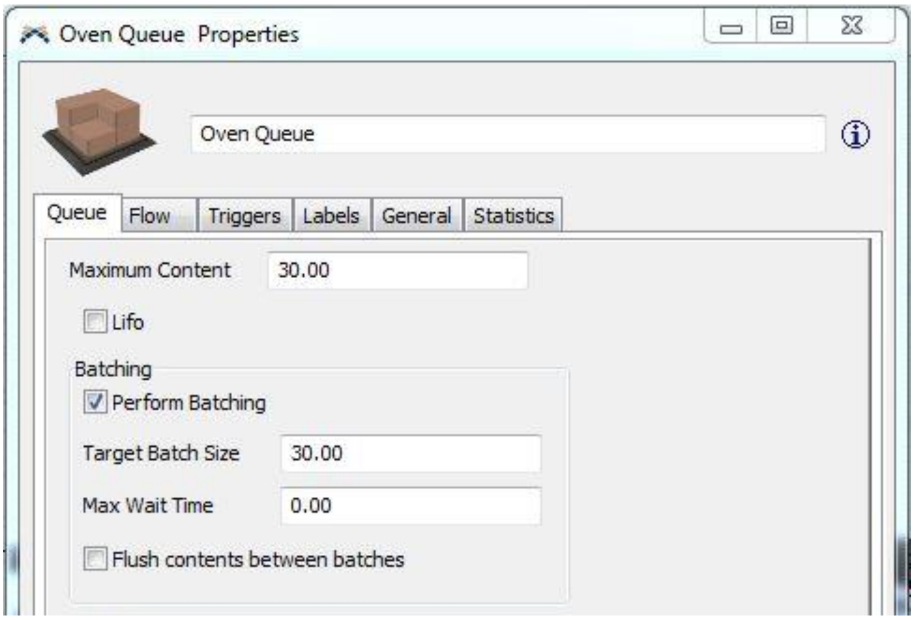



Figure 33. Oven Batching

Do batching before oven process because the oven must wait for 30 item before start. This is done by checking the perform batching box and set batch target to 30 units.

7. Set oven processing and setup time

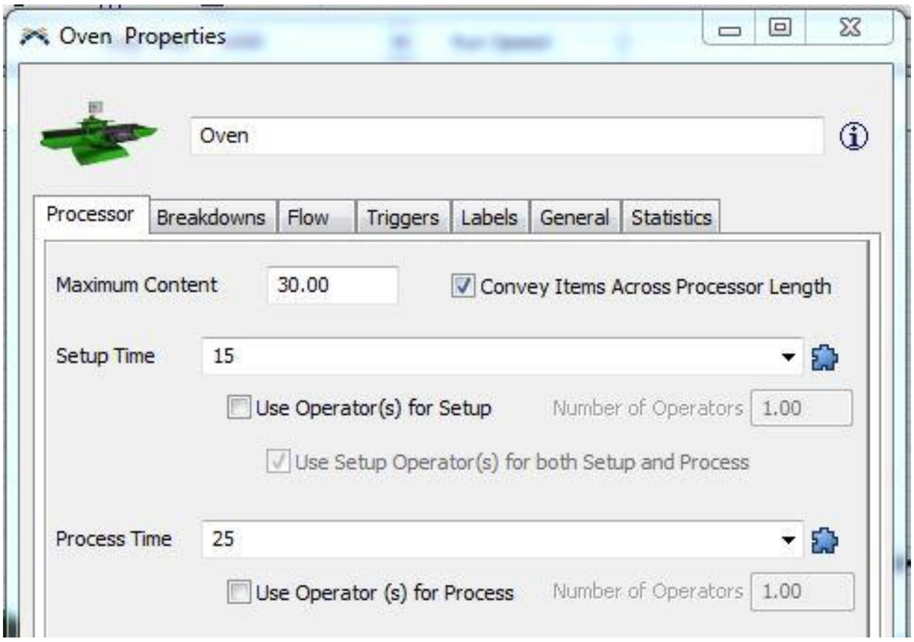



Figure 34. Oven Properties Processor Tab

Set oven processing time to 25 and setup time to 15 and also capacity to 30 because this is batch work. The time value are obtained by timer.

8. Define jobshop route

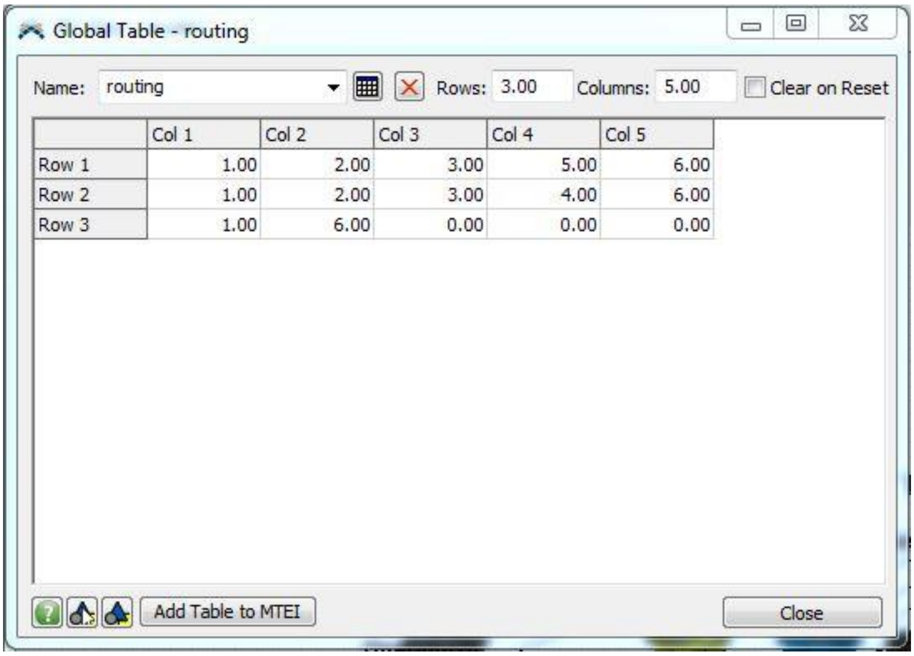



Figure 35. Global Table

Add global table to the model based on global table data for the jobshop routing process.

9. Edit queue properties

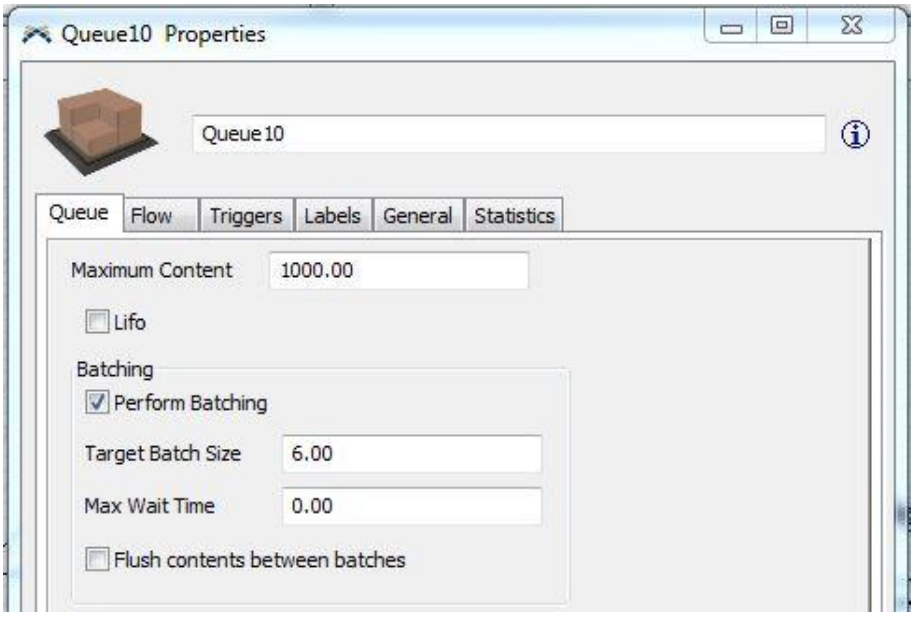



Figure 36. Queue Properties Queue Tab

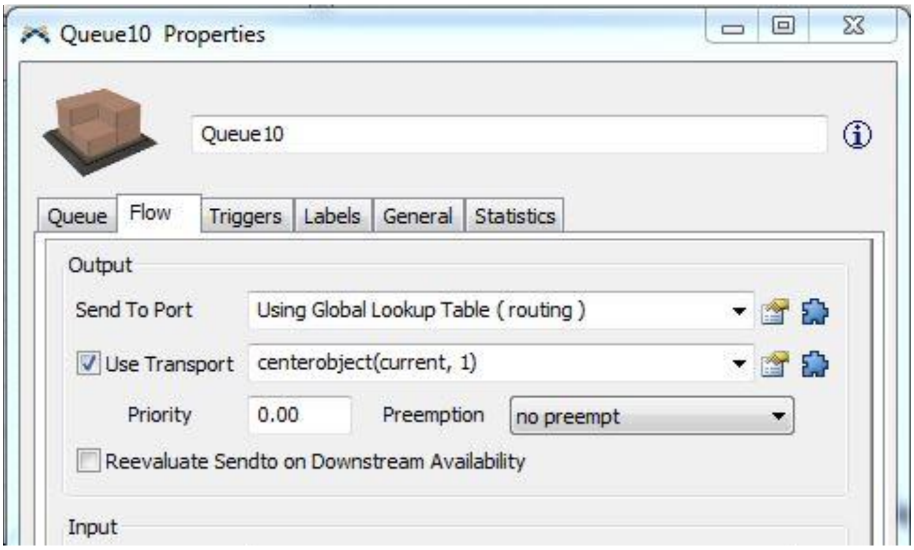



Figure 37. Queue Properties Flow Tab

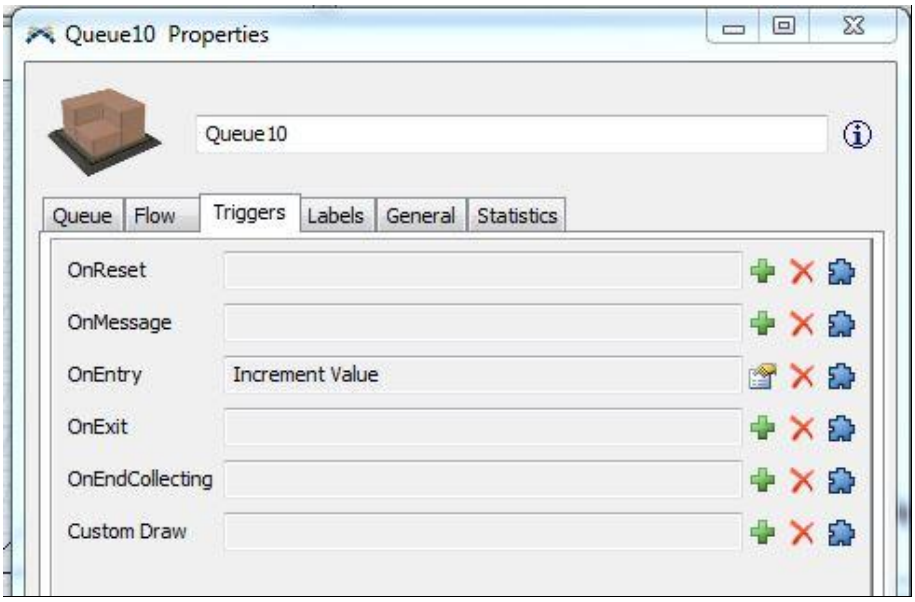



Figure 38. Queue Properties Triggers Tab

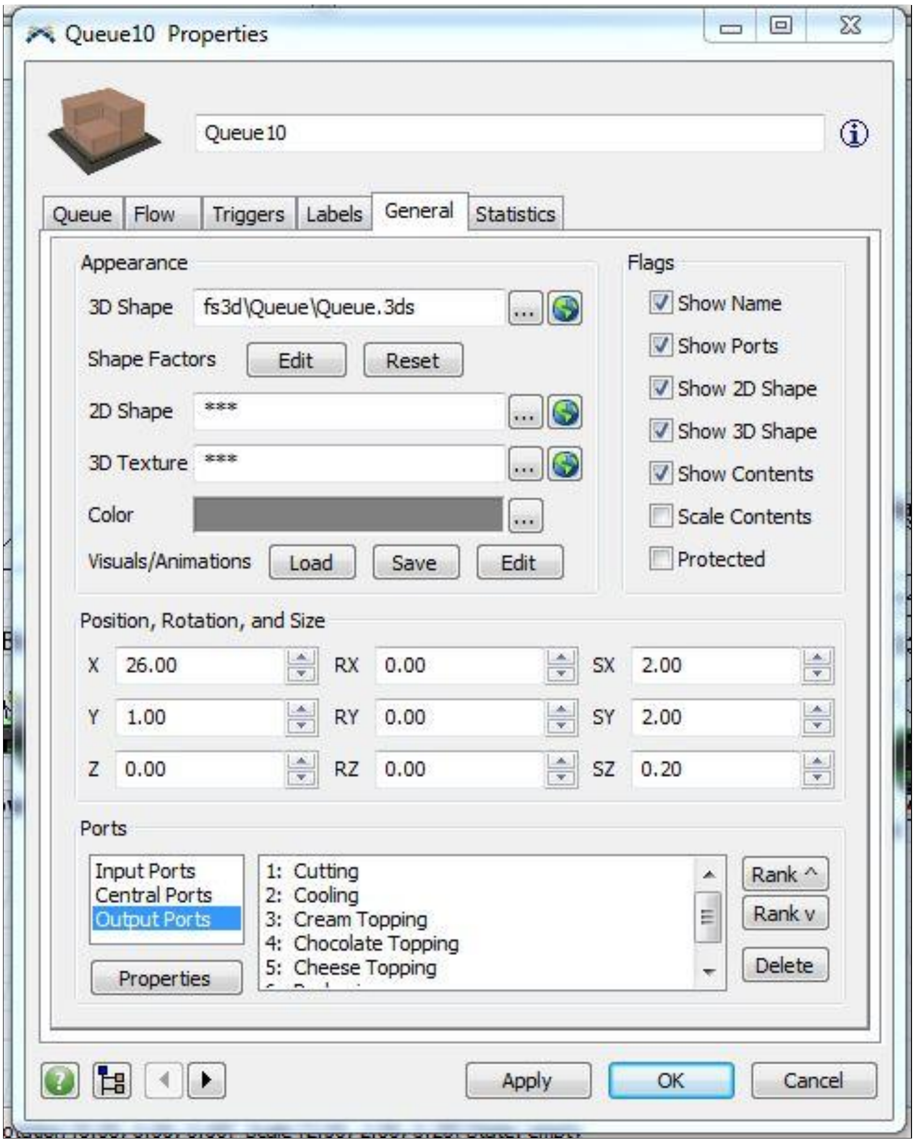



Figure 39. . Queue Properties General Tab

Set the queue into batch work which consist of 6 items in one batch because the after cutting the pieces will be processed 6 pieces at a time in the cooling and topping machines. Ensure that send to port in flow tab is set to global table lookup with vertical lookup based on flowitem type while horizontal lookup is based on “step” label, ensure that every item entering this queue will have incremented “step” label value in the triggers tab and also ensure that the output ports sequence are correct.

10. Set cutting processing time and pieces result

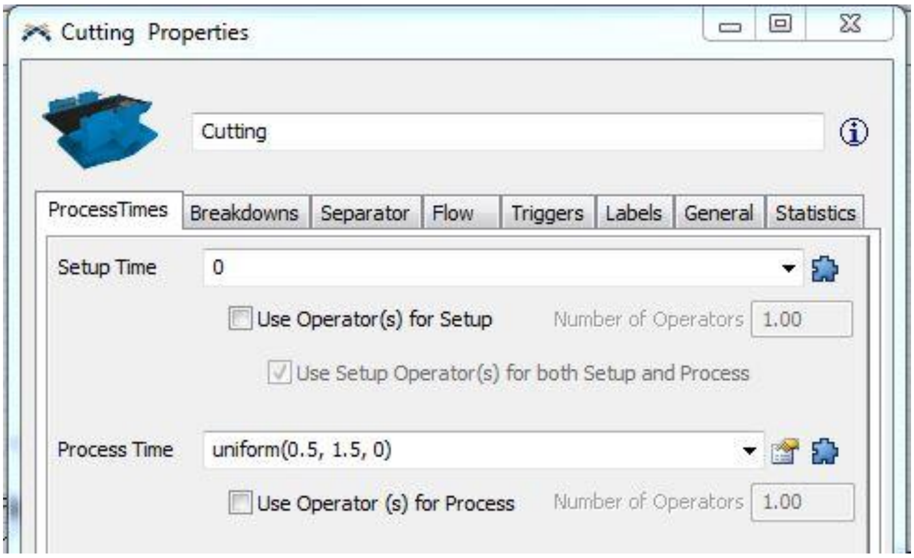



Figure 40. Cutting Properties Processing Tab

Set the process time of cutting machine to uniform distribution (0.5, 1.5, 0) and output to 6 pieces. The time is set to uniform distribution because based on interview this process is said to have processing time between 30 seconds to 90 seconds.

11. Set cooling processing time

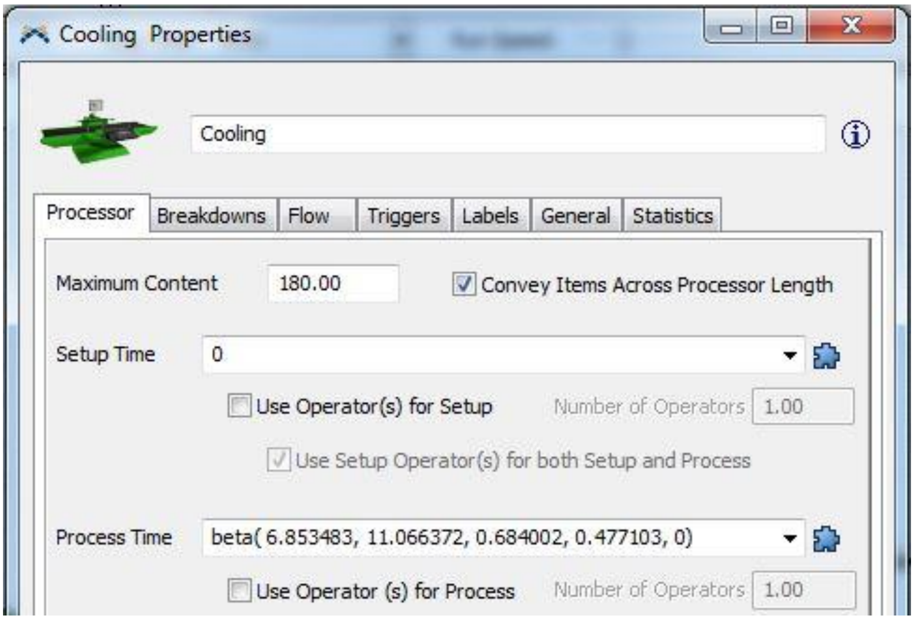



Figure 41.Cooling Properties Processor Tab

Match the processing time of cooling machine with Expertfit result.

12. Set cream topping processing time

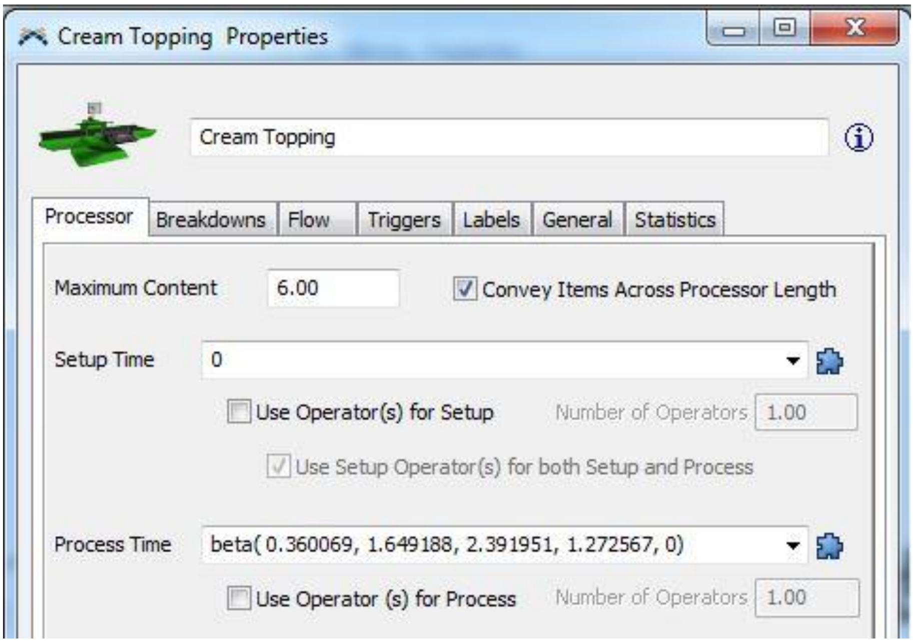



Figure 42. Cream Topping Properties Processor Tab

Match the processing time of cream topping machine with Expertfit result and also set capacity to 6 to ensure that the pieces passing through this process is done in a batch.

13. Set cheese/chocolate topping processing time

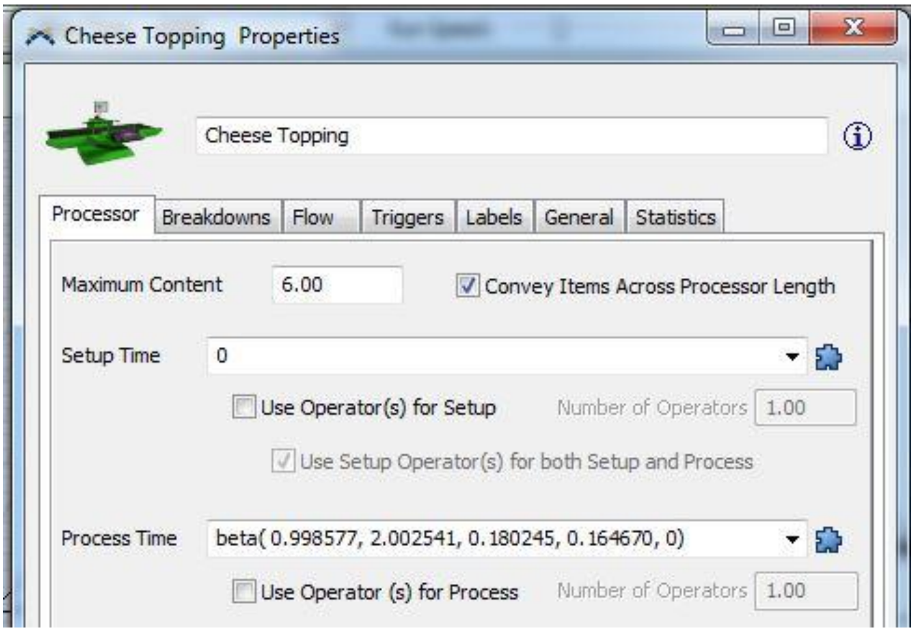



Figure 43. Cheese/Chocolate Topping Properties Processor Tab

Match the processing time of cheese and chocolate machine with Expertfit result and also set capacity to 6 to ensure that the pieces passing through this process is done in a batch. These two machine has same processing time because they are done by the same operator with the same process, the difference is only the material used in the real process.

14. Set box arrival time

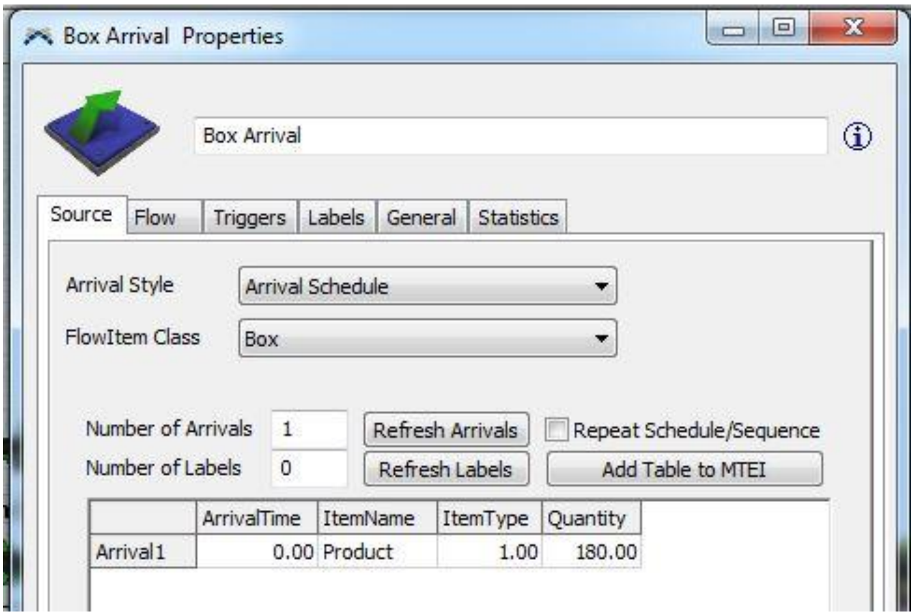



Figure 44. Box Arrival Propesties Source Tab

Change the arrival style to arrival schedule with quantity 180 because there will be 180 pieces of cake to pack. This is for one time simulation

15. Set packaging time and combining mode

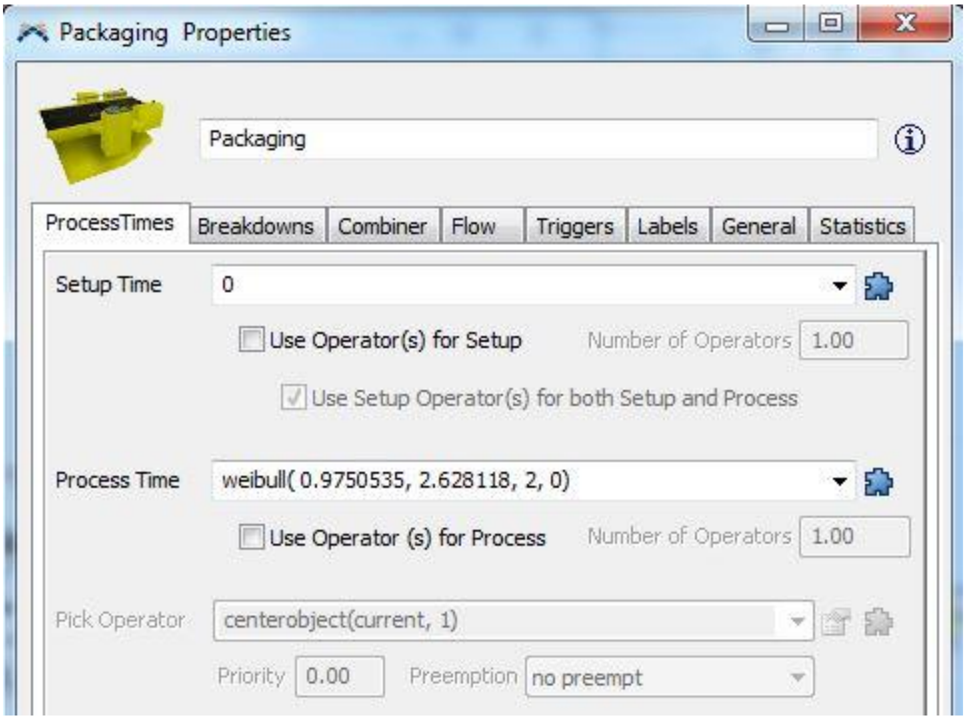



Figure 45. Packaging Properties Process Time Tab

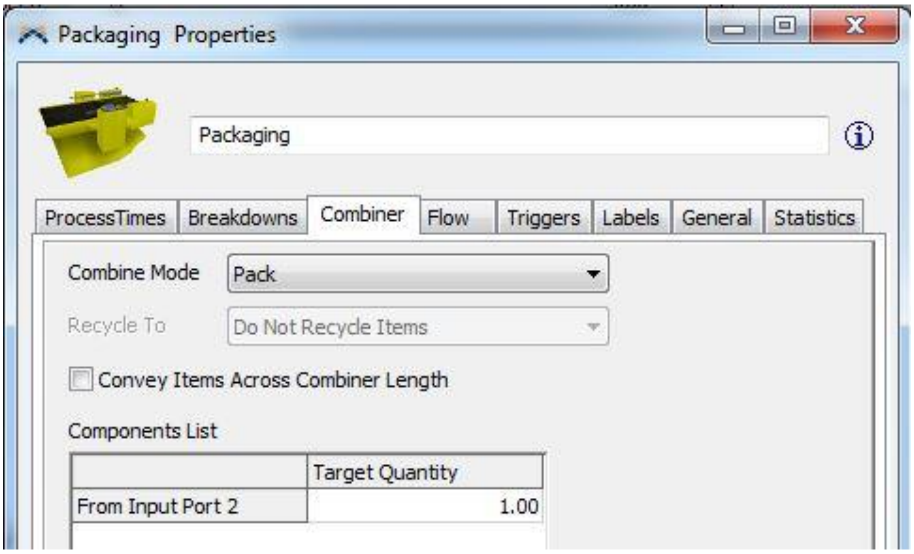



Figure 46. Packaging Properties Combiner Tab

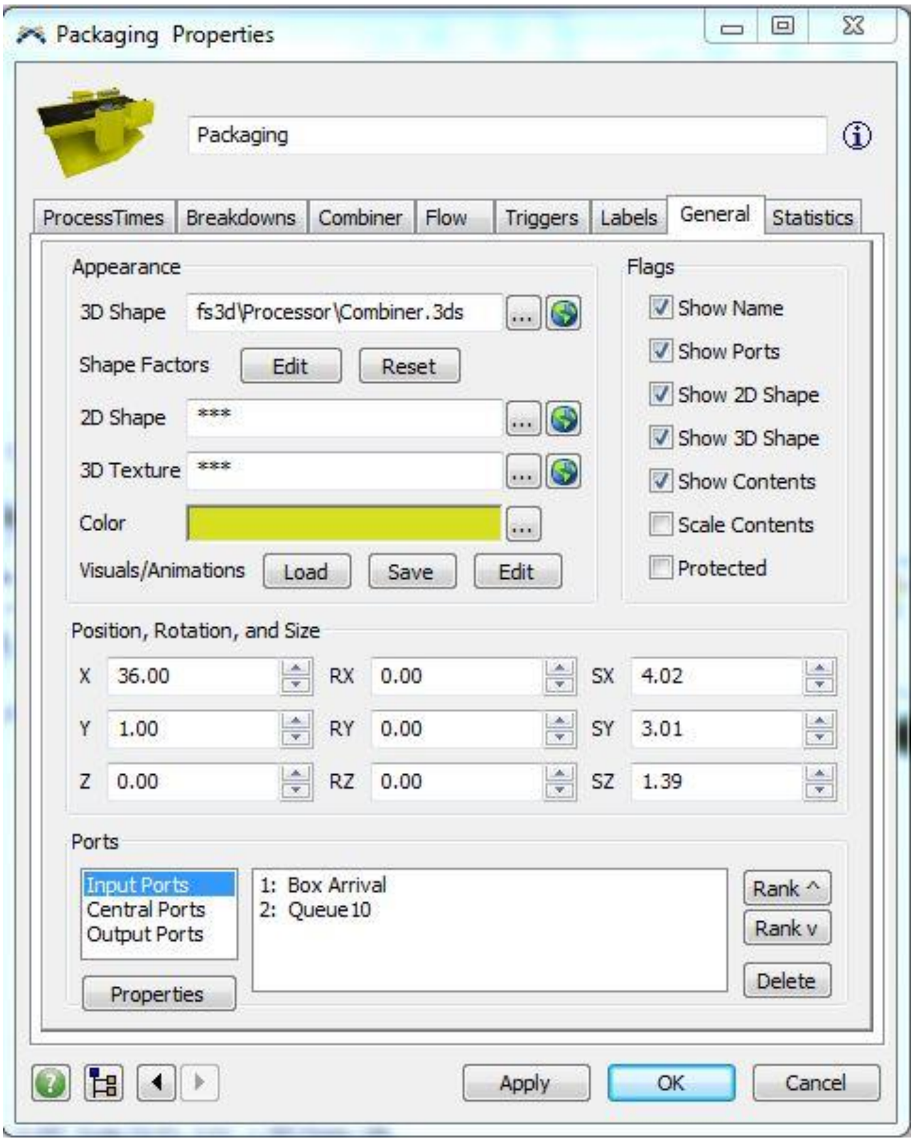



Figure 47. Packaging General Tab

Match the processing time of packaging machine with Expertfit result and also set the combine mode to package mode and also ensure that the queue is the second input port.

16. Set working time

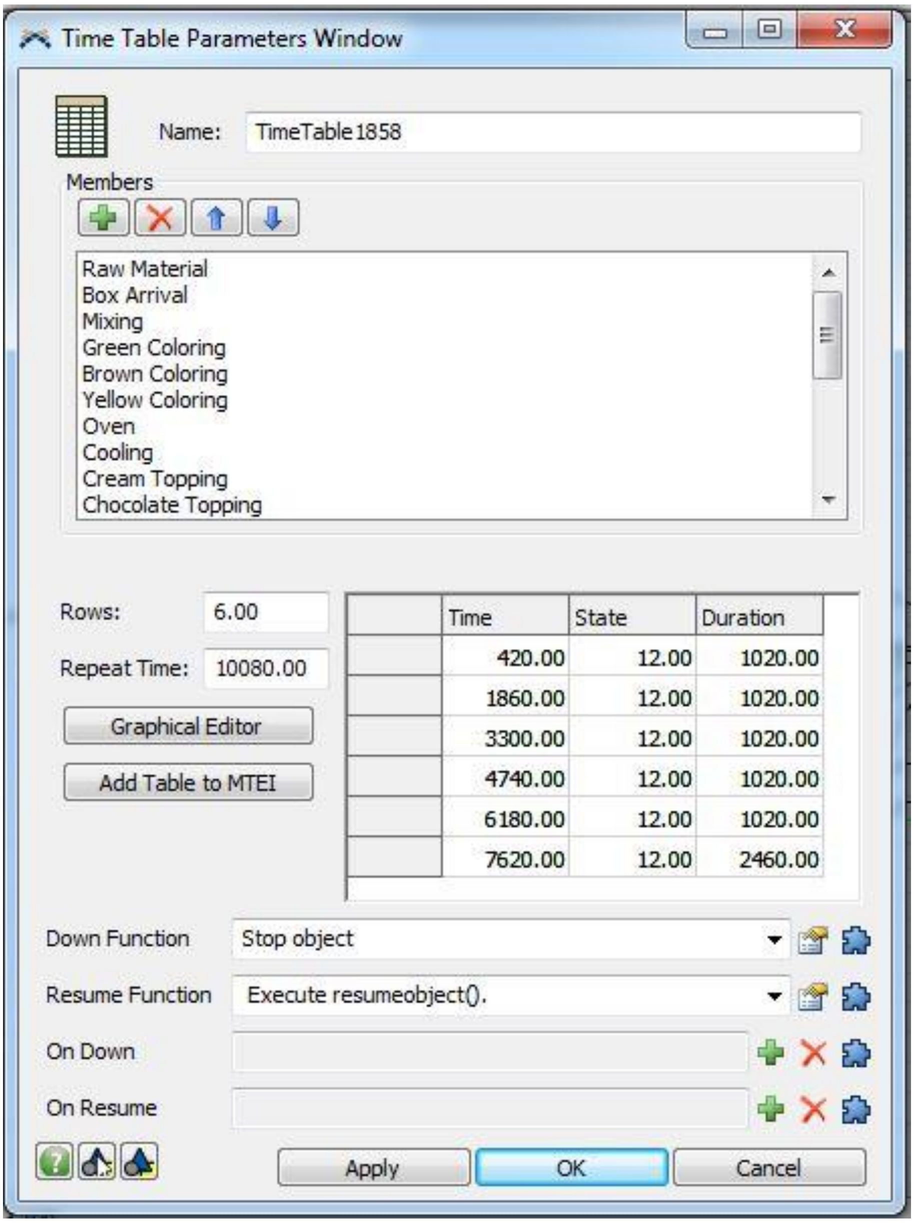



Figure 48. Time Table

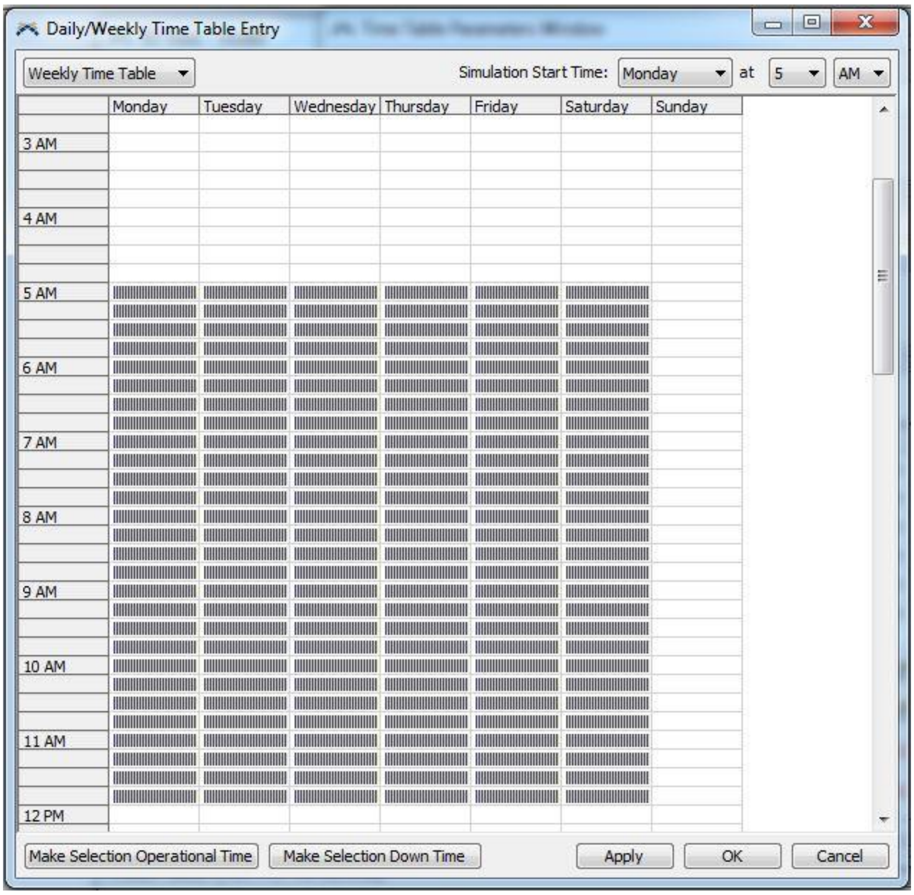



Figure 49. Time Table Graphical Editor

Insert all of the objects and task executor into the time table and set 5 a.m. to 12 a.m. on Monday to Saturday as operational time

### 4.2.2 Validation

1. History Data and Simulation Data Table

Table 13. Historical Data Table

| Total Output | Comulative Frequency | Relative Frequency |
|---|---|---|
| 343 | 0 | 0 |
| 344 | 0 | 0 |
| 345 | 0 | 0 |
| 346 | 1 | 1 |
| 347 | 1 | 0 |
| 348 | 1 | 0 |
| 349 | 1 | 0 |
| 350 | 1 | 0 |

| Total Output | Comulative Frequency | Relative Frequency |
|---|---|---|
| 351 | 2 | 1 |
| 352 | 5 | 3 |
| 353 | 5 | 0 |
| 354 | 8 | 3 |
| 355 | 9 | 1 |
| 356 | 15 | 6 |
| 357 | 17 | 2 |
| 358 | 20 | 3 |
| 359 | 25 | 5 |
| 360 | 25 | 0 |
| 361 | 26 | 1 |
| 362 | 28 | 2 |
| 363 | 28 | 0 |
| 364 | 28 | 0 |
| 365 | 30 | 2 |

From the table above show about cumulative and relative frequency demand of Bolu Kidang cake shop for one week.

Table 14. Simulation Result Data Table

| Total Output | Comulative Frequency | Relative Frequency |
|---|---|---|
| 343 | 1 | 1 |
| 344 | 1 | 0 |
| 345 | 1 | 0 |
| 346 | 2 | 1 |
| 347 | 2 | 0 |
| 348 | 2 | 0 |
| 349 | 3 | 1 |
| 350 | 3 | 0 |
| 351 | 3 | 0 |
| 352 | 3 | 0 |
| 353 | 3 | 0 |
| 354 | 3 | 0 |
| 355 | 3 | 0 |
| 356 | 3 | 0 |

| Total Output | Comulative Frequency | Relative Frequency |
|---|---|---|
| 357 | **3** | **0** |
| 358 | **3** | **0** |
| 359 | **3** | **0** |
| 360 | **30** | **27** |
| 361 | **30** | **0** |
| 362 | **30** | **0** |
| 363 | **30** | **0** |
| 364 | **30** | **0** |
| 365 | **30** | **0** |

From the table above show about cumulative and relative frequency demand after simulation in Bolu Kidang cake shop for one week.

2. Validation of Two Mean Test

Table 15. Two Mean Test Data Table

| | **NYATA(1)** | **SIMULASI(2)** |
|---|---|---|
| Mean | 356,8 | 358,3 |
| SD (v) | 4,088672325 | 4,136882 |
| n | 30 | 30 |

The table above is data about mean of weekly demand in Bolu Kidang cake shop and mean after simulation, and also we can see there are standard deviation of Bolu Kidang and after simulation, the data above is used to calculate validation of two mean test.

$$Sp^2 = \frac{(n1-1)\,v1^2 + (n2-1)\,v2^2}{n1 + n2 - 2}$$

$$Sp^2 = \boxed{16{,}91551703}$$

$$Z\ hitung = \frac{Mean\ 1 - Mean\ 2}{\sqrt{Sp^2 * (1/n1 + 1/n2)}}$$

$$Z\ hitung = \boxed{-1{,}412518844}$$

Figure 50. Z Calculation

This figure above is calculation process of validation of two mean tests. The data of this calculation is from two mean test data table above, then processed in formula Sp^2 until find the result of Z calculation.

$$-1.96 < \boxed{-1{,}412518844} < 1.96$$

Figure 51. Result of Two Mean Test

The result of Z calculation is 1.75813642, from figure above we can give statement that "Ho is accepted" because the average of simulation result is same with average of reality weekly demand in Bolu Kidang cake shop.

3. Validation of Two Variance

$$\text{F Hitung} = \frac{V_1\ \text{^}2}{V_2\ \text{^}2}$$

$$\text{F Hitung} = \boxed{0{,}976828555}$$

Figure 52. Validation of Two Variance Calculation

F Tab 0,975 < F hitung < F tab 0,025
Are as
follows

$$\boxed{0.475964774} < \boxed{0{,}976828555} < \boxed{2.100995817}$$

Figure 53. Validation of Two Variance Result

The figures above shows the process of validation based on variance comparison. Based on the figures it can be infered that F Hitung is inbetween 0.476 and 2.101 which is 0.977, thus the variance of simulation and actual output is the same

4. Validation Chi *Square*.

Table 16. Relative Frequency Data of Total Output

| **Total Output** | **Relative Frequency** | |
|---|---|---|
| | **Historis (Expected)** | **Simulasi (Actual)** |
| **343** | **0** | **1** |
| **344** | **0** | **0** |
| **345** | **0** | **0** |
| **346** | **1** | **1** |

| Total Output | Relative Frequency | |
|---|---|---|
| | Historis (Expected) | Simulasi (Actual) |
| 347 | 0 | 0 |
| 348 | 0 | 0 |
| 349 | 0 | 1 |
| 350 | 0 | 0 |
| 351 | 1 | 0 |
| 352 | 3 | 0 |
| 353 | 0 | 0 |
| 354 | 3 | 0 |
| 355 | 1 | 0 |
| 356 | 6 | 0 |
| 357 | 2 | 0 |
| 358 | 3 | 0 |
| 359 | 5 | 0 |
| 360 | 0 | 27 |
| 361 | 1 | 0 |
| 362 | 2 | 0 |
| 363 | 0 | 0 |
| 364 | 0 | 0 |
| 365 | 2 | 0 |

From the table above the total output is grouped into 5 groups with minimum historical relative frequency 5.

Table 17. Total Outpur Relative Frequency Grouping

| Total Output | Relative Frequency | |
|---|---|---|
| | Historis (Expected) | Simulasi (Actual) |
| 343-352 | 5 | 3 |
| 353-356 | 10 | 0 |
| 357-358 | 5 | 0 |
| 359 | 5 | 0 |
| 360-365 | 5 | 27 |
| total | 30 | 30 |

Based on this grouping the Chitest will be conducted with comparison of probability for $\alpha = 0.05$ and chitest on the relative frequency grouping with confidence level n-1 = 4. The chitest result will be valid if Chi-square of calculation is lower than Chi-square from table.

Table 18. Chi-Square result

| | |
|---|---|
| **Probabilitas** | **0,0000** |
| **Chi Kuadrat Hitung** | **117,6000** |
| **Chi Kuadrat Tabel** | **9,4877** |

In the Chi-square validation, it can be infered that the data is of simulation is not appropiate with the actual data. This is because the calculated Chi-square based on total output relative frequency grouping is 117.6 which is higher than the Chi-square from the table which is 9.4877.

### 4.2.3 Report Analysis

There are two reports that needs to be analyzed in this report. The reports are summary report and state report which are as follows:

# Table 19.Initial State Report

| Object | Class | idle | processing | busy | blocked | generating | empty | collecting | releasing | waiting for operator | waiting for transporter | breakdown | scheduled down | conveying | travel empty | travel loaded | offset travel empty | offset travel loaded | loading | unloading | down | setup | utilize |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| /Raw Material | Source | 0,00 | 0,00 | 0,00 | 0,00 | 33,98 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 66,02 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| /Mixing | Processor | 32,80 | 1,15 | 0,00 | 0,03 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 66,02 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| /Green Coloring | Processor | 33,50 | 0,09 | 0,00 | 0,39 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 66,02 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| /Brown Coloring | Processor | 13,84 | 0,09 | 0,00 | 20,05 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 66,02 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| /Yellow Coloring | Processor | 33,52 | 0,09 | 0,00 | 0,36 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 66,02 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| /Brown_Green | Combiner | 20,15 | 0,39 | 0,00 | 0,00 | 0,00 | 0,00 | 13,44 | 0,00 | 0,00 | 0,01 | 0,00 | 66,02 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| /Green_Yellow | Combiner | 13,70 | 0,46 | 0,00 | 0,00 | 0,00 | 0,00 | 19,82 | 0,00 | 0,00 | 0,01 | 0,00 | 66,02 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| /Brown_Yellow | Combiner | 20,20 | 0,36 | 0,00 | 0,00 | 0,00 | 0,00 | 13,41 | 0,00 | 0,00 | 0,01 | 0,00 | 66,02 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| /Oven | Processor | 32,68 | 0,81 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 66,02 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,49 | 0,00 |
| /Queue10 | Queue | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 13,18 | 0,00 | 20,80 | 0,00 | 0,00 | 0,00 | 66,02 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| /Cooling | Processor | 32,32 | 1,46 | 0,00 | 0,20 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 66,02 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| /Cream Topping | Processor | 33,13 | 0,63 | 0,00 | 0,17 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,06 | 0,00 | 66,02 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| /Chocolate Topping | Processor | 33,43 | 0,36 | 0,00 | 0,12 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,07 | 0,00 | 66,02 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| /Cheese Topping | Processor | 33,58 | 0,32 | 0,00 | 0,07 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,02 | 0,00 | 66,02 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| /Packaging | Combiner | 11,63 | 19,98 | 0,00 | 0,00 | 0,00 | 0,00 | 2,37 | 0,00 | 0,00 | 0,00 | 0,00 | 66,02 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| /Box Arrival | Source | 0,00 | 0,00 | 0,00 | 22,60 | 11,38 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 66,02 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| /Storage | Sink | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 33,98 | 0,00 | 0,00 | 0,00 | 0,00 | 66,02 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| /Operator20 | Operator | 33,91 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 66,02 | 0,00 | 0,03 | 0,04 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| /Operator21 | Operator | 33,85 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 66,02 | 0,00 | 0,06 | 0,06 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| /Operator22 | Operator | 32,74 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 66,02 | 0,00 | 0,17 | 1,04 | 0,01 | 0,02 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| /Operator23 | Operator | 33,60 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 66,02 | 0,00 | 0,16 | 0,22 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| /Cutting | Separator | 32,60 | 0,98 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,40 | 0,00 | 66,02 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| /Oven Queue | Queue | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,43 | 33,56 | 0,00 | 0,00 | 0,00 | 0,00 | 66,02 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |

Table 20. Initial Summary Report

| Object | Class | stats_content | stats_contentmin | stats_contentmax | stats_contentavg | stats_input | stats_output | stats_staytimemin | stats_staytimemax | stats_staytimeavg | state_current | state_since |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| /Raw Material | Source | 0 | 0 | 63 | 64 | 0 | 128 | 0 | 0 | 0 | 12 | 6180 |
| /Mixing | Processor | 0 | 0 | 64 | 1,270815744 | 128 | 128 | 21,39229965 | 37,50473022 | 28,96571054 | 12 | 6180 |
| /Green Coloring | Processor | 0 | 0 | 9 | 0,041014823 | 42 | 42 | 0,146191671 | 5,952118874 | 2,84958709 | 12 | 6180 |
| /Brown Coloring | Processor | 5 | 0 | 14 | 0,051626526 | 43 | 38 | 0,187576517 | 8,633795738 | 3,013657657 | 12 | 6180 |
| /Yellow Coloring | Processor | 0 | 0 | 10 | 0,045933059 | 43 | 43 | 0,163059026 | 6,841879368 | 3,118243837 | 12 | 6180 |
| /Brown_Green | Combiner | 0 | 0 | 2 | 0,991553567 | 38 | 19 | 0,77534008 | 2865,088379 | 152,3636156 | 12 | 6180 |
| /Green_Yellow | Combiner | 1 | 0 | 2 | 0,010883872 | 47 | 23 | 0,682233334 | 3,012800694 | 1,380922805 | 12 | 6180 |
| /Brown_Yellow | Combiner | 0 | 0 | 2 | 0,99019636 | 38 | 19 | 0,445307732 | 2868,05542 | 152,1766019 | 12 | 6180 |
| /Oven | Processor | 0 | 0 | 30 | 0,323480284 | 60 | 60 | 15,03012943 | 40,13585663 | 15,95687666 | 12 | 6180 |
| /Queue10 | Queue | 0 | 0 | 168 | 59,38057316 | 1176 | 1176 | 0,002508346 | 1635,90918 | 230,5842808 | 12 | 6180 |
| /Cooling | Processor | 0 | 0 | 52 | 0,791410751 | 252 | 252 | 6,876666546 | 11,50918484 | 9,389712839 | 12 | 6180 |
| /Cream Topping | Processor | 0 | 0 | 5 | 0,026120817 | 252 | 252 | 0,00012364 | 2,074155807 | 0,309917761 | 12 | 6180 |
| /Chocolate Topping | Processor | 0 | 0 | 6 | 0,017861871 | 138 | 138 | 0,000317511 | 2,535102606 | 0,387006091 | 12 | 6180 |
| /Cheese Topping | Processor | 0 | 0 | 3 | 0,010847255 | 114 | 114 | 0,000236526 | 2,070015907 | 0,283117223 | 12 | 6180 |
| /Packaging | Combiner | 0 | 0 | 2 | 0,748308325 | 720 | 720 | 0 | 1025,395996 | 4,751648391 | 12 | 6180 |
| /Box Arrival | Source | 0 | 0 | 179 | 110,4723961 | 0 | 360 | 0,02688919 | 1750,137939 | 836,3987122 | 12 | 6180 |
| /Storage | Sink | 1 | 1 | 1 | 0 | 360 | 0 | 0 | 0 | 0 | 12 | 6180 |
| /Operator20 | Operator | 0 | 0 | 3 | 0,000904642 | 128 | 128 | 0,01414214 | 0,056748878 | 0,02061966 | 12 | 6180 |
| /Operator21 | Operator | 0 | 0 | 5 | 0,001563021 | 184 | 184 | 0,015513018 | 0,130094245 | 0,024804487 | 12 | 6180 |
| /Operator22 | Operator | 0 | 0 | 12 | 0,066738944 | 2352 | 2352 | 0,01425486 | 11,52117825 | 0,129579453 | 12 | 6180 |
| /Operator23 | Operator | 0 | 0 | 1 | 0,003038184 | 720 | 720 | 0,018493541 | 0,020090668 | 0,019292104 | 12 | 6180 |
| /Cutting | Separator | 0 | 0 | 5 | 0,171954676 | 60 | 360 | 0,015461194 | 10,03620434 | 0,578245658 | 12 | 6180 |
| /Oven Queue | Queue | 1 | 0 | 30 | 1,143064911 | 61 | 60 | 0 | 2877,07959 | 55,62921386 | 12 | 6180 |

Based on the tables, it can be infered that there are several problems in the system. Some of them is natural because of certain condition in the production such as high idle rate in the system due to fast production process. The problems that are unnatural in the system are high block rate on the Box Arrival Source (22,6%) and High Average Staytime on Queue10 (230,584 minutes) where both of them affects to makespan of production. High block rate on box arrival may indicate two conditions, the first one is the boxes are blocked due to long processing time which causes the boxes to wait for a finished cake to be packaged or the pace of finished cake arrival is just not fast enough so some of the box must wait for the cake that will be packaged. On the other hand, Queue10 where most of the flowitem pass through this object, high average staytime on this object indicates that there is bottleneck in several processes around the object.

## 4.3 Design of Experiment

Based on the report analysis there are two problems that are related to makespan in the report. The problems will be overcomed with experiment designs which are as follows:

### 4.3.1 Scenario 1

The first problem that will be overcomed is the Box Arrival Block Rate. As mentioned in the Report Analysis, this is caused by low pace of cake that will be packaged. Based on the model, pace of production is affected by the processing time needed in production, capacity, and also cake’s raw material arrival. The processing time is an unchageable variable in the system while capacity is already set to be maximum in the system and is very costly to change this, so the most possible solution is changing raw material arrival. Initially the raw material is set to arrive every 2 days (840 minutes working time) and the scenario is set to show how reducing or increasing the arrival time will affect the Box Arrival Block Rate.

Table 21. Box Arrival Initial State Report

| Object | Class | blocked | generating | scheduled down |
|---|---|---|---|---|
| /Box Arrival | Source | 22,60 | 11,38 | 66,02 |

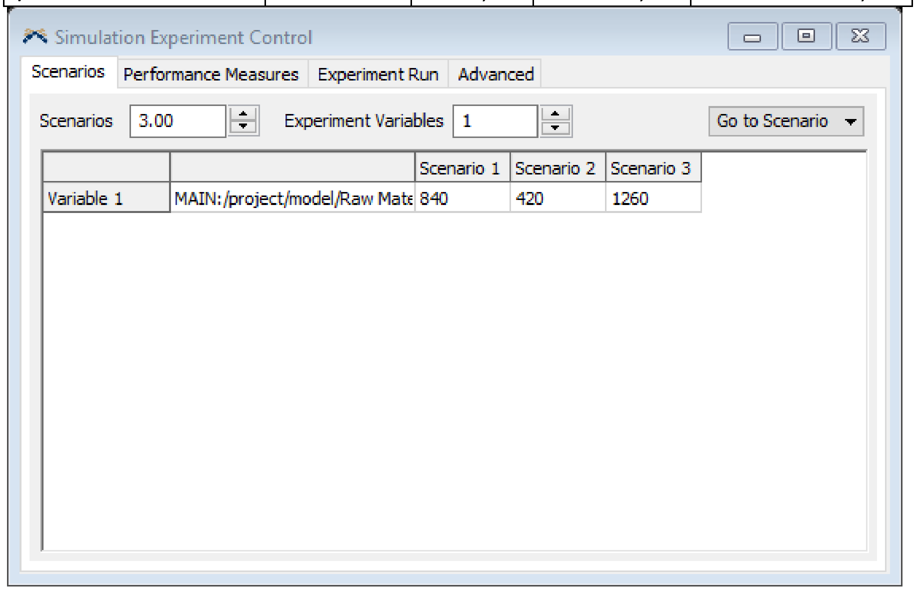



Figure 54. Scenario Design 1

4.3.2 Scenario 2

Supporting the first scenario, the second scenario will try to reduce the average staytime of item on Queue10. With the reduce of average staytime on this object the makespan of the system will minimize which means it is more optimal. This is done by doubling the quantity of Packaging, Cream Topping, Chocolate Topping, and Cheese Topping machine. The experiment is also followed by multiplying the quantity 3 times, 4 times, and 5 times to ensure that the impact is visible.

Table 22. Queue10 Average Content Staytime

| Object | Class | stats_staytimeavg |
|---|---|---|
| /Queue10 | Queue | 230,5842808 |

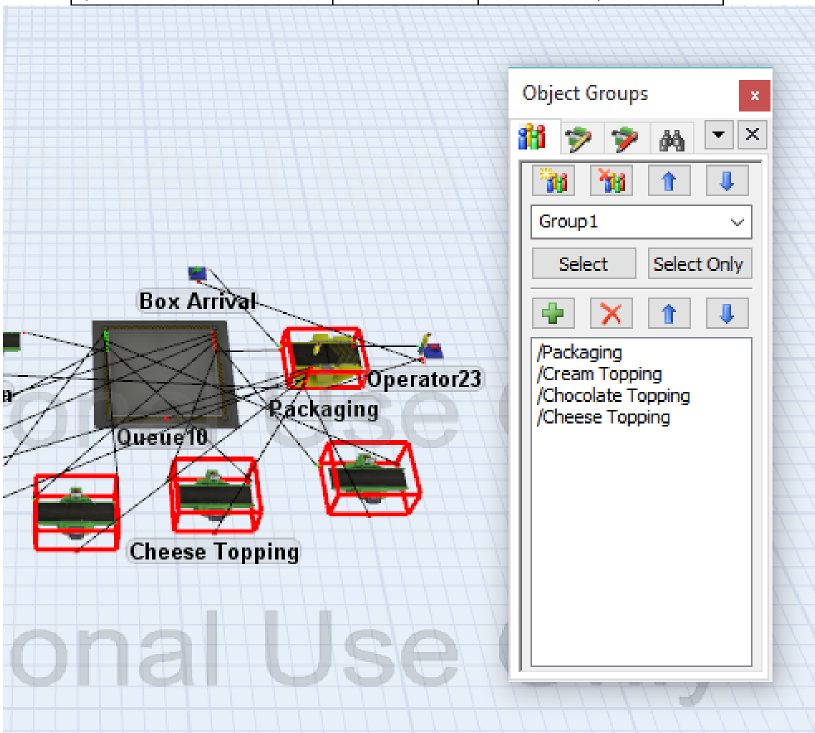



Figure 55. The Objects Grouping

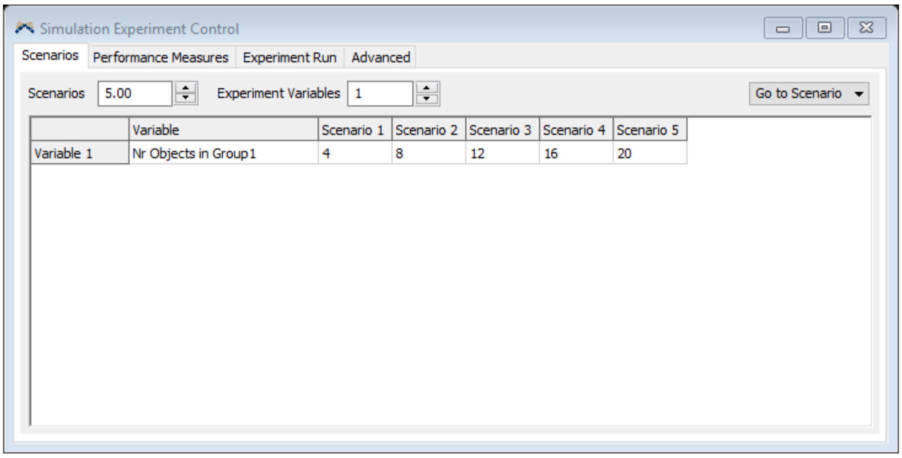



Figure 56. Scenario 2 Design

# Chapter V. DISCUSSION

## 5.1 Preliminary Analysis Model

From the initial model of Bolu Kidang cake production, there are several information that needs to be highlighted. The highlighted information include output of the system which are most likely 360 (though sometimes it is lower), the capacity of packaging, combiner, and cutting machine which are very limited (1 input for cutting machine and 2 for packaging and combiner), very fast processing time of every machine, Queue10 which becomes the main pivot of production after the oven, the arrival time of raw material (on the $1^{st}$ day and $3^{rd}$ day). All of this information are related into one chain of production and affects the makespan of production.

With so many entities affecting the production makespan in Bolu Kidang cake production, some of the entitity may be affecting the production makespan more than the other entities. Considering the entity that are less affecting the makespan may include the capacity which are set to maximum of each material except for the combiners and some job shop processing on Queue10 which are maximized for a batch of 6 items where the input of 30 unit from oven each are cut into 6 causing the queue to have a maximum 180 capacity but are packaged one piece at a time on the packaging machine. But somehow the average staytime of content in Queue10 can be reduced by doubling the machines that are connected to this object. The average staytime in Queue10 gives direct impact to the makespan of production.

Other entity that gives impact to the makespan of production in Bolu Kidang is the arrival time of material. Logically thinking, slower arrival time of material may cause emptiness in processing (idle) time but faster arrival time also needs faster processing pace. Without proportional processing speed the possibilities of idle time or bottleneck may increase.

Related to bottleneck in production, as mentioned in the previous chapter, there is bottleneck in this system on box arrival. This is caused by unproportional arrival time with production pace. This problem will be discussed further in the following subchapter.

## 5.2 Analysis of Scenario Model 1

Scenario Model 1 is designed to reduce block rate in Box Arrival Source. Previously it is mentioned that the arrival time is not proportional with the production pace which causes emptiness or too many content waiting for queue on packaging machine which causes the box to be blocked.

With difficulty to decide whether to reduce or increase the arrival time of the second batch of raw material from supplier because of not clear information of block cause whther from emptiness or queue, the scenario is made with 3 experiment. First, not changing anything (keeping it 2 days arrival difference). Second, reducing the arrival time to be 1 day difference. Last but not least, is increasing the day difference to 3 days.

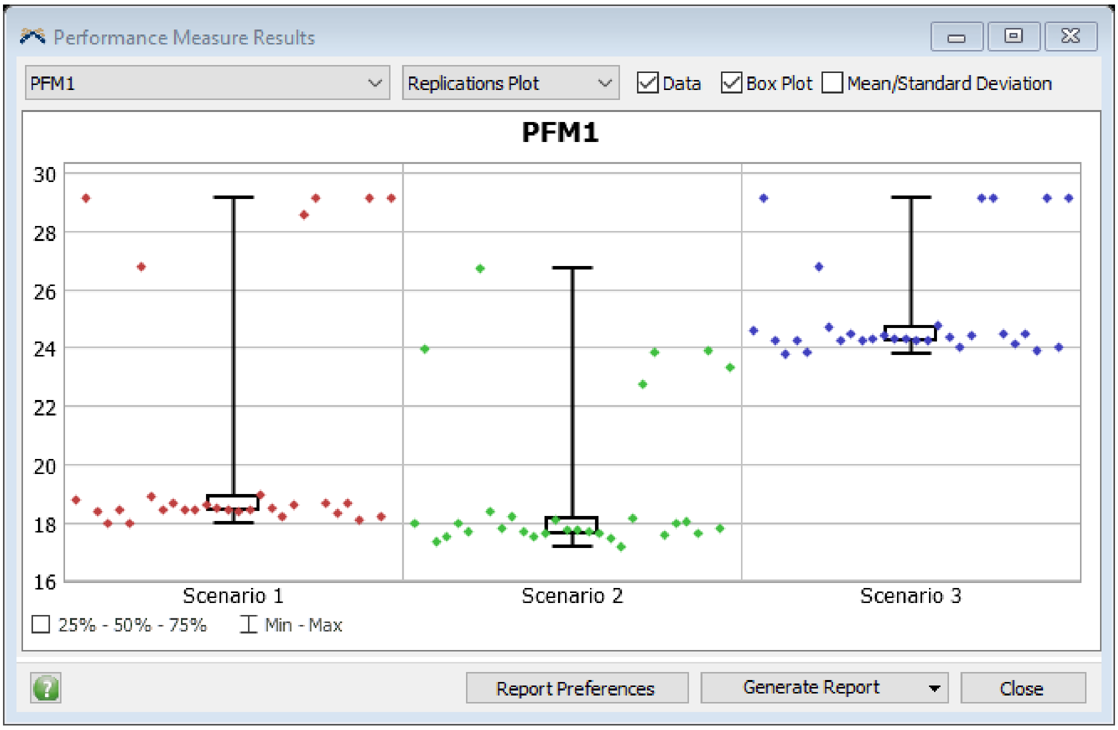



Figure 57. Scenario Model 1 Result

From the scenario design, the experiment result shows that reducing the arrival time to be 1 day difference gives better results (refer to Figure 57). Based on the experiment, reducing the arrival time gives results in slighty lower variance as well as sligtlhy lower mean on the block rate. On contrary, increasing the arrival time, greatly reduces variance but also greatly increase block rate mean which is not a good choice.

### 5.3 Analysis of Scenario Model 2

The second scenario is designed to reduce average staytime on Queue10 by multiplying the quantity of several machine linked to Queue10. The machine that is designed to be doubled are Packaging, Cream Topping, Chocolate Topping, and Cheese Topping machine. These machines are chosen because they are operated after the content has passed through the cooling machine which has 180 capacity (all queue can pass this machine).

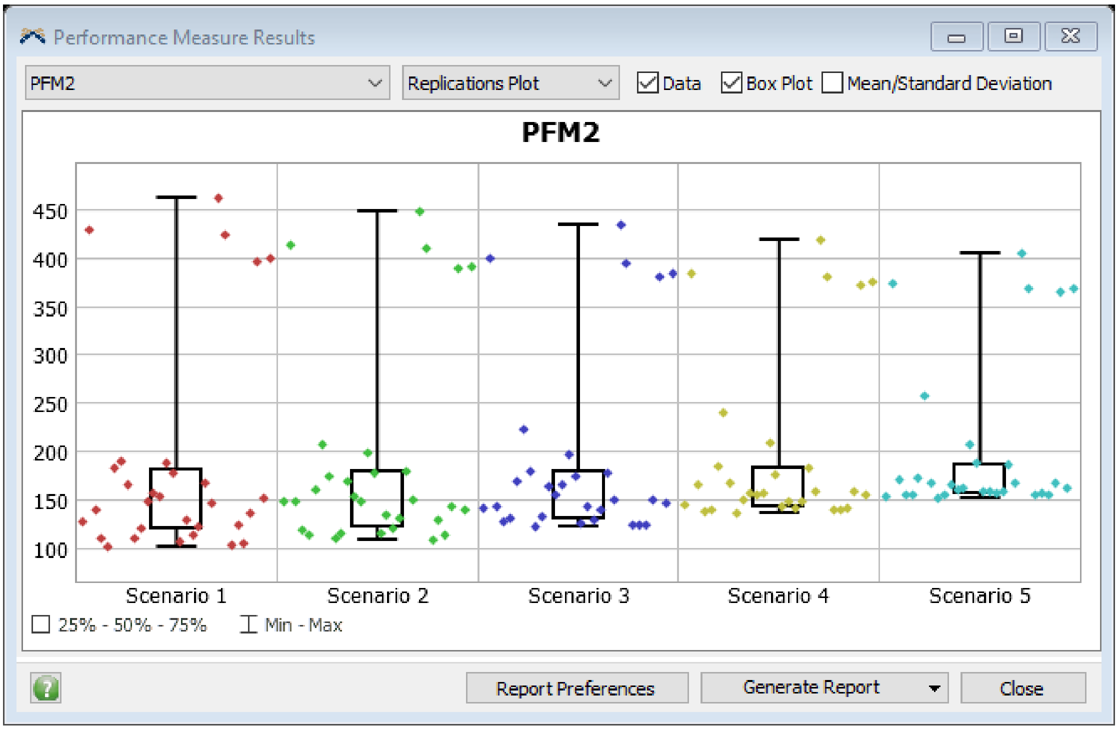



Figure 58. Scenario Model 2 Result

The figure above shows the result of experiment where respectively from left to right the quantity of designated machine is doubled, tripled, timed 4, and timed 5. The result obtained from the scenario is doubling the quantity of selected machines reduces variability of staytime slightly where doubling also reduces the mean slightly but starting from triple to timed 5 the mean increases. Therefore it is better to double the quantity of selected machines.

# Chapter VI. CONCLUSION AND RECOMMENDATIONS

## 6.1 Conclusions

Thus, the conclusion of this report are as follows:

1. The company can minimize makespan by changing the interval of raw material arrival to 1 day interval and doubling the quantity of Packaging, Cream Topping, Chocolate Topping, and Cheese Topping machine.
2. The problems in the system that may affect makespan includes high bottleneck on Box Arrival and high staytime on Queue10.
3. In order to overcome these problem, the interarrival of material is reduced from 2 days to 1 day for Box Arrival bottleneck while the high staytime on Queue10 can be slightlhy reduced by doubling the Packaging, Cream Topping, Chocolate Topping, and Cheese Topping machine

## 6.2 Recommendations

For further research, the types of cake produced may vary which will give different result an probably different problems. These problems impact on makespan may vary and have different solutions. Solving this problem using different methods such as Johnson Algorithm may also be intresting to follow in the future.

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