REDESIGN OF THE MODELLING DEPARTMENT AT FLO

Senior Design Project

Aybike Dilek

Emir Doğanay

Serdar Kami Üçkardeş

2018 - 2019

MEF UNIVERSITY

FACULTY OF ENGINEERING

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Project Title	: Redesign of the Modelling Department at FLO
Student(s) Name	: Aybike Dilek
	Emir Doğanay
	Serdar Kami Üçkardeş
Date	: 11/01/2019

I hereby state that the design project prepared by Your Name (Title Format) has been completed under my supervision. I accept this work as a "Senior Design Project".

dd/mm/yyyy

Advisor's Name (Asst. Prof. ...)

I hereby state that I have examined this senior design project by Your Name (Title Format). This work is acceptable as a “Senior Design Project”.

dd/mm/yyyy
Department Chair’s Name

Head of the Department of
Industrial Engineering

ACADEMIC HONESTY PLEDGE

In keeping with MEF University Student Code of Conduct, I pledge that this work is my own and that I have not received inappropriate assistance in its preparation. I further declare that all resources are explicitly cited.

NAME	DATE	SIGNATURE
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ABSTRACT

REDESIGN OF THE MODELLING DEPARTMENT AT FLO

Aybike Dilek
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Serdar Kami Üçkardeş

MEF UNIVERSITY
Faculty of Engineering
Department of Industrial Engineering

Advisor: Asst. Prof. Utku Koç

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It is essential for companies to get the maximum yield using the least amount of resources. Most companies, however, use many resources that they consider necessary to increase the efficiency, but they are unimportant.

The purpose of this project is to measure the efficiency of FLO's reconstructed modelling department and to suggest a better solution accordingly. For this purpose, a simulation model that simulates the existing system will be prepared with Arena Software, the actual data will be entered and the results of different scenarios will be observed.

Keywords: Simulation, Department Reorganization, Arena Software

ÖZET

FLO'NUN MODELLEME DEPARTMANININ YENİDEN TASARIMI

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Endüstri Mühendisliği Bölümü

Tez Danışmanı: Asst. Prof. Utku Koç

Ocak, 2019

Şirketler için en az kaynağı kullanarak en fazla verimi almak çok önemlidir. Fakat çoğu şirket verimi artırmak adına gerekli gördükleri ama aslında önemsiz olan pek çok kaynağı bilmeyerek kullanmaktadırlar.

Bu projenin amacı, FLO'nun yeniden tasarladığı modelleme depatmanının verimliliğinin ölçülmesi ve buna bağlı olarak daha iyi bir çözümün önerilmesidir. Bu amaç doğrultusunda Arena Yazılımı kullanılarak mevcut sistemi örnekleyen bir simülasyon modeli hazırlanacak ve gerçek veriler girilip, farklı senaryoların nasıl sonuçlandığı gözlemlenecektir.

Anahtar Kelimeler: Simülasyon, Departman Düzenleme,Arena Yazılımı

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1. INTRODUCTION

1.1. Project Description

The main topic of this project proposes a decision support tool that helps the management of FLO to improve the efficiency in the modelling department. The aim of the project is creating a representative simulation model of the modelling department and proposing the best option regarding the number of employees, work hours, waiting for schedules in different situations. In this project, the senior students of Industrial Engineering department of MEF University collaborated with FLO's modelling department.

1.1.1. Company Description

Ziylan Mağazacılık ve Pazarlama A.Ş is the largest shoe retailer in Turkey. It sells more than 26 million shoes per year in the domestic market through retail stores, wholesale and export markets.

The Group was established in a 50-square-meter small workshop in the early 1960's in Gaziantep and came into operation to manufacture tailored shoes. The small-scale mass production company moved to İstanbul in the 1970's. The company, commencing small-scaled mass production after a while, changed its course to Istanbul in 70's. Ahmet Ziylan, who founded Ziylan Ayakkabı in 1985, commenced mass production by manufacturing the first sports shoes there.

Today, Ziylan Group is by far in the leading position in retail shoe sector in Turkey with its licensed brands such as FLO, which is the first shoe store of Turkey offering current fashion and wide range of products at affordable prices; Polaris shoe group as had a significant success in the health and comfort domestic market with its '5 Point' product range. Kinetix is a sports shoe brand for the dynamic and energetic masses; Dockers by Gerli is a brand that attracts the urban, active, dynamic and self-confident. Lumberjack is a globally known brand that was acquired in 2012. Sport in Street is the new destination for sneaker shoes. The range of kids' shoes is complimented by the Spiderman, Ben 10 and the Winx collections.

With over 396 stores in the domestic market, Ziylan Group encompasses Flo, Polaris and Sport in Street brands shoes. Globally, Ziylan exports to over 25 countries worldwide. It also has 22 stores abroad.

Flo brand introduced the ‘’shoe store chain’’ system into Turkey in 2001 and now with over 200 stores is one of the most active representatives of Ziylan Group. Ziylan acquired internationally recognized Lumberjack brand in 2012.

The company today employs 5.000 people and manufactures more than 3.500.000 pairs of shoes per year.

E-mail: info@ziylan.com.tr

Web Link: http://www.ziylan.com.tr (http://www.ziylan.com.tr/en, n.d.)

1.1.2. Modelling Department (Production & Manufacturing Department)

Modelling department is one of the biggest department of the company. There are 68 employees in this department. Modelling department is divided into five divisions within itself. Which are; designing department, cutting department, sewing department, assembly department, and warehouse. Employee numbers are as follows; 23 designers, 5 of them are the manager, 45 production employees (employees who work at cutting, sewing, and assembly departments), 4 of them are the manager, two warehouse specialists and a manager of modelling department. There are some other departments than those mentioned above in the modelling department such as; export and kitchen. However, they have not been analyzed, because they do not affect the project directly or indirectly.

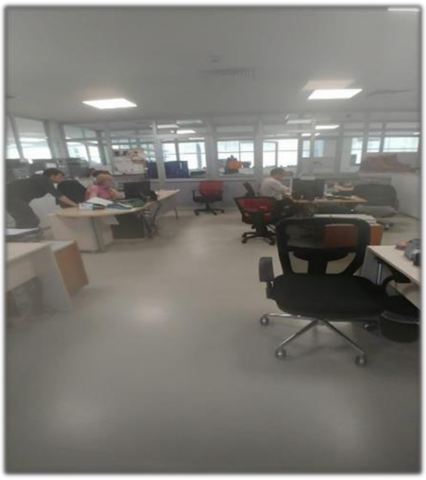
The cycle briefly runs in the modelling department as follows;

The draft of the footwear reaches the modelling department, and designers try to find the best materials (leather, sole, etc.) for that product. After making the decision, with using some programs (Shoemaster), they design and develop footwear. When the designing process is completed, warehouses’ work begins. They check stocks whether the selected material exists or not. If the material is not available, offices’ manager orders that. If it is, the production stage begins. Sample becomes ready by passing through cutting, sewing and assembly departments respectively. If the R&D Department accepts the sample, the sample passes the coloring phase and follows the same line.

1.1.2.1. Designing Department

Design department is the department where the process begins. Drafts, sketches, drawings, etc. from R&D Department or customers are modeled here. Since all the designers are specialized in some type of products, this department is also divided into 4 in itself. Which are;

1. "Men Shoe" designers, eight designers 2 of them are the manager,
2. "Woman Shoe" designers, seven designers 1 of them is the manager,
3. "Sports Shoe" designers, five designers 1 of them is the manager,
4. "Child Shoe" designers, three designers 1 of them is the manager.



Designers use some software (Shoemaster) and some advanced printers, there are two printers in the department, to complete their job. After these processes (modelling and printing) each designer prepares a folder and send them to the cutting department.

1.1.2.2. Cutting Department

The cutting department is the second station of the process. Cutting department employees collect required related components of products, if they are available (leather etc.), if not employee starts operation with similar material, just after taking the folder from the designer. There are 12 employees, 1 of them is the manager, in this department. Cutting operation times varies according to employees' seniority, footwears' complexity and the related phase. After the completion of cutting operation, the cut pieces and folder are transferred to the sewing department.

1.1.2.3. Sewing Department

The Sewing Department is the third stage of the operations. In this department pieces of footwear are sewn by highly skilled workers with using machines (post machine), eyelets, where the shoelaces would come from, are also added to footwear in this department. In the company, there are 20 employees, 1 of them is the manager, in the sewing department. Sewing operation times varies according to employees' seniority, footwear's complexity and the related phase. After the completion of sewing operation, the pieces are moved to the assembly (lasting) department.

1.1.2.4. Assembly (Lasting) Department

The Assembly Department is the fourth and the last stage of the preparation of shoe samples' operation. This department molds the top part "upper" into their final shape either on a wooden or a metal patter called "Last." That is why, the department is called "Lasting." Also, in this department workers add all the soles to footwear. The heel and the accessories are then attached (optional), which completes the assembly operation of the shoe. And the samples get ready. In Ziylan, there are ten employees, 1 of them is the manager and various machines in this department. The operation time in assembly department varies according to footwear's complexity and the related phase.

1.2. Problem Definition

Modelling Department has a sequential flow between internal modelling departments. This flow increases the waiting period in the queues, causes an uneven distribution of work among the employees and delay in serial production. All these negatively affect the Flow in an efficiency sense.

1.3. Motivation

Studying this project is essential because FLO has recently changed its modelling department organization. However, the management doesn’t know how this decision affects them concerning money and time usage. The simulation model will help us to determine the ideal number of employees needs to be hired and work schedule. Also, the simulation approach can be applied to similar operations with some changes which makes it quite useful.

1.4. Broad Impact

Since, no change has been made on the layout, machine type, scrap rate or material type; no impact on security, health or environment can be mentioned. However, there can be some consequences of firing some of the employees due to the low-level utilization. This situation creates an ethical and social problem. All the possible outcomes of a decision should be thought carefully so that no one suffers from that decision. Because, in case of any unjust treatment, the people may sue the company to get their rights and this will create some economic and social impact for the company. That is why, the company should use the employees in a different position within the company instead of removing them. It increases the company’ efficiency and reduces the broad negative impacts.

1.4. Success Criteria, Resource Estimation and Risk Analysis

The project will be counted as successful if the proposed simulation model represents the reality as much as possible and the analysis of the system can be applying to increase efficiency. The project does not require any physical resources to be used, but it is essential that having related information given by FLO to form the simulation model using Arena software. The significant risk of the project is that the simulation model does not reflect the real life. Because, in that case, the tool will be unable to generate appropriate solutions in different scenarios. Even if it does, it will be unreliable, and that means the failure of the project. Therefore, constant communication with the modelling team of FLO, to be sure about the validation and verification of the Arena Model, is highly essential throughout the project.

2. LITERATURE REVIEW

The papers we read during this study can be grouped under two main headings which are Simulation Approach and ARENA Usage.

Under Simulation Approach, we handled the studies about how to implement the simulation method into real-life cases by analyzing the examples. We can say that this part represents the theoretical part of the project where we prepare ourselves to create a representative simulation model of the system. On the other hand, we analyzed the studies about how a simulation model is designed in ARENA software technically. The general structure, working principle, and task of each node were understood under this section.

2.1. Simulation Approach

Altuger and Chassapis (2009) proposed a decision support system which line behavior and outcomes are obtained by using an Arena-based simulation model. Its primary purpose is to evaluate the results of different techniques and choose the best one among them. Another study by Wang et al. (2009) analyze the emergency services of hospitals and propose a simulation model to improve them. It is quite interesting that the study says "this simulation model can help us to identify process bottlenecks, and adjust resources allocation or staff dimensioning without disturbing the actual system" since we handle more or less the same topic. In all of the articles that we analyze, the researchers start with the conceptual model design and try to figure out how they convert it to an Arena model [1, 2, 3].

2.2. Arena Usage

Altuger and Chassapis (2009) explain how they build a simulation model for their purpose in detail. They first create the system flow by using the nodes that ARENA provides. Then, they put the numeric data related to the times, failures, reliabilities, etc. in the nodes and run the model. Another study belongs to Teilans et al. (2008) shows how to convert a UML diagram that describes the behavior of the system on the ARENA model and how to transform the models and algorithms later. Both of these studies help us to transfer the idea in our minds into ARENA simulation environment [1, 2, 3].

3. METHOD

We will first provide the problem definition of our study (Redesign of the Modelling Department at FLO), and then give the mathematical model that we propose as a solution method in this section.

3.1. Simulation Model Objective

The aim is to reorganize the Modelling Department and find the feasible solution to improve efficiency and effectiveness in each internal department. In the solution part of the problem, a simulation model was designed according to a real current system of the Modelling Department. The Arena software was used to develop the simulation model.

3.2. System Description

In the Modelling Department, the system starts with the designing process in the design department. After this process, a sample goes to the cutting department, sewing department, and assembly department respectively. We called this process as sampling phase.

After the Assembly Department Process, the designer of the sample checks sample' quality, and if the sample has any problem, the sample goes to the design department and produces again. We called this process with another name as rework because, on this process, sample' process times are different than the sampling process.

According to this flow, after assembly operation, the sample can go to rework, or it can go to the launch process (R&D Checking Process), directly. Each sample can rework at most one time with 40% possibility.

If the sample goes to rework operation, the sample will follow same procedures with different processing times. Then; reworked sample goes to the launch process (R&D Checking Process)

Otherwise, the sample goes directly to launch process (R&D Checking Process) without rework operation, and it completes the sampling phase.

In the launch process (R&D Checking Process), some of the samples are eliminated. The elimination process takes inconstant time according to workload level of the R&D Department. If a sample passes the launch, it goes to the coloring phase.

In the coloring phase, the sample goes design department again and follows the same procedure until the tooling process. In average three, four, five and six colors of the sample are produced in the coloring phase. All generated color sets go to tooling phase. The system was simulated two months' period according to the company's interest.

3.3 Arena Model Description

Input data has been checked many times; the company has visited numbers of times and meetings has been appointed several times, to make the simulation model and its' outputs reliable. Observations and the description of the simulation model are as follows:

(PRIVATE INFO)

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

3.3.1. Arena Model Verification

A basic model was created according to the system description. After that, interviews were made with the company to ensure verification phase. During company visits, feedbacks were also taken from the Modelling Department Manager and updated simulation model dynamically. At the end of the semester the Manager approved simulation model and the created model has been finalized.

3.3.2. Arena Model Validation

The data, which shows the process time of each department, was shared with us ,and analyzed using Input Analyzer and Excel. It is observed that the data, which was obtained from the company, was not reliable, and decided to collect data during the summer period. In the Summer Period, the data collection process could not be done because of some technical problems. During the second semester, the data on hand is updated (process times) according to discussions with employees in each department and the manager's observations. After the completion of 'process time update' process, the results were reported to the manager. Then, the results of arena model and the managers' output results were compared. Also, the arena model was run for 100 replications, and the average value for each variable is ued, which was in the report. The results, which is provided by the manager's data, was in our model's confidence interval. The value of half-with was used to define the model's confidence interval.

	OUTPUTS								
	Utilizations							Results	
	Designers				Operators				
Scenarios / Variables	Man	Woman	Child	Sport	Cutting	Sewing	Assembly	# Accepted Model	Color Set
Half Width	< 2%							2,36	8,37

Fig:1 Half-width range for the model

4. ANALYSIS

4.1 Input and Output Analysis

After the validation process, work on the improvement process was started, which was the second step of senior design project. The arena report is analyzed, and the variables determined.

Two types of variable were used. These were input variables and output variables. In the sensitivity analysis, input variables were changed in each scenario, and the output variables were used to do analysis.

It was proved that, there was an uneven workload distribution in the Modelling Department, with our arena model. First, the value of utilization for each internal department was checked. According to the utilization results, the worker numbers in each internal department were changed one by one on the experimental phase. That was why, the first input variables were worker numbers in each internal department and the first output variable was utilization levels of each internal departments.

Then, the time constraint was checked, and wanted to see the effect of time, on the number of our color sets and samples. The second input variable was time (runtime) and output variables were the number of color sets and number of samples produced.

Lastly, it was desired to observe whether the change in the number of drafts had any effect on the number of color sets and number of samples. The number of drafts were defined as the last input variable of the system.

As a summary, input variables of the system are the number of Man Designer, number of Women Designer, number of Child Designer, number of Sports Designers, number of Cutting Employees, number of Sewing Employees, capacity of Assembly department, amount of drafts send by R&D and work time.

Each input variable were changed one by one to analyze system sensitivity and each scenario was worked for 100 replications to obtain more reliable results.

Utilization level of each internal department, approved sample amount and the amount of color sets were taken as output variables.

4.2 Base Scenario

After the definition of inputs and outputs, the current system's inputs were entered to the created Arena simulation model to get the outputs. These were the current system's inputs, which were obtained from the company.

	INPUTS									
	Resources							Time (hour)	# Ordered Model	Approval Time (day)
	Designers				Operators					
Scenarios / Variables	Man	Woman	Child	Sport	Cutting	Sewing	Assembly			
Base Scenario	8	7	3	5	12	10	14	550	1500	13

Fig:2 Input variables of the current system.

With entering the inputs above, to the simulation model, the following outputs were obtained:

	OUTPUTS								
								Results	
Scenarios / Variables	Man	Woman	Child	Sport	Cutting	Sewing	Assembly	# Accepted Model	Color Set
Base Scenario	57.80%	57.70%	38.30%	43.10%	84.90%	80.18%	76.99%	1238	4531

Fig:3 Output variables of the current system.

According to outputs of the current system, it was recognized that; Man designer's utilization was 57.80 %, woman designer's utilization was 57.70 %, child designer's utilization was 38.30%, and lastly, the sports designer's utilization was 43.10 %. It was recognized that man and women designers were busier than child and sports designers in designing department

Cutting department's utilization was 84.09 %, sewing department's utilization was 80.18%, and assembly department's utilization was 76.99% in the current system of modelling department. In overall, designers work less than operators in current system because the simulation model simulates last 50 days of the modelling department, and in that period nearly after 35 days, the draft coming process ends which reduces the utilization of designers, and operator tries to prepare color sets. Totally 1500 drafts come to modelling department in 50 days period, and nearly after 35 days the draft transfer ends because the drafts come with this distribution Expo(15) minutes.

Lastly, the number of the color set produced was average 4531 and accepted model number was average 1238 out of 1500 at the end of the season. The numbers were average values, because the simulation model was run 100 times (replications) for the basic scenario. Basic scenario was used in the analysis phase as a base.

4.3 Design of Experiments

The experiments are designed for each input variables and its different values. The result of each different scenario was also recorded in an excel file.

	INPUTS										OUTPUTS								
	Resources							Time (hour)	# Ordered Model	Approval Time (day)	Utilizations							Results	
	Designers				Operators						Designers				Operators				
Scenarios / Variables	Man	Woman	Child	Sport	Cutting	Sewing	Assembly				Man	Woman	Child	Sport	Cutting	Sewing	Assembly	# Accepted Model	Color Set
Base Scenario	8	7	3	5	12	10	14	550	1500	13	57.80%	57.70%	38.30%	43.10%	84.90%	80.18%	76.99%	1238.0	4531.0
Man	10	7	3	5	12	10	14	550	1500	13	46.11%	57.71%	38.64%	43.23%	84.64%	80.18%	77.00%	1238.0	4535.0
	9	7	3	5	12	10	14	550	1500	13	51.56%	57.50%	38.34%	43.21%	85.02%	80.27%	77.09%	1238.0	4540.0
	7	7	3	5	12	10	14	550	1500	13	66.23%	57.53%	37.93%	43.41%	84.90%	80.15%	76.97%	1237.0	4534.0
	6	7	3	5	12	10	14	550	1500	13	76.06%	58.12%	38.47%	43.34%	84.71%	79.99%	76.81%	1230.0	4517.0
Woman	8	9	3	5	12	10	14	550	1500	13	57.91%	44.82%	38.48%	43.02%	84.96%	80.22%	77.01%	1235.0	4535.0
	8	8	3	5	12	10	14	550	1500	13	58.04%	50.33%	38.34%	43.06%	84.97%	80.23%	77.03%	1235.0	4540.0
	8	6	3	5	12	10	14	550	1500	13	57.89%	67.19%	38.29%	43.19%	84.85%	80.13%	76.94%	1235.0	4529.0
	8	5	3	5	12	10	14	550	1500	13	58.14%	79.92%	38.66%	43.18%	84.63%	79.90%	76.73%	1229.0	4508.0
Child	8	7	5	5	12	10	14	550	1500	13	57.52%	57.88%	23.33%	43.00%	84.88%	80.14%	76.95%	1237.0	4533.0
	8	7	4	5	12	10	14	550	1500	13	57.66%	57.67%	28.92%	43.30%	84.93%	80.19%	77.00%	1236.0	4533.0
	8	7	2	5	12	10	14	550	1500	13	57.86%	57.57%	57.36%	43.36%	84.90%	80.15%	76.99%	1238.0	4531.0
Sport	8	7	3	7	12	10	14	550	1500	13	57.57%	58.05%	38.61%	30.57%	85.00%	80.27%	77.07%	1237.0	4541.0
	8	7	3	6	12	10	14	550	1500	13	57.60%	58.00%	38.72%	35.74%	85.00%	80.27%	77.10%	1235.0	4538.0
	8	7	3	4	12	10	14	550	1500	13	57.59%	57.88%	38.34%	54.10%	84.86%	80.12%	76.94%	1235.0	4530.0
	8	7	3	3	12	10	14	550	1500	13	57.92%	57.52%	39.11%	70.84%	84.74%	80.01%	76.85%	1234.0	4525.0
Cutting	8	7	3	5	14	10	14	550	1500	13	58.16%	57.83%	38.44%	43.25%	82.99%	83.64%	80.43%	1266.0	4791.0
	8	7	3	5	13	10	14	550	1500	13	58.17%	57.81%	38.43%	43.36%	83.91%	83.68%	80.45%	1266.0	4793.0
	8	7	3	5	11	10	14	550	1500	13	57.40%	57.48%	38.17%	42.62%	86.08%	74.43%	71.28%	1191.0	4085.0
	8	7	3	5	10	10	14	550	1500	13	56.78%	56.95%	37.54%	42.40%	87.43%	68.61%	65.53%	1132.0	3648.0
Sewing	8	7	3	5	12	12	14	550	1500	13	58.00%	57.45%	38.20%	43.23%	84.92%	66.83%	77.03%	1238.0	4537.0
	8	7	3	5	12	11	14	550	1500	13	57.97%	57.73%	38.65%	42.54%	84.93%	72.91%	77.00%	1239.0	4538.0
	8	7	3	5	12	9	14	550	1500	13	57.54%	57.57%	38.10%	42.63%	84.89%	84.97%	73.30%	1206.0	4248.0
	8	7	3	5	12	8	14	550	1500	13	56.87%	56.97%	37.84%	42.63%	84.97%	86.63%	66.20%	1141.0	3691.0
Assembly	8	7	3	5	12	10	16	550	1500	13	57.68%	57.70%	38.73%	43.16%	84.89%	80.17%	67.35%	1238.0	4532.0
	8	7	3	5	12	10	15	550	1500	13	57.98%	57.48%	38.22%	43.26%	84.91%	80.18%	71.86%	1237.0	4532.0
	8	7	3	5	12	10	13	550	1500	13	57.78%	57.70%	38.78%	42.88%	84.92%	80.18%	82.63%	1235.0	4512.0
	8	7	3	5	12	10	12	550	1500	13	57.44%	57.40%	38.51%	42.69%	84.91%	80.17%	84.16%	1195.0	4152.0
Time	8	7	3	5	12	10	14	500	1500	13	62.62%	62.43%	41.48%	46.83%	83.38%	78.58%	75.16%	1138.0	3873.0
	8	7	3	5	12	10	14	525	1500	13	60.30%	60.11%	39.96%	45.01%	84.17%	79.41%	76.08%	1199.0	4188.0
	8	7	3	5	12	10	14	575	1500	13	55.68%	55.51%	36.89%	41.46%	85.55%	80.88%	77.81%	1275.0	4860.0
	8	7	3	5	12	10	14	600	1500	13	53.69%	53.53%	35.58%	39.93%	86.15%	81.52%	78.56%	1318.0	5185.0
Approval Time (day)	8	7	3	5	12	10	14	550	1500	2	58.18%	58.58%	38.60%	43.66%	97.21%	92.02%	88.78%	1311.0	5464.0
	8	7	3	5	12	10	14	550	1500	5	58.14%	58.64%	39.21%	43.23%	93.90%	88.82%	85.61%	1309.0	5198.0
	8	7	3	5	12	10	14	550	1500	10	58.26%	57.64%	38.94%	43.57%	88.27%	83.40%	80.20%	1280.0	4764.0
	8	7	3	5	12	10	14	550	1500	12	57.91%	57.82%	38.59%	43.11%	86.06%	81.28%	78.12%	1252.0	4615.0
	8	7	3	5	12	10	14	550	1500	14	57.66%	57.69%	38.54%	42.82%	83.79%	79.09%	75.92%	1223.0	4457.0
	8	7	3	5	12	10	14	550	1500	15	57.60%	57.78%	38.06%	42.85%	82.69%	78.03%	74.85%	1214.0	4369.0

Fig:4 Design of Experiments with one variable change

4.4 Output Analysis

According to the design of experiments, the analysis of outputs was done with the advisor. It was dedicated to investigating each scenario with single variable change and some scenarios with multivariable change. The output analysis was done by comparing color set amount of each scenario and base scenario.

4.4.1. Scenarios with single variable change

These were the scenarios with single variable change, which were investigated to find improvements in the system.

	INPUTS										OUTPUTS									ANALYSIS
	Resources							Time (hour)	# Ordered Model	Approval Time (day)	Utilizations							Results		% Change
	Designers				Operators						Designers				Operators					
Scenarios / Variables	Man	Woman	Child	Sport	Cutting	Sewing	Assembly				Man	Woman	Child	Sport	Cutting	Sewing	Assembly	#Accepted Model	Color Set	
Man	10	7	3	5	12	10	14	550	1500	13	46.11%	57.71%	38.64%	43.23%	84.64%	80.18%	77.00%	1238	4535	0.09%
	9	7	3	5	12	10	14	550	1500	13	51.56%	57.50%	38.34%	43.21%	85.02%	80.27%	77.09%	1238	4540	0.20%
	8	7	3	5	12	10	14	550	1500	13	57.80%	57.70%	38.30%	43.10%	84.90%	80.18%	76.99%	1238	4531	0.00%
	7	7	3	5	12	10	14	550	1500	13	66.23%	57.53%	37.93%	43.41%	84.90%	80.15%	76.97%	1237	4534	0.07%
	6	7	3	5	12	10	14	550	1500	13	76.06%	58.12%	38.47%	43.34%	84.71%	79.99%	76.81%	1230	4517	-0.31%

Fig:5 Man Designer effects on the system

Man Designer number were changed one by one to understand man designer’s effects on the number of the color set. When one unit of man designer number was increased, it had no significant effect on outputs regarding color set. This scenario was the same for two unit increase according to base scenario that means we increased the number of man designer from 8 to 10. It didn’t increase the system’s output significantly according to the base scenario. Lastly, the number of man designer were decreased by one and two unit, it was observed that decreases also had no effects on outputs.

When we increased the number of man designer, man designer’s utilization ratio decreased or when we decreased the number of man designer, man designer’s utilization ratio increased as we expected.

When we increased the number of man designer from 8 to 9, the outcomes became 4540 from 4531, but when we increased number of man designer from 8 to 10, the results became 4535 from 4531. This difference occurred because we took 100 runs for each scenario. These values were average of 100 runs.

Arena Simulation model produces average values for more than one replications. These average values can be different for every 100 runs because the model works different randomization in confidence interval for each run.

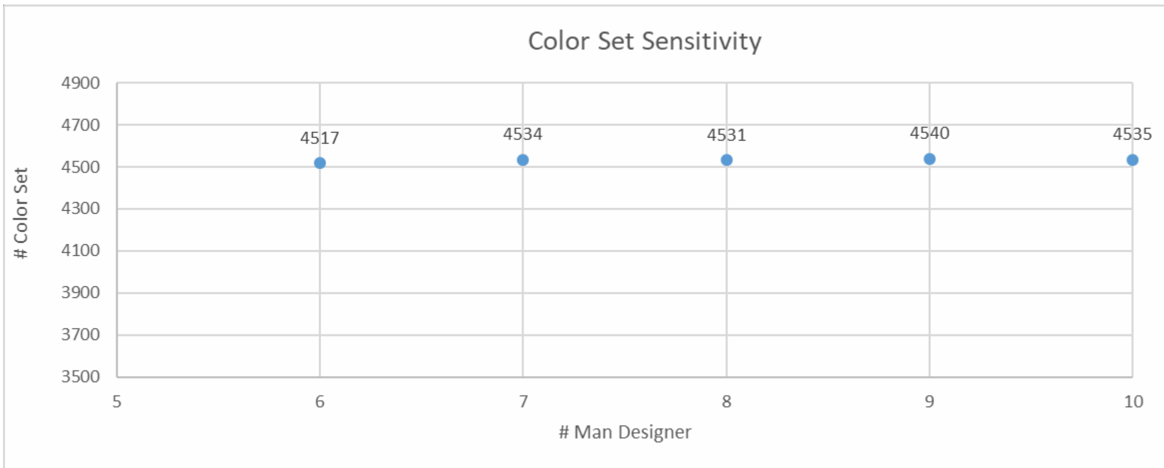


Fig 6: Scatter plot of man designer effects on the number of the color set.

We could explain the scatter plot as there was no significant effect on the number of the color set when we increased or decreased the number of men designer one or two units according to the base scenario.

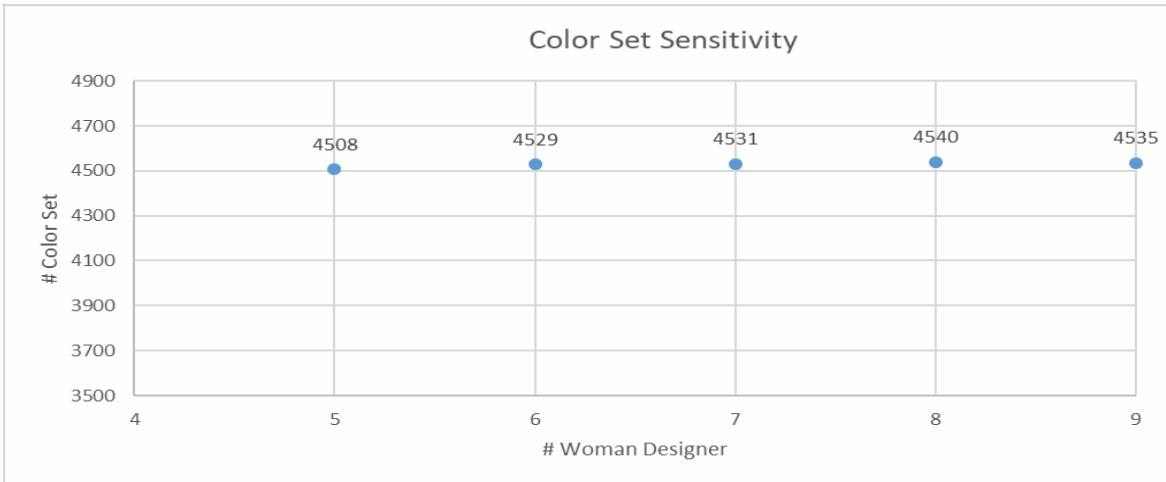


Fig 7: Scatter plot of woman designer effects on the number of the color set.

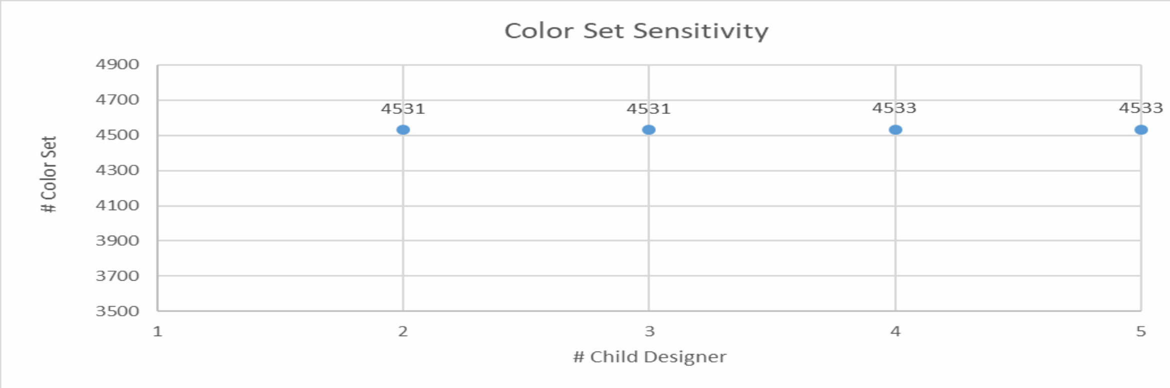


Fig 8: Scatter plot of child designer effects on the number of the color set.

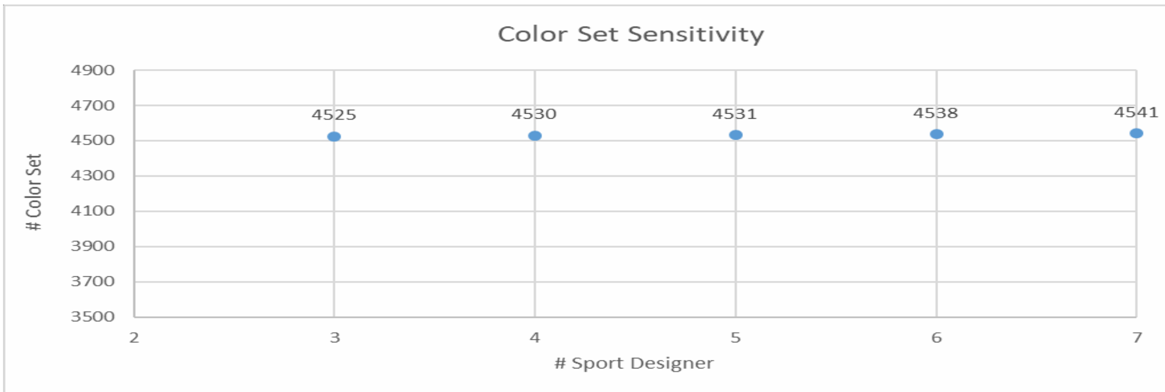


Fig 9: Scatter plot of sport designer effects on the number of the color set.

Also, the above scenario was applicable and the same for all remaining type of designers (Woman, Child, and Sport).

	INPUTS										OUTPUTS									ANALYSIS
	Resources							Time (hour)	# Ordered Model	Approval Time (day)	Utilizations							Results		% Change
	Designers				Operators						Designers				Operators					
Scenarios / Variables	Man	Woman	Child	Sport	Cutting	Sewing	Assembly				Man	Woman	Child	Sport	Cutting	Sewing	Assembly	#Accepted Model	Color Set	
Cutting	8	7	3	5	14	10	14	550	1500	13	58.16%	57.83%	38.44%	43.25%	82.99%	83.64%	80.43%	1266	4793	5.78%
	8	7	3	5	13	10	14	550	1500	13	58.17%	57.81%	38.43%	43.36%	83.91%	83.68%	80.45%	1266	4791	5.74%
	8	7	3	5	12	10	14	550	1500	13	57.80%	57.70%	38.30%	43.10%	84.90%	80.18%	76.99%	1238	4531	0.00%
	8	7	3	5	11	10	14	550	1500	13	57.40%	57.48%	38.17%	42.62%	86.08%	74.43%	71.28%	1191	4085	-9.84%
	8	7	3	5	10	10	14	550	1500	13	56.78%	56.95%	37.54%	42.40%	87.43%	68.61%	65.53%	1132	3648	-19.49%

Fig 10: Cutting Employee effects on the system

We changed Cutting Employee number one by one to understand cutting employee' effects on the number of the color set. When we increased one unit cutting employee number, it had a significant effect on outputs in terms of the color set. This scenario wasn't the same for two unit increase according to base scenario, that means we increased the number of cutting employee from 12 to 14 the system didn't improve as much as one unit increase. It didn't increase the system's output significantly according to the one unit increasing scenario. Lastly, when we decreased the number of cutting employee, which affected the system significantly for one or two unit decrease. The total number of color set changed -9.84% for one unit decrease scenario and – 19.49% for two unit decrease scenario.

When we increased the number of cutting employee, cutting employee's utilization ratio decreased or when we reduced the number of cutting employee, cutting employee's utilization ratio increased as we expected.

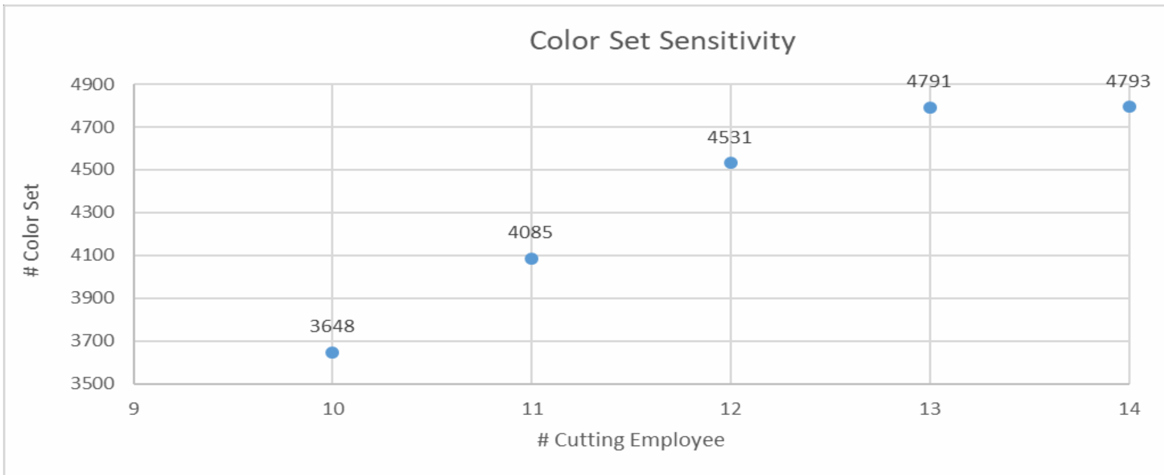


Fig 11: Scatter plot of cutting employee effects on the number of the color set.

We could explain the scatter plot as there was a significant effect on the number of the color set when we increased or decreased the number of cutting employee one unit according to the base scenario. Also, we observed that 13 cutting employee was an ideal number of cutting worker for the system. The system' number of cutting employee was increased more than one unit according to the base scenario; the color set didn't change significantly. When the system' number of cutting employee was reduced under 13 cutting employee, the outputs decreased rapidly.

	INPUTS										OUTPUTS									ANALYSIS
	Resources							Time (hour)	# Ordered Model	Approval Time (day)	Utilizations							Results		% Change
	Designers				Operators						Designers				Operators					
Scenarios / Variables	Man	Woman	Child	Sport	Cutting	Sewing	Assembly				Man	Woman	Child	Sport	Cutting	Sewing	Assembly	# Accepted Model	Color Set	
Sewing	8	7	3	5	12	12	14	550	1500	13	58.00%	57.45%	38.20%	43.23%	84.92%	66.83%	77.03%	1238	4538	0.15%
	8	7	3	5	12	11	14	550	1500	13	57.97%	57.73%	38.65%	42.54%	84.93%	72.91%	77.00%	1239	4537	0.13%
	8	7	3	5	12	10	14	550	1500	13	57.80%	57.70%	38.30%	43.10%	84.90%	80.18%	76.99%	1238	4531	0.00%
	8	7	3	5	12	9	14	550	1500	13	57.54%	57.57%	38.10%	42.63%	84.89%	84.97%	73.30%	1206	4248	-6.25%
	8	7	3	5	12	8	14	550	1500	13	56.87%	56.97%	37.84%	42.63%	84.97%	86.63%	66.20%	1141	3691	-18.54%

Fig 12: Sewing Employee effects on the system

In the simulation model, instead of taking the number of employee in the sewing department as 20, we received the number of employee in the sewing department as10 because two workers need to work together to complete one shoe in the system.

We changed Sewing Employee number one by one to understand sewing employee' effects on the number of the color set. When we increased one unit sewing employee, it had no significant effect on outputs in terms of the color set. This scenario was the same for two unit increase according to base scenario that means we increased the capacity of assembly department from 10 to 12. It didn't increase the system's output significantly according to the base scenario.

Lastly, when we decreased the number of sewing employee that affected the system significantly for one or two unit decrease. The total number of color set changed -6.25% for one unit decrease scenario and – 18.54% for two unit decrease scenario.

When we increased the number of sewing employee, sewing employee's utilization ratio decreased, or when we decreased the number of sewing employee, sewing employee's utilization ratio increased as we expected.

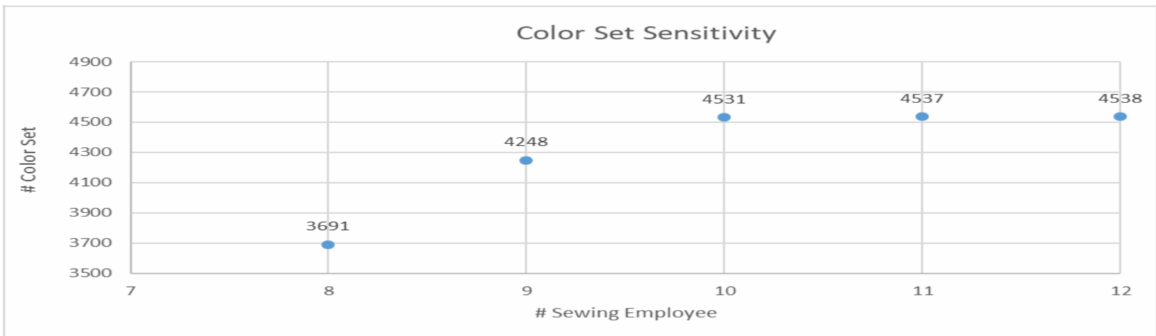


Fig 13: Scatter plot of sewing employee effects on the number of the color set.

We could explain the scatter plot as there wasn't a significant effect on the number of the color set when we increased the number of sewing employee one or two units according to the base scenario. Also, we observed that 10 number of sewing employee was an ideal number for the system. When we decreased the number of sewing employee under 10, the output number decreased rapidly.

	INPUTS										OUTPUTS									ANALYSIS
	Resources							Time (hour)	# Ordered Model	Approval Time	Utilizations							Results		% Change
	Designers				Operators						Designers				Operators					
Scenarios / Variables	Man	Women	Child	Sport	Cutting	Sewing	Assembly				Man	Women	Child	Sport	Cutting	Sewing	Assembly	# Accepted Model	Color Set	
Assembly	8	7	3	5	12	10	16	550	1500	13	57.68%	57.70%	38.73%	43.16%	84.89%	80.17%	67.35%	1238	4533	0.04%
	8	7	3	5	12	10	15	550	1500	13	57.98%	57.48%	38.22%	43.26%	84.91%	80.18%	71.86%	1237	4532	0.02%
	8	7	3	5	12	10	14	550	1500	13	57.80%	57.70%	38.30%	43.10%	84.90%	80.18%	76.99%	1238	4531	0.00%
	8	7	3	5	12	10	13	550	1500	13	57.78%	57.70%	38.78%	42.88%	84.92%	80.18%	82.63%	1235	4512	-0.42%
	8	7	3	5	12	10	12	550	1500	13	57.44%	57.40%	38.51%	42.69%	84.91%	80.17%	84.16%	1195	4152	-8.36%

Fig 14: Assembly Employee effects on the system

In the simulation model, instead of the number of employees, who were working in the assembly department, the capacity of the department was taken as a resource because there was a serial complex workflow in the assembly department.

We changed Assembly Capacity one by one to understand assembly capacity' effects on the number of the color set. When we increased one unit assembly capacity, it had no significant effect on outputs in terms of the color set. This scenario was the same for two unit increase according to base scenario that means we increased the capacity of assembly department from 14 to 16. It didn't increase the system's output significantly according to the base scenario. Lastly, when we decreased the capacity of the assembly department that affected the system significantly for two unit decrease. The total number of color set changed -8.36% for two units, but for one unit decrease, it had no significant effect on outputs regarding the color set.

When we increased the capacity of the assembly department, assembly department's utilization ratio decreased, or when we decreased the capacity of the assembly department, assembly department's utilization ratio increased as we expected.

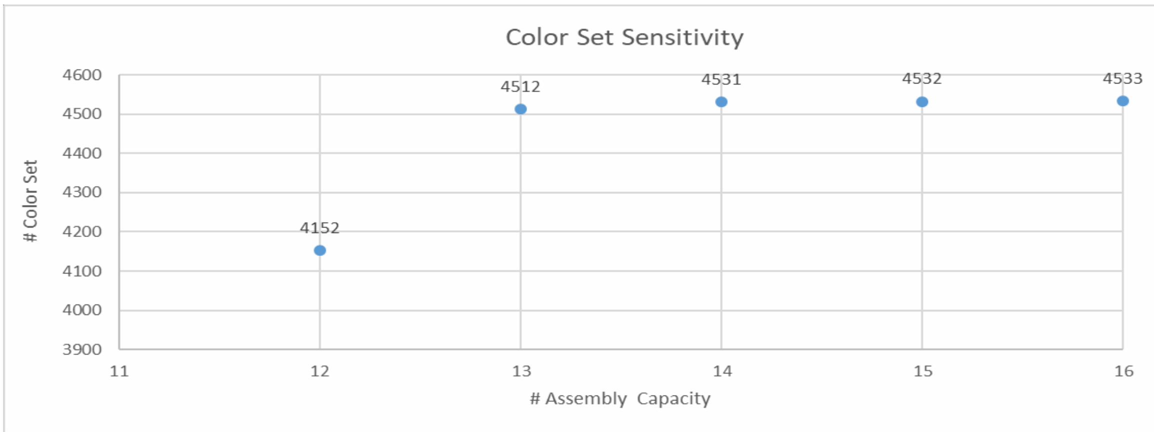


Fig 15: Scatter plot of assembly capacity effects on the number of the color set.

We could explain the scatter plot as there wasn't a significant effect on the number of the color set when we increased the capacity of assembly department one or two units according to the base scenario. Also, we observed that 13 assembly capacity was an ideal number for the system. When we decreased the capacity level under 13, the output number decreased rapidly.

	INPUTS										OUTPUTS									ANALYSIS
	Resources							Time (hour)	# Ordered Model	Approval Time (day)	Utilizations							Results		% Change
	Designers				Operators						Designers				Operators					
Scenarios / Variables	Man	Woman	Child	Sport	Cutting	Sewing	Assembly				Man	Woman	Child	Sport	Cutting	Sewing	Assembly	#Accepted Model	Color Set	
Time	8	7	3	5	12	10	14	500	1500	13	62.62%	62.43%	41.48%	46.83%	83.38%	78.58%	75.16%	1138	3873	-14.52%
	8	7	3	5	12	10	14	525	1500	13	60.30%	60.11%	39.96%	45.01%	84.17%	79.41%	76.08%	1199	4188	-7.57%
	8	7	3	5	12	10	14	550	1500	13	57.80%	57.70%	38.30%	43.10%	84.90%	80.18%	76.99%	1238	4531	0.00%
	8	7	3	5	12	10	14	575	1500	13	55.68%	55.51%	36.89%	41.46%	85.55%	80.88%	77.81%	1275	4860	7.26%
	8	7	3	5	12	10	14	600	1500	13	53.69%	53.53%	35.58%	39.93%	86.15%	81.52%	78.56%	1318	5185	14.43%

Fig 16: Time effects on the system

We changed the working time of the system to understand run time' effects on the number of the color set. When we increased the employed amount of the system, the color set amount increased linearly, or when we decreased the working amount of the system, the color set amount decreased linearly. Like when we raised the running time from 550 to 575, the color set amount increased to 7.25% or when we reduced the running time from 550 to 525, the color set amount decreased as 7.57%.

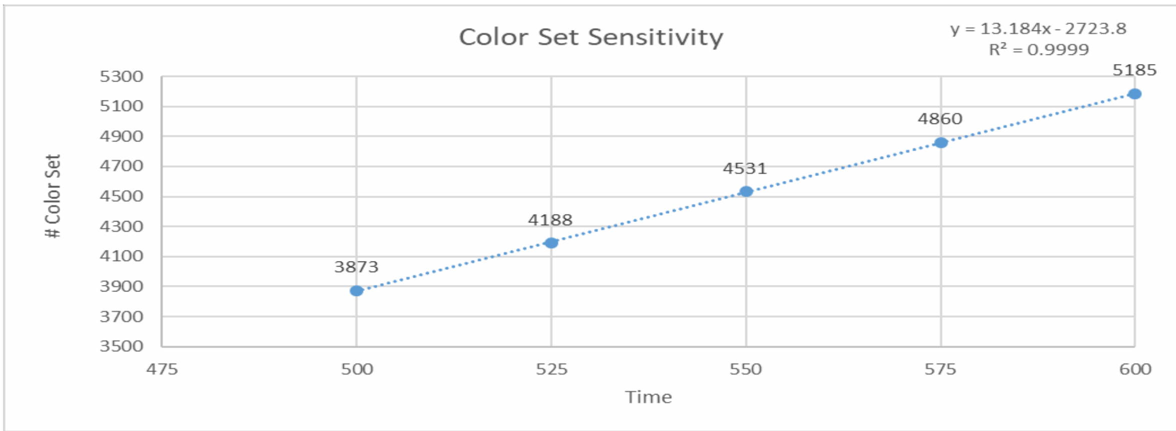


Fig 17: Scatter plot of time effects on the number of the color set.

We could explain the scatter plot as there was a positive, strong linear relationship between time and color set amount. We defined this relationship with a mathematical equation on the graph. That means, when we increase one unit of time, it increases average 13.184 units of the color set end of the season. This equation provides forecast opportunity for the company.

	INPUTS										OUTPUTS									ANALYSIS
	Resources							Time (hour)	# Ordered Model	Approval Time (day)	Utilizations							Results		% Change
	Designers				Operators						Designers				Operators					
Scenarios / Variables	Man	Woman	Child	Sport	Cutting	Sewing	Assembly				Man	Woman	Child	Sport	Cutting	Sewing	Assembly	# Accepted Model	Color Set	
Approval Time (day)	8	7	3	5	12	10	14	550	1500	2	58.18%	58.58%	38.60%	43.66%	97.21%	92.02%	88.78%	1311	5464	20.59%
	8	7	3	5	12	10	14	550	1500	5	58.14%	58.64%	39.21%	43.23%	93.90%	88.82%	85.61%	1309	5198	14.72%
	8	7	3	5	12	10	14	550	1500	10	58.26%	57.64%	38.94%	43.57%	88.27%	83.40%	80.20%	1280	4764	5.14%
	8	7	3	5	12	10	14	550	1500	12	57.91%	57.82%	38.59%	43.11%	86.06%	81.28%	78.12%	1252	4615	1.85%
	8	7	3	5	12	10	14	550	1500	13	57.80%	57.70%	38.30%	43.10%	84.90%	80.18%	76.99%	1238	4531	0.00%
	8	7	3	5	12	10	14	550	1500	14	57.66%	57.69%	38.54%	42.82%	83.79%	79.09%	75.92%	1223	4457	-1.63%
	8	7	3	5	12	10	14	550	1500	15	57.60%	57.78%	38.06%	42.85%	82.69%	78.03%	74.85%	1214	4369	-3.58%

Fig 18: Approval Time effects on the system

We changed the approval time of the system to understand approval time 'effects on the number of the color set. When we increased the approval time of the system, the color set amount decreased rapidly, or when we reduced the approval time of the system, the color set amount quickly increased. Like when we increased approval time from 13 to 14, the color set amount decreased as 1.63 %, or when we decreased the approval time from 13 to 12, the color set amount increased as 1.83%.

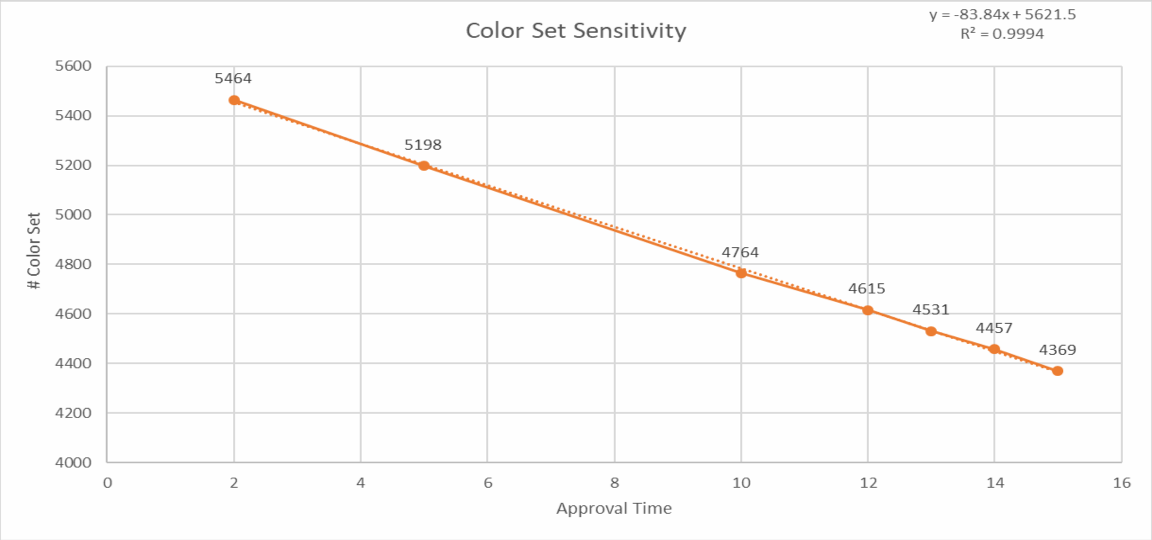


Fig 19: Scatter plot of time effects on the number of the color set.

We could explain the scatter plot as there was a negative linear relationship between approval time and color set amount. We defined this relationship with a mathematical equation on the graph. That means, when we increase one unit of approval time, it decreases average 83.84 units of the color set end of the season. This equation provides forecast opportunity for the company.

4.4.2 Sensitivity Analysis

After the investigation of each single variable change scenario, the sensitivity analysis was done for the one-unit changes of each variable.

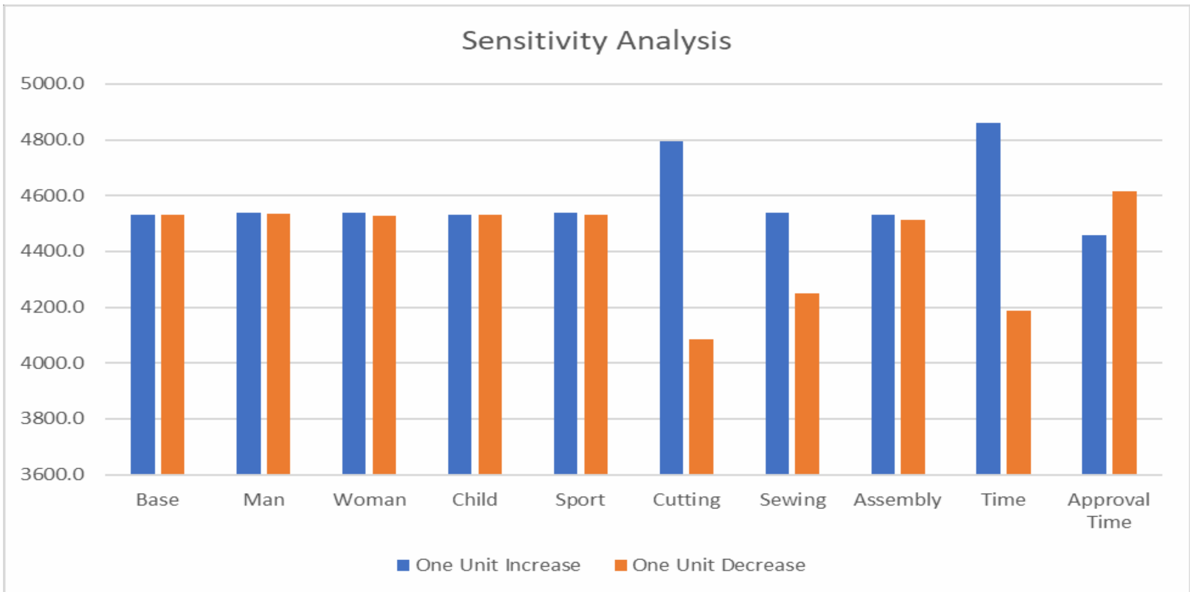


Fig:20 Sensitivity Analysis Chart

We observed cutting, sewing, time and approval time variables affected the system in terms of the number of the color set when one unit increase or decrease in these variables according to the sensitivity chart. The designer didn't affect the system, and the effect of the assembly capacity was negligible.

4.4.3 Scenarios with multivariable change

According to the single variable change scenarios, some multivariable change scenarios were also run.

	INPUTS										OUTPUTS									ANALYSIS
	Resources							Time (hour)	# Ordered Model	Approval Time (day)	Utilizations							Results		% Change
	Designers				Operators						Designers				Operators					
Scenarios / Variables	Man	Woman	Child	Sport	Cutting	Sewing	Assembly				Man	Woman	Child	Sport	Cutting	Sewing	Assembly	#Accepted Model	Color Set	
Base Scenario	8	7	3	5	12	10	14	550	1500	13	57.80%	57.70%	38.30%	43.10%	84.90%	80.18%	76.99%	1238	4531	
S1	8	7	2	5	13	10	14	550	1500	13	57.78%	57.86%	58.34%	43.68%	83.94%	83.71%	80.46%	1265	4796	5.85%

Fig 21: Child Designer and Cutting Employee simultaneous effect on the system

When the number of child designer was decreased from 3 to 2, and the number of cutting employee was increase from 12 to 13, the color set amount increased as 5.85% with the same run time according to the base scenario.

	INPUTS										OUTPUTS									ANALYSIS
	Resources							Time (hour)	# Ordered Model	Approval Time (day)	Utilizations							Results		%Change
	Designers				Operators						Designers				Operators					
Scenarios / Variables	Man	Woman	Child	Sport	Cutting	Sewing	Assembly				Man	Woman	Child	Sport	Cutting	Sewing	Assembly	#AcceptedModel	ColorSet	
Base Scenario	8	7	3	5	12	10	14	550	1500	13	57.80%	57.70%	38.30%	43.10%	84.90%	80.18%	76.99%	1238	4531	
S1	8	7	2	5	13	10	14	550	1500	13	57.78%	57.86%	58.34%	43.68%	83.94%	83.71%	80.46%	1265	4796	5.85%
S2	8	7	2	4	13	11	14	550	1500	13	58.30%	58.17%	57.89%	53.79%	83.91%	78.11%	82.20%	1282	4926	8.72%

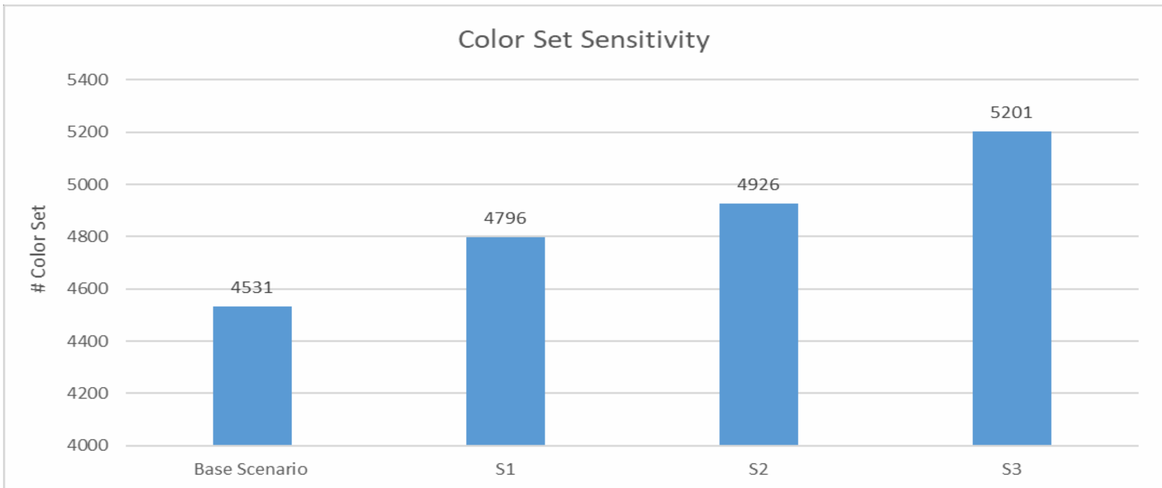
Fig 22: Child Designer, Cutting Employee, Sewing Employee, and Sport Designer simultaneous effect on the system

When the number of child designers and sport designers were decreased to 2 and 4 respectively, and the number of cutting employees and sewing employees were increased to 13 and 11 respectively, the color set amount increased as 8.72% with the same run time according to the base scenario. In this scenario, more increase was obtained than scenario one (S1).

	INPUTS										OUTPUTS									ANALYSIS
	Resources							Time (hour)	# Ordered Model	Approval Time (day)	Utilizations							Results		% Change
	Designers				Operators						Designers				Operators					
Scenarios / Variables	Man	Woman	Child	Sport	Cutting	Sewing	Assembly				Man	Woman	Child	Sport	Cutting	Sewing	Assembly	#Accepted Model	ColorSet	
Base Scenario	8	7	3	5	12	10	14	550	1500	13	57.80%	57.70%	38.30%	43.10%	84.90%	80.18%	76.99%	1238	4531	
S1	8	7	2	5	13	10	14	550	1500	13	57.78%	57.86%	58.34%	43.68%	83.94%	83.71%	80.46%	1265	4796	5.85%
S2	8	7	2	4	13	11	14	550	1500	13	58.30%	58.17%	57.89%	53.79%	83.91%	78.11%	82.20%	1282	4926	8.72%
S3	8	7	2	4	13	11	14	550	1500	10	58.60%	58.37%	58.35%	54.00%	87.44%	81.46%	85.80%	1313	5201	14.79%

Fig 23: Child Designer, Cutting Employee, Sewing Employee, Sport Designer and Approval Time simultaneous effect on the system.

When the number of child designers and sport designers were decreased to 2 and 4 respectively, and the number of cutting employees and sewing employees were increased to



13 and 11 respectively, and also the approval day was decreased from 13 to 10, the color set amount increased as 14.79% with the same run time according to the base scenario. In this scenario, more increase was obtained than scenario one (S1).

Fig:24 Bar graphs for multi-change scenarios.

5. RESULTS

According to our single variable change scenarios and multivariable change scenarios we obtained the following results:

The number of designers in each category (Man, Woman, Child, Sport) doesn't affect the amount of color set, the company end of the season produced that. That is why the decreasing number of designing department one unit or two units don't affect the system in terms of color set or this change doesn't affect the system in terms of completion time of the same amount of color set.

The cutting department is a bottleneck for the modelling department. 13 number of cutting employee is sufficient for the current system.

When the company reduces their approval time, they can produce more color set with the same amount of worker and time or they can provide the same amount of color set with the less amount of working effort with the same amount of employee.

Also, when they change the number of worker balance in the internal departments, that means they increase employee amount in one internal department and reduce employee amount in another internal department at the same time, they can produce more color set about 15% withholding total employee number as constant. (Multi change scenarios.**)**

6. CONCLUSION

We tried to prepare a verified and validated simulation model of FLO's modelling department to analyze the system. We want to create a real system with Arena Simulation Model and work on different scenarios on this system to optimize the current system. Before providing any suggestion, we tried to understand the basic system. Then, we designed experiments with single change variable and multi-change variable. According to our analyzing results, the designer number is more than the system need and cutting employee number is less than the modelling department need. Also, there is a negative linear relationship between approval time and the current system output in term of the color set.

6.1. Life-Long Learning

We conclude that prepare a project in professional practice is different from our degrees project. Project Management is an essential skill to complete the project on time. Also, we observe that we need to improve our basic lecture knowledge to work on a specific project. In our analysis, we used Arena Simulation Software which is learned on the university. It helps us to create a current system as real as possible. We got data from the company, and we analyzed the data using our excel skills. After that, we realized that their data didn't seem reliable after we searched for it we recognized that the company started a new data collection process and the employees didn’t use the system correctly. Thanks to “Excel” we realized very quickly there is abnormally on their provided data. After it, we changed our schedule. We experienced how we can produce solutions when the change in the project takes place. During that times we consulted our mentors in the company and university to create solutions. Finally, we analyzed according to our model with using our statistic knowledge.

6.2. Professional and Ethical Responsibilities of Engineers

Firstly, we tried to be unbiased when we verified our model with company advisor each time on our relations because according to our conclusion, company will decide their new strategy in modelling line and it will affect the employees who work in the Modelling Department. After that, we took permission to share a photo or an analysis their provided data in the project. Since it’s a big company, we observed the safety of employees in their working environment is emphasized and carefully managed by the managers of each department. Also, we will also consider that our recommendations will support the green background.

6.3. Contemporary Issues/Future of Industry

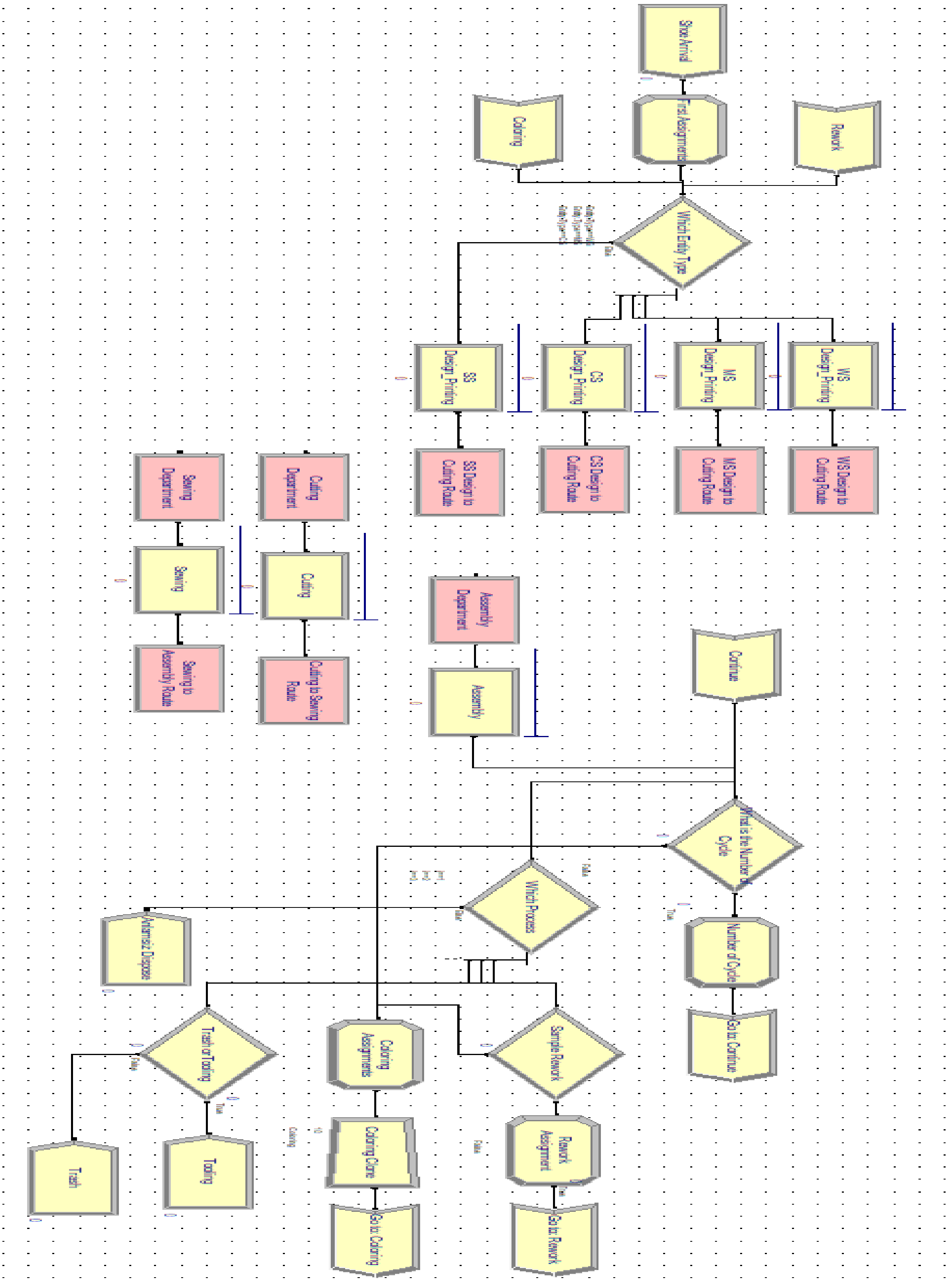
As contemporary tools, we used Arena Simulation Model, Excel and VBA to create a reliable conclusion about the project. Primarily, we used the pivot table and input analyzer to summarize our cumulative data that was obtained by the company. Thanks to software we analyzed data quickly and commented. Then we created current system simulation mode using Arena, and then we built a dashboard using VBA to make our system more user – friendly.

In twenty years, shoe production is expected to use more robotics instead of human force since the cost of this technology will be affordable in the future. The second expected outcome is to implement an AI system for the manufacturers. So that the AI will predict the sales in the future and that information will be used to prepare production planning. Lastly, the little part of the modelling department automated with robotic technology even today, the company has plans to increase automation to reduce long-term cost.

6.4. Team Work

We lead our team with our advisor Utku Koç was based on his weekly feedbacks on our project. His feedback was one of the most critical guides for us to manage this project. Other than that, the company's Modelling Department Manager Mustafa Yener helped us to remain in the right way by informing us about what we need about the department. Teamwork in that group wasn't complicated with three people because we prepared our project schedule beginning of the project and we separated work packages. So, we tried to distribute the responsibilities of the project evenly and we expected each other to complete the task was given on time. That mutual support helped us to achieve our plan.

APPENDIX A



Shoe Arrival
First Assignments
Coloring
Rework
Which Entity Type
SS Design_Printing
CS Design_Printing
MS Design_Printing
WS Design_Printing
SS Design to Cutting Route
CS Design to Cutting Route
MS Design to Cutting Route
WS Design to Cutting Route
Sewing Department
Sewing
Sewing to Assembly Route
Cutting Department
Cutting
Cutting to Sewing Route
Assembly Department
Assembly
Continue
What is the Number of Cycle
Number of Cycle
Go to Continue
Which Process
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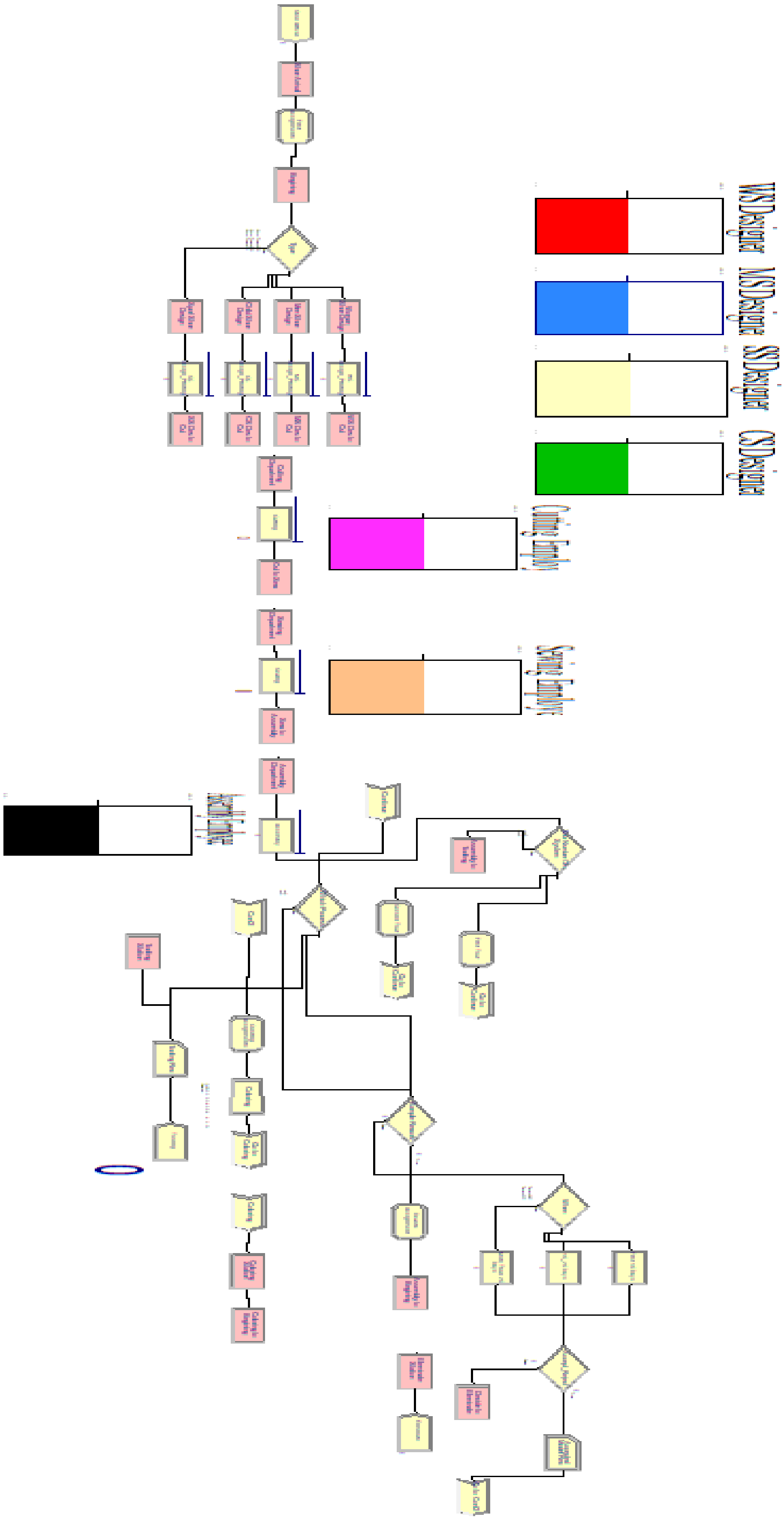
Trash or Tooling
Trash
Tooling
Coloring Assignments
Coloring Clone
Go to Coloring
Sample Rework
Rework Assignment
Go to Rework


WS Designer
MS Designer
SS Designer
CS Designer

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We are thankful because we managed to complete our Redesign of the Modelling Department of Flo project within the time given by our supervisors Utku Koç. This assignment cannot be completed without the effort and co-operation of our group members, Aybike Dilek, Emir Doğanay and Serdar Kami Üçkardeş. We also sincerely thank Mustafa Yener, for the guidance and sharing his experience with us along the project. Last but not least, we would like to express our gratitude to all of the Modelling Department employees for the support and willingness to spend some times with us to fill in our questions.

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