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Workflow Optimization of World Micro, Inc. Quality Department

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Workflow Optimization of World Micro, INC.

Quality Department

Optimistic Optimizers Team

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Executive Summary

The purpose of this project is to provide an optimized solution to the World Micro company for the current problems that they are experiencing. The quality department is going through challenging times where bottlenecks, long lead times, and extended work hours are hurting the company earnings and worker productivity.

This project has a time range of 4 months and was predicted to achieve a 5% improvement in efficiency, but the actual results and economic analysis reported a cost reduction of over 30%. The goal was to increase the number of lots tested per day, optimize the limited resources, and reduce total costs.

The first action taken was to collect time studies for the whole process with the purpose of identifying the current position of the company in terms of total cycle time of the process. Then, the creation of a value stream map was necessary to mark the starting point. This map was very important because it became the main tool that helped us measure the progress accomplished at the end of the project. The value stream map shows the entire process and its departments, accompanied by their respective times. The idea behind the creation of value stream maps was to identify value-added time from the non-value-added time and drive waste out of the process.

Once the value stream map was finished, we identified the main problems by selecting the tasks that reported the highest amount of wasted time and conducted research to know how other companies were solving similar problems. We focused on improving a bottleneck in the process and optimizing the workforce. To do so we collected a second round of time studies to simplify a subprocess into task. The new data collected guided us to minimize the scope of possible root cause problems and by implementing six sigma tools we found the root cause to one of the problems.

Linear programing was used to find a solution to the bottleneck that was causing long lead times by optimize the workforce allocation and minimize cost. The results from lingo and the time studies were used in creating arena simulation. The objective of creating the arena simulation was to apply the previous solutions and provide visual support to our suggestions. Also, arena simulation was used to run two different reports that answers the question of "what if" we add another machine or add another operator.

Finally, the results and recommendations were presented in a simplified way to add clarity. Foe any question regarding this project, please contact the team optimistic optimizers at nricci@worldmicro.com .

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Chapter 1: General Information

1.1 Introduction

Our group member Nick is currently an intern at World Micro, which is an electronic components distributor for companies manufacturing a variety of commercial, aerospace and military products. When electrical components are purchased from the open market, they need to be traced back to the OEM (Original Equipment Manufacturer) or have a series of tests performed to verify that the parts are authentic and work.

1.2 Overview

When parts arrive at the warehouse in Roswell, they are subjected to the following:

- Entered as inventory: counted, put into a bin, check paperwork, and assign a lot number
- Electrical testing: Verifies functionality of the part
- X-ray: To see location of the dyes and bond wires within the part
- XRF: Tests for the presence of ROHS Materials
- Decapsulation: Melt the top of the components with acid to get a clear view inside the part and take images using a microscope
- Heated Solvents Test: Checks for possible resurfacing and repackaging of a component
- Create a report on results of tests and deliver a pass or fail rating on authenticity of component.

1.3 Objective

The problem in the quality department process is that cycle times are too long, causing late deliveries, bottlenecks, and compromised quality. The objective of this project is to improve the flow of the quality inspection department by reducing cycle times, waste, and unnecessary part transportation while optimizing the available labor force.

1.4 Justification

Currently, World Micro is unable to meet demand, the current backlog has led to shipments being delayed and as consequences the company's earnings are retained. The company is currently having to pay employees to come into work on the weekends and work extended hours in order to make some of the shipment dates and retain customers. World Micro is trying to determine what options to take in order to make the process more efficient.

1.5 Project Background

World Micro and its wholly owned subsidiary, MIT Distributors, are global franchised distributors specializing in commodities such as electronic components, specialty hardware, wire & cable, electromechanical, and interconnect products. Their capabilities include global sourcing & procurement, kitting & assembly, inventory management programs, AOG fulfillment, quality testing & inspection, ITAR/export compliance, and engineering & technical support. By focusing on quality systems & custom tailored programs, World Micro and MIT are able to provide supply chain solutions that exceed our customers' rigid requirements and expectations. We are ISO 9001:2015, AS9120, AC 00-56, and Small Business Certified, ITAR Registered, and ERAI Members.

1.6 Problem Statement

The current process time for World Micro's quality testing and inspection is no efficient causing long lead times, extra work hours, extra expenses in outsourcing services and the loss of customer by not being able to fulfil, process and delivery orders on time. The possible options to improve the process lead times are to hire additional quality technicians, buy additional equipment, or increase the amount of shipment lots to be sent for outside testing.

Chapter 2: Literature

2.1 Research

The following articles and journals show various unique ways to find an optimal solution for similar issues that other businesses and workers have had. Finding the root cause of the problem is the first task and this can be achieved by methods such as using a cause and effect diagram, time study analysis, and value stream mapping are a few methods used in these studies along with being implemented in the project. Once the issue or bottleneck for the total processes are found, simulations and other solving software utilizing various algorithms are implemented giving an optimal solution from different possibilities such as a worker being assigned to a task they are best at doing, or changing/adding resources (machines/laborers) to the process which can lead to improvement in the total system.

“A simulation-based optimization framework for product development cycle time reduction”

This study shows the methodology to reduce the cycle times similar to this project, but instead it pertains to product development. The study determines the optimum sequence of activities execution within product development projects (PDPs). The simulated annealing (SA) algorithm is used to find the near-optimal solutions to difficult optimization problems that cannot easily be determined. This algorithm is not perfect but can get close to an optimal solution to a problem. SA constructs a sequence of solution configurations, ‘a path’ through a set of permissible solutions. A configuration of the sequence of tasks is compared to another configuration of the same tasks and the objective function is compared. In this case of this problem being a minimization problem, if the objective function decreases, this configuration is immediately accepted. Several iterations are needed to continuously find a more optimal solution until a near optimal global solution can be found. Some of our models have and will require several different iterations to find the closest global optimal solution.

“Optimization Of Cycle Time In Hyundai Motors India LTD”

This study involves improving the cycle times within the build body and ‘respot’ line which has a target time that is not being met, and is 10 seconds too slow, affecting the overall production rate. Time studies were done to find the target cycle time by using quantitative analysis. Observation of each of the processes was completed to analyze each task within each process to outline the entire sequence and help with identifying problems. A fishbone diagram (cause and effect diagram) was used to identify the factors that affect the cycle time and show potential problems, most importantly show the root cause problem of the entire process. Another chart identifies the main issues by encircling them, showing the time saved for each process changed. One of these changes is the robot that is responsible for the task changes its start position into a ‘ready’ position saving about 3 seconds in the process. There are several other tweaks done to the process to lower the process time down to a total of 62 seconds compared to the original 72 seconds. With these changes shortening the cycle time, one can expect a more efficient and productive line in the factory.

"A simulation-based optimization framework for product development cycle time reduction"

This study involves the use of simulation software to be able to optimize cycle times and reduce times helping to create a more efficient workplace. The software used in this study is Arena and SIMIO. One of the methods used in this study is a process called internal benchmarking which helps in finding throughput, cycle-time/flow time, and work-in-progress. There were three different possible scenarios in the performance of the system, these scenarios involve the best case, practical worst case and worst case scenarios. Regardless of the possible scenarios it was found that with a certain interarrival time in the case of this study of 15 minutes the work-in-progress and throughput of the system was at or near the best possible throughput after several simulations. The cycle times are important for our project as we are trying to optimize our cycle times for the several processes at World Micro.

"Tool allocation to smooth work-in-process for cycle time reduction and an empirical study"

This study involves semiconductor manufacturing and using a method called 'tool allocation' to help reduce the cycle times and also help lower WIP (Work-in-Progress) levels on lots of semiconductors. Several variables that affects the cycle times and WIP levels are weighed accordingly and at the end of the study the results showed the utilization rates of the fabricators raising from 82.28% to 98.83% and the reducible WIP increasing from 7.8% to 17.0%. Cycle times are analyzed throughout the study, which is similar to the method used in the studies with our project. Adding prioritization to certain lots on processes that have a higher cycle times allows for more throughput and a higher efficiency through the system as a whole.

"Solving production bottleneck through time study analysis and quality tools"

This academic journal looks at methods to help find bottlenecks and devises some solutions to reduce the impact of bottlenecks. Once the bottleneck is found from time study data, the particular process that is identified as the bottleneck is further broken down and each portion of this particular process is timed as well as a motion study for the process is also completed. Once this data has been collected pareto charts and an Ishikawa diagram are created to help find the root cause, which we have adopted a similar method with our project finding the cycle times of each process to be able to find what process is causing the bottleneck in the entire system.

Chapter 3: Experimental

3.1 Problem solving Approach

The approach to optimize the current process in quality testing department will be based on TQM principles and our team will be using lean manufacturing and six sigma tools to improve the area.

1. **Data collection**. The first step in the project in improving quality testing department is to collect time studies to know the current situation of the company in terms of productivity and efficiency.
2. **Analyze data.** The second step in improving KPACS process is to create a value stream map to visualize the whole process as a unit. The value stream map will show non-value added time, bottlenecks, waiting time, cycle times, tack times and efficiency at operational level.
3. **Identify root cause problems**. We will be using the magnific seven (pareto chart, cause and effect, scatter plots, check sheets, histogram, control charts, stratification) to analyze data and eliminate waste from the process.
4. **Brainstorm possible solutions** and eliminate the non-optimal solutions.
5. **Create a simulation** to test our potential solution.
6. If the results desired are obtained, then a **presentation of results** and report will be elaborated.
7. If the results are not what we expected, we will evaluate the simulation, calculations and results to identify possible mistakes.

3.2 Requirements

The requirements for this project is to provide World Micro a more efficient and feasible solution with the purposes of improving the flow of their system, reducing cycle times by minimizing waiting time and shortening their lead times.

3.3 Minimum Success Criteria

The project is considered successful given that the project is able to optimize the labor force by ensuring each employee works on the processes they are quickest and most efficient at completing. Another goal of the project is to improve process flow by removing any possible bottlenecks within the complete process. Finally, having a reduction of the complete cycle time by at least 3.0% of the total quality process at World Micro is necessary.

3.4 Schedule

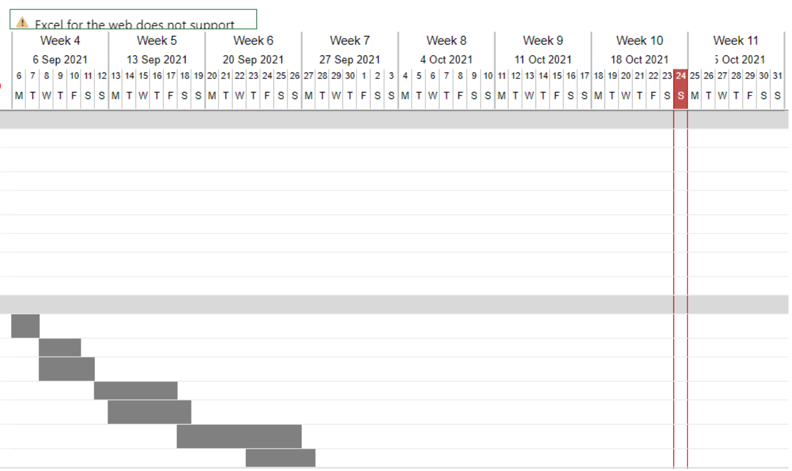
Workflow Optimization of QC Department Project Schedule

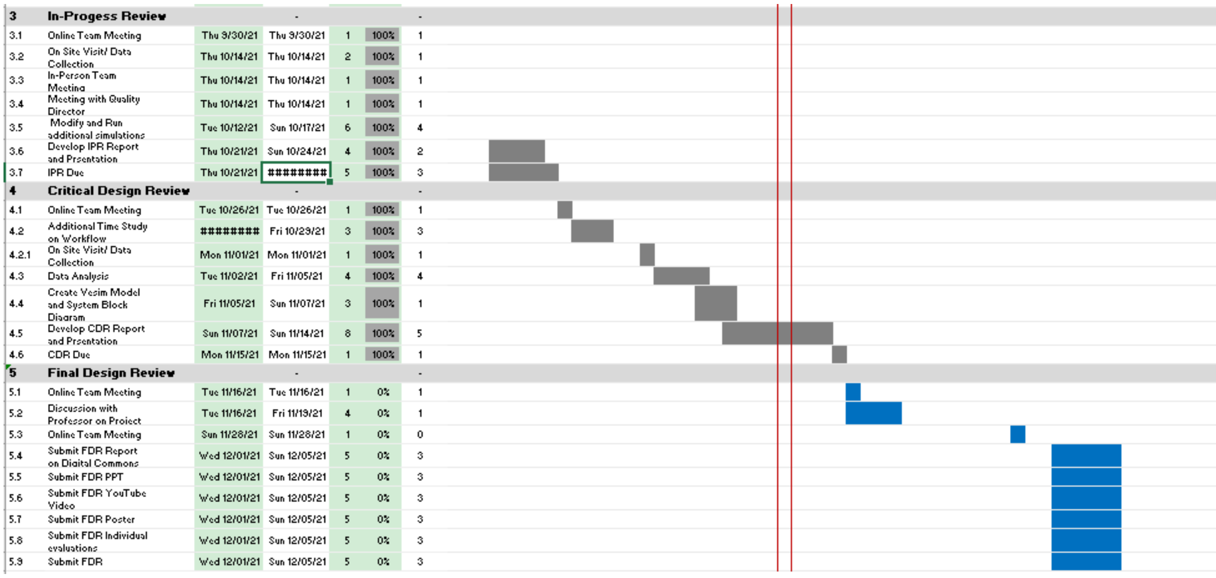
World Micro, INC.

Project Start Date: 8/16/2021 (Monday)   Display Week: 4

Project Lead: Nick Ricci

WBS	TASK	LEAD	START	END	DAYS	% DONE	WORK DAYS
1	**Initial Design Review**			-			-
1.1	IDR Document Created		Fri 8/20/21	Fri 8/20/21	1	100%	1
1.2	Develop Topic and Team Name		Mon 8/16/21	Sun 8/22/21	7	100%	4
1.3	Assign Titles		Mon 8/16/21	Sat 8/21/21	6	100%	5
1.4	Project outline and Calander		Fri 8/20/21	Mon 8/23/21	4	100%	2
1.5	Email Professor		Fri 8/20/21	Sun 8/22/21	3	100%	1
1.6	Work on budget plan		Fri 8/20/21	Mon 8/23/21	4	100%	2
1.7	Develop IDR Report and Presentation		Mon 8/16/21	Sun 8/22/21	7	100%	5
1.8	IDR Due		Mon 8/16/21	Mon 8/23/21	8	100%	6
2	**Preliminary Design Review**			-			-
2.1	On Site Visit/ Data Collection		Mon 9/06/21	Tue 9/07/21	2	100%	2
2.2	Current System Analysis		Wed 9/08/21	Fri 9/10/21	3	100%	3
2.3	Generate simulation model of current system		Wed 9/08/21	Sat 9/11/21	4	100%	3
2.4	Propose viable solutions		Sun 9/12/21	Fri 9/17/21	6	100%	5
2.5	Run new system simulation		Mon 9/13/21	Sat 9/18/21	6	100%	5
2.6	Develop PDR Report and Prsentation		Sat 9/18/21	Sun 9/26/21	9	100%	6
2.7	PDR Due		Thu 9/23/21	Mon 9/27/21	5	100%	3





3	**In-Progess Review**		-			-
3.1	Online Team Meeting	Thu 9/30/21	Thu 9/30/21	1	100%	1
3.2	On Site Visit/ Data Collection	Thu 10/14/21	Thu 10/14/21	2	100%	1
3.3	In-Person Team Meeting	Thu 10/14/21	Thu 10/14/21	1	100%	1
3.4	Meeting with Quality Director	Thu 10/14/21	Thu 10/14/21	1	100%	1
3.5	Modify and Run additional simulations	Tue 10/12/21	Sun 10/17/21	6	100%	4
3.6	Develop IPR Report and Prsentation	Thu 10/21/21	Sun 10/24/21	4	100%	2
3.7	IPR Due	Thu 10/21/21	########	5	100%	3
4	**Critical Design Review**		-			-
4.1	Online Team Meeting	Tue 10/26/21	Tue 10/26/21	1	100%	1
4.2	Additional Time Study on Workflow	########	Fri 10/29/21	3	100%	3
4.2.1	On Site Visit/ Data Collection	Mon 11/01/21	Mon 11/01/21	1	100%	1
4.3	Data Analysis	Tue 11/02/21	Fri 11/05/21	4	100%	4
4.4	Create Vesim Model and System Block Diagram	Fri 11/05/21	Sun 11/07/21	3	100%	1
4.5	Develop CDR Report and Prsentation	Sun 11/07/21	Sun 11/14/21	8	100%	5
4.6	CDR Due	Mon 11/15/21	Mon 11/15/21	1	100%	1
5	**Final Design Review**		-			-
5.1	Online Team Meeting	Tue 11/16/21	Tue 11/16/21	1	0%	1
5.2	Discussion with Professor on Project	Tue 11/16/21	Fri 11/19/21	4	0%	1
5.3	Online Team Meeting	Sun 11/28/21	Sun 11/28/21	1	0%	0
5.4	Submit FDR Report on Digital Commons	Wed 12/01/21	Sun 12/05/21	5	0%	3
5.5	Submit FDR PPT	Wed 12/01/21	Sun 12/05/21	5	0%	3
5.6	Submit FDR YouTube Video	Wed 12/01/21	Sun 12/05/21	5	0%	3
5.7	Submit FDR Poster	Wed 12/01/21	Sun 12/05/21	5	0%	3
5.8	Submit FDR Individual evaluations	Wed 12/01/21	Sun 12/05/21	5	0%	3
5.9	Submit FDR	Wed 12/01/21	Sun 12/05/21	5	0%	3

Figure 1 : Gantt Chart Last Updated: 11/13/2021

A portion of the Gantt chart is shown in the figure above. The schedule is divided into sections for each review with corresponding tasks that show where the team is in terms of progress during the duration of the project. The start date and end dates of each task are outlined along with the percentage complete for each task. The chart also has progress bars for each task outlining which tasks should take longer than others. The Gantt chart assists the team in keeping up with the deadlines associated with each task. The figure shows a portion of the full chart outlining the tasks within the second and third group of tasks.

3.5 Flow Chart

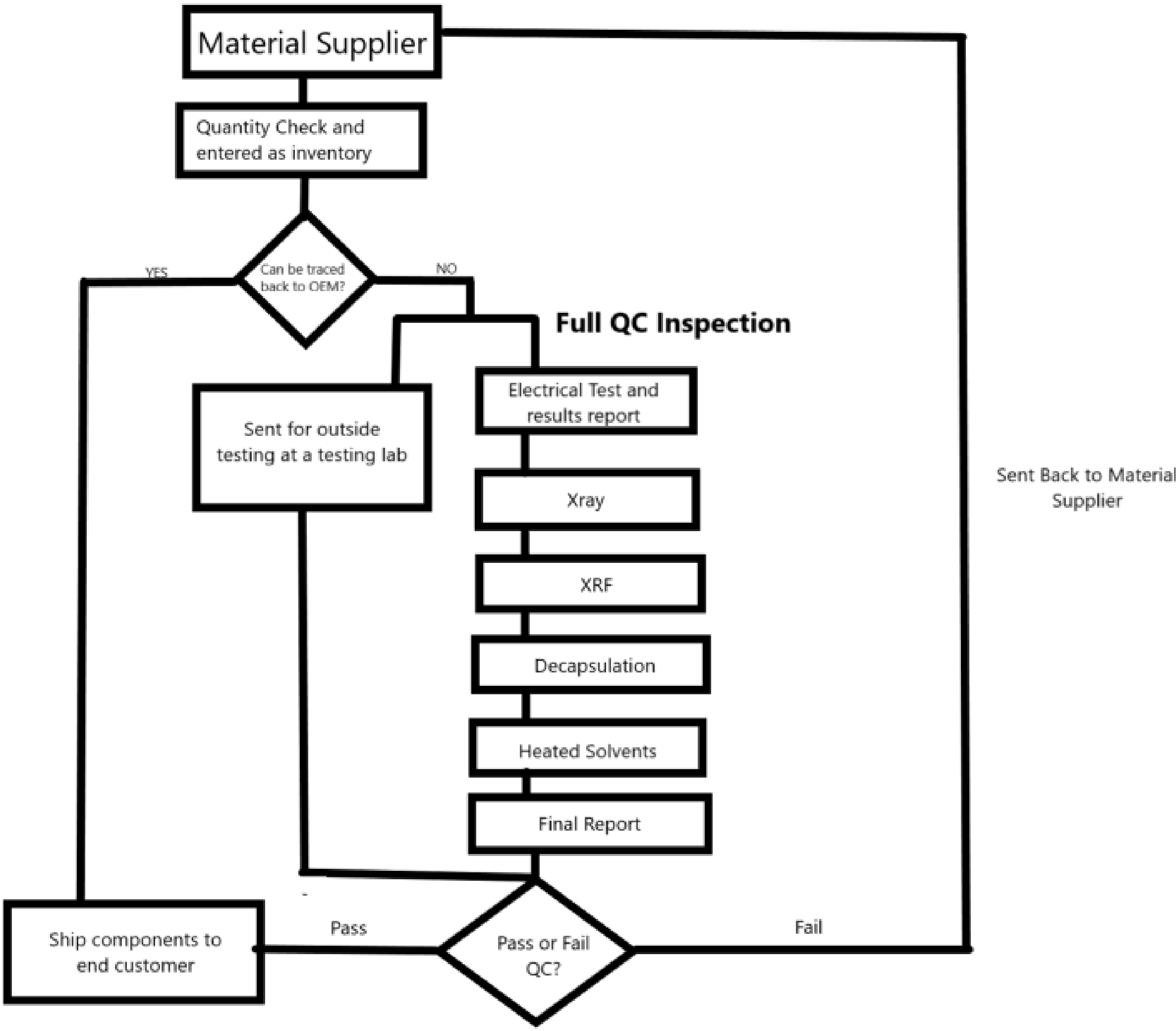


Figure 2: Flow Chart of QC Inspection Process

3.5.1 "Realtime X-ray Imaging"

After parts go through basic electrical testing, the following test performed is X-ray imaging. This test is not destructive on the components and is performed at World Micro using a Glenbrooke Jewelbox 70T (as shown in the picture below), which is also used at the author's company, SMT Corporation, as shown in the figure below. The use of X-rays allows the user to view the insides of components and inspect bond wires, printed circuit boards, and the dyes contained inside of the components. The picture below shows a VGA/BGA microchip, where the center square is the dye and the edges are the leads that are used to connect the chip to the board or other components.

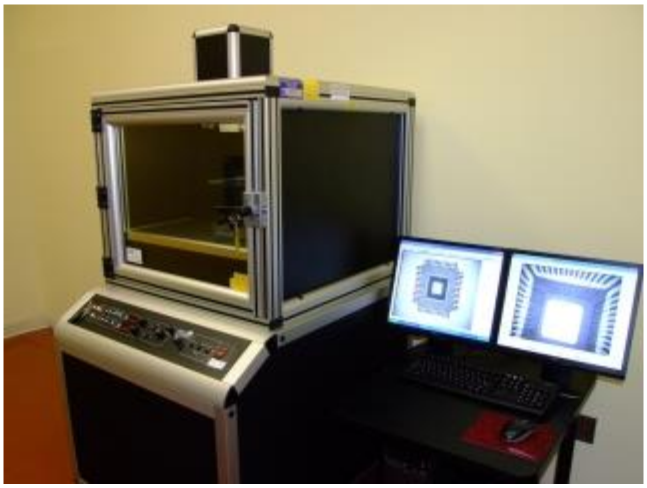


Figure 3: *Glenbrooke Jewelbox 70T from SMT Corp. Lab*

3.5.2 "X-ray fluorescence"

(XRF) analysis simplifies quality assurance inspections for complex global supply chains"
One of the tests that World Micro uses to test various products for legitimacy and compliance with regulations is X-ray fluorescence (XRF) testing. Ensuring a product that is legitimate and works properly is of major importance for companies across the globe. X- ray fluorescence testing is a testing method that is simple to implement and not considered to be destructive to products. This form of testing requires little to no preparation for the tested samples and also gives accurate measurements of various types of samples such as solids, liquids and powdered

samples. The application of XRF testing is being compliant with Restriction of Hazardous Substances (RoHS) guidelines which bans products that have potentially toxic materials in them, such as Lead (Pb), Mercury (Hg) and Polybrominated Biphenyls (PBB). XRF testing is able to easily identify these materials which if not identified to can result in heavy fines and possibly being placed on a banned supplier list, leaving the company in a difficult position. XRF testing also allows for detection of counterfeit materials, which can be life-threatening in the aerospace and defense industries. Without a doubt, the XRF method is vitally important to the quality assurance methods at World Micro and across many industries throughout the world.

3.5.3 "Heated Solvents"

Another test performed regularly for counterfeit detection by World Micro is heated solvents testing. The application of this is to test if the part has been resurfaced or tampered with after leaving the original equipment manufacturer and shows the base layer of the component. The test is performed by having half of the component soak in chemical solution called Dynasolve for about 45 minutes and then observing under a microscope to view any possible resurfacing as shown in the figure below.

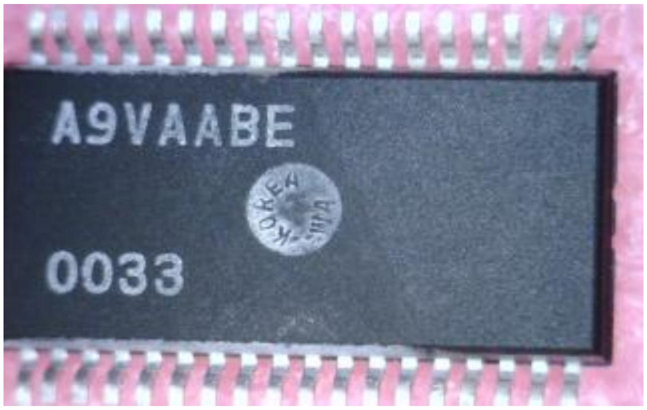


Figure 4: Counterfeit Part after Dynasolve

3.5.4 "Decapsulation, Delidding, and Verification"

Decapsulation is considered to be the last line of defense in identifying counterfeit components. This test is performed at World Micro using a Nisene JetEtch 3 Pro (shown below in fiure 5), which is an acid-etch decapsulator. The test itself can be described as, "... the act of using abrasive acids to etch the surface of the device until the internal die is revealed, allowing for visual inspection..." with the use of a microscope with a 4K camera attachment. Figure 6 below shows how a part looks after going through the process, where the internal dye is exposed and visible for further inspection with the microscope. The pictures taken from the microscope are then used in the report when ruling on the authenticity of the parts.

Figure 5: Nisene JetEtch 3 Pro from SMT Corp. Lab

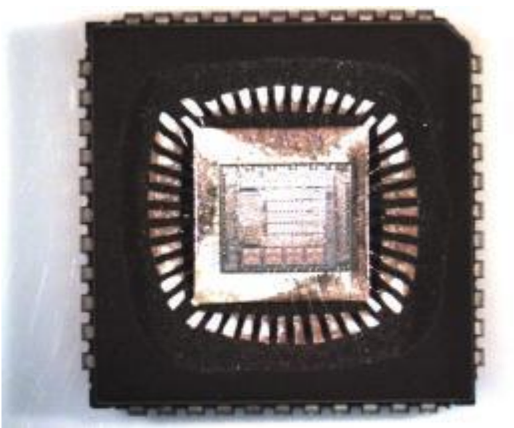


Figure 6: VGA/BGA Chip after being acid-etched

3.6 Value Stream map

The Value stream map shows that cycle times in every operation are greater than tack times, which is not optimal. Also, by analyzing the map we identify a huge bottleneck in between writing the report and shipping department. Bottlenecks are the result of an inefficient layout of the process, which need special attention.

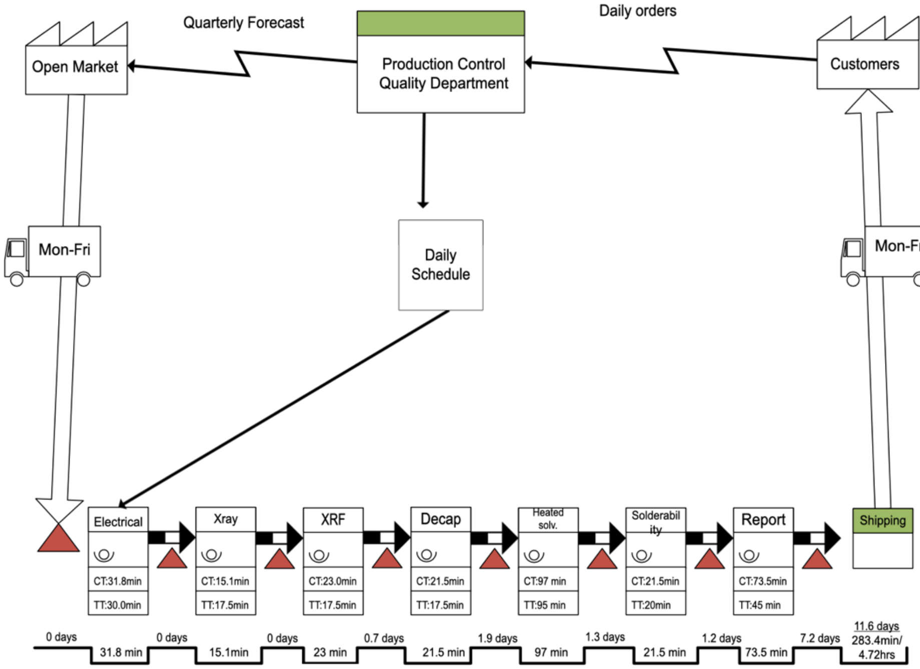


Figure 7 Value Stream Map developed from first round of time studies.

A possible solution to improve the flow in this process is to create cells or identify internal and external tasks with the purpose to perform them in a parallel way instead of in sequence.

It is necessary to comment that the creation of cells is a major project that requires months of work and because of time constraints we will not consider that option.

3.7 Cause-and-Effect Diagram

Writing the report is the most critical operation in the quality testing department.

We conducted cause and affect analysis to identify the root cause of the delay on writing the report. There are several potential reasons that are causing long cycle times but the most critical that we identify is the low work force. The person responsible for doing the report is not being able to his job because of assisting on the floor performing testing.

This job requires to review the results from all test performed which requires reviewing every test performed, grammar, clarity of concepts and pictures but this resulted no to be a major issue because mistakes are not common.

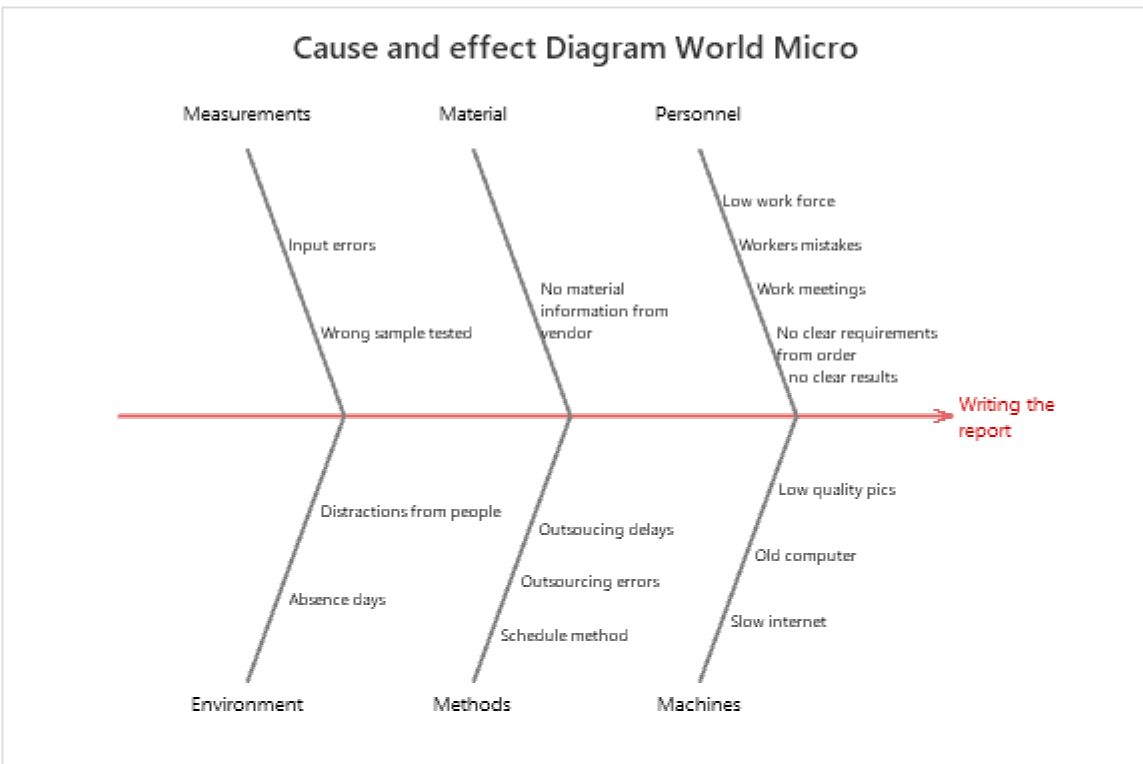


Figure 8 : Cause and effect diagram of possible reasons for bottlenecks in the QC inspection process.

3.8 Responsibilities

This project has four members, each with different responsibilities to ensure that the project will be complete and thorough. The Project Manager is Nick Ricci, whose roles was to provide the necessary data from World Micro, and also ensure that the project is meeting the necessary deadlines to be fulfilled within the time required. Nick has also arranged the meetings throughout the project to ensure proper communication among the team and resolving any potential issues through these meetings. The Financial Advisor is Darius Ruffin who provides the necessary information on the costs along with overseeing the budget during the duration of the project. He also assisted with simulations and providing an economic analysis. The Project Coordinator is Rosa Lopez Gomez and she provides the scheduling for the project along with arranging the necessary data to create time studies showing the approximate times of each process. Her duties also involved a simulation that shows the optimal solution throughout the entire work process. The Technical Expert is Joshua Fennell, and he is involved with finding research outside of World Micro that assists in gauging which direction the project should focus on to give the best solution to the problem.

3.9 Budget

Table 1 Budget

Budget of Project		
Solution	**Cost Per Hour**	**Total Cost**
Reduce number of Technicians	- $23 per Technician	People in the QC Dept.) = $161 an hour, reducing workforce to 5 people would lead to an hour cost of $115 an hour for the workforce.
Buy a 2nd Decapsulator	N/A	$100,000
Buy a 2nd Heated Solvents Station	N/A	$4500 for Ductless Fumehood and $300 for Scientific Hotplate (Cost does not include cost of acids used)
Send For Outside Testing (White Horse Laboratories)	N/A	Average cost per sample is $25 and number of samples is dependent on the size of the lot. The larger the size of the lot, the more samples needed to be tested. Average lot size is 23 samples: 23 samples * $25 = $575
Task Ability Training (Training Tanner to perform Solderability Testing)	$23 an hour (for the individual training Tanner), additionally one can get J-STD-001 Certification (Certificate of Knowledge in Solderability materials and processes) which costs $65 but is not a necessity.	$23 an hour * 80 hours (2 weeks of training)= $920 , $920 + $65 = $985

From Table 1 above, the costs and benefits associated with potential solutions to improving the cycle time are listed above. A potential cost-saving measure is to remove a technician if after optimization a technician may not be required to perform the quality tests which gives a savings listed on the table. Extra stations to the Heated Solvents and Decapsulation tests are costs that could greatly improve the cycle time, but are investments that will take time to have the benefits begin to appear. The addition of these extra stations will have one of the largest impacts on cycle time improvement. There is also the option of sending the samples to White Horse Laboratories that can perform any of these quality tests on their own with the associated costs shown. Depending on the size of the entire lot determines the samples required, so costs will increase as the lot sizes increase. The final piece of the budget is task training for technicians (Specifically Tanner for Solderability Testing), which is shown as an hourly cost.

4.0 Materials and Resources

Material Required/used:

- Arena Simulation Software
- Stopwatch (Time Study)
- Microsoft Office and Teams
- Lingo

Resources Available

- Handheld Agilent Multimeter (Electrical Testing)
- Glenbrooke Jewelbox 70T (Xray)
- Gen3 Must3 System (Solderability)
- Nisene JetEtch 3 Pro (Decapsulation)
- Sulfuric and Nitric Acid
- Microscope
- Additional acids and Acetone (Heated Solvents)

Chapter 4: Experimental Procedure

4.1 Method

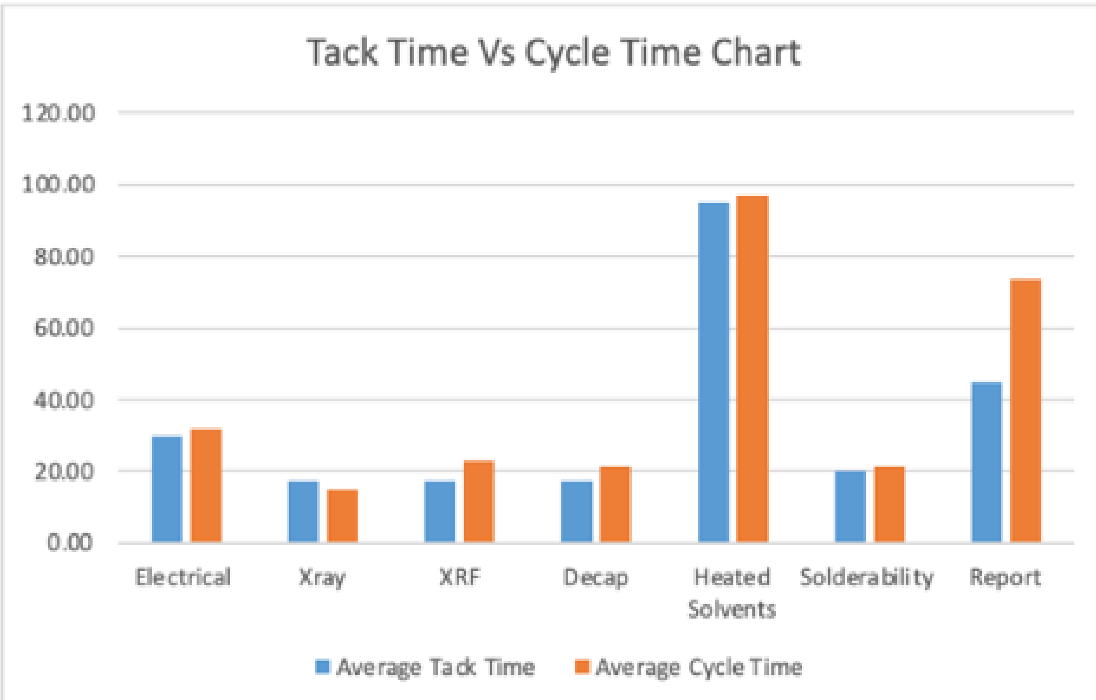
The first action taken was to perform time studies of the process. It was necessary to mark a starting point in order to measure progress. The time studies consisted in recording the time required to perform task and the waiting time as well. The results are summarized in the next table.

Table 2 Time study results

Operation	Average Tack Time	Average Cycle Time
Electrical	30.00	**31.87**
Xray	17.50	**15.1**
XRF	17.5	**23**
Decap	17.5	**21.5**
Heated Solvents	95	**97**
Solderability	20	**21.5**
Report	45	**73.5**

The results of this data analysis show that almost all the rest cycle times exceed their tack times, which is not efficient. In order to identify possible solutions, it is necessary to perform another round of time study at detail task level. The next graph shows the comparison between cycle time and tack times.

Table 3 Tack time vs cycle time



4.2 Calculations

One of the objectives in this project is to decrease total cycle time by optimizing the workforce. Optimistic Optimizers team is going to classify this issue as an assignment problem in order to find the fastest and cheaper work distribution.

The next table shows the machines and workers' time associated with each machine.

The value of 400 has being assigned to jobs that workers are not able to perform. It could be any high number that the system will not consider assigning that machine to any worker. Other way to exclude machines from workers could be to add more constraints to the LP but this time we decided to use a high value to add simplicity and clarity to the model.

4.3 Assignment distribution problem

The next table shows the time that each worker takes to perform a specific job. Workers that has not being trained to operate a machine the number of 400 is being assigned. For example, Tanner is an electrical machine operator that each test takes him an average of 30 minutes to be completed but he can not operate the x ray machine for instance the hypothetical number of 400 was assigned.

Table 4 Assignment distribution time table

	Electrical	Xray	XRF	Decap	Heated Solvents	Solderability	Report
Seth	27	10	14	21	96	27	75
Hogan	32	10	16	23	96	26	79
Aimee	31	10	11	400	97	22	200
Nick	36	14	19	400	400	400	400
Tanner	30	400	400	400	400	400	400
Kate	400	400	400	400	400	400	78
Kyle	31	10	11	400	97	400	400

The next table shows how decision variables are assigned to its time. This table will be useful when writing the objective function and constrains.

Decision variables: X11 = 27, X12 = 10, X13 = 14, X15 = 96, X16 = 27, X17 = 75…X77 = 400

Table 5 Assignment distribution decision variables table

	Electrical	Xray	XRF	Decap	Heated Solvents	Solderability	Report

Seth	X11	X12	X13	X14	X15	X16	X17
Hogan	X21	X22	X23	X24	X25	X26	X27
Aimee	X31	X32	X33	X34	X35	X36	X37
Nick	X41	X42	X43	X44	X45	X46	X47
Tanner	X51	X52	X53	X54	X55	X56	X57
Kate	X61	X62	X63	X64	X65	X66	X67
Kyle	X71	X72	X73	X74	X75	X76	X77

4.3.1 Linear Programing Model

This LP is the result of multiplying time and the decision variables. The objective of this LP model is to minimize time and reduce cost by assigning machines to the most efficient worker.

Objective function:

Min=27*x11+10*x12+14*x13+21*x14+96*x15+27*x16+75*x17+32*x21+10*x22+16*x23+23*x24+96*x25+26*x26+79*x27+31*x31+10*x32+11*x33+400*x34+97*x35+22*x36+400*x37+36*x41+14*x42+19*x43+400*x44+400*x45+400*x46+400*x47+30*x51+400*x52+400*x53+400*x54+400*x55+400*x56+400*x57+400*x61+400*x62+400*x63+400*x64+400*65+400*66+78*x67+31*x71+10*x72+11*x73+400*x74+97*x75+400*x76+400*x77;

Subject to:

x11+x12+x13+x14+x15+x16+x17=1;
x21+x22+x23+x24+x25+x26+x27=1;
x31+x32+x33+x34+x35+x36+x37=1;
x41+x42+x43+x44+x45+x46+x47=1;
x51+x52+x53+x54+x55+x56+x57=1;
x61+x62+x63+x64+x65+x66+x67=1;

} Workers constrains

x11+x21+x31+x41+x51+x61+x71=1;
x12+x22+x32+x42+x52+x62+x72=1;
x13+x23+x33+x43+x53+x63+x73=1;
x14+x24+x34+x44+x54+x64+x74=1;
x15+x25+x35+x45+x55+x65+x75=1;
x16+x26+x36+x46+x56+x66+x76=1;
x17+x27+x37+x47+x57+x67+x77=1;
x67=1;

} Machines constrain

$$x_{ij} = \begin{cases} 1 & \text{if I is allocated to j} \\ 0 & \text{otherwise} \end{cases}$$

4.3.2 Lingo Solution Report

Infeasibilities: 0.000000
Total solver iterations: 7
Elapsed runtime seconds: 0.11

Model Class: LP

Total variables: 48
Nonlinear variables: 0
Integer variables: 0

Total constraints: 14
Nonlinear constraints: 0

Total nonzeros: 135
Nonlinear nonzeros: 0

Variable Value Reduced Cost
X11 0.000000 27.00000
X12 0.000000 0.000000
X13 0.000000 3.000000
X14 1.000000 0.000000
X15 0.000000 0.000000
X16 0.000000 5.000000
X17 0.000000 75.00000
X21 0.000000 32.00000
X22 0.000000 0.000000
X23 0.000000 5.000000
X24 0.000000 2.000000
X25 1.000000 0.000000
X26 0.000000 4.000000
X27 0.000000 79.00000
X31 0.000000 31.00000
X32 0.000000 0.000000
X33 0.000000 0.000000
X34 0.000000 379.0000
X35 0.000000 1.000000

X41 0.000000 32.00000
X42 1.000000 0.000000
X43 0.000000 4.000000
X44 0.000000 375.0000
X45 0.000000 300.0000
X46 0.000000 374.0000
X47 0.000000 396.0000
X51 1.000000 0.000000
X52 0.000000 360.0000
X53 0.000000 359.0000
X54 0.000000 349.0000
X55 0.000000 274.0000
X56 0.000000 348.0000
X57 0.000000 370.0000
X61 0.000000 496.0000
X62 0.000000 486.0000
X63 0.000000 485.0000
X64 0.000000 475.0000
X67 1.000000 0.000000
X71 0.000000 31.00000
X72 0.000000 0.000000
X73 1.000000 0.000000
X74 0.000000 379.0000
X75 0.000000 1.000000
X76 0.000000 378.0000
X77 0.000000 400.0000
X65 0.000000 0.000000
X66 0.000000 74.00000

Row Slack or Surplus Dual Price
1 52672.00 -1.000000
2 0.000000 0.000000
3 0.000000 0.000000
4 0.000000 0.000000
5 0.000000 -4.000000
6 0.000000 -30.00000
7 0.000000 96.00000
8 0.000000 0.000000
9 0.000000 -10.00000
10 0.000000 -11.00000
11 0.000000 -21.00000
12 0.000000 -96.00000
13 0.000000 -22.00000
14 0.000000 0.000000
15 0.000000 -174.0000

X41 0.000000 32.00000
X42 1.000000 0.000000
X43 0.000000 4.000000
X44 0.000000 375.0000
X45 0.000000 300.0000
X46 0.000000 374.0000
X47 0.000000 396.0000
X51 1.000000 0.000000
X52 0.000000 360.0000
X53 0.000000 359.0000
X54 0.000000 349.0000
X55 0.000000 274.0000
X56 0.000000 348.0000
X57 0.000000 370.0000
X61 0.000000 496.0000
X62 0.000000 486.0000
X63 0.000000 485.0000
X64 0.000000 475.0000
X67 1.000000 0.000000
X71 0.000000 31.00000
X72 0.000000 0.000000
X73 1.000000 0.000000
X74 0.000000 379.0000
X75 0.000000 1.000000
X76 0.000000 378.0000
X77 0.000000 400.0000
X65 0.000000 0.000000
X66 0.000000 74.00000

Row Slack or Surplus Dual Price
1 52672.00 -1.000000
2 0.000000 0.000000
3 0.000000 0.000000
4 0.000000 0.000000
5 0.000000 -4.000000
6 0.000000 -30.00000
7 0.000000 96.00000
8 0.000000 0.000000
9 0.000000 -10.00000
10 0.000000 -11.00000
11 0.000000 -21.00000
12 0.000000 -96.00000
13 0.000000 -22.00000
14 0.000000 0.000000
15 0.000000 -174.0000

4.4 LP Results

The next table displays a feasible solution obtained from the assignment distribution problem that minimizes the cycle times to the lowest possible value, which means that this is the most efficient work distribution to operate.

Table 6 Assignment problem model solution

	Electrical	Xray	XRF	Decap	Heated Solvents	Solderability	Report
Seth	27	10	14	21	96	27	75
Hogan	32	10	16	23	96	26	79
Aimee	31	10	11	400	97	22	200
Nick	36	14	19	400	400	400	400
Tanner	30	400	400	400	400	400	400
Kate	400	400	400	400	400	400	78
Kyle	31	10	11	400	97	400	400

Cost Associated with these assignments = 21 + 96 + 22 + 14 + 30 + 78 + 11 = 272

272 minutes is the lowest possible cost to performed quality testing. Currently the Total cycle time is 283. Applying this new job assignment can result in a reduction of 11 minutes/ lot.

Long cycle times in writing the Report

The cause and effect diagram results help to find the root cause to the problem of long cycle times in writing the report having just the necessary people to work each machine is causing the person responsible to create the report to go and assist other workers in their job resulting in delaying his/her own. A potential solution to long cycle times in writing the report is to hire a person to provide assistance to the workers. This person will act as a floater performing different job every day according.

Long total cycle times in the entire process

The approach taken to increase the flow in the testing in quality department was to treat the issue as an assignment problem. We developed an LP model to optimize the job distribution and assign jobs to the workers that best suit them. The purpose of this LP is to minimize time that will result in shorter cycle times and a cost reduction by calculated the lowest possible cost to perform the jobs.

Chapter 5: Results

5.1 Analysis

Our team created an arena simulation with the objective in offering more efficient ways to operate and we will be using SAP crystal reports, OptQuest, and Process analyzer from arena to conduct some analysis and provide a feasible solution.

5.1.1 Current System

The current system flows in a parallel way that is resulting in several delays thought out the system and the work force utilization is very low. The current time distribution of each process was obtained from the previous time studies conducted earlier in the semester. The workforce schedule implemented in the arena simulation model is the current 40 hour work week that is used at World Micro.

Table 7 Task Assignment arena simulation

Operation	Operator	Distribution	Time (min)	Allocation
Electrical	Seth	Constant	80	Value added
Xray	Hogan	Constant	30	Value added
XRF	Aimee	Constant	45	Value added
Decap	Nick	Constant	30	Value added
Heated solvents	Tanner	Constant	160	Value added
Solderability	Kate	Constant	40	Value added
Report	Kyle	Constant	120	Value added

The figure below shows the simulation of the current process. The arrival time of orders was calculated as an average of 1 order every hour. Λ = 60 minutes and the

The model is being ran for a period of 40 hours equivalent to 1 week of work.

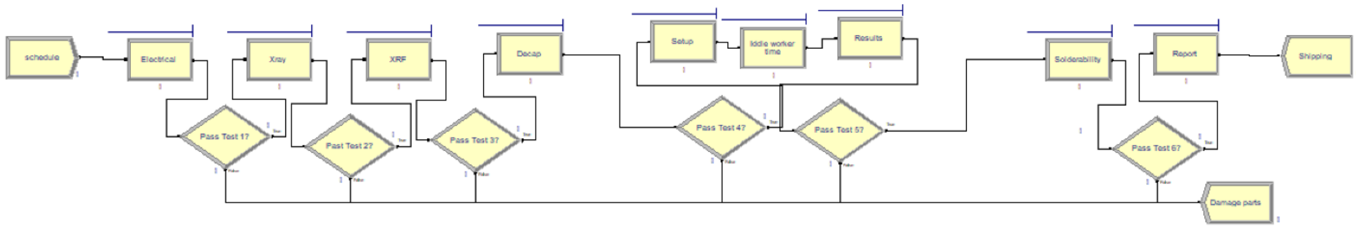


Figure 9 Arena model current system

The process as it is right now is averaging an output of 20 lots per week by assigning one worker per machine. The total output includes lots that were trashed because of test failure.

Key Performance Indicators

System	Average
Number Out	20

Figure 10 Key performance indicators current system

The main problem with the current operation strategy in the quality department is the resources utilization. The simulation of the current process shows that workers are being underutilized which is not optimal. The main goal in optimizing the current model is to maximize the total output of the system and increase resources utilization.

Replication 1	Start Time:	0.00	Stop Time:	40.00	Time Units:	Hours

Resource Detail Summary

Usage

	Inst Util	Num Busy	Num Sched	Num Seized	Sched Util
Aimee	0.24	0.72	3.00	39.00	0.24
Hogan	0.16	0.49	3.00	39.00	0.16
Kate	0.10	0.30	3.00	18.00	0.10
Kyle	0.18	0.90	5.00	18.00	0.18
Machine1	0.92	0.92	1.00	70.00	0.92
Nick	0.22	0.45	2.00	36.00	0.22
Seth	0.33	1.33	4.00	41.00	0.33
Tanner	0.13	0.92	7.00	70.00	0.13

Figure 11 Current resources utilization

5.1.2 Model Optimized

The optimized arena simulation has several changes that were needed in order to make better use of the workers. As shown in table 8, one of the biggest changes was the removal of Nick and Kate in the process. When meeting with management at World Micro, they suggested to develop a model of the process without those two in the process as they were moved from sales and engineering and added to the process when bottlenecks were becoming more apparent. Another change made in the optimized model was to implement training on the employee Tanner. Tanner was a relatively new employee of World Micro when this time study was conducted, and a suggestion of ours was to train him to be able to do solderability testing to improve his overall utilization. Additionally, the optimized simulation has an extra electrical and heated solvents stations that were used to improve resources utilization.

Table 8 Optimized task assignment arena simulation

Operation	Operator	Distribution	Time (min)	Allocation
Electrical	Tanner	Constant	30	Value added
Electrical 2	Kyle	Constant	30	Value added
Xray	Aimee	Constant	14	Value added
XRF	Kyle	Constant	11	Value added
Decap	Seth	Constant	21	Value added
Heated solvents	Seth	Constant	96	Value added
Solderability	Tanner	Constant	22	Value added
Heated solvents2	Aimee	Constant	96	Value added
Report	Hogan	Constant	75	Value added

The optimized model shows the addition of a person and a machine/station in the operation of heated solvents with the purpose of utilize personnel more efficient and allow the process to flow better and increase total output of order in the system. The resource named “Machine 1” and “Machine 2” were added in the resources of this model to represent the idle/ non-value added time during the heated solvents test when the part being tested has to sit in Dynasolve solution for a time period of about an hour.

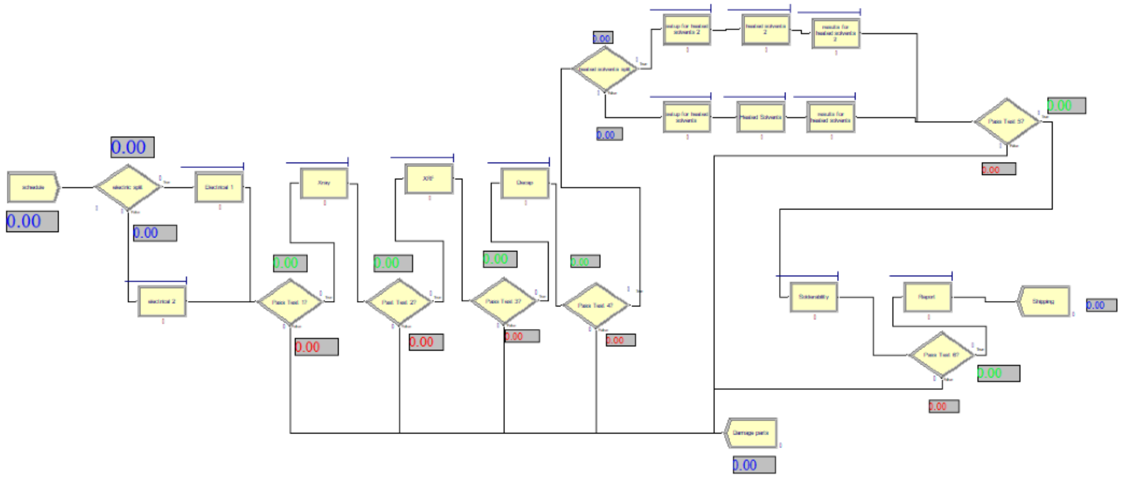


Figure 12 Arena model Optimized

The total output has increased by 10 orders to 30 total orders for the week ,as shown below in figure 13, from adding an additional electrical testing station that is operated by the same person that is performing the heated solvent tests. The cycle time for heated solvents is an average of 96 minutes but only 30 minutes are value added, the resulting 66 minutes the operator waits on the machine. Therefore, we decided to assign an extra task to the operation while waiting on the heated solvents process to finish. The operator will be performing heating solvents and electrical testing simultaneously rather than in parallel.

Key Performance Indicators

System	Average
Number Out	30

Figure 13 Optimized key performance indicators

Then, figure 14 shows the effect in resources utilization by performing job simultaneously.

Resources utilization increased because of the workforce reduction, before optimizing the system there were a total of seven workers but now the number is being reduced to five workers.

Productivity and total output in orders improved dramatically.

Resource Detail Summary

Usage

	Inst Util	Num Busy	Num Sched	Num Seized	Sched Util
Aimee	0.44	0.44	1.00	73.00	0.44
Hogan	0.90	0.90	1.00	29.00	0.90
Kate	0.00	0.00	1.00	0.00	0.00
Kyle	0.39	0.39	1.00	56.00	0.39
Machine1	0.94	0.94	1.00	35.00	0.94
Nick	0.00	0.00	1.00	0.00	0.00
Seth	0.57	0.57	1.00	76.00	0.57
Tanner	0.60	0.60	1.00	57.00	0.60

Figure 14 Optimized resource detail summary

5.2 Sensitivity analysis

The sensitivity analysis will provided the possible solution to “what if” we add a person in the report operation and what if we add a person and a machine in heated solvents. Sensitivity analysis will be performed by using two different reports, OptQuest and Process Analyzer both found in Arena tools.

5.2.1 OptQuest report

OptQuest is a report that optimizes, maximize or minimize, systems by analyzing input, decision variables, controls and constraints, and suggest feasible solutions.

In this report resources are used as decision variables, the objective is to maximize the output in the system and the constrain is that the total sum of resources cannot exceed 7.

According to the results from OptQuest report there are several feasible solutions, but we will only consider the one with the greatest output. As shown in figure 15, solution 7 is a feasible solution that suggest adding an extra worker in the operation of writing the report to increase the total output to 34 orders/week.

Note: This report is ran using the optimized model where the addition of an extra machine in electrical and headed solvents tasks are already in place.

Best Solutions **Optimal solution found.**

Best Solutions

Included	Simulation	Objective Value	Status	Aimee	Hogan	Kyle	Machine1	Seth	Tanner
☐	7	34	Feasible	1	2	1	1	1	1
☐	3	31	Feasible	1	1	1	1	1	2
☐	4	31	Feasible	1	1	1	1	2	1
☐	6	31	Feasible	1	1	1	2	1	1
☐	1	30	Feasible	1	1	1	1	1	1
☐	2	30	Feasible	1	1	2	1	1	1
☐	5	30	Feasible	2	1	1	1	1	1

Figure 15 OptQuest solutions report

5.2.2 Process analyzer

Process analyzer is a reporting tool available in Arena that is very useful for analyzing data with the objective in increasing product yield. This report is especially useful in the way the saves considerable amount of time when we try to test different scenarios without the necessity of changing anything in the simulation. This report was run under three different scenarios that we considered important to analyze. The first scenario is the current optimized simulation, the second one we decided to test the possibility of adding a second person in the operation of writing the report which resulted in an increase of four orders in the total output, and the third trial was testing the possibility of adding two people in the operation of heated solvents which cause an increase in the total output by two orders as shown below in figure 16.

	Scenario Properties					
	S	Name	Program File	Reps	Aimee	Hogan
1		Current	1 : library edition of model.p	1	1.0000	1.0000
2		Report	1 : library edition of model.p	1	1.0000	2.0000
3		Heated solve	1 : library edition of model.p	1	2.0000	1.0000

Controls							
Aimee	Hogan	Kate	Kyle	Machine1	Nick	Seth	Tanner
1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1.0000	2.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2.0000	1.0000	1.0000	1.0000	1.0000	1.0000	2.0000	1.0000

			Responses		
Entity 1.NumberIn	Entity 1.NumberOut	System.NumberOut	Aimee.Utilization	Hogan.Utilization	Kate.Utilization
41.000	30.000	30.000	0.440	0.897	0.000
41.000	34.000	34.000	0.440	0.508	0.000
41.000	32.000	32.000	0.229	0.910	0.000

Machine1.Utilization	Nick.Utilization	Seth.Utilization	Tanner.Utilization
0.941	0.000	0.570	0.603
0.941	0.000	0.570	0.603
0.942	0.000	0.272	0.569

Figure 16 Results process analyzer report

5.3 Final Solution

1. Add an extra heated solvents machine and assign it to Seth.
2. Add an extra device to perform electrical test for a total of two devices and let Tanner to do this job.

3. Assign the xray machine to Aimee and allow her to perform this test in a simultaneously way while waiting on heated solvents test machine to finish.
4. Assign the XRF machine to Kyle.
5. Assign the decap machine to Seth and allow him to perform this job simultaneously while waiting on heating solvents machine to finish the test.
6. Assign solderability machine to Tanner.
7. Assign report to Hogan.
8. Train Tanner to perform solderability test.
9. Add an additional person in the operation of writing the report.

Table 9 Results

Operation	Operator	Distribution	Time (min)	Allocation
Electrical	Tanner	Constant	30	Value added
Electrical 2	Kyle	Constant	30	Value added
Xray	Aimee	Constant	14	Value added
XRF	Kyle	Constant	11	Value added
Decap	Seth	Constant	21	Value added
Heated solvents	Seth	Constant	96	Value added
Solderability	Tanner	Constant	22	Value added
Heated solvents2	Aimee	Constant	96	Value added
Report	Hogan	Constant	75	Value added
Report 2	Nick or Kate	Constant	75	Value added

Cost Associated with these assignments = 21 + 96 + 22 + 14 + 30 + 78/2 + 11 = 198 minutes

Numbers in red are the improvements resulted from the simulation where 21 minutes for decap and 14 minutes for xray operations will be performed simultaneously while waiting on heated solvents machine to finish the test and the time spent in writing the report will be reduce by half by adding a person. Currently the Total cycle time is 283. Applying this new job assignment can result in a 30% cycle time reduction. Also, savings in workforce are possible since we reduced the total workforce for the process from 7 quality technicians to 5 technicians.

5.4 Economic analysis

There were multiple design alternatives that yielded favorable results, but there were two that were the most optimal. One of the solutions was to remove Nick and Kate from the process and train Tanner on solderability, leaving 5 workers in the system with a more evenly dispersed worker utilization. This alternative is good because World Micro saves $95,680/year by removing two employees from the system, and the investment into training Tanner only cost $985 dollars. With this amount of savings, it would be feasible to invest in an additional Heated Solvents machine as well. The initial cost is only $4,800, and with the increase in lots/week, the addition revenue created would cover any maintenance cost. Also, there will be no need for any additional workers because two workers can perform Heated Solvents and Electrical or Decap simultaneously. Conversely, even without the addition of a new heated solvents machine, production increased from 20 lots/week to 30 lots/week, which, as a result, leads to increased sales and revenue. Furthermore, Tanner's utilization increased from 0.13 to 0.60. This is because he was only capable of performing electrical testing, in combination with an overpopulated system.

Removing workers from the system and training Tanner allowed for production to increase and cost to decrease, which is a win-win scenario. The other alternative introducing an additional report writer. With this design, production is higher than the previously suggested alternative, at 34 lots/week. The annual savings would be cut in half at $47,840/year, because only one person is removed from the system. In this alternative no training would take place because Kate is already knowledgeable on writing reports. So her utilization would increase, however Tanner's would stay the same because he is only capable of performing electrical testing. Additionally, the estimated profit from and additional 4 lots/week is difficult to account for due to the variation in products for each lot. Considering this, we concluded that the 5 person system is the most optimal recommendation because, the utilization of each employee is high and evenly dispersed, also the savings per year is consistent.

Chapter 6: Recommendations

We recommend adding:

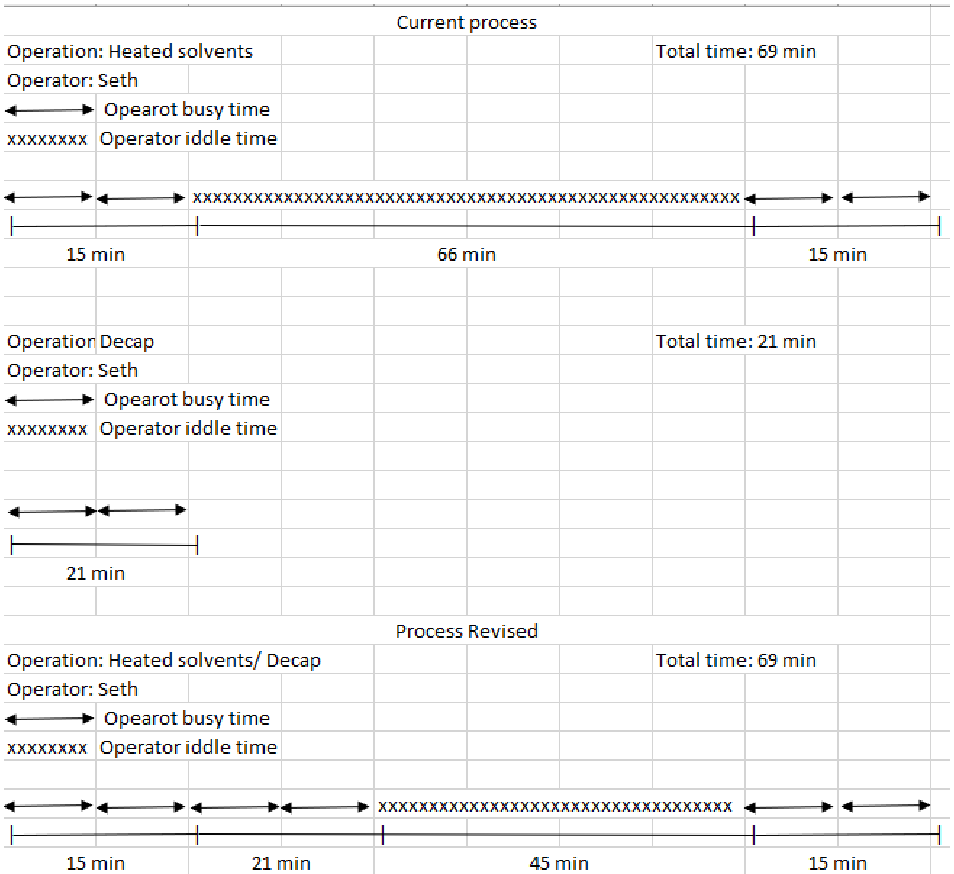
- 1 more electric machine (the company already has it).
- 1 more heated solvent machine.
- Train Tanner in solderability.
- Change the process from performing tasks sequence to simultaneously.

Recommended job assignment

Machine	Capacity	Operators
Electrical	2	Tanner/ Kyle
X ray	1	Aimee
XRF	1	Kyle
Decap	1	Seth
Heated solvents	2	Seth/Aimee
Solderability	1	Tanner
Report	1	Hogan

This is the recommended job assignment that we calculated to have the best results in maximizing output and minimizing cost.

The main change that had the greatest savings in time was using the waiting time in heated solvents machine to perform another operation like for example decap. The same process will be applying to Aimee. He will be performing heated solvents and x-ray simultaneously for a saving time of 14 minutes.



Visual process revised

It is recommended to apply these new job assignments and process revised for a total output in the system of 30 lots per week by employing 5 technicians for a total cost of $11,385.00 per week in labor cost.

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Appendix A: Acknowledgements

Appendix B: Contact Information (Student and Advisor Contacts)

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Appendix C: Reflections

Challenges Faced

- Only half of the group was able to visit World Micro due to a new requirement of visiting members being fully vaccinated.
  - Originally, management was going to allow a negative rapid test result to be enough to visit.
  - Livestreamed the visit on Teams in order for everyone to see the process and workplace.
- A second round of time studies needed to be conducted due to new employees being introduced into the process.

Task Completion Chart

Group Member	Tasks Completed
Rosa Lopez Gomez	Lingo Task Assignment Problem, Value Stream Map, Developed Arena Model, Cause and Effect Diagram, Process Analyzer, Sections of Report Done: Experimental Procedure, Results, Final Solution
Joshua Fennell	Sections of Report Done: Literature Review, Minimum Success Criteria, Responsibilities, Budget
Darius Ruffin	Iterations of Arena Model, Sections of Report Done: Problem Solving Approach, Requirements,
Nick Ricci	Budget, Gantt Chart, Data collection of time studies, Flow Chart, Sections of Report Done: General Information, Materials and Resources, Literature Review, Schedule

Appendix X: (Supporting details and documentation)

Process Time Study

Waiting Time (days)	Start Date	**Decap**	Date Completed	Waiting Time (days)	starting date	**Heated Solvents**	Date Completed
3	8/30/21	25.00	8/30/21	0	8/30/21	90.00	9/2/21
1	8/28/21	20.00	8/28/21	0	8/28/21	95.00	8/30/21
0	9/6/21	30.00	9/6/21	0	9/6/21	95.00	9/7/21
1	9/4/21	20.00	9/4/21	0	9/4/21	100.00	9/4/21
0	8/27/21	20.00	8/28/21	1	8/28/21	95.00	8/28/21
0	8/6/21	25.00	8/12/21	6	8/12/21	100.00	8/12/21
0	8/6/21	25.00	8/13/21	7	8/13/21	105.00	8/16/21
0	9/3/21	20.00	9/3/21	0	9/3/21	95.00	9/3/21
0	8/25/21	15.00	8/30/21	5	8/30/21	100.00	8/30/21
2	8/12/21	15.00	8/12/21	0	8/12/21	95.00	8/16/21
0.7	TCT=	21.50	average WT=	1.9	TCT=	97.00	average WT=
	TTT=	17.5			TTT=	95.00	

Electrical	Date Completed	Start Date	**Xray**	Date Completed	Start Date	**XRF**	Date Completed
26.37	8/27/21	8/27/21	15.00	8/27/21	8/27/21	25.00	8/30/21
23.54	8/27/21	8/27/21	10.00	8/27/21	8/27/21	25.00	8/28/21
45.12	9/6/21	9/6/21	20.00	9/6/21	9/6/21	20.00	9/6/21
34.28	9/3/21	9/3/21	13.00	9/3/21	9/3/21	30.00	9/4/21
42.08	8/27/21	8/27/21	15.00	8/27/21	8/27/21	20.00	8/27/21
15.37	8/6/21	8/6/21	15.00	8/6/21	8/6/21	25.00	8/6/21
35.26	8/6/21	8/6/21	20.00	8/6/21	8/6/21	20.00	8/6/21
23.54	9/3/21	9/3/21	13.00	9/3/21	9/3/21	20.00	9/3/21
45.58	8/25/21	8/25/21	15.00	8/25/21	8/25/21	25.00	8/25/21
27.53	8/10/21	8/10/21	15.00	8/10/21	8/10/21	20.00	8/12/21
31.87		TCT=	15.10		TCT=	23.00	average WT=
30.00		TTT=	17.50		TTT=	17.50	

waiting time	starting date	Solderability	Date Completed	waiting time	starting date	Report	Date Completed	waiting time
3	9/2/21	20.00	9/2/21	0	9/2/21	85.00	9/9/21	7
2	8/30/21	0.00	9/3/21	4	9/3/21	65.00	9/9/21	6
1	9/7/21	25.00	9/7/21	0	9/7/21	90.00	9/7/21	0
0	9/4/21	30.00	9/5/21	1	9/5/21	60.00	9/6/21	1
0	8/28/21	20.00	8/30/21	2	8/30/21	70.00	9/6/21	7
0	8/12/21	25.00	8/17/21	5	8/17/21	65.00	9/2/21	16
3	8/16/21	30.00	8/16/21	0	8/16/21	75.00	9/3/21	18
0	9/3/21	15.00	9/3/21	0	9/3/21	75.00	9/3/21	0
0	8/30/21	20.00	8/30/21	0	8/30/21	70.00	9/1/21	2
4	8/16/21	30.00	8/16/21	0	8/16/21	80.00	8/31/21	15
1.3	TCT=	21.50	average WT=	1.2	TCT=	73.50	average WT=	7.2
	TTT=	20			TTT=	45		