NORTHERN ILLINOIS UNIVERSITY

Manufacturing Efficiency Improvements on High Variation Lines

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Department Of

Industrial and Systems Engineering

By

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Motorola Solutions Inc. is a manufacturer of high quality telecommunications equipment. Their newer facility in Elgin, IL builds and assembles portable and mobile radios. Given the high variation in product mix and demand, management teams and line leads struggle to allocate the right number of workers to maximize efficiency. By creating a current state discrete event simulation model using Arena Simulation, important performance metrics were captured such as line efficiency, worker utilization, product wait times, etc. The goal is to use these performance outputs to develop an excel tool that Motorola can utilize for employee allocation.
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Capstone Approval Page

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Manufacturing Efficiency Improvements on High Variation Lines at Motorola Solutions, Inc.

By: Molly Schultz, Kodi Platt, and Saad Aldakhil

6 May, 2019
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1. Introduction

Motorola Solutions Inc., a company known for the manufacturing of telecommunications equipment, is headquartered in Chicago, Illinois. However, their manufacturing plant resides in Elgin, IL. According to Business Wire, in 2018 Motorola Solutions had net sales of approximately $7.3 billion, most of which comes from the companies rugged portable and mobile radios. The Elgin location’s production area is divided into four value streams. This project will focus on Value Stream 1 (VS1) and Value Stream 2 (VS2). VS1 produces portable radios and VS2 produces mobile radios. Within VS1 and VS2, the production lines are divided into build and customize lines. The customization lines obtain partially assembled radios from operations in Malaysia and finish the full assembly before shipping to the customer. This allows Motorola Solutions’s products to be highly customizable in terms of appearance, functionality, and program specifications. Build production lines assemble the entire radio in-house to satisfy the Buy American Act, which states that at least 50 percent of the total cost of the product must be manufactured in the United States. The build lines are not utilized as often as only a select few customers require the entire radio to be built in the USA.

The Elgin manufacturing location experiences a fluctuating demand cycle, which leads to hiring and training a variable number of employees to meet varying demand levels. The company currently relies on experience and outdated “playbooks” to decide on the number of employees to hire and where to allocate them on the production lines. This project will explore this problem and offer a solution in the form of a dynamic tool for employee allocation.

2. Process Background

2.1 Order Processing

After customers place an order, any required materials for that order are released from the warehouse using Oracle, an inventory tracking system. The radios are placed onto carts and staged before assembly. Orders on VS1 are typically placed into a box holding up to 50 radios and stacked onto the staging carts. Each cart can hold upwards of 800 radios. VS2 staging carts are slightly different considering the size difference between the products. The mobile radios are
much larger and are single stacked with up to ten fitting on a staging cart. As orders move through the line, staging carts are transported to the vend station where assembly begins.

### 2.2 Process Steps on VS1

VS1 is made up of three lines each containing 10-12 stations and typically 10-19 workers. When demand is low VS1 usually runs one line with 5-7 workers, but during peak demand periods it can utilize all three production lines with up to 40 workers to increase throughput. At the vend station each radio is assigned a serial number along with any required Federal Communications Commission (FCC) labels. During this process, the radio also gets scanned from Oracle to Parent Child Tracking (PCT) which is used to track products through the assembly line. After the vend station some models get leak tested for waterproofness. If the radio passes, then the radio is sent to inspection. Inspection is split into two stations, a visual inspection and a full button functionality test. After inspection, the device is programmed to customer specifications. Once the radio is programmed, a dust cover is installed and the radio moves to the initial packaging station. Each individual radio is placed into plastic clamshell packaging and typically boxed in quantities of 6, 8, or 10 radios. In the next station, launch, the radios are scanned from PCT back into Oracle. From launch the box moves to the over pack station where any required accessories such as the manuals, antennas, batteries, and clips are gathered, scanned for confirmation, and placed into a larger box. Later this box is weighed, assigned shipping labels, sent through the tape machine, and stacked on a pallet awaiting transport to shipping. An overview and layout of VS1 is show in Figure 1.

![Figure 1: VS1 Layout and Processes](image-url)
2.3 Process Steps on VS2

Lines 4 and 5 of VS2 contain 10 stations with 6-7 workers on the line typically. These two lines are dedicated to production of “legacy” radio models. Line 7 is dedicated to producing the newest model, APX8500. Line 7 has an extra station where the radio buttons are tested, but is otherwise similar to lines 4 and 5.

The vend station on VS2 is similar to the station on VS1 with the tasks of pulling the radio from the staging cart and assigning the mobile radio a serial number. However, on VS2 there are more components that are scanned into PCT and the worker must remove parts from packaging to prep for the attach station. The attach station installs the control-head to the radio. After attach, the radio is sent to a flash programming station where the it is programmed to the customer requirements. Next, the radio goes to testing where the audio, screen, and complete functionality is tested. After the test station, the device moves to the inspection station where the radio is visually inspected for defects. Once inspection is complete, the radio goes to LP5 where all accessories are scanned with the radio and packaged into a tray. After LP5, the radio and accessories are packaged into a large box, taped, weighed, and scanned into Oracle. The order is finally placed onto a pallet to be taken to shipping. An overview and layout of VS2 is show in Figure 2.

![Figure 2: VS2 Layout and Processes](image-url)
3. Problem Description

Currently, the company uses “playbooks” for deciding upon the number of employees to schedule. The playbooks contain three configurations of employees for low, medium, and high demand. The playbooks were made with outdated cycle times, do not account for specific demand or all product types, and do not offer options for different headcounts. The line leads realize these playbooks are incorrect and rely on experience to make decisions. During slower periods of the year, this poor employee allocation leads to low efficiency. During the busier, higher demand periods, when the company is less focused on efficiency and more focused on throughput, the line leads would still benefit from information on where to place employees to get the best throughput when they potentially do not have a full line. This information not only helps the line leads, but also management teams in determining the proper number of employees or contractors to hire.

The problem this project aims to address can be summarized as follows. Due to the fluctuating nature of the demand and lack of set procedure for employee allocation, Motorola Solutions struggles to have the appropriate number of workers and which stations to assign them to in order to maintain efficiency on the portable and mobile customization lines.

4. Objectives and Deliverables

4.1 Project Objectives

For the first quarter of 2019, Motorola Solutions has seen an average efficiency of 55.1 percent on VS1 and 66.3 percent on VS2. The goal of this project is to increase this efficiency by 10 percent through improving employee allocation. Motorola Solutions currently measures this metric on a weekly basis by using product earned hours, actual production totals, and available employee hours. This objective should be achieved by implementation of the delivered tool during May 2019.

Obtaining this objective will benefit the company by leading to more effective management of resources for portable and mobile lines. Underutilizing employees leads to poor morale while
having too few employees results in not meeting quarter end goals. This project will result in a tool that will aid the company in deciding upon the optimal number of employees and the best way to assign them during different demand periods.

In order to meet this objective, a current state simulation model was created to test different combinations of employees and stations to find the most efficient configuration to meet a specified demand. Simulation was chosen as a solution method because of the ability to test the production line under various situations without having to witness and record data in real time. Simulation also allows for variation in cycle times, product types, and employee skill levels that other methods cannot account for.

4.2 Project Deliverables

The results from this simulation model were used to aid in developing an excel calculation tool to be delivered to the company. The key stakeholders, plant manager and line leads, will use the tool to decide upon how many employees to schedule for the best efficiency.

Additionally, the simulation models will be submitted to the company for future use and updates.

5. Timeline

The project was broken into five phases to organize tasks as shown in Figure 3. Below is the overall timeline for the project. The orange line indicates the current date. The red cells indicate if a milestone was completed later than planned.

Phase one consisted of the project kick-off and data collection. Collecting cycle time data proved to be more time consuming than expected due to the lack of control over the product mix. As a result, this milestone was completed two weeks later than planned. Phase two was made up of analyzing the data collected and creating a current state simulation model. Because of the delay in data collection, phase two and three were also delayed. In order to make up for this delay, some milestones in phase three were completed simultaneously with phase two. Phase three contains milestones related to model validation and stakeholder input. Completing some of these milestones at the same time proved to be helpful because the team was able to work directly with
stakeholders, like the plant manager and line leads, to create the simulation model in a way that was accurate to reality and with meaningful outputs.

Phase four and five contain milestones for the project implementation and close-out. The nature of these tasks allowed for some of the milestones to be completed simultaneously.

<table>
<thead>
<tr>
<th>PROJECT TITLE</th>
<th>Manufacturing Efficiency Improvements</th>
<th>COMPANY NAME</th>
<th>Motorola Solutions</th>
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<td>MENTOR</td>
<td>Rigo Sanabria</td>
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Figure 3: Project Timeline

6. Project Scope

As previously stated, the Motorola Solutions facility manufactures mobile and portable radios and provides network integration services. This project focuses on the manufacturing side of Motorola Solutions’ services. Specifically, the scope includes Value Stream 1 and Value Stream 2 customization lines. These lines make up a large percentage of revenue, so it is beneficial to Motorola Solutions to focus on them. For the sake of this project, each value stream is defined as when the first operator picks a product for processing at the first station and ends where the products placed on pallets ready for shipping.
Other lines and departments inside the facility such as build, customer quality assurance, Value Stream 4, warehouse, and shipping are outside of this project scope. Because they are out of the control of the team, the production schedule and planning are also outside of the scope.

Both value streams have a variety of products. In this project, the products which make up at least the top 80 percent of demand has been studied and included in analysis. The products were chosen using a Pareto chart which can be seen in Figure 4. A total of eight products on VS1 and four products on VS2 made up 80 percent of demand on each line. These products are shown in Table 1 below.

| Products in Scope |
|-------------------|-------------------|
| VS1               | VS2               |
| APX900            | APX2500           |
| APX1000           | APX6500           |
| APX2000           | APX6000           |
| APX600xe          |                  |
| APX8000           |                  |
| APX8000xe         |                  |
| SRX2200           |                  |

7. Historical Data Analysis

7.1 Simulation Model Inputs

7.1.1 Demand Analysis

Weekly production data was provided to get an idea of the product mix and demand trends on VS1 and VS2. As shown in Figure 4, Motorola Solutions typically sees an increase in demand as the quarter progresses and more so toward the end of the year. To account for this, contractors are hired temporarily to allow Motorola Solutions to meet their goals. Determining the correct number of workers needed on the customization lines of VS1 and VS2 is the first step to increasing the efficiency. In addition, the demand data was used to determine product mix
flowing through the lines. Using Pareto charts shown in Figures 5 and 6, the top 80% of products on VS1 and VS2 were determined. Since only three or four products make up the top 80% on VS1, the product focus was expanded to also include the APX900, APX1000, APX4000, and SRX2200. The product mix was then entered into Arena using a discrete distribution.

Figure 4: Weekly Production for VS1
Figure 5: Pareto Chart for VS1

Figure 6: Pareto Chart for VS2
7.1.2 Test Station Processing Times

The leak and program stations are semi-autonomous; process times are recorded onto the server at Motorola Solutions. These times were pulled for the entire year of 2018 for analysis in order to derive a standard processing time for different product types. Once the data was filtered by product family, each set of process times were put into a Boxplot using Minitab to determine outliers.

As seen in Figure 4, there were many outliers in the data causing some concern. After an in-depth analysis outliers were determined to be operators leaving radios on the program or leak stations and going on break resulting in excessive cycle times. These outliers were simply removed to increase the accuracy of the data. In order to properly input the cycle times into Arena, each Boxplot was split up into four different uniform distributions representing each of the four quartiles in a Boxplot. The first distribution goes from the minimum value (excluding outliers) to the first quartile. The second includes process times from the first quartile up until the median. The third quartile includes values from the median to the third quartile. Finally, the last distribution went from the third quartile to the maximum value (excluding outliers).

![Boxplot of Cycle Times at Program](image)

Figure 7: Boxplot of Cycle Times at Program

7.1.3 Batch Size Data

When doing cycle time studies at the vend station on VS2, it was noticed that the vend worker had to print off paperwork for the first radio in each order. The printer is located away from the workstation which causes approximately a 34 second delay. To properly measure this in Arena,
batch size data was analyzed to get an idea of how often the worker was required to perform this task. The data was broken down into the top 80% of batch sizes which were 1, 2, 3, 10, and 20. This was fit to a discrete distribution to determine the frequency of the vend station print delay.

7.2 Data Used for Model Validation

7.2.1 Hourly Production and Headcount Data

Hourly production and headcount data were obtained from Motorola Solutions. Historical production quantities and headcount values were tested in the simulation model to find the total simulation time to produce the given quantity. Then, using a paired t-test, the results were compared to a total shift time of eight hours. The results of the paired t-test for VS1 and VS2 model validation can be seen in figure 4 and figure 5 respectively. The p-value of .268 and .776 show that there is no statistical difference between the run time of the simulation and historical data for VS1 and VS2 respectively.

![Paired T-Test and CI: Actual, Simulation](image)

Figure 8: Validation VS1
7.2.2 Efficiency Data

Efficiency data was used to compare the optimal efficiency found through simulation to historical efficiency. This was after the allocation tool was developed to determine the potential impact of the project. It was found that with any amount of workers, the suggested solutions consistently achieved a higher throughput with a higher efficiency when comparing to historical data. These comparisons will be further reviewed and explained in the results section.

8. Data Collection

8.1 Cycle Time Collection

Manual cycle times studies were conducted at each station on VS1 and VS2. This process consisted of filming employees performing tasks until roughly five samples were collected. Motorola Solutions made the recommendation to film the employees so the videos could be analyzed afterward to ensure the samples accurately reflected the standard operating procedures. After analyzing each set of cycle times it was determined that five samples would not fit an accurate distribution. Therefore, more cycle times were collected for each product at every station. To find the required sample size, a 95% confidence interval was used to calculate the margin of error. The equation is as follows:

\[
\text{Required Sample Size} = \frac{1.96 \times \sigma}{\sqrt{n}}
\]

(1)
In equation 1 above, \( \sigma \) is the standard deviation of the initial sample and \( n \) is the suggested margin of error. After speaking with the project sponsor a recommended margin of error was given as \( \pm 5 \) seconds. This required sample size calculation is then used as a target to confirm enough samples were collected to fit the data to an accurate distribution.

### 8.2 Comparison of Means

Each product produced by Motorola Solutions can be model one, two, or three. The project initially focused on cycle time collection for model three radios. Model three radios have the longest production time so they were initially the focus to find conservative cycle times. After collecting data for a brief period, it was determined that the scope would need to extend to more models because of the limited production of model three. Figure 9 shows a Two-Sample T-Test which compares the means of two data sets. With an observed p-value equal to 0.173, these two data sets could be combined. This procedure was repeated for all instances in which cycle time data existed for both model 2 and 3.

### 8.3 Removing Outliers

Once cycle time studies were completed, boxplots were used to find any outliers in the data. Outliers skew data away from the true value, so analyzing each set of data and extracting the outliers is crucial before fitting to a distribution. An example of one of the boxplots can be seen in Figure 10. The boxplot shows a variety of useful parameters including the mean, median, first and third quartiles, and which values are considered outliers. Next, outlier cycle times needed to be analyzed further to confirm it was indeed an outlier. If it was determined that the outliers did not reflect normal cycle times, they were simply removed.
8.4 Fitting to Distributions

The purpose of fitting each set of cycle times to a distribution is to accurately reflect the variance seen in reality. Motorola Solutions’ production lines have high variance in cycle times due to several factors such as the changing product mix and different skill levels of workers. Simply using an average for cycle times would not capture that variation when creating a current state simulation model. Instead, the individual distribution identification tool in Minitab was used to find the best distribution with the highest p-value.

As shown in Figure 11, a goodness of fit test was done for each set of cycle times. A distribution was considered a good fit if the p-value was above 5 percent. Most data sets followed either a normal, exponential, or Johnson transformation distribution. The Johnson transformation simply transforms non-normal data into a normal distribution. An attempt was made to refit any Johnson transformations to a lognormal distribution however, none of the p-values surpassed 5 percent.
9. Simulation Model

A simulation model was created to represent the current state of VS1 and VS2. The two models were created separately because workers and resources are never shared between the two value streams. Keeping the value streams in separate files reduces the model size and increases the speed at which the simulation will run. In section 8.1, the major components to the logic for VS1 are described in detail. The simulation model for VS2 is very similar to the model for VS1. Although the products are different between the two value streams, the assembly lines follow a similar sequence and logic. For this reason, the logic for VS2 will not be described in detail.

9.1 Assumptions for simulation

In order to build the simulation models several assumptions were made. The assumptions were used to generalize a variable process and human activity in order to represent it with the most accuracy possible within the simulation model.

The assumptions include:

- A “pull” mechanism was applied, so orders enter the system whenever the vend worker is free. This leads to the vend worker being completely utilized. The vend worker is not considered a bottleneck even at 100 percent utilization because this can be explained by the model logic.
- The line starts empty and idle. No remaining work in progress units from the last shift are present at the start of a shift.
• Orders consist of one radio only. The model of that radio varies based on a discrete distribution calculated from the weekly demands from 2015 - 2018.

• No set-up or changeover times between product types were considered at each station. This means that any product type can be processed by any station in any order.

• Buffers between stations are assumed to have an infinite capacity in order to detect bottlenecks.

• Products move in one-piece flow through the line.

• A shift is eight hours long. Employees take a fifteen-minute break and a thirty-minute lunch. Otherwise, employees are available for the rest of the shift. The total available time for an employee is 435 minutes.

• Employees are stationed at a specific station for the entire shift unless another station has no worker assigned.

• Stations with no worker assigned will request the least busy worker to operate the station when an order arrives.

• Lines four and five of VS1 and VS2 are facing each other, so employees and stations can be shared.

• Program and testing stations can be used for any product type.

9.2 VS1

When beginning to construct the simulation model several variables, attributes, sets, and resources were defined. For example, an expression for each station was defined which contains eight distributions. Each of the distributions represents the processing time for a product type at that station. Sets were created to contain workers, stations, product types, and product pictures. For example, “Set_Insp1Workers” contains all eight inspections workers on lines 4 and 5. Workers capacity was based on the break schedule using the preemption rule, to ensure that workers leave to break exactly at break start and resume the process after break. Multiple indexes were defined as an attribute to reference products, workers, and stations to their sets.

In general, the logic for each station can be classified as entity creation, general process logic, worker-machine logic, or a shared worker station. Entity creation refers to the creation of order and holding in a staging cart. General process logic applies to all processes that do not fall under any other specific category. Worker-machine situations are those in which a worker must load
and unload an automated testing or programming machine. A shared worker logic is defined as one in which multiple workers are shared amongst a defined set of stations.

### 9.2.1 Entity Creation

As seen in Figure 9, for VS1 the orders enter a system in a constant flow. The arrivals are currently assumed to be infinite. The infinite arrivals help to measure worker productivity, line efficiency and identifying bottlenecks at full demand. A product type attribute is assigned to each order based on historical demand data.

A global variable “L3Running” is used to test if the third line is active or not. Line 3 only operates in case of very high demand. The variable has been placed to examine the effect of adding a third line to the value stream. Because data has not been acquired for how orders are split between the lines, an assumption that the percentage of splitting between the lines will not affect the simulation results is made. This assumption is valid because the rate of arrivals to the system far exceeds the vend worker, first station, processing speed. A staging cart was modeled as a hold to ensure that orders remain in the cart until a vend worker is free. The total time in the system is recorded between the product leaving the staging cart until it gets to the shipping pallets.
9.2.2 General Process Logic

Throughout the VS1 model, the same logic has been applied to all stations except for leak and dry, inspections 1 and 2, and programming. When a product enters a station, a decide model tests if there is a worker assigned to the station by checking the number scheduled for the necessary resource. In case there is a worker assigned, the product waits in the queue until the worker finishes processing the previous product. In case that there is no worker at that station, the product will seize the least busy worker from a set that contains all workers. On lines 4 and 5, the resources are shared, so the set will contain all line 4 and 5 workers. For line 3 that set contains line 3 workers only because line 3 is farther distance from the other lines and the resources are not shared. After seizing a worker, an index is assigned to that worker to ensure that specific worker is released after processing the product. Additionally, after each process station the efficiency is recorded. Motorola Solutions records efficiency by comparing the earned hours, as found using equation 2 with the total available working hours. The total available working hours is defined as the number of workers multiplied by the number of hours worked per employee. This is a valid and simple efficiency calculation that is easy to use in practice. Because of the enhanced abilities offered by simulation, the efficiency could be recorded using the total processing time at each station. This gives a more accurate efficiency value compared to using the earned hours.

\[
\text{Earned Hours} = \text{Standard processing time} \times \text{Number out} \quad (2)
\]
Efficiency = \frac{\text{Earned Hours}}{\text{Total Available Hours}} \quad (3)

Efficiency = \frac{\text{Total Accumulated Processing Time}}{\text{Total Available Time}} \quad (4)

### 9.3.3 Worker with Machine Logic

Most of the processes on VS1 are done manually by the employees. Some operations, however, require automated processing. For example, leak and programming stations require the worker to plug and unplug the radio from a machine at the start and end of the process. Due to the nature of worker-machine interactions and the fact that multiple products can be processed simultaneously, additional modules and logic changes were made that differentiate this logic from the general logic used for a process station in the rest of the model.

The process was broken into several steps. As seen in Figure 11, a product seizes the programming worker to be loaded to the programming machine then releases that worker to proceed to process the next product in queue. After the programming time is over, the product is held until the worker is free to come and complete the process. A variable, “picked,” was used in that hold to ensure that multiple products are not attempting to seize the worker at the same time. Initially, the value of picked is zero. It changes to one as soon as a product seizes the worker. Then variable is then reset to zero if the product is either placed in the programming machine or delivered to the next station.

Figure 15: Programming Logic
9.2.4 Shared Worker Logic

Inspection 1 and inspection 2 share workers between the two stations. Instead of seizing from a set of inspection 1 workers only, a set of all inspection workers was defined for inspection 1. The product will seize the worker based upon the preferred order rule as seen in Figure 12. To ensure that the workers assigned at that station should be seized first by the product before requesting another inspection worker, the set was created with inspection 1 workers listed first followed by inspection 2. For example, if a product reaches inspection 1 station on line 4, it would attempt to seize either of the two workers assigned to the station first. In the case where no worker is available at the station, it will seize one of the inspection 2 workers. If both of these workers are also busy, it will seize an inspection worker from line 5. If all of these workers are busy, it will wait in queue. If there are no inspection workers scheduled, the product will follow the same logic seen in section 8.2.2 and seize the least busy worker from the set of all workers.

![Figure 16: Seize Resource Logic](image)

9.3 VS2

The simulation model for VS2 is very similar to the logic for VS1, so as previously stated the logic will not be covered in this report. The differences between the two models occur mostly in the expressions, process times, and the number of stations and employees. Other than these changes, the two models follow a similar logical pattern.
One key difference in VS2 is the introduction of a future state model. The VS2 lines are currently undergoing a change which will decrease the time spent at the bottleneck station, LP5. Because of this, the model for VS2 was set to include an increased number of workers and stations for the LP5 station. This version of the model could not be validated due to the lack of historical data on the additional stations. It was assumed that all additional stations and operators will function and perform exactly the same as their duplicates.

### 9.4 Process Analyzer for Arena

An additional tool was used to analyze scenarios in the model. The company requested for the current state models to be used to create an average production rate for different employee headcounts. Results were found by selecting multiple scenarios similar to the current employee allocation methods used by Motorola Solutions. Throughput and efficiency were output for every scenario. The results of this scenario analysis show that adding more workers does not necessarily increase throughput. This can be observed in figure 15. These outputs are based on the current state and do not reflect improvement in allocation of workers.

![Figure 17: VS1 Employee Headcount and Efficiency from Process Analyzer](image-url)
9.5 OptQuest for Arena

OptQuest for Arena was used to find the best arrangement of employees given a specific headcount. The controls for this optimization were binary variables for each employee to be stationed on the line. 0 indicates no employee is assigned and 1 indicates 1 employee is assigned. The constraint for the optimization is the total headcount in order to find the best allocation for each level. The objective was to maximize efficiency as this is the goal of this project. From the optimization, the following responses were obtained:

- Throughput
- Efficiency
- Average Time in System
- Total Number of Workers
- Employee Station Assignments

Optquest produces thousands of solutions. From these solutions, the top 25 were evaluated for each headcount. One solution was chosen based on the likelihood of implementation, best efficiency, and total throughput.

11. Employee Allocation Tool

11.1 VS1 Calculator

After collecting all of the OptQuest results and compiling them into a single master spreadsheet the excel calculator can now be developed. Since OptQuest ran thousands of simulations for each number of workers, it was manually sorted into a summary table containing the best solutions. The summary table shows the throughput, efficiency, and allocation for a specific number of employees ranging from 3-40. The layout of the calculator is shown below in Figure 16.

For ease of use any cell in which the user does not need to edit has been locked. This helps keep the file neat and eliminates the possibility of destroying any equations. As shown above, the cells which are editable are colored to tell the user which cells can be changed. The only values the user needs to input is the demand of each product type and the actual headcount if the demand is
unknown. In terms of calculations, this excel tool first sums up the total demand to search through the summary table to find the optimal crew size. A VLOOKUP function is then used to search for the optimal crew size and pull all the other key metrics such as maximum expected output, efficiency, average time in system, and allocation. The takt time is a simple calculation driven by the total demand the user inputs. The total available time is 435 minutes, which is a full shift with breaks removed. The allocation simply gives the number of workers required at each station. This requires line leads to know that if four inspection 1 workers are required, they will need two employees on line 4 and two on line 5. This is because the max capacity for each inspection station is two workers. Therefore, as long at the station capacity is known, line leads should be able to evenly distribute workers using this tool.

<table>
<thead>
<tr>
<th>Product</th>
<th>Demand (Per Shift)</th>
<th>Optimal Crew Size</th>
<th>Actual Crew Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>APX5000</td>
<td>100</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>APX1000</td>
<td>75</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>APX2000</td>
<td>0</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>APX5000</td>
<td>0</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>APX7300</td>
<td>0</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>APX9000</td>
<td>100</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>BAK2200</td>
<td>300</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Total Demand</td>
<td>575</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Max Expected Output</th>
<th>Expected Efficiency (%)</th>
<th>Avg Time in System (min)</th>
<th>Total Takt Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>515</td>
<td>79.87%</td>
<td>23.20</td>
<td>0.76</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vani</th>
<th>Leak/Dry</th>
<th>Inspection 1</th>
<th>Inspection 2</th>
<th>Program</th>
<th>Dust</th>
<th>Packer</th>
<th>Launch</th>
<th>Pick Accessories</th>
<th>Over-Pack</th>
<th>Weight-ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual Crew Size</td>
<td>Max Expected Output</td>
<td>Expected Efficiency (%)</td>
<td>Avg Time in System (min)</td>
<td>Total Takt Time (min)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>368</td>
<td>79.77%</td>
<td>27.07</td>
<td>0.76</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vani</th>
<th>Leak/Dry</th>
<th>Inspection 1</th>
<th>Inspection 2</th>
<th>Program</th>
<th>Dust</th>
<th>Packer</th>
<th>Launch</th>
<th>Pick Accessories</th>
<th>Over-Pack</th>
<th>Weight-ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employee Allocation</td>
<td>Use this section if DEMAND is unknown to determine best allocation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 18: VS1 Employee Allocation Tool

11.2 VS2 Calculator

The employee allocation tool for VS2 is almost identical to the tool used for VS1. The user will however have fewer products to enter demand for considering the simulation model for VS2 only included three products. Again, OptQuest results were pulled into a master spreadsheet and used to make a second summary table for VS2. The employee allocation tool for VS2 is shown below in Figure 17. The colored cells again are the only editable cells eliminating any potential user error.
Figure 19: Employee Allocation Tool for VS2

12. Recommendations

It is recommended that Motorola Solutions begin using the employee allocation tool to determine the best headcount before adding additional temporary workers during times of high demand. It is also recommended that Motorola Solutions use the tool to find the best allocation of the workers if the actual current headcount is different than the suggested headcount due to weather, hiring problems, or other reasons.
References