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Senior Design Project For Engineers

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A-Set Process Improvement

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SIEMENS

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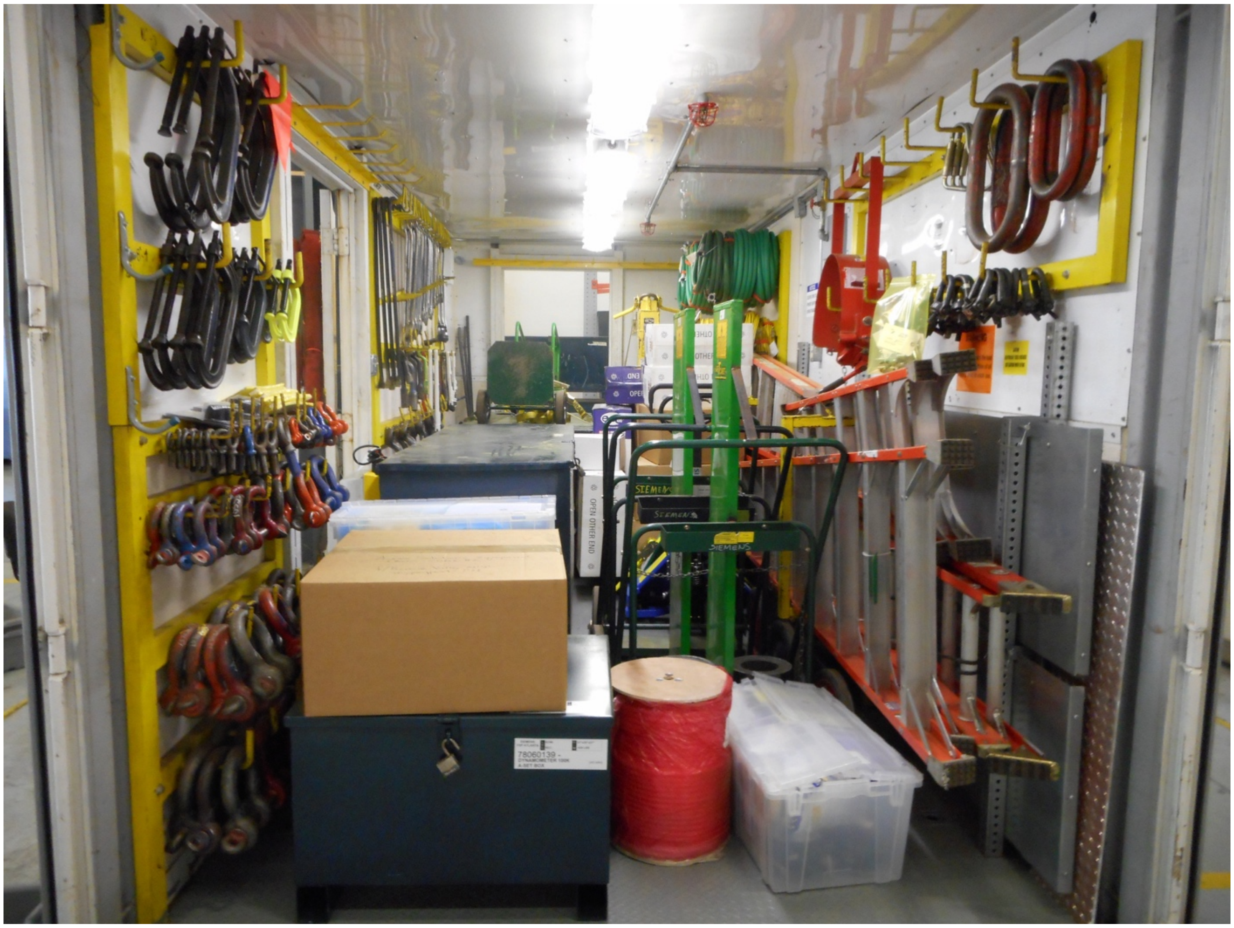

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EXECUTIVE SUMMARY

Siemens Energy offers world-class products and solutions for power generation. They help their clients worldwide to successfully operate conventional power plants by renting out their toolkits. Clients can work on anything from gas or steam turbines, generators, turbines, or even hybrid power and storage. One of Siemens' more profitable toolkits would be the A-Set, or as the floor assemblers refer to as 'the majors,' which consists of two large conex containers filled with thousands of tools ready for any type of operation at power plants. By looking at how long it takes floor assemblers at the Siemens Facility in Suwanee, GA to unload, degut, perform inventory, etc. on A-Sets coming in from use, our teams goal is to optimize the process and cut down on time to reduce the turnover rate.

From time studies performed at the facility, the collection of logbooks kept since early 2016, and interviews taken from leads in involved departments, it was found that the average turnover rate of an A-Set is roughly 12 days, from start to finish. Given the processes involved with ensuring that the A-Set is ready to be "white-tagged" or ready to be sent out again to a new client, our team used tools such as Arena ® Simulation Software, DMAIC, statistical analysis, and process mapping to assess the system to be able to cut down on time. Through the analysis of the data and simulations run from Arena ®, the Mechanical Jack process was found to be the bottleneck in which the entire process would be waiting on.

Following the acknowledgement of the bottleneck, the implementation of a solution involving an additional floor assembler and a priority system set to allow the Mechanical Jack process to begin faster, we were able to reduce the turnover time from 12 days to 8.55 days, while also increasing the revenue flow by increasing the amount of A-Sets Siemens could theoretically turn out in the same period of time with the reduction in time per turnover.

With the turnover time being reduced, it is important to note that while in our calculations we accounted for additional A-Sets being turned out, that the Siemens facility in Suwanee could use the extra time shaved off per cycle in whatever which way they prefer. Initial recommendations would be to use the extra time to turnover more A-Sets, but another option could be to cross train their workers to circumvent any other slow processes that they may come up against through the reallocation of their workers from process to process as their priority levels increase.

Regardless of what the facility decides to do with the reduction of turnover time, our team was successful in our endeavors and the following report will delve into what each process consisted of, as well as the direction our team chose to assess the system and give a formal recommendation to Siemens Energy.

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CHAPTER 1: INTRODUCTION

The Central Tool and Instrument Facility in Atlanta, GA supports the activities of the Siemens Power Field Service with equipment used during regular routine maintenance or crisis events like outages and unexplained error. This facility impressively reaches all over the world by being strategically placed near three major highways and just miles away from the world's busiest airport, Hartsfield-Jackson International Airport.

The goal of this facility is to be able to respond quickly to customer needs. It features various mechanical shops properly equipped to repair all supporting tools. It hosts several labs that repair, clean, and calibrate sensitive tools like torque wrenches and industrial weight scales. A critical job for this facility is to turnaround tool containers from being completely used to fully repaired quickly. These fully replenished containers are subsequently shipped to large scale power plants, industrial sites, constructions zones.

The Siemens Power Service is an entity that can supply on-site repair, inspections, and outage services by having hundreds of well-trained technicians; along with highly-skilled and distinguished engineers all around the world. For the scope of this project, the team focused on A-Set tool kits for gas and steam turbines.

1.1 OVERVIEW

A-Set tool kits are comprised of thousands of pieces separated into two different containers that are shipped to the same location, which is based upon the needs of customers. These kits are leased to different customers around the world and when the job is finished or the customer has no use for the kits anymore, they are shipped back to the Central Tool and Instrument Facility in Atlanta. Once the kits are back in Siemens' possession, a dynamic process begins to make the kit fully operational before its next assignment. An upside to this facility is the ability to use flexible manufacturing and production techniques. For instance, workers are generally trained and skilled in various disciplines. Interviews conducted by the team displayed how many of the employees started in one section and then subsequently moved to another. For example, an employee was recently switched from the mechanical pneumatic lab to working with digital gauges at the electrical II lab. This may seem inefficient but the skills and training career Siemens employees have has allowed them to be flexible and multi-faceted.

1.2 OBJECTIVE

The objective of this project is multifaceted in which there are several areas of concern dealing with the A-Set turnover process. Firstly, and most importantly, the focus of this project is to decrease the total amount of turnover time from 12 days to about 5–7 days. To accomplish this, a time-study will be conducted to find bottlenecks and inefficient processes within the current system. As research is conducted, the scope of the project will begin to focus on the surrounding support staff that work in conjunction to complete A-Set turnover. This support includes various technicians and engineers in shops (or laboratories) that specialize in a specific set of tools and materials. These labs include; mechanical (pneumatic, jacks, and chain hoist), electrical I (tools), electrical II (digital gauges and instruments), and torque (i.e. wrenches). These shops must go through an extensive time study to find the faults in their respective system which ultimately effects the overall time of A-Set turnover.

1.3 JUSTIFICATION

The inefficiency in the A-Set turnover process must be studied to fully understand the faults not only within the specific system in question, but determining the inefficiencies of the overall facility. There are several factors that contribute to the latency of production, so they must be identified and study in detail. Once a complete knowledge of the situation has been obtained, a goal is established to create purpose.

The justification for the changes will be seen in the amount of time saved during an A-Set turnover. The need for overtime hours will diminish because A-Set orders will be properly handled, so there will be no need for extra work outside of normal hours of operation. The availability of completed A-Set kits will also increase which will allow for more potential orders to be received and processed. If A-Set inventory is full and accurate at this facility, then Siemens can lease these kits at a higher demand because they are now able to reach all over the world in a timely manner. This will ultimately increase sales because the kits are being used and replenished in time before it’s next assignment.

Siemens has a similar facility in Houston, TX that is much larger and can conduct various task that outside the scope of the facility in Atlanta, GA. A major point of similarity is A-Set turnover. The Houston facility has successfully mastered this system by standardizing the process which can be completed within 5-7 days. This project will try to match that level of success using new design ideas.

1.4 PROJECT BACKGROUND

Siemens has employed the group at Kennesaw State University to find anomalies within the A-Set turnover process. These hiccups within the system must be studied at length to ensure proper understanding of how and why they keep occurring. Siemens is searching for a way to improve A-Set turnover times by minimizing several key factors like time spent on inefficient practices, employee turnover rates, and shop/lab bottlenecks while maintaining the current level of excellence seen throughout the Siemens corporation throughout the world. Any changes or improvements with the system must follow strict safety guidelines to ensure workers are practicing safe workplace ideas while all changes to the standardization of work are made and observed.

For the successful completion of this project there are several prerequisites needed. To begin, team members must have complete access to the facility (The Central Tool and Instrument Facility in Atlanta, GA) to conduct proper time studies of not only the A-Set process but the surrounding support systems, i.e. all repair, instrument, and supply shops. The group will also need the full support of Siemens to provide information like data and warehouse layout along with full employee availability (to conduct interviews and request feedback). There is no proposed budget because the purpose of this study is to find ways to improve the system within the given restraints (size/space of facility, safety regulations, and resource availability). There is a possibility for having to incur cost for the addition of workforce/labor, but that will be concluded when all results are analyzed and compared.

Assuming successful completion of this project, the overall process of A-Set turnover will undergo a complete overhaul. A standardized process will be improved upon; if an existing system is already in place, or a newly designed system will be developed to efficiently clean, repair, and restock these kits for their next assignment. Successful completion of this project would result in a large decrease of overall A-Set turnover times while maintaining all workplace safety regulations.

CHAPTER 2: LITERATURE REVIEW

To properly conduct a research project of this scale and magnitude, a literary review of scholarly articles, books, or previous company research is needed. The purpose of the review is to compose a theoretical background (past, present, and future) for the hypothesis chosen. The literature will also guide the study toward any previous findings and research methodologies while providing any rationale or relevance of the current study.

2.1 BREAK SCHEDULING

An initial proposed solution was concentrated on mainly reconfiguring how actual time is spent during the work day. After an extensive search, the group focused on comparing multiple methods for conducting *Human Reliability Analysis* (HRA). These HRA's are then used to find adequate rest breaks and work-rest policies. Pasquale et al. [1] make it clear that simulation based methods are "currently uncommon" which is a slight concern to the group because simulation is incorporated throughout the entire report. But based on previous use of simulation software, the group is comfortable with relying on the results of the simulation to justify recommendations. Something important to understand is that currently "no methodology has a general consensus" [1] and managers are not interested in undertaking any method because of their complexity.

Work-rest policies are centered around recovery. Pasquale et al. [1] states that recovery "is the process that repairs the negative effects of strain" and the results of a recovery effort is maximized when the individual is engaged in demand reducing activities []. The issue with creating these policies is that the benefits are not equal among workers, so parameters like length and timing of breaks are difficult to understand and eventually implement. Another contributing factor to the rise of complex work-break scheduling is the lack of research and study done on this topic. The relatively few studies that have been conducted have concluded that frequent, short duration breaks are necessary for workers who are "particularly fatigued or worker continuously for an extended period [1].

These break scheduling problems are common among several industries especially those where a rest period is indispensable. For the scope of this project, the Siemens Central Tooling and Instrument Facility A-Set turnover process contains a monotonic and mentally exhaustive aspect. Thousands of tools ranging in size, complexity, and cost must be accounted for by hand. Several hundred pages of stock manifest is used to count each tool. These book-style manifest are intimidating to the workers which negatively effects how the process is approached and handled. More research is needed to find common relationships among diverse workers with respect to work-breaks so that an adequate policy can be mandated. The potential benefits of this include higher worker awareness, productivity, and ultimately improved profits. Because of this lack of knowledge and research, the group has decided to forego this option. Pursuing research in this topic would require R&D funds which will incur a cost before any economic benefit is realized.

2.2 HR BUNDLES IN FLEXIBLE PRODUCTION SYSTEMS

John Paul Macduffie [2], an associate professor of Management at the Wharton School, University of Pennsylvania, concludes that "flexible production plants with team-based work systems, 'high-commitment' HR (Human Resource) practices, and low inventory and repair buffers consistently outperformed mass production plants." A flexible plant, like The Central Tool and Instrument Facility, must have certain conditions met to see real increases in economic improvement if innovating human resource practices are used. Macduffie [2] continues to explain that not only can you improve plant economics but performance also if the perfect "HR bundle" is implemented.

A HR bundle is a set of human resource initiatives that are packaged and implemented together, not individually. To explain further, a successful and useful bundle should have "interrelated, overlapping HR practices" [2] like problem-solving groups, off-the-job and on-the-job training, and job rotation, while boosting motivation with performance-based pay (extrinsic) and rewarding the workforce for participation in redesign and standardization of work processes (intrinsic) [2]. The research group chose to include this journal to show the importance of upper management toward efficiency.

The HR department is just as crucial to the efficiency of a plant as the actual workers who manufacture the product. The Siemens facility the group is studying can be considered as flexible production because employees can rotate among different labs and the entire facility is multifaceted because it undertakes various task like repair, design, and ship. In order for this facility to operate at an optimized capacity, human resource policies like "employment security, compensation that is particularly contingent on performance, and a reduction of status barriers between managers and workers [2]." After reading this specific journal and time-study of the process at the facility, the group has determined that the incongruent relationship of the HR department and the highly skilled workers is causing massive detriment to the overall efficiency.

2.3 INSTALLED BASED INFORMATION/DATA (IBI/IBD)

Rämänen, Jussi, et al. [3] interestingly establishes the importance of collecting data manually. There is a direct relationship between the quality and data that was gathered manually. When a company uses a specific group to collect data the quality of that collected information is tied to several factors. These factors are the monetary or discretionary company bonuses tied to the auxiliary task of collecting data; secondly, how does the data relate to the daily operations of the system; and lastly, will this extra work benefit the data collector in any way (organizationally or monetarily).

The authors dive deeper into the benefits of manual data gathering because of the downfalls or imperfections in using remote sensors and computers. “Human observation is needed to form a deeper understanding of the failure cause” [3] so proper diagnosis can fix the problem or issue long term. Temporary patches are inexpensive at first but overall cost will increase as time progresses Reliability is a function of time so it declines as the age of a product or system increases. Digitally collected data is also having an unintentional consequence in that it can possibly collect to much data. Organizations tend to make the crucial mistake of not finding the “information truly needed to be defined [3].” This leads to the collection of an excess amount of data which tends to not be financial responsible if it is just being stored for later use. There is a higher chance of finding the necessary information using smaller sets of information.

The most important aspect this article addresses is the defining of specific data collections groups and their benefits plus downfalls [4]. The first group is the staff already working at the firm. These are employees who have other primary task and those dedicated to only collecting data. Secondly, the actual customers of the service can be a great value to the data collection process considering they are using the product in real time. This first-hand knowledge is incredibly valuable. Lastly, the remaining “other” category holds several different options that are unique to the first two categories. There is an important idea addressed by this article. The quality of the manually collected data can be “negatively affected by poor management structures that do not promote accuracy, completeness, and timeliness of data report [4].”

This particular Siemens facility does make an effort to collect information but most of it is either considered highly confidential (which means it is not easily and readily available) or large chunks are missing entirely. Ultimately, this crucial data needed to track workplace efficiency or find inefficient aspects of the system is nonexistent, which falls on the responsibility of upper management to motivate workers to collect high-quality data.

2.4 TOOLING REPAIR PRIORITY

Fortunately for the group, repair priority in manufacturing and production settings has been studied quite extensively. Researchers at the University of Michigan, University of Cincinnati, and the GM Research and Development Center [5] have stressed that "maintenance prioritization is a crucial task in production systems." They go on to say that priority in repairs is even more important in industries with "more maintenance work-orders than available people or resources that can handle them []." One of the largest problems facing the Siemens facility currently is the lack of skilled workers. The facility employs a small number of people and only ~50% of those workers are adequately trained to fixed complicated and complex tools. These tools include torque wrenches, electrical/mechanical pumps and jacks, gauges (digital and analogue), and scales that range from 1 lb. to 1,000,0000 lbs. in mass. The problem persists even further when focusing only on the A-Set turnover process.

During this study and extensive literary review, the group has chosen a repair priority system to further optimize the A-Set system. Currently, Siemens employs a more ad hoc system when choosing which parts to repair from the A-set. This essentially random sequence will "not only waste maintenance labor" [5] but increase the amount of down time between of workers in the A-set area. The combination of a lack of skilled workers and random repair prioritization is proving to be detrimental to the overall success and efficiency of this facility. It must be noted that the experience of workers is highly valued within this facility. The majority of employees at this Siemens facility have been associated with the company for more than 5 years and their knowledge is used as inputs for the system.

The issue with this type of sequencing is that there is to much variation in both the production system and the repair system. This randomness then creates conflicts between the required work and available resources [5] which is completely unavoidable without a proper priority system. The scope of this project will focus on using Installed Based Information/Data (discussed in the previous section) and a tooling repair priority systems to completely optimize the process. IBI should be used to measure performance degradation of A-sets and the tools within them to make proper assessments toward the maintenance schedule. It is important to understand that Siemens safety regulations forces constraints upon the system but they can be worked around and should become analogous to the safety standards already practiced.

CHAPTER 3

3.1 PROBLEM SOLVING APPROACH

The problem-solving method this project will be using is the Plan-Do-Check-Act cycle (PDCA) because of its benefits when used to "enhance workplace efficiency and production quality [6]." The method starts with the Plan stage in which the scope of project is defined. This stage describes all the objectives and milestones the project is trying to achieve. All strategies created in the Plan stage will be implemented in the Do stage. A process is created and implemented into the system to collect data and measure performance. The Check stage then assess the change and analyzes the changes to the system, both good and bad. Finally, the Act stage will either implement the newly created system or design a new plan based on the analytical studies.

The team will use this approach as a guide to keep the project from losing focus. This cycle is iterative so the team assumes multiple PDCA cycles needed to reach a conclusive solution. A new system will be designed and tested within a computer simulation. The proposal that yields the most favorable results will move forward to conduct a human study. This may go beyond the nature of the assignment but a comprehensive human study is likely necessary to validate the findings. The next paragraph will detail another method the group will be using to conduct further research using simulation software.

Using simulation techniques to research trends within an organization is a tool widely unexplored. Preliminary research has shown great results toward the validation of theoretical hypothesis and providing a relatively inexpensive tool for underfunded research activity. Kennesaw State University has provided the group with a powerful tool named *Arena: Simulation*, which creates digital representations of system's processes and allows for the comparison of various situations. These situations can have similar parameters with different inputs and number of resources.

The benefits of this tool can extend to the supporting organization, Siemens Inc. High reliability and confidence in the results of the simulation can be properly implemented in real world applications. Potential benefits include lowered fixed cost (e.g. insurance premiums), a boost in employee participation, and an increase in profits through an efficient replenishment and stocking system.

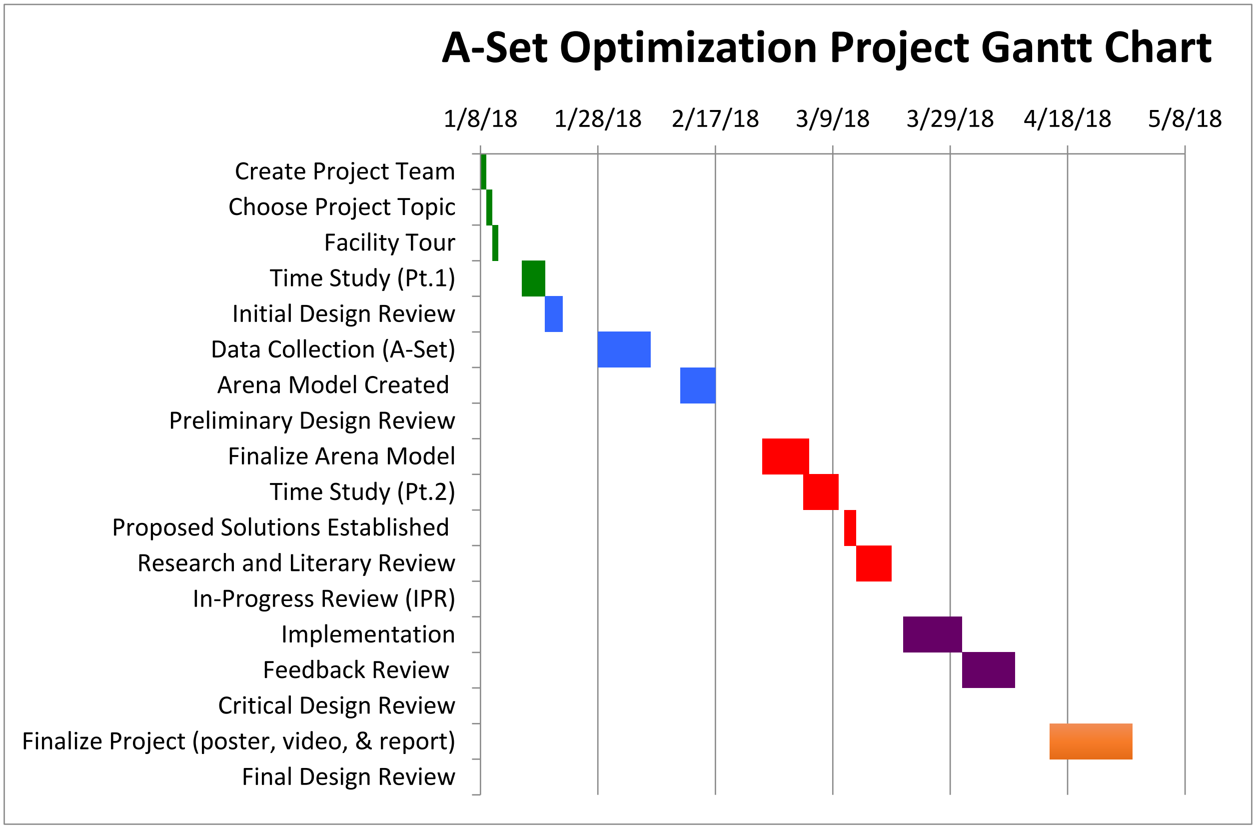
3.2 REQUIREMENTS

The following list displays the set of goals or requirements that must be accomplished to consider this a successful research project:

- Reduce the turnover rate of A-Sets from 15 days to 5-7 days.
- Time-study each step of the A-Set process to create a computational accurate representation of the system
- Determine which aspect of the A-Set process are causing production bottlenecks
- Establish a set of proposed solutions that are feasible and within the scope of the project
- Conduct a literary review to get a better comprehension of the topic and proposed solutions
- Run a cost/benefit analysis to compare each proposed solution
- Prepare weekly and monthly updates to both Kennesaw State University and management at the Central Tool and Instrument Facility

3.3 GANTT CHART

Chart 3.3.1 – Gantt Chart for A-Set Optimization Team



3.4 FLOW CHARTS

Figure 1.1 displays the current flow chart or the order in which the A-Set turnover system happens. This is what technicians are trained with to standardize the work procedure. The scope of this research will focus primarily on optimizing this procedure to create more efficiency.

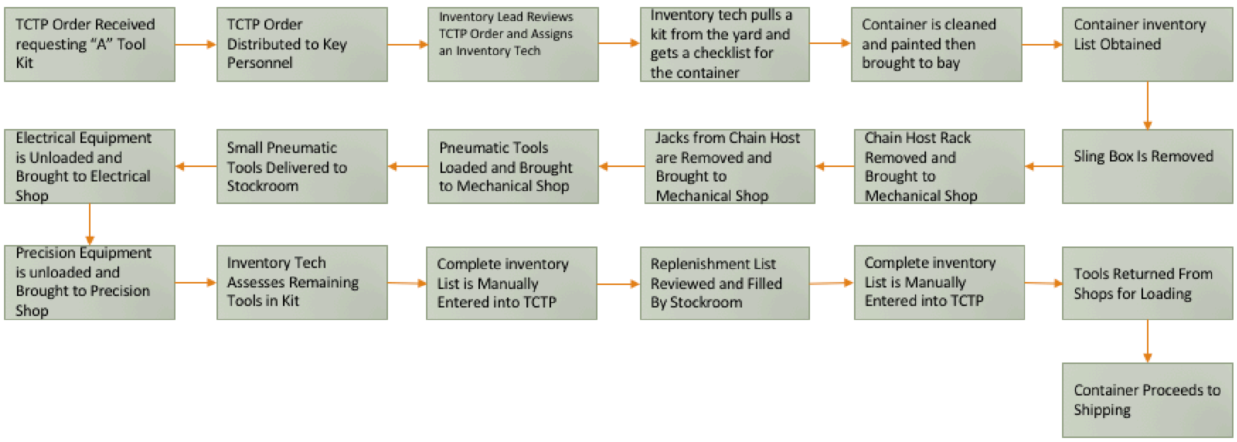


Figure 3.4.1 – Flow chart of the A-Set replenishment process

3.5 PROJECT MANAGEMENT

This project is a coordination between Kennesaw State University and Siemens. The point of contact and lead project coordinator is Ernie Ayala. Mr. Ayala is a process engineer who is in charge of educational outreach and university project cooperative opportunities. Dr. Adeel Khalid, an Industrial and Systems engineering professor at Kennesaw State University, is the student support professor who will act as the university liaison to Siemens. In terms of the student group, this project will be led by Gabriel Rubio. Mr. Rubio has the task of designating work to all other group members. This position must also enforce the completion of tasks in a timely manner while satisfying all other time constraints. Along with his duties as project manager, Mr. Rubio will also construct all simulations needed to conduct this study.

3.6 RESPONSIBILITIES

The responsibilities of the actual group members are multi-faceted in order to have a successful completion of this project. As mentioned in the previous section, Gabriel Rubio will lead the project toward completion. His duties not only involve coordinating with employees at the Siemens facility, but trading ideas with other groups under the Siemens umbrella. Mr. Rubio is also in charge of creating the simulation and running analysis on various proposed solutions and scenarios. Davis Jackson is in charge of conducting cost/benefit analysis of all proposed solutions in order to justify a selection. This part of the research is extremely important because the analysis will guide the group if any implementation is successfully granted. Lastly, Christopher Olaya will be in charge of the research. Literary reviews of past journal entries and company research is necessary to have a foundational understanding of the problem. This will allow the research group to focus on how to solve the problem instead of reinventing the wheel. Mr. Olaya will also serve as the technical writer for the report, which means amassing all the information and data collected and finding consensus in a report.

3.7 SCHEDULE

Table 3.7.1 – Team and Project Schedule

Task Name	Start	End	Duration (days)	Percent Complete
Create Project Team	1/8/18	1/9/18	1	100%
Choose Project Topic	1/9/18	1/10/18	1	100%
Facility Tour	1/10/18	1/11/18	1	100%
Time Study (Pt.1)	1/15/18	1/19/18	4	100%
Initial Design Review	1/19/18	1/22/18	3	100%
Data Collection (A-Set)	1/28/18	2/6/18	9	100%
Arena Model Created	2/11/18	2/17/18	6	100%
Preliminary Design Review	2/19/18	2/19/18	0	100%
Finalize Arena Model	2/25/18	3/5/18	8	100%
Time Study (Pt.2)	3/4/18	3/10/18	6	100%
Proposed Solutions Established	3/11/18	3/13/18	2	100%
Research and Literary Review	3/13/18	3/19/18	6	100%
In-Progress Review (IPR)	3/19/18	3/19/18	0	100%
Implementation	3/21/18	3/31/18	10	100%
Feedback Review	3/31/18	4/9/18	9	100%
Critical Design Review	4/9/18	4/9/18	0	100%
Finalize Project (poster, video, & report)	4/15/18	4/29/18	14	100%
Final Design Review	4/30/18	4/30/18	0	100%

3.8 BUDGET

The team will not incur any budgetary needs from either Kennesaw State University or the Siemens corporation. This project will be run using the funds and time of all team members, which is equally split. Extensive time was spent collecting data and interviewing several employees. These visits were scheduled based on the availability of each team member. Transportation and food cost were covered by each team member

There is a possibility of a new budget being created after a comprehensive study is found. Preliminary results show that adding an additional worker will alleviate over-using other resources. Simulation results and data will justify any addition of newer resources and the implementation of any recommendation.

3.9 MATERIALS REQUIRED

Some essential materials are required for the successful completion of this project. Extensive data must be given/collected to quantify measurements from the process. Computational software is needed to simulate the process without disturbing day-to-day operations. The team will be designing new systems using the *Arena: Simulation* software. This powerful software can model any system and study it completely by changing various factors like resource availability, plant size, or interchangeability.

3.10 RESOURCES AVAILABLE

A plethora of resources are available for the successful completion of the project. To begin with, the supporting staff at the Siemens corporation, specifically those employed at The Central Tool and Instrument Facility. Along with all the professors at Kennesaw State University including Dr. Adeel Khalid, the senior design professor running this class. Kennesaw State University has several computer rooms with updated software like *Arena: Simulation* to fulfill computational requirements.

CHAPTER 4: PROPOSED SOLUTIONS

4.1 COOPERATIVE GUTTING OF A-SET

This solution involves a tiered system in which the number of people gutting an A-Set depends on the condition it was brought back in. The system involves three coded tiers. Code green, yellow, and red. Code green means the set came back in relatively good condition and only requires two people to gut. Code yellow means the set came back in reasonable condition but still requires a lot of work to complete. Code yellow requires 3 people to complete. Code red means the set came back in terrible condition and will require extra hands to complete in a timely fashion. A code red set will need 4 or more people. The advantage of this proposed solution is less fatigue on individual Floor Assemblers while starting the inventory process sooner.

In order for this solution to be effective customer feedback must be of the highest quality. Customers must give honest and detailed feedback of the condition of the A-Set before and after its use. The information collected at the beginning of the job will give logistically data like location, specific use, time frame, and initial inventory count. Conversely, the information given at the end of the product's life cycle or use will give the condition of the conex container with detailed records of good and faulty tools. In order to shift responsibility to parent company of the A-Set, insufficient records are kept in order to maintain deniability of damaged kit pieces.

Data collected will be skewed and unreliable, which means Siemens AG would have to incur the cost of collecting their own data using current employees. This solution seems like something that would help the process decrease turnover time but seems costlier than beneficial. The group has determined this to be non-feasible solution which will not be evaluated using a Cost/Benefit Analysis.

4.2 PRIORITY LABELING SYSTEM

A priority labeling system has been proposed to speed up the inventory step of the A-Set process. Through a simulated flow chart of the system, the group identified a bottleneck which occurs at the Mechanical Jack (MJ) shop. Because of the scope of this research, the group created a reactionary response to this issue that is solely focused within the A-Set turnover process. We consider this the "front-end process." First, specially barcoded stickers would be placed on the parts associated with the MJ shop, this requires only 30 stickers specially printed with a barcode. These parts become more identifiable to the Floor Assembler and are subsequently counted for inventory. The parts should then be transported immediately to the MJ shop so they can be cleaned, tested, repaired, and certified. This is considered a feasible solution because a Cost/Benefit Analysis (CBA) displays a gain in profit after incurring all the cost that come with this option. After preliminary testing of this solution, the group found that this will also have some time saving benefits.

4.3 ADDITIONAL FLOOR ASSEMBLER

Looking beyond the scope of this project, this solution will help each shop produce faster turn-around times. Currently there are a few shops that take more than five days to complete an order. This can be due to priority orders being placed before original orders. Having more staff on hand can decrease the chance of orders taking more than five days. Currently only 3 shops would need one extra employee. The group has determined that increasing the resources in each shop would alleviate the stress of the current workload. Shops, on average, take more than five days which means that an additional set of resources would have some positive impact.

If the group applies this solution to just the A-Set process, then it can determine if this would work. Adding three (3) A-Set workers would be wasteful because the cost would overtake the benefit. Through preliminary simulation results, we determined that one (1) additional Floor Assembler would be more beneficial. This additional resource would alleviate the workload of the other employees working in this section.

CHAPTER 5

5.1 COST/BENEFIT ANALYSIS (CBA) RESULTS

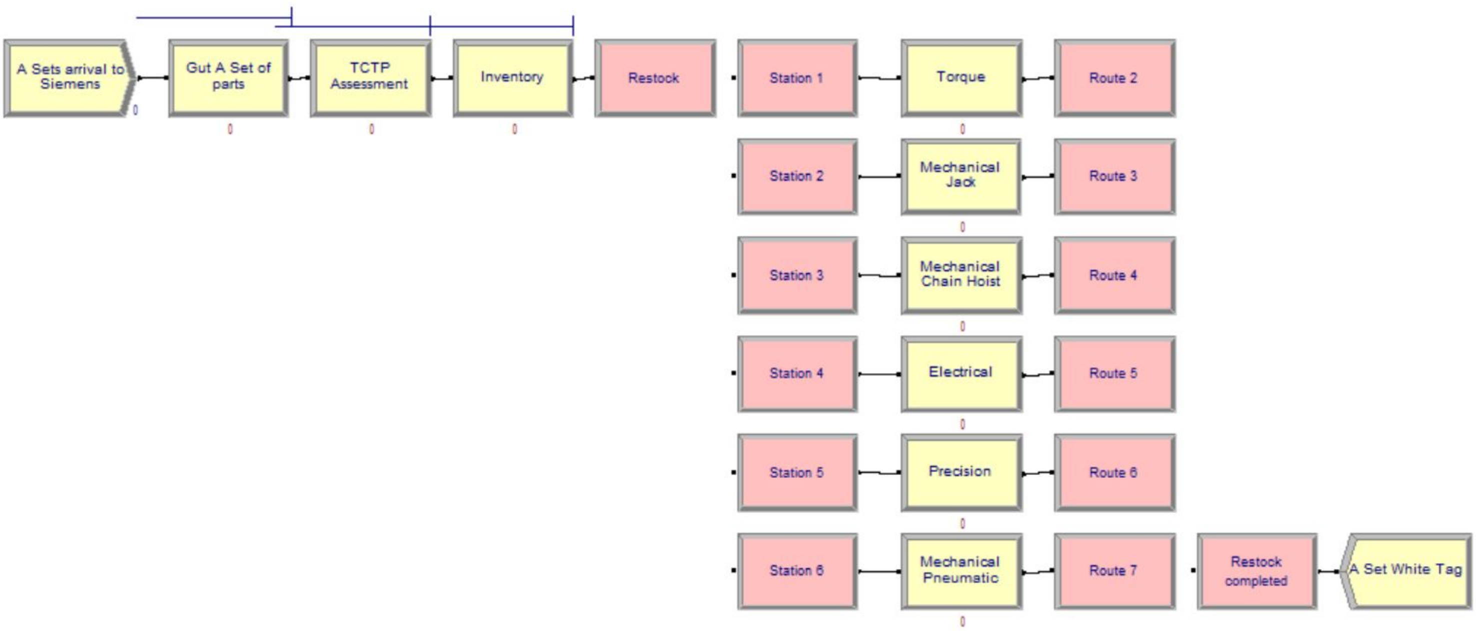
A cost-benefit analysis is a tool used by various industries to estimate and sum up the total "equivalent money value of benefits and costs to the community of projects to establish whether they are worthwhile. [7]" The definition described contains a focus toward the community but it can extend to private organizations, public firms, and even in the non-profit sector. The benefit of this type of analysis is that it brings all aspects of the project together with comparisons using a single type of common measurement. Typically, the most convenient type of measurement is money. In other words, "all benefits and costs of a project should be measure in terms of dollars. [7]" Conversely, a project's cost/benefit should be displayed with respect to a certain time frame. Watkins [7] perfectly describes this as "a dollar available five years from now is not as good as a dollar available now" and it is not entirely dependent on inflation, which is the reduction of purchasing power per unit of money. Inflation is typically based on market trends over time but a CBA is more concerned with potential investments. Per Watkins, "a dollar available now can be invested and earn interest for five years and would be worth more than a dollar in five years [7]."

For the purpose of this research, the group has chosen to conduct a cost/benefit analysis of each proposed solution in order to essentially rank the recommendations from most feasible (and potentially most profiting) to least feasible or fiscally unattractive. The CBA will also justify an action of implementation. The research group can effectively give recommendations based on the results of the analysis. Validation of the analysis and implementation must happen with a 'with-or-without' analysis as well. Both before and after snapshots of the project must be compared to see if actual gains are represented. Because of time and budget constraints the group chose to use a computational simulation to forecast how these proposed solutions will effect the overall efficiency of the system. The specific software used was Arena ® simulation developed by Rockwell Automation.

5.1.1 SIMULATION

Developed by Rockwell Automation in 2000, Arena ® is a discrete event modeling software that helps to optimize complex processes. Since its inception the software has gone through extensive changes as recently as late 2016 (version 15.0) [8]. Arena ® can be used in any type of process that has "variability, constrained or limited resources, or complex system interactions [8]." There are multiple versions of Arena ® (i.e. business and student) but for this project, the group was limited to the student version which constrains the potential of the simulation created. Even though this is a concern, the group proceeded to confide in the results as a basis for simple analysis and justification. The figure below displays a screenshot of the simulation model using Arena ®. This is just a snapshot as model for display purposes and full-size view of the model will be provided in the appendices. Also, an animation of the model will also be previewed and provided in full to validate and confirm results.

Figure 5.1.1.1 – Arena ® simulation model for A-Set replenishment process



The important aspect of this version of the simulation model is that it is an accurate representation before any changes have been made (current system). Using this model, the simulation produced 91 total A-sets received and 84 A-Sets finished (white tagged) in one (1) fiscal year. This matches the data provided to the group by Siemens upper management, which records 86 total A-Sets in the same fiscal year. The group confirmed this information using a simple percent (%) error formula:

$$\% \text{ Error} = |(\text{Experiment \#} - \text{Actual \#}) / (\text{Actual \#})| * 100$$

$$\% \text{ Error} = |\ (84 - 86) / (86)\ | * 100$$

$$\mathbf{\% \text{ Error} = 2.33\%}$$

A 2.33% error is within an acceptable range, which allowed the group to continue using this model for all future analysis. The proper foundation for this model is needed in order to accurately represent the complex system.

5.1.2 CBA: LEAD SYSTEM

Initial Costs:

Training: Cost of training to understand labels and send to Mechanical Jack on priority = (time to train new process) * (3 employees) * ($25/hr.)

- Time of training for new system should not be long, estimating time it takes to train current employees to recognize Mechanical Jack parts by their label and to send them right away should be 1 to 3 business days at the most
- Business day = 8:00 am to 5:00 pm = 8 hours
- At most 24 hours at $25/hr = $600
- employees = **$1800 total**

Stickers: Each sticker estimated at $1.25

- Stickers: Each sticker estimated at $1.25
- Implementation of stickers by employees to label Mechanical Jack specific pieces = (# of stickers needed) *($1.25/sticker) + (number of hours needed for workers to attach the labels to the Mechanical Jack tools)*($25/hr)
- Estimated 30 pieces need labeling per kit
- 7 kits = 210 pieces
- 210*$1.25 = **$262.50**
- Estimated time to label all pieces in each A Set is at most one business week = (5 days)*(8 hour days) = **40 hours**
- ($262.50) + (10 hours)*($25/hr) = **$512.50**

Reoccurring Costs:

Relabeling stickers every quarter year due to weathering or damage = 3 times a business year

- ($512.50) * (3 times a year) = $4650
- **$2312.50/year**

Benefits:

Increase in revenue in A-Sets = (Revenue of A-Set on average) * (# of increased A-Set output in simulated run with process proposal)

- 84 A Sets turned out in simulation before implementation
- 86 A Sets turned out in simulation after implementation

- Estimated A Set revenue is $20000 per A Set turned out
- Added A Sets = (2) * ($20000/A Set) = **$40000**

($40000/year * t) – ($1537.50/year * t) – ($1800) = profit/year ($)

where: t = # of years of solution implementation

5.1.4 CBA: ADDITIONAL EMPLOYEE TO A-SET'S

Reoccurring cost:

- $52,000 per year with added employee a5 $25/hr

Benefits:

- Increase in revenue in A-Sets = (Revenue of A-Set on average) * (# of increased A-Set output in simulated run with process proposal)
  - 84 A Sets turned out in Simulation before added employee
  - 85 A Sets turned out in Simulation after added employee
  - Estimated A Set revenue is $20000 per A Set turned out
    - **$20,000** in added revenue
- Reduced labor = [(# of hours' employees are working before proposal) - (# of hours' employees are working after proposal)] * ($25/hr.)

Table 5.1.4.1 – Baseline time of current and experimental process

Process	Current time per process (days)	Process after added employee (days)	Time difference (days)
Gut A Set of parts	15.11	10.02	5.090
TCTP Assessment	15.17	10.11	5.054
Inventory	42.74	29.03	13.71

- 23.85 days reduced total
  - Each business day = 8 hours
  - 190.8 hours
  - (190.8 hrs.) * ($25/hr.) = **$4,770.10 saved per year**

[($24,770.10/year) * t] - [($52,000/year * n * t] = profit/year ($)

where: t = # of years of project implementation n = # of added employees

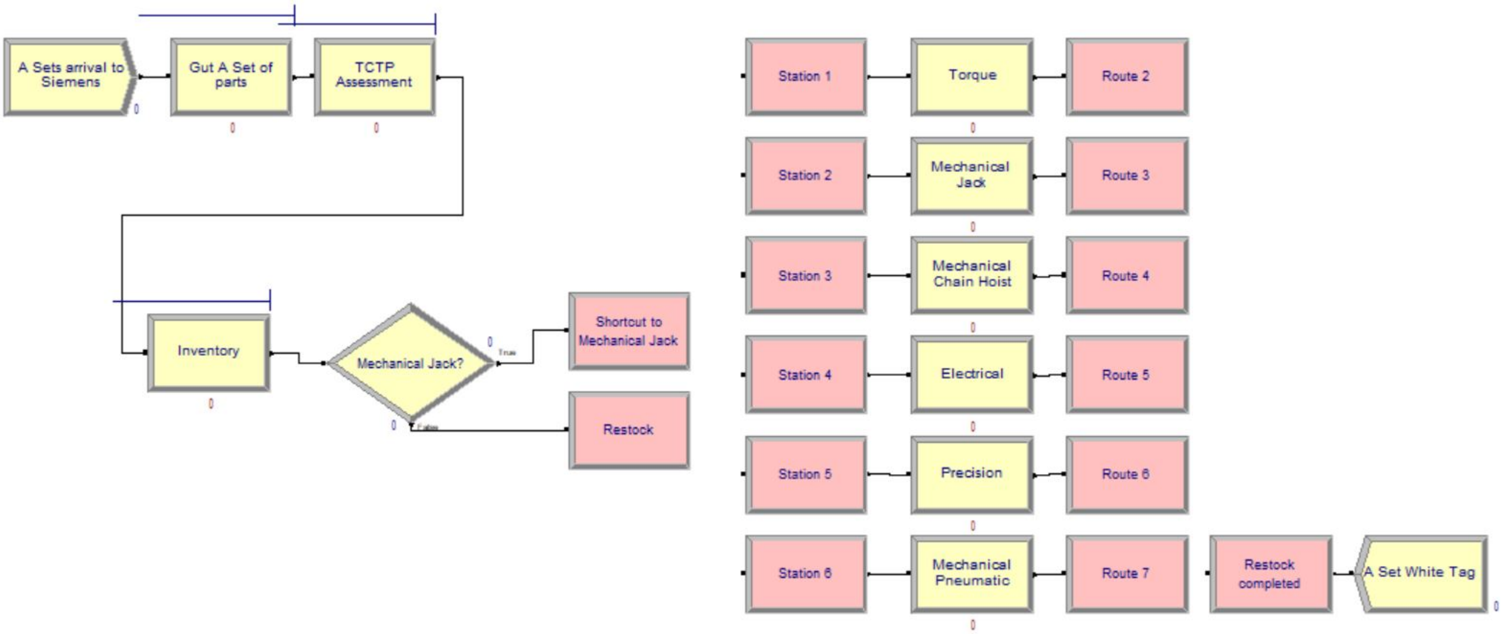


Figure 5.4.1.1 – Arena ® simulation model for A-Set replenishment process with Mechanical Jack Priority system

5.1.5 CBA: COMBINATION ANALYSIS

- Initial Costs:
  - $1800 from training for labels
- Reoccurring Costs:
  - $1537.50 for stickers and their yearly maintenance
  - $52,000 for salary for new employee
- Benefits:
  - Additional 4 A-Sets
    - $20,000 each minimum = $80,000
  - Reduced labor =
    - 22.463 days reduced
    - $4492.60 total saved
- Profit = Revenue – Costs

- $83,306.78/year - $53,537.50/year -$1800
- Profit on year one = $29,155.10
- Profit after = $30,955.10/year
-

5.2 DISCUSSION

The two feasible solutions were chosen based on a heuristic evaluation of facility and information provided. As previously stated, the lead system involves stamping or labeling stickers on specific tools and parts associated with the Mechanical Jack shop. This shop is responsible for the cleaning, testing, repairing, and certifying of 30 tools used in the A-Set. Conversely, adding an additional Floor Assembler will ease the workload and ultimately contribute to the increase in production. The group also considered a combinatory solution that incorporated concepts from both feasible solutions. The chart below displays an overall comparison of each of the three solutions based on the goals established during this research's conception:

Table 5.2.1 – Comparison of Feasible Solutions

	Time Savings	**Turnover time**	**Cost Annually**	**ROI**
Baseline	-	12 days	-	-
Priority System	1.42 days	10.58 days	$1537.50	$38,462.50 (gain)
Added Floor Assembler	0.26 days	11.74 days	$52,000	$27,229.90 (loss)
Combination	3.45 days	8.55 days	$53,537.50	$30,955.10 (gain)

The goal benchmark for this research was simply to reduce the turnover time of an A-Set and that was accomplished with each feasible solution. Out of the three, the group determined that the combination of both the priority system and added Floor Assembler with decrease the process by the most amount of days. Due to a secondary goal of increasing profit, the Cost/Benefit Analysis found a Return on Investment (ROI) of each feasible solution. Interestingly, the solution with the highest days saved did not have the highest return. The priority system of Mechanical Jack parts resulted in the largest return of $40,000 increase in profit, based on several assumptions.

Siemens AG employed our group to find a way to decrease the turnover time of A-Sets and that became the primary goal of this research. With that being said, the best feasible solution to reach that goal is to implement the combination. A time savings of 3.45 days will decrease the turnover time of an A-Set to 8.55 days, which his only 1.55 days above the prospective achievable range. With these results the group did not have a successful completion of this project based on the benchmarks set by Siemens AG. Even though the goal was not achieved, Siemens AG and the research group are motivated by the data and information resulting from this study. Analyzing time sheets and conducting time-study research, the group has found a bottleneck within the overall process of A-Set turnover. This issue has been identified clearly and will not only decrease the turnover times of an A-Set more, but will affect other processes and systems that are happening simultaneously in a positive manner. Further detail and explanation will be discussed in Chapter 6.

CHAPTER 6

6.1 RECOMMENDATIONS

Based on the Cost/Benefit Analysis, the best feasible solution would be to combine key aspects of the additional Floor Assembler and Mechanical Jack priority system. This is based on the results of the simulation along with the calculated analysis. The following table displays a comparison of the combination solution with the baseline, or the current time of turnover:

Table 6.1.1 – Baseline vs. Combination comparison

	Time Savings	**Turnover time**	**Cost Annually**	**ROI**
Baseline	-	12 days	-	-
Combination	3.45 days	8.55 days	$53,537.50	$30,955.10 (gain)

Unfortunately, due to time constraints, the next step of this process could not be completed, which would have included the implementation of the proposed solution and an analysis of that implementation. The evaluation of implementation has concluded that the additional Floor Assembler theoretically should be hired in Quarter 1 of a new fiscal year and employed for a minimum of one year. Siemens AG has advised the group that a labeling system with stickers was previously used but was terminated for undisclosed reasons. This means that the labeling part of this solution could happen immediately and with little to no impact on the current day-to-day process.

The cost of hiring one more Floor Assembler will be $52,000 per year but it is justified with not only a decrease in turnover time but an actual return on investment of $28,000 per year. This profit gain is based on the assumption that an A-Set is leased for only one (1) month at a time. Siemens AG has determined that leasing time for individual customers is sensitive information so that is why the assumption was used. Also, the price of leasing an A-Set was given to be $20,000 per month. There is no corroborating information to support this amount so an assumption was made for the ease of calculation and analysis. A potential barrier for this step would be the locating of a well-qualified candidate for this position. The job requirements include the ability to lift up to 80 lbs. and the ability to manage the inventory of thousands of parts.

A change in perspective toward the goals of the facility must be done in order for these implementations to work. This includes a change in how data is collected. It is understandable that data collected by this facility could compromise the company as a whole if seen or distributed illegally. This should not deter the importance of the quality data collection. There are several ways to go about collecting useful data which should be explored using a literary review as this topic has been studied and written about extensively. For further guidance, the group suggest the reading of Rämänen, Jussi, et al [3] and Pakdil Fatma and Leonard M Karen [9] who stress the importance of collected data not only manually but with remote sensors and customer feedback. Siemens AG would benefit from the data because it allows the ability to measure trends and forecast future demands. If this idea is widely shared among the entire company, then acknowledgment of failure in quality at this facility is key to a successful road toward a truly lean production system.

It is also recommended that the culture of the facility be identified and aligned to match their goals. Any successful lean system has a culture that closely matches not only what the goals of the facility are but how they can be achieved. The following figure gives an example used by Kim S. Cameron and Robert E. Quinn in the *Diagnosing and Changing Organizational Culture* [10] in which it displays how to use qualitative parameters to make quantitative data:

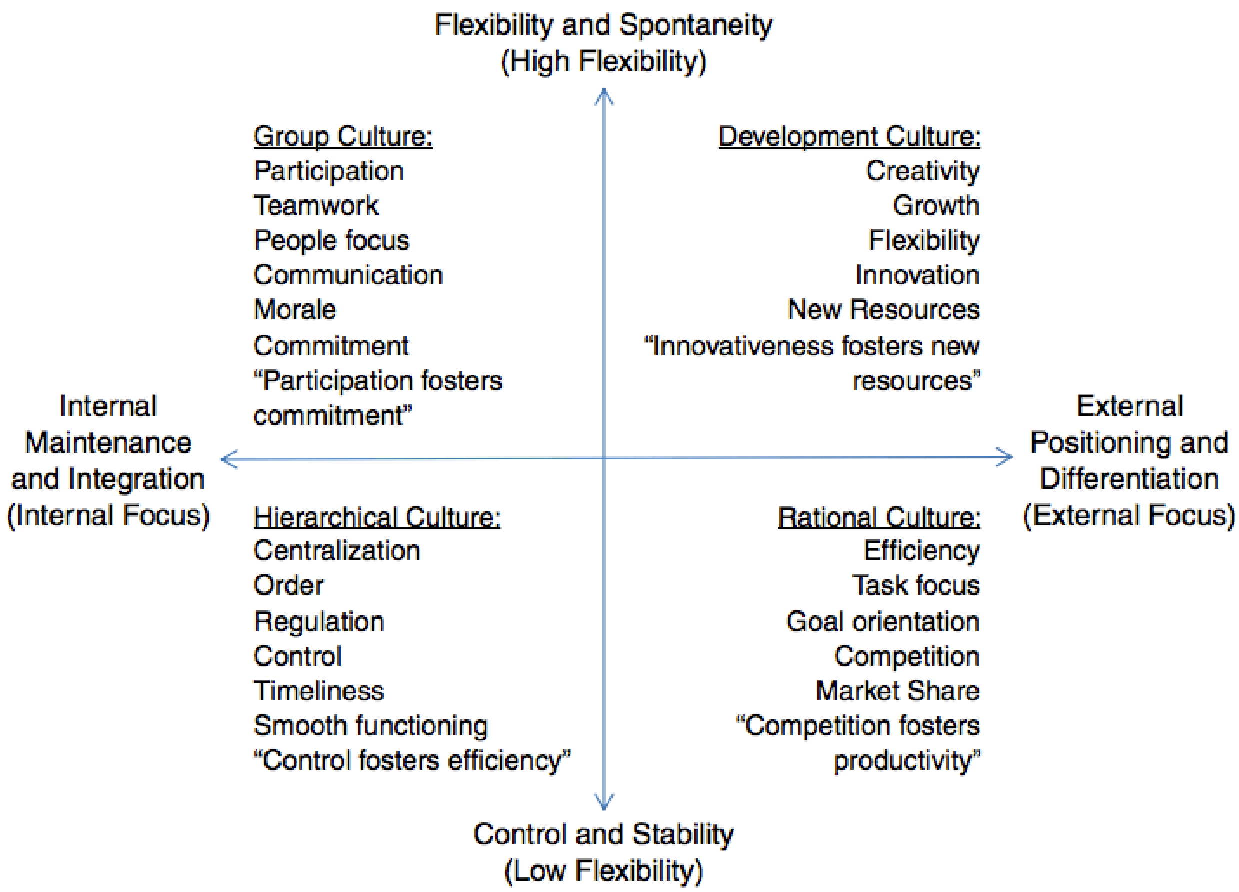


Figure 1.5 – Competing Values Framework chart for culture identification [9]

Each quadrant contains a topic which is given a value between 1 (least important) to 10 (most important). These values are tallied and calculated in a specific way to form a pictograph of the culture of that organization or system. The following figure is an example of what a completed Competing Values Framework looks like:

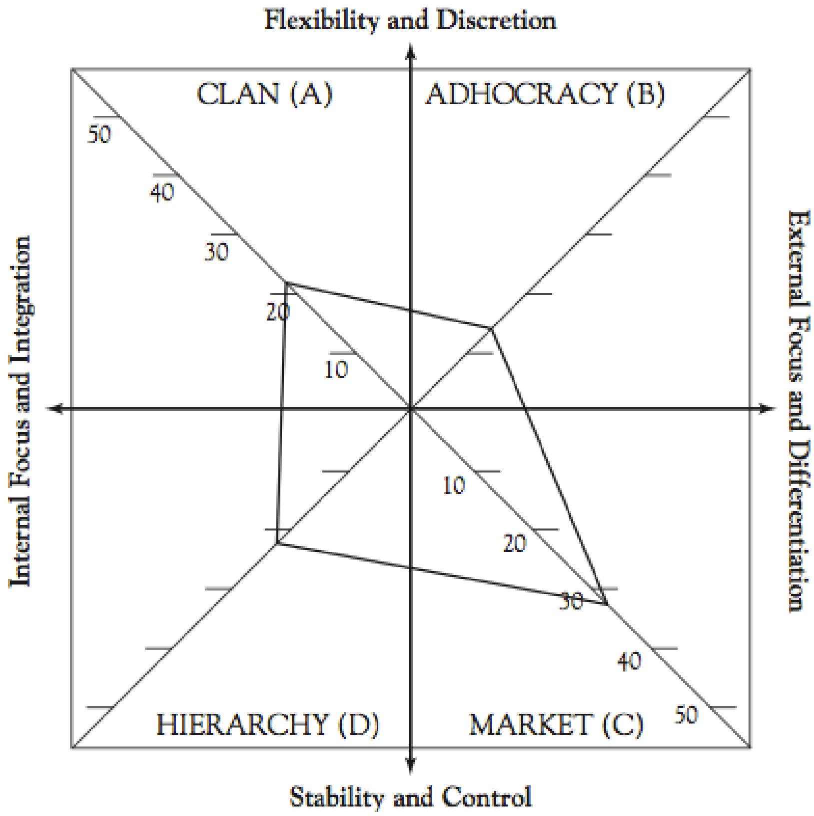


Figure 1.6 – Example of a completed Competing Values Framework chart [10]

Further reading of this book will detail how to complete this analyses with all supporting documentation and information necessary to complete at your own discretion. The group has chosen this as a suggestion to help this facility better align their culture to the overall goals of company. This is a perfect way to eliminate waste by first identifying where the majority of waste is coming from. Benefits include improved increased employee satisfaction, production, and worker efficiency [10].

6.2 CONCLUSIONS

A combination of both feasible solutions will be the best option in terms of time savings on the turnover process of an A-Set. There is also very little cost to implement this solution. The salary spent for an addition Floor Assembler will be justified with an increase production of A-Sets. A small increase of just 1-2 A-Sets per year can have a potential gain in profits anywhere between $40,000 to $480,000 annually. This solution would not only decrease the amount of time it takes to produce a completed A-Set to about 8.55 days but will positively impact annual revenue. This return on investment should ease any worries by upper management and corporate toward taking on this venture. Also, as previously mentioned, a sticker system was used before in this facility and abandoned, so the foundation for implementation is there and can be built upon. A potential barrier for this part of the solution would be a refresh or update of any software program and hardware (stickers) used.

It should be kept in mind that these are just preliminary results and should be used as a guide toward total elimination of waste and the accomplishment of the goals set by Siemens AG. For instance, the group concluded that a priority system in response to the slow production times of the Mechanical Jack shop was the best possible solution considering the scope of the project. Since there was a specific focus on the A-Set process there was no need to go pursue that system any further. The Mechanical Jack shop was identified as a bottleneck to the A-Set process and extensive time study should be conducted to find out why this is the most time consuming shop. After the errors and faults are identified, a refresh and overhaul of the system is needed. These implementations must be studied (with Cost/Benefit Analysis) to justify continuation or termination.

A change in perspective toward the goals of the facility must be done in order for these implementations to work. This includes a change in how data is collected. It is understandable that data collected by this facility could compromise the company as a whole if seen or distributed illegally. This should not deter the importance of the quality data collection. There are several ways to go about collecting useful data which should be explored.

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APPENDIX A: ACKNOWLEDGEMENTS

The group, which consist of Christopher Olaya, Davis Jackson, and Gabriel Rubio would like to acknowledge several people who contributed to the successful completion of this research and project First, we would like to thank the Department of Systems and Industrial Engineering at Kennesaw State University. More specifically, the Senior Design course professor Dr. Adeel Khalid. The group would have never had the opportunity to work on this project without the strong relationship between KSU and Siemen AG.

This relationship was forged by Ernie Ayala, Services Project Manager, who based in Houston, Texas. Mr. Ayala has made it his specialty to create bonds between higher institutions and Siemens AG. Mr. Ayala has special projects across the nation with the University of Houston, University of Central Florida, and now Kennesaw State University. His expertise in project management and overall Siemens operations guided the group with helpful suggestions and feedback. This allowed the group to have a successful project that can potentially benefit Siemens AG in the long run.

We would also like to thank Blanche Singleton and Larry Holsey, who are Plant Manager and Operations Manager, respectively, of The Central Tool and Instrument Facility in Atlanta, GA. Their support allowed the group to work freely within facility to conduct the research and collect data. A sense of respect was shared between the KSU group and employees at the facility to ensure there is no disruption on day-to-day operations. Special care and attention toward safety was practiced because Siemens AG is committed to environment and worker safety. We would like to thank Gregory Gordon and his Floor Assembly team, who gave us unprecedented access to the A-Set turnover system. This first-hand view of the process allowed the group to clearly define each step and find deficiencies.

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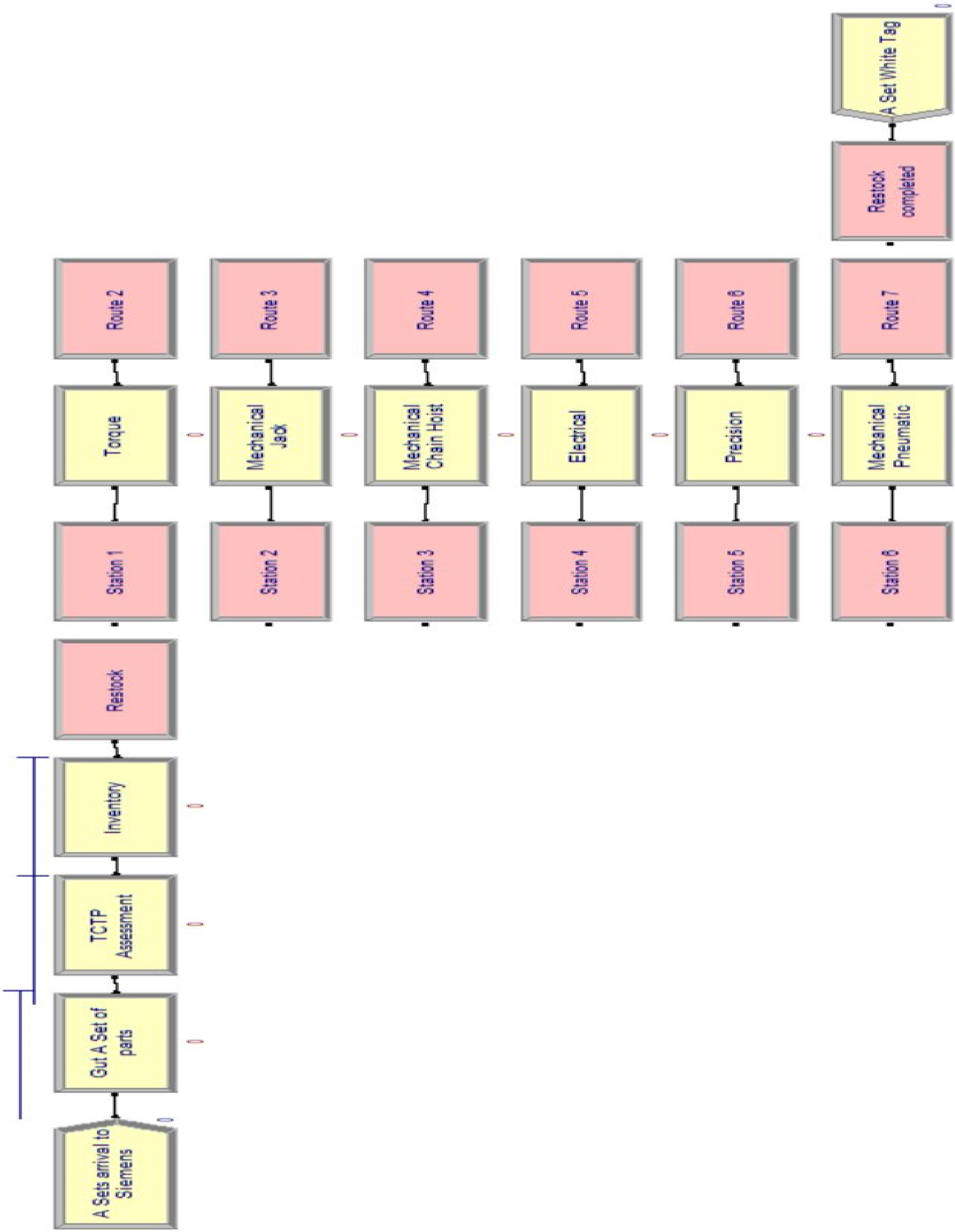
APPENDIX C: REFLECTIONS

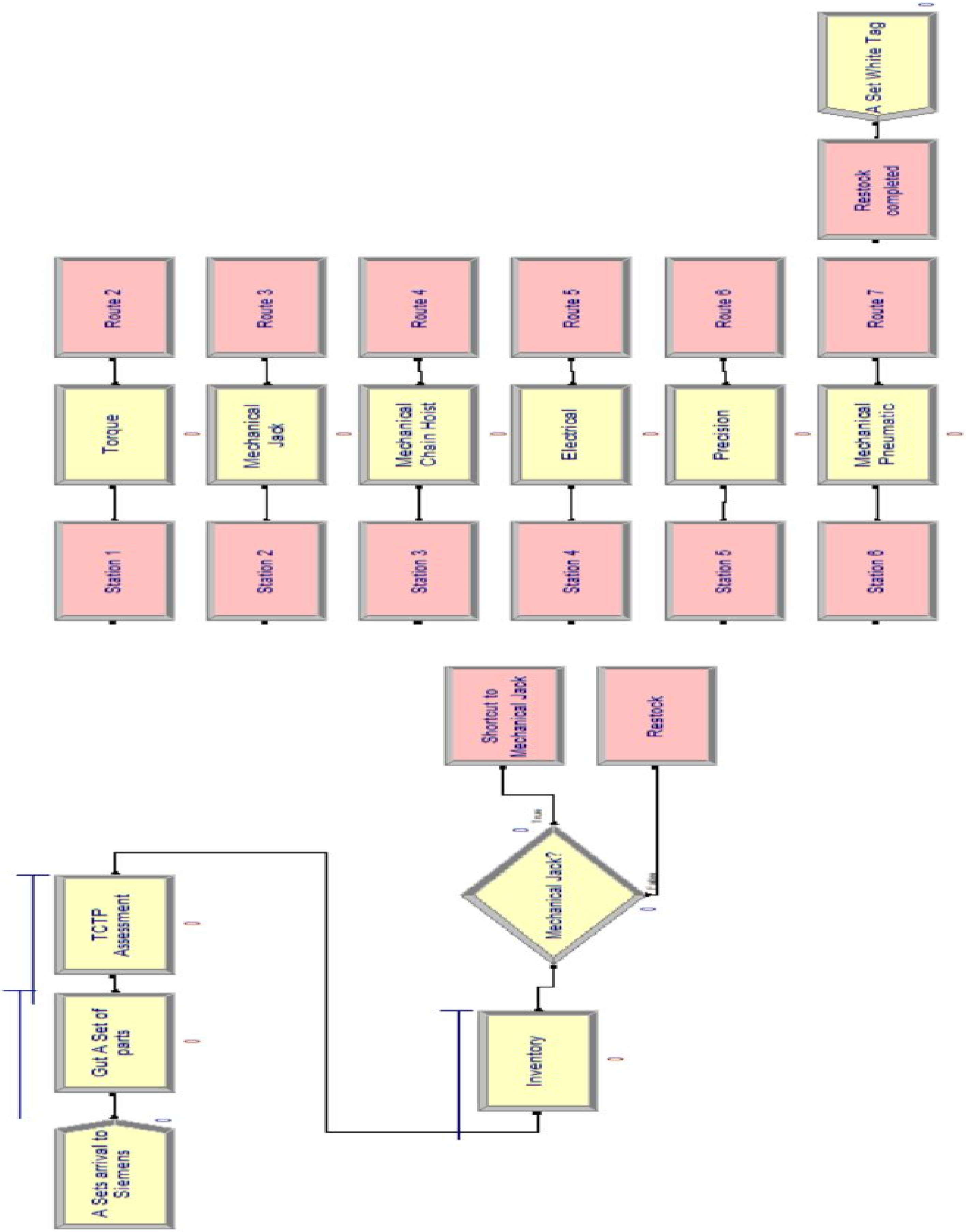
Christopher Olaya
As a senior at Kennesaw State University (KSU) I am appreciative of the opportunity to work with Siemens AG. This partnership has given me the opportunity to experience how a company deals with issues and faults that are harming their system. The first-hand knowledge I learned in invaluable because it is unlike anything I have ever experienced. A couple of years ago, I was invited to conduct research at North Carolina State University (NCSU) and it gave me experience in the world of research by working with a distinguished professor and the fellow graduate and undergraduate group. Because this was a project that involved working in a laboratory, I did gain any experience in working with a team. Conversely, the project done at Siemens AG is more closely aligned with my potential career choice.

Gabriel Rubio
Working with Siemens Energy for this Capstone project allowed me to use all the techniques and information I have attained over the course of the past four years here at Kennesaw State University. It feels wonderful to see a solution come to fruition after working hard over the course of the last few months.

Davis Jackson
I had a wonderful time working on this project both with my group members, as well as with the continued support of the other senior design students. During this experience, I developed a better sense of how to integrate my Industrial and Systems Engineering skills to the real work with projects.

APPENDIX D: SUPPORTING INFORMATION


A Sets arrival to Siemens
Gut A Set of parts
TCTP Assessment
Inventory
Restock
Station 1
Torque
Route 2
Station 2
Mechanical Jack
Route 3
Station 3
Mechanical Chain Hoist
Route 4
Station 4
Electrical
Route 5
Station 5
Precision
Route 6
Station 6
Mechanical Pneumatic
Route 7
Restock completed
A Set White Tag


A Sets arrival to Siemens
Gut A Set of parts
TCTP Assessment
Inventory
Mechanical Jack?
Shortcut to Mechanical Jack
Restock
Station 1
Torque
Route 2
Station 2
Mechanical Jack
Route 3
Station 3
Mechanical Chain Hoist
Route 4
Station 4
Electrical
Route 5
Station 5
Precision
Route 6
Station 6
Mechanical Pneumatic
Route 7
Restock completed
A Set White Tag

		Electrical	Gutting	Inventory	MCH	MJ	MP	Precision	TCTP	Torque	Total	
	Baseline											
	Average time (baseline)	5.3343	0.166	0.4696	7.5548	10.1706	7.632	5.1391	0.1667	1.3515	37.9846	5.426371429
	Average wait time (baseline)	-	0.1162	0.4314	-	-	-	-	0.2195	-	0.7671	
Baseline	-	-	-	-	-	-	-	-	-	-	-	
	Accumulated time (baseline)	464.09	15.1095	42.7369	664.82	925.52	641.09	436.82	15.1667	122.98	3328.3331	
	Accumulated wait time (baseline)	-	10.5728	39.2582	-	-	-	-	19.9739	-	69.8049	
	-	-	-	-	-	-	-	-	-	-	-	
	Total A-Sets in (baseline)	88	91	91	91	91	85	87	91	91	-	
	Total A-Sets out (baseline)	87	91	91	88	91	84	85	91	91	-	
	A-Sets	-	-	-	-	-	-	-	-	-	84	
	Average time (Added Employee)	5.6145	0.1101	0.319	7.6247	10.6268	7.0684	5.27	0.1111	1.2323	37.9769	
	Average wait time (Added Employee)	-	0.07721205	0.2949	-	-	-	-	0.1449	-	0.51701205	
	Difference in average cycle time	-0.2802	0.0559	0.1506	-0.0699	-0.4562	0.5636	-0.1309	0.0556	0.1192	0.0077	0.2621
Added Employee	Accumulated time (Added Employee)	482.85	10.0199	29.0303	678.6	967.04	600.82	447.95	10.1124	112.14	3338.5626	
	Accumulated wait time (Added Employee)	-	7.0263	26.8385	-	-	-	-	13.1853	-	47.0501	
	Difference in accumulated time	-18.76	5.0896	13.7066	-13.78	-41.52	40.27	-11.13	5.0543	10.84	23.8505	
	Total A-Sets in (Added Employee)	89	91	91	91	91	85	86	91	91	-	
	Total A-Sets out (Added Employee)	96	91	91	89	91	85	85	91	91	-	**Difference between baseline**
	A-Sets	-	-	-	-	-	-	-	-	-	85	+1
	Average time (Priority System)	5.6116	0.163	0.4696	8.0907	10.442	8.9402	4.8699	0.1667	1.1521	39.9058	
	Average wait time (Priority System)	-	0.1122	0.4343	-	-	-	-	0.218	-	0.7645	
	Difference in average cycle time	-0.2773	0.003	0	-0.5359	1.42404	-1.3082	0.2692	0	0.1994	1.19823902	1.42403902
Priority System	Accumulated time (Priority System)	493.82	14.8313	42.7332	728.17	146.19	768.86	423.68	15.1667	103.68	2737.1312	
	Accumulated wait time (Priority System)	-	10.2075	39.5171	-	-	-	-	19.8342	-	69.5588	
	Difference in accumulated time	-29.73	0.2782	0.0037	-63.35	8.09418	-127.77	13.14	0	19.3	11.082384	
	Total A-Sets in (Priority System)	90	91	91	90	15	87	88	91	90	-	
	Total A-Sets out (Priority System)	88	91	91	90	14	86	87	91	90	-	**Difference between baseline**
	A-Sets	-	-	-	-	-	-	-	-	-	86	+2
	Average time (Combination)	5.5737	0.1094	0.3204	7.9804	8.6807	8.2623	5.2284	0.1111	1.1701	37.4365	
	Average wait time (Combination)	-	0.0748506	0.2921	-	-	-	-	0.146	-	0.5129506	
	Difference in average cycle time	-0.2394	0.0566	0.1492	-0.4256	3.18534	-0.6303	-0.0893	0.0556	0.1814	2.24353902	3.44673902
Combination	Accumulated time (Combination)	496.06	10.7238	29.1583	726.21	156.25	727.08	460.09	10.668	106.48	2722.7201	
	Accumulated wait time (Combination)	-	7.3354	26.5779	-	-	-	-	14.0167	-	47.93	
	Difference in accumulated time	-31.97	4.3857	13.5786	-61.39	-1.96582	-85.99	-23.27	4.4987	16.5	24.787184	
	Total A-Sets in (Combination)	91	98	96	91	18	88	89	98	91	-	
	Total A-Sets out (Combination)	89	98	91	91	18	88	88	96	91	-	**Difference between baseline**
	A-Sets	-	-	-	-	-	-	-	-	-	88	+4
*Priority system running at 16.67% of tools going to MJ before other processes												
*Time savings												
*Time loss												
	Notes:											
	Solution	Time savings per cycle		$ from A-Sets	Costs		Total				**System**	**Cycle times**
	Added employee	0.2621		$20,000	$52,000/year		$32,000 loss				Baseline	12
	Priority system	1.424039		$40,000	$1800 first year, $505(		$33,150 first year; $34,950 per year after				Added employee	11.7379
	Comnbination	**3.446739**		**$80,000**	**$52,000**		**$28,000 gain**				Priority System	10.57596098
											Combo	8.55326098