A Lean Six Sigma Evaluation to Improve a Manufacturing Validation Process

Kayla J. Buczkowski
Applications Service Engineer at A&D Technology and
Masters of Engineering Management and Masters of Industrial Engineering
Candidate of the College of Engineering
Lawrence Technological University
Southfield, MI 48075, USA
kbuczkows@ltu.edu

Abstract

A&D Technology designs and produces hardware systems with software integration for data acquisition and control applications. Every system manufactured at A&D undergoes a manufacturing validation process known as a Checkout. To maintain a competitive advantage in industry, A&D conducts continuous improvement projects, following their ISO mindset at a cultural level. This paper will discuss an ongoing Lean Six Sigma project in which the A&D manufacturing validation process is being improved, following the DMAIC framework with a heavy focus on the Plan-Do-Check-Act cycle. Data from the past two years of projects will be analyzed and new tools and standards will be created to improve the validation process of supplier hardware that has been installed in A&D manufactured systems.

Keywords
Hardware Configuration, Manufacturing, Validation, Lean Six Sigma, ISO.

1. Introduction
To maintain a competitive advantage in industry, companies need to continue identifying and improving processes. The process of interest here is manufacturing validation. Manufacturing validation is critical to conducting quality control on manufactured systems prior to shipping products to end users. This can reduce or eliminate problems experienced by the end user when utilizing the systems purchased. Some companies implement quality control on a batch of products while others implement quality control on every product. Frequency is dependent on product and manufacturer. A&D Technology has a manufacturing validation process that is conducted on every system prior to being shipped to an end user. It is important that this manufacturing validation process be as efficient as possible and improved whenever possible.

1.1 Background
At A&D Technology, the Application Engineering (AE) team is responsible for developing and implementing application code. iTest is the proprietary software A&D sells for data acquisition and control applications. The application code the AE team is responsible for is written in iTest's native coding language known as VCL. Part of the implementation process of projects sold by A&D is integrating iTest application code with hardware. This hardware is assembled by A&D manufacturing and validated in house by the AE team. The validation process is referred to as a Checkout.

The most common hardware that is assembled into systems created by A&D Technology is supplied by Gantner Instruments. In 2018, Gantner released a new line of hardware modules known as X.Series, which was created as an eXtended version of the Q.Series, originally released in 2009. Upon the release of this new hardware line, A&D did a sudden transition to using the new hardware to maintain a competitive advantage in the industry by using the latest technology in their assembled systems. This sudden transition resulted in a significant learning curve that the A&D AE team had to navigate to transition from Q.Series to X.Series. The general notion felt by the AE team was that checkout timing increased upon the shift to this new hardware line.

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1.2 Project Charter

Checkouts are a critical part of every A&D customer project because checkouts are the quality control steps conducted on each manufactured system. Throughout this paper, the data trends will be analyzed to conclude that checkout times need to be more consistent before they can be improved. This desired result is listed in the objective statement as defined in Table 1, the Project Charter for this project. The first goal is to create standard operating procedures and tools that will lead the AE team closer to the goal of improving checkout time consistency.

Table 1. Project Charter

Problem Statement	Scope
Checkouts are a critical part of every A&D project before hardware assembled by the manufacturing team can be shipped. Delays and tedious processes can slow down checkouts and reduce morale of all affected teams. Increasing the efficiency of checkouts and creating methods to standardize checkouts would help improve A&D on numerous fronts.	IN: Creating tools (physical or virtual), creating standard operating procedures, and modifying existing standard operating procedures for the A&D Application Engineering team and, if needed, the manufacturing team. OUT: Modifying the hardware being "checked out" in any way that is not deemed allowable by the hardware supplier (Gantner). Checkouts that do not involve the iTest product line with hardware integration.
Objective Statement	**Timeline**
Create standard operating procedures and/or tools (physical or virtual) that will result in checkout times becoming more consistent.	Phase 1 – Create List of Settings: 9/17/2021 Phase 2 – Create Checkout SOP: 1/28/2022 Phase 3 – Create Fillable Form for Values: 8/12/2022 Phase 4 – Create Hardware Templates: 10/1/2022 (Delayed) Phase 4 – Analyze Results: TBD
Business Case	**Team Members**
Checkout timing consistency will reduce the number of projects with shipping delays due to excessive checkout time.	Champion: Chris Bahn Dr. Neil Murray, Master Black Belt Mentor Kayla Buczkowski, Black Belt Trainee A&D Application Engineering Team Members A&D Manufacturing Team A&D Financial Liaison Gantner Instruments Support and Development Teams

2. Literature Review

Research conducted by the University of Alberta Edmonton in Canada found that software development companies need to continue exploring ways to "advance quality, productivity, and predictability" to maintain a competitive advantage in their industry (Al-Baik and Miller 2016). The research concluded that implementing Kaizen into software-centric organizations is difficult, and to be successful, the Kaizen mindset needs to be integrated into the organizational culture (Al-Baik and Miller 2016). Kaizen is the ideology of improving productivity through sustained continuous improvement of targeted processes within an organization (Environmental Protection Agency 2022).

A&D Technology is a certified ISO 9001:2015 company. The ISO 9001:2015 standard states that "this International Standard employs the process approach, which incorporates the Plan-Do-Check-Act (PDCA) cycle and risk-based thinking" (ISO 9001:2015: Quality management systems - Requirements 2015). Thus, this multi-phase, Lean Six Sigma project represents a good demonstration of this cultural mindset. The ISO standard also states "risk-based thinking enables an organization to determine the factors that could cause its processes and its quality management system to deviate from the planned results" (ISO 9001:2015: Quality management systems - Requirements 2015). The current checkout process is inconsistent, which makes it difficult to achieve "planned results" from the beginning. A&D first needs to improve the consistency and have planned results before the checkout process can be analyzed for how or why it may deviate from those planned results.

3. Project Continuation Using Six Sigma Framework

Six Sigma is a quality philosophy that can be used to measure and improve performance, practices, and products. "It drives customer satisfaction and bottom-line results by reducing variation, waste, and cycle time, while promoting the use of work standardization" (American Society for Quality n.d.). The Greek letter Sigma (σ) can be used to represent a deviation from the mean, or a measure of how far a process deviates from perfection. The number of deviations in a given sample size can be used to determine what Sigma Number the process could be quantified with.

"Six Sigma focuses on reducing process variation and enhancing process control, whereas lean drives out waste… and promotes work standardization and flow" (American Society for Quality n.d.). This project will take a Lean Six Sigma approach to both drive out waste and focus on reducing process variation.
This continuous improvement process has been underway and is currently in phase 4 of the identified phases. Because the goal of this project is to improve the consistency of checkout times, there will be no Sigma Number, or number of deviations, analyzed. Instead, the project will utilize the Six Sigma DMAIC framework to determine a path forward in achieving the identified goal. DMAIC stands for Define, Measure, Analyze, Improve, and Control.

This project will utilize the following DMAIC tools:

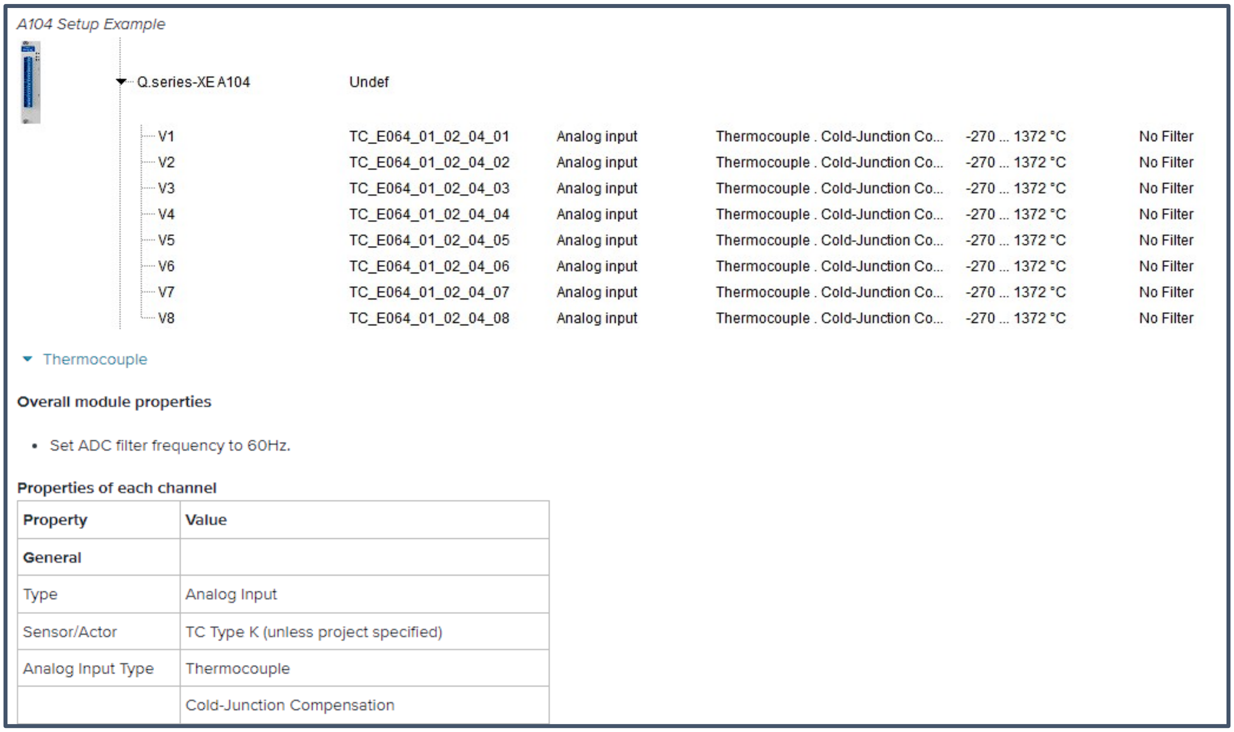
- D – Value Stream Map
- M – Data Collection Plan, Scatter Plot
- A – Basic Statistical Tools, Time Trap Analysis, Painstorming
- I – Countermeasures, Brainstorming and Kaizen
- C – Standard Operating Procedures, Plan-Do-Check-Act

4. DMAIC Process

4.1 Define

During the Define phase, goal scope, business case, timeline, and involved team members were identified. This was laid out in the Team Charter, as shown in Table 1. The timeline listed in the Team Charter is based on the phases that have already been completed.

During phase one, the problem identified was that AE team members were each struggling with identifying settings that each piece of hardware needed to contain. Whether checkouts are available is project dependent, and the AE conducting the checkout may be different for each checkout. Each AE had to determine what settings were needed during hardware setup. Those identified settings became tribal knowledge because it was not written down for reference in the future. The phase one action determined to be needed was creating a list of settings for all common pieces of hardware, so checkouts would no longer be reliant on tribal knowledge. This was created and communicated to the AE team on the date listed in the timeline section of the Team Charter. A subset of this document is included in Figure 1 below.



A104 Setup Example

Q.series-XE A104	Undef				
V1	TC_E064_01_02_04_01	Analog input	Thermocouple . Cold-Junction Co...	-270 ... 1372 °C	No Filter
V2	TC_E064_01_02_04_02	Analog input	Thermocouple . Cold-Junction Co...	-270 ... 1372 °C	No Filter
V3	TC_E064_01_02_04_03	Analog input	Thermocouple . Cold-Junction Co...	-270 ... 1372 °C	No Filter
V4	TC_E064_01_02_04_04	Analog input	Thermocouple . Cold-Junction Co...	-270 ... 1372 °C	No Filter
V5	TC_E064_01_02_04_05	Analog input	Thermocouple . Cold-Junction Co...	-270 ... 1372 °C	No Filter
V6	TC_E064_01_02_04_06	Analog input	Thermocouple . Cold-Junction Co...	-270 ... 1372 °C	No Filter
V7	TC_E064_01_02_04_07	Analog input	Thermocouple . Cold-Junction Co...	-270 ... 1372 °C	No Filter
V8	TC_E064_01_02_04_08	Analog input	Thermocouple . Cold-Junction Co...	-270 ... 1372 °C	No Filter

Thermocouple

Overall module properties

- Set ADC filter frequency to 60Hz.

Properties of each channel

Property	Value
General	
Type	Analog Input
Sensor/Actor	TC Type K (unless project specified)
Analog Input Type	Thermocouple
	Cold-Junction Compensation

Figure 1. Example Subset of Hardware Settings

After completion of phase one, the Six Sigma Project Champion noticed that critical steps in the checkout process were being missed. However, the steps missed had little commonality between each checkout. Upon evaluation of possible causes, it was noticed that there was no written document in one place that defined the steps to be conducted during a checkout. The process itself was either tribal knowledge or spread across multiple documents. Thus, led to the creation of phase two of this continuous improvement project: Creation of a Standard Operating Procedure (SOP) that could be followed during a checkout. This document was titled *System Checkout Process* and is required to be followed by all members of the AE team when conducting checkouts. The document itself is to be used as a check sheet, so each checkout should contain a local copy for the specified system. The local copy for each system will ensure that the process followed was documented if the master SOP were to be updated in the future. It is stated in the SOP that the AE conducting the checkout is to check off each item when completed, and sign, or initial, and date all subsection headers.

The *System Checkout Process* SOP outlines the process that should be followed, but due to the custom build created for each A&D project, the specified hardware modules could be different for each system. The list of settings that needs to be assigned to each module was created in phase one, but phase two was only intended to outline the checkout process. Neither created document specifies which values each hardware module should be tested at, how it should be tested, and what information is to be written down and stored for future reference. It should be noted that all hardware modules supplied by Gantner Instruments are tested prior to arriving at the A&D facility. In the past, it was not necessary to verify full module performance, only initial functionality. During this project, it was decided that confirming full module performance and recording module properties and tested values could result in improved customer confidence in A&D. Phase three of this project was to create a fillable form for each piece of hardware checked during the checkout process. This fillable form could be created using a generation tool made during this phase. Each module's fillable form was contained in one Excel spreadsheet.

Upon completion of phase three, AE team members would have to include both a signed *System Checkout Process* document and a filled out spreadsheet containing each piece of hardware's properties and tested values as checked during the checkout process. Now that the process and testing details have been defined, the process can be analyzed to identify additional phases. The main tool used for this will be a Value Stream Map.

4.1.1 Value Stream Map

A Value Stream Map (VSM) is a tool that can be used to quantify the number of resources needed, component parts needed, assembled parts created, time spent waiting, and time spent working in each step in a process. The process evaluated for this project being the checkout process, as defined in the SOP created during phase two. The cycle time of each process should identify the time spent by an AE, on average, to conduct each segment of the checkout process. Figure 2 below shows the process boxes, data boxes, and inventory boxes of the VSM. The full VSM is included in the Appendix of this paper for reference.

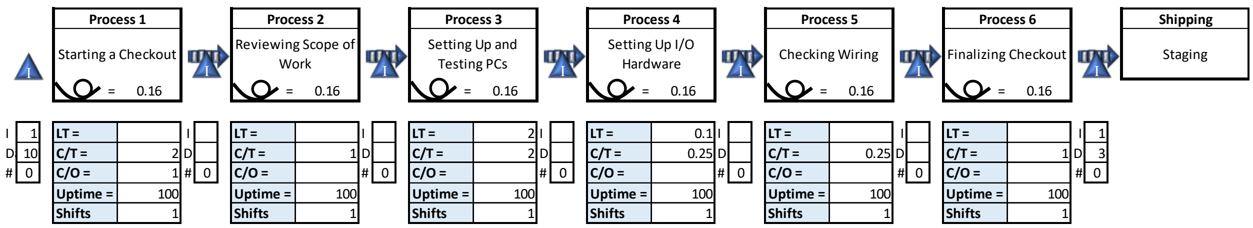


Figure 2. Checkout Process Value Stream Map

The cycle, changeover, and lead times written in the VSM are the assumed time, in hours, based on discussions between the project Champion and the Application Engineering team members. Process 1 has some setup time, marked as changeover time, to gather all necessary validation tools from the previous station, or storage, and bring them to the station of focus. The cycle times during processes 1 through 3, and process 6, are working time completed by an AE. The lead time listed in processes 3 and 4 are due to software installs or loading times that do not require user interaction, but also prevents other work from being completed during that time.

Processes 4 and 5 of the VSM are based on the number of hardware modules included in the manufactured system. In other words, more modules result in an increased checkout time. However, the average cycle time per module listed assumes that each module takes approximately the same amount of time. This is one possible source of inconsistency because different modules may take different amounts of time, in practice. In process 4, the cycle time is the setup time involved in applying the settings to each module, as listed in the Gantner module required settings described during phase one. Looking at process 5, the cycle time is how much time it takes to test each module. These are the two places where inconsistencies could be occurring: setup time and testing time.

4.2 Measure

The Measure phase of the DMAIC process highlights the collection of data. Project data that involved manufactured systems at A&D was collected and used to generate scatter plots. Thus, showing the first tabular and graphical views of available data.

4.2.1 Data Collection Plan

The only source of data currently available is the record of how many hours AEs have logged while conducting a checkout. Data available goes back over the last two years. This data will be reviewed to create a ratio of the average amount of time one (1) hardware module took to checkout. Over the last two years, 36 data points are available to be analyzed as shown in Table 2.

Table 2. Checkout Data Sets

Set #	Hours Charged	# of Systems	# of Modules	Hours/Module
1	18	1	28	0.64
2	33	1	11	3.00
3	46	1	11	4.18
4	5	1	3	1.67
5	39.5	2	37	0.53
6	10	1	26	0.38
7	134	1	5	26.80
8	24	1	23	1.04
9	16	1	12	1.33

10	96	3	35	0.91
11	33	1	27	1.22
12	99	8	51	0.24
13	38.5	4	36	0.27
14	22	1	50	0.44
15	31	2	10	1.55
16	10	1	4	2.50
17	74	1	21	3.52
18	16	1	23	0.70
19	8	1	18	0.44
20	62	2	34	0.91
21	40	1	35	1.14
22	74	1	30	2.47
23	7.5	1	51	0.15
24	41	2	24	0.85
25	27	2	6	2.25
26	46	1	23	2.00
27	24.5	1	29	0.84
28	76	2	49	0.78
29	61	1	11	5.55
30	26	1	1	26.00
31	74.5	1	18	4.14
32	71.5	1	20	3.58
33	151	4	36	1.05
34	40.5	2	13	1.56
35	38	1	26	1.46
36	74	2	66	0.56

4.2.2 Scatter Plot

The data collected, as shown in Table 2, results in Figure 3 scatter plot. Data set 7 and 30 are outliers and should be removed prior to any further analysis. This leaves 34 data points for further statistical analysis. Upon review of the outliers, they were from projects of a different A&D products line or had a different kind of hardware. This project's scope is restricted to hardware with iTest integration.

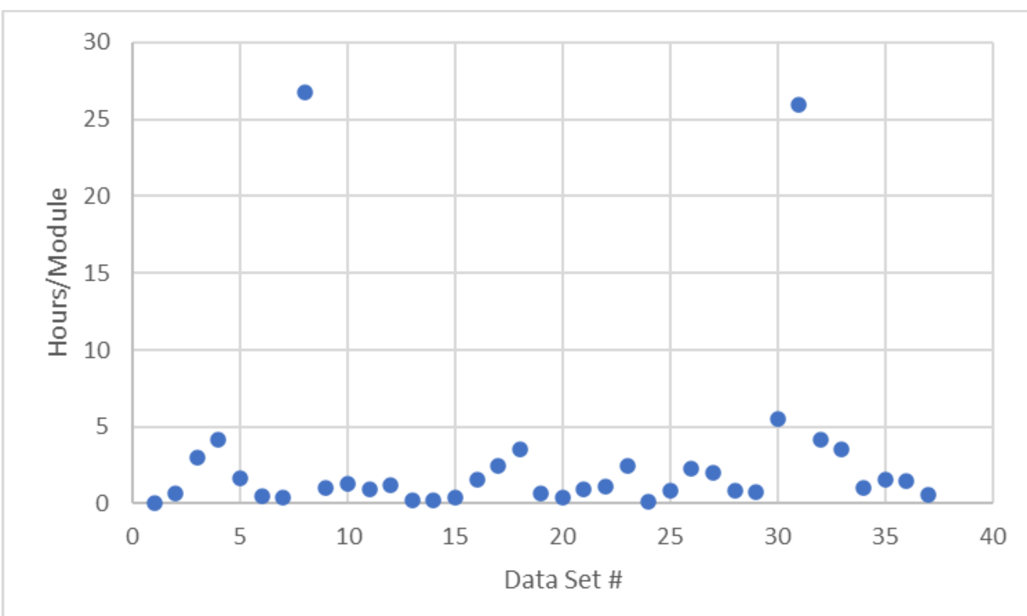


Figure 3. Scatter Plot of Checkout Data Sets

Removing the outliers results in an updated scatter plot shown in Figure 4. At a glance, the scatter plot gives the first insight into the inconsistency of the checkout process time.

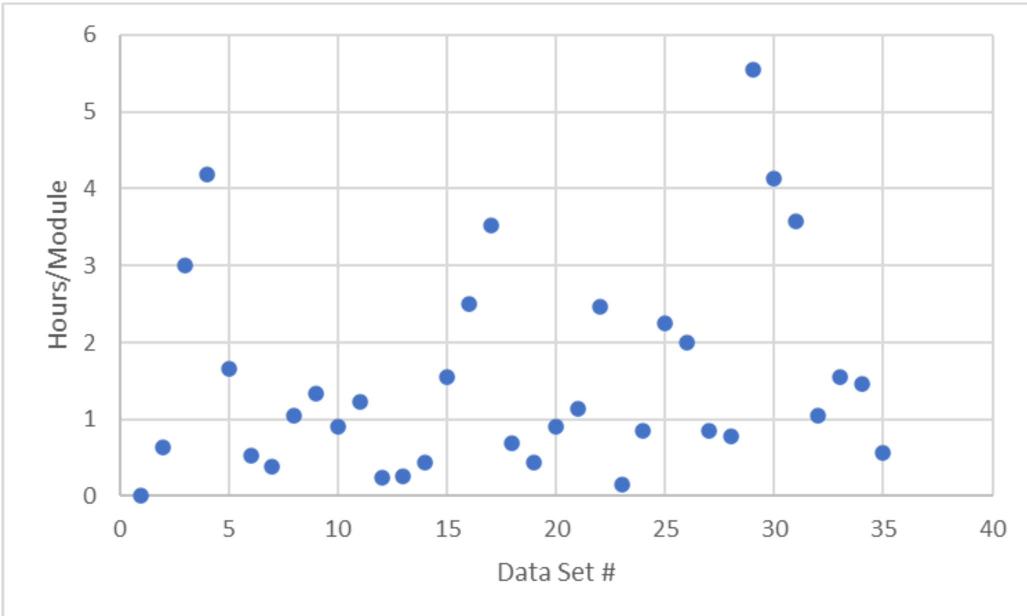


Figure 4. Scatter Plot of Checkout Data Sets without Outliers

4.3 Analyze

Data collection done during the Measure phase of the DMAIC process leads to the Analyze phase. During which the tabulated data could be input into statistical analysis tools to generate meaningful trends.

4.3.1 Basic Statistical Tools

The Figure 4 scatter plot from the measurement step of the DMAIC process does not show an easily identifiable pattern in the data. Figure 5 is a histogram of the data that results in a lognormal distribution curve. Meaning the logarithm of the sample data follows a normal distribution. The lognormal probability plot in Figure 6 shows a P-Value of 0.983 and AD of 0.127, which gives us a high confidence level in our data following the lognormal distribution trend.

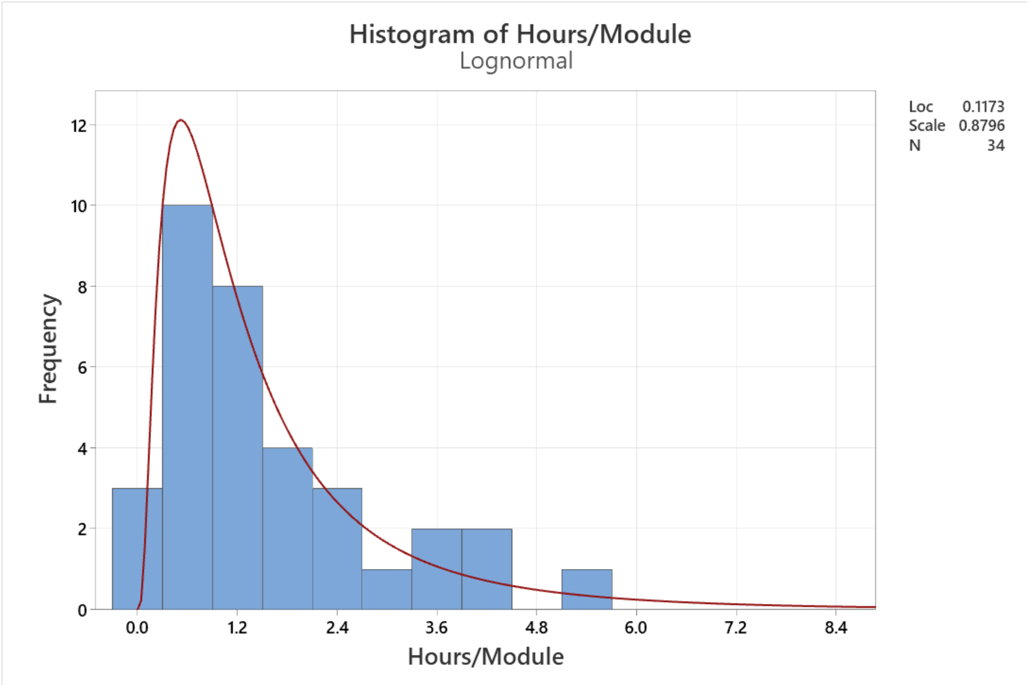


Figure 5. Hours per Module Histogram

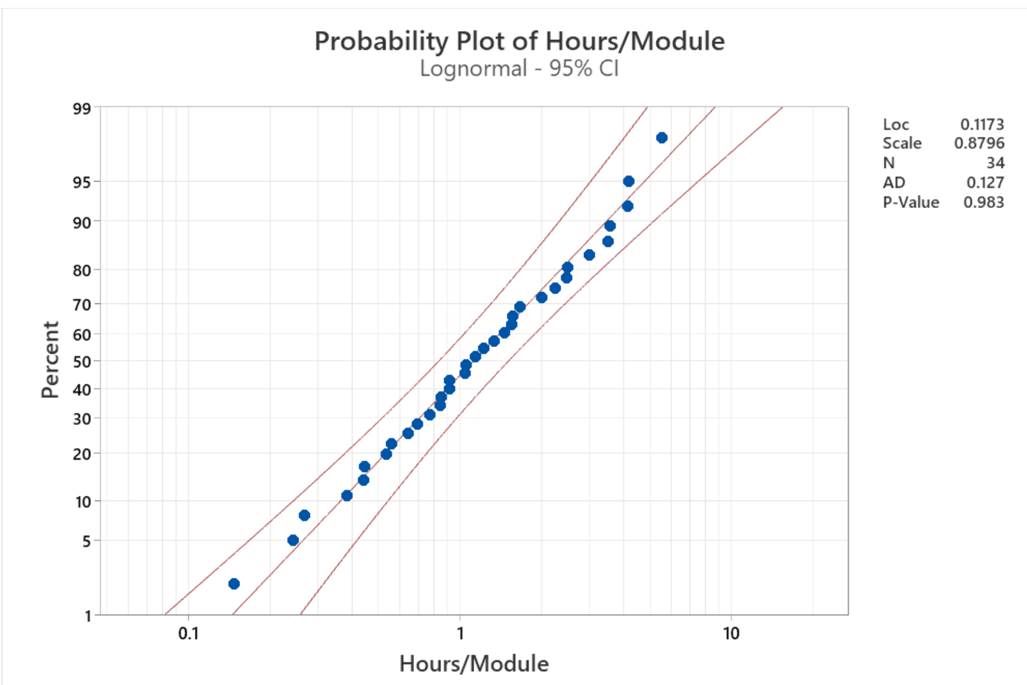


Figure 6. Hours per Module Lognormal Probability Plot

Figure 7 shows the descriptive statistics of the 34 data set sample. The data reflects a mean time of 1.58 hours per module with a standard deviation of 1.33 hours. The 1.58 average hours per module is greater than the 0.25 hours per module defined in the VSM shown in Figure 2. Part of this discrepancy is because the calculation for hours per module does not take into account all six processes shown in the VSM of the checkout process. Those six hours that were not removed during the statistical calculations are not module dependent. However, removing those six hours would result in data set number 4 of Table 2 being a negative value, which is incorrect, so those six hours were not removed when analyzing the data sets during this evaluation.

Descriptive Statistics

N	N*	Mean	StDev	Median	Minimum	Maximum	Skewness	Kurtosis
34	0	1.58434	1.32606	1.09573	0.147059	5.54545	1.34839	1.30403

Figure 7. Checkout Data Sets Descriptive Statistics

The Process Capability Sixpack Report is shown in Figure 8. The Xbar chart and R chart indicate that one of the subsets of the data could be viewed as “out-of-control,” which is a positive interpretation given that this evaluation is being conducted regarding the inconsistency of checkout times. The upper and lower specification limits shown on the capability histogram are the desired upper and lower specifications of the checkout process. Thus, there are many checkout times that deviate from the upper specification limit until the consistency of the checkout process is improved.

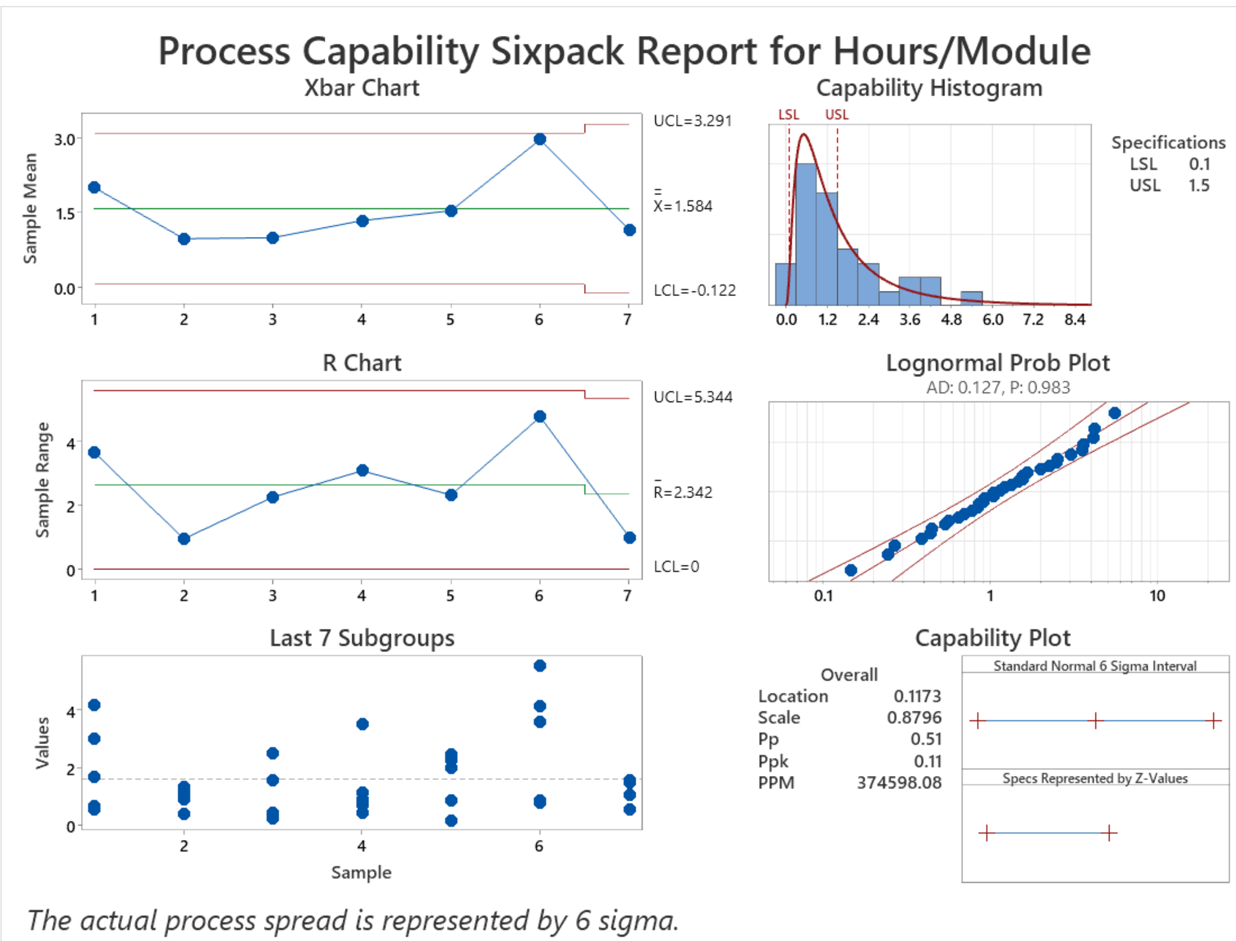


Figure 8. Hours per Module Process Capability Sixpack Report

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4.3.2 Time Trap Analysis
A Time Trap Analysis involves identifying the steps in the process that do not add value to the product from the customer perspective. Identifying the non-value-added steps can lead to discussions on whether they are needed and if they can be minimized or removed from the process. A common time trap is documentation. Documentation does not, typically, add value from the customer perspective. Thus, the phase two SOP filled out as a checklist and phase three module testing documentation would be considered non-value-added steps of the process. However, they are necessary to ensure the process is properly documented and the same values are tested between systems or between hardware in the same system. Process 1, 2, and 6 of the VSM could also be considered time traps because they involve reviewing documentation or sending documentation to various departments. They are still necessary steps in the checkout process, but they could be evaluated in the future to determine if the time could be minimized.

4.3.3 Painstorming
What could we do to make the problem worse? That is the biggest question that needs to be answered during Painstorming. Are there any negative impacts as a result of the first three phases of this continuous improvement project?

Phase one was the implementation of the list of settings for each module. Also included in this document are common troubleshooting steps related to each module. Not following this list of settings and troubleshooting steps means the AE conducting the checkout may spend excess time identifying which settings are needed. They could also conduct the wrong troubleshooting steps, resulting in increased checkout time.

Phase two was the creation of the checkout SOP. Not following this could result in the same errors that occurred before it existed. Steps getting missed, parts not getting checked before shipment, etc.

Phase three added a form that needed to be created and filled out for each module to ensure the configuration of the module and values tested are recorded. Not recording this information could result in lowered customer confidence. If a module does not work after it arrives at the customer site, and this form was not filled out, then there is no confirmation that the module settings were correct or that the module was tested to show full functionality prior to leaving the A&D facility.

4.4 Improve
Many improvements to the checkout process have already been implemented in phases one through three of this project. However, following the DMAIC framework, another Improve phase still needs to be conducted on the current post-phase three implementation. This is when the process will be evaluated for failure modes as well as brainstormed to determine if another phase of the project can be identified.

4.4.1 Countermeasures for Possible Failure Modes (based on Painstorming)
During the Painstorming section of the Analyze phase of the DMAIC process, different theories were identified as to what behavior could result in making the problem worse. The theories could be summed up into one overall possible problem: not following the identified process or utilizing the created tools. The best countermeasure for this is training. Ensuring all new hires are trained to follow the SOP and utilize the necessary forms. This could be a check done by the AE team supervisor or by a different department in the form of an internal audit. Given how new many of the recently developed tools and SOPs are, the AE team will be conducting internal audits on the checkout process starting in 2023.

4.4.2 Brainstorming and Kaizen
Brainstorming was done throughout the course of this project to identify what the different phases should be, and which phase would result in increasing the consistency of checkout times. First, creating SOPs and fillable forms to document the process and get better analytics. Next, evaluating the process that has been defined so the time of each step of the process can be evaluated and minimized. Of the six processes involved in conducting a checkout, as identified in the VSM, two of them are dependent on the number of modules. Processes 4 and 5 of the VSM are dependent on the number of modules, and, therefore, have the highest amount of variation.

Focusing on these two processes, with the goal of improving checkout time consistency, there are two opportunities for improvement. The first being process 4 and ensuring the setup of all hardware modules takes the same amount of

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time. This could be done by creating templates for copying and pasting a master set of settings for each module. Theoretically, copying the settings should be faster than manually entering the list of settings created during phase one. The second being process 5 and ensuring the testing time for each hardware module is the same. One method of improving testing time could be creating an adapter that would be identical regardless of module type. Reducing the testing time by speeding up the transition period between testing each module type.

Brainstorming leads to ideas for further improvements, which brings up the concept of Kaizen. Kaizen, as described earlier, is the ideology of improving productivity through sustained continuous improvement of targeted processes within an organization (Environmental Protection Agency 2022). This continuous improvement, Lean Six Sigma project is an example of how Kaizen is being implemented on a cultural level by A&D Technology. Three phases of this project have already been completed. Implementing Brainstorming and Kaizen has led to a need for phase four. It is also important to keep future improvements in mind. For instance, this project was sparked due to a general notion on the AE team that a new hardware line by Gantner led to increased checkout times at A&D. Perhaps an improvement could be made to the A&D process that would reduce the learning curve for new product or supplier hardware launches.

4.5 Control

The biggest DMAIC tool used throughout this project has been the PDCA cycle within the Control phase. This is the feedback loop of the project, during which the plan of action for the brainstormed phase four ideas can be detailed.

4.5.1 Standard Operating Procedures

Examples of Standard Operating Procedures (SOPs) have already been discussed during the overview of phase two. SOPs can be defined as sets "of step-by-step instructions compiled by an organization to help workers carry out routine operations" (VIAR n.d.). The implementation of phase four and new module templates would need to include the creation of an SOP. That way the method of applying a template and knowing which template to select is identical for each hardware module.

4.5.2 Plan-Do-Check-Act Cycle

This continuous improvement project in itself is a Plan-Do-Check-Act (PDCA) cycle. Each phase (1-3) has been planned, implemented, evaluated, and then acted upon by developing the next phase. This paper is the Check and Act of phase three by identifying how the process can continue to be improved via Brainstorming a phase four. Planning of phase four has already taken place internally at A&D. Phase four will utilize the template feature in Gantner's GI.Bench software, which is used for setting up the hardware modules. The feature allows templates to be saved for each module type and reapplied only for identical module types.

Upon testing this feature to begin creation of an SOP of the template application process, it was discovered that the feature had a bug on the software side. A&D discovered this and reported it to Gantner. The bug was fixed by the Gantner software development team so A&D can start testing the template feature in the near future and develop an SOP before rolling out the process to the rest of the team members.

Once the updated process is in place, A&D will need to Check that the updated process is being followed. If the process is not being followed, Act by identifying ways the process can be consistently followed by all team members. If the process is being followed, continue evaluating the process and see if there are other ways it can be improved.

The identified phase four is based on the improvement identified during Brainstorming. Utilizing the module templates is intended to improve the consistency of checkout times by ensuring the setup time for each module type is identical. Other ideas that were brainstormed involved developing methods to make the verification time identical regardless of module type. One way this could be attempted is by developing a connecting adapter for quick interchange between modules. Then the equipment used for each module type would not be different, so reduction would be on the transition between each module for verification. Due to the delay caused by the GI.Bench software bug, A&D began planning phase five, which is the connecting adapter. Parts for this connecting adapter have already been ordered, so once phase four is completed, phase five can begin.

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6. Conclusion

This continuous improvement project was sparked by a general notion amongst the members of the AE team at A&D Technology that checkout times were increased due to the release of the new Gantner X.Series product line. Three phases of this continuous improvement project have been enacted to solidify the process on the A&D side and gather data to see if there was any truth to this feeling. After reviewing the data, it was determined that it was impossible to tell if checkout times were increased based on how inconsistent checkout times were. The first step needed to be to improve consistency of checkout times.

Phase four is the next step in improving the checkout process, which will be to implement Gantner's module template feature of GI.Bench along with an SOP of how to apply the templates. Phase five has also already been planned and will be implemented upon completion of phase four. Phase five will be development of a connecting adapter for quick interchange between modules; thus, reducing the transition time between verification of each module.

This project came to fruition after the release of the new Gantner X.Series product line. Therefore, another future improvement phase could be to brainstorm and develop improvements on reducing the learning curve of future new product or hardware launches.

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Biography

Ms. Buczkowski is currently employed as an Applications Service Engineer with A&D Technology and is pursuing the dual Master's program of Engineering Management and Industrial Engineering at Lawrence Technological University as well as her Professional Engineering license in Mechanical Engineering. She graduated from Michigan Technological University in May 2018 with a Bachelor's of Science in Mechanical Engineering, minoring in Music Performance. Working for A&D Technology, Ms. Buczkowski has become one of the company's experts in battery testing, engine testing, and hardware-in-the-loop testing. She integrates her company's software, iTest, at their office in Ann Arbor, MI as well as at customer facilities around the globe. Currently, acting as one of the administrators of A&D Technology's service department and is the lead trainer in charge of training internal employees and customers on A&D products. Ms. Buczkowski has spent four years working for A&D Technology, but also accumulated an additional two years of design and testing experience through internships and co-ops during her undergraduate studies. During her time attending Michigan Tech in Houghton, MI, Ms. Buczkowski performed with the Keweenaw Symphony Orchestra, serving as principal percussionist for four of her five years. As a final project for her Music Performance minor, she conducted a song with the Keweenaw Youth Symphony Orchestra. After graduation, she has maintained her appreciation for music performance and currently plays with the Dexter Community Orchestra.

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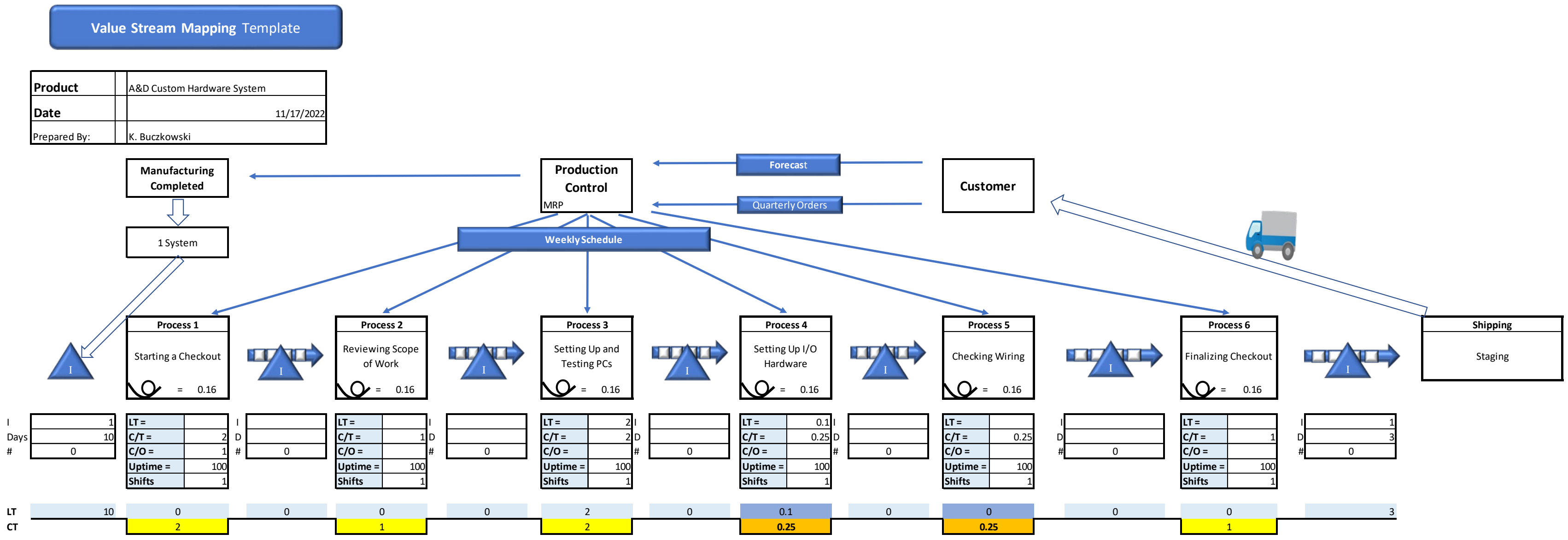
Appendix

Value Stream Map



\# of modules 25

Average = 25

Factor	Value	U/M
LT	12	Days
+	2.5	Days
Total LT =	14.5	Days
PT	5	Hours
+	12.5	Hours
Total PT =	17.5	Hours
Operators	1	Count
Total WIP	10	EA

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