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Visual Management in Engineering Can Improve Resource Utilization and Reduce Administrative Non-Value Added Time

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VISUAL MANAGEMENT IN ENGINEERING CAN IMPROVE RESOURCE UTILIZATION AND REDUCE ADMINISTRATIVE NON-VALUE ADDED TIME

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I dedicate this thesis to my family and the many Civilian/Military colleagues in my life who have supported me and inspired me to continue challenging myself. I can genuinely accredit any success that I have had, or will have, to the love of family and the support of friends.

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Brian Trent May 2021 42 Pages

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This research has demonstrated how Visual Management (VM) can be used in an engineering environment to improve engineering resource utilization. Furthermore, it reduces the administrative time associated with unclear project scope, schedule, budget, and task alignment amongst engineers and project leadership. The research references a case study in which low engineering utilization was directly impacting overall project success. Inconsistent visibility of scheduled engineering activities, changes in tasking, and project metrics created uncertainty and resulted in greater than appropriate administrative time. The methodology used was to implement visual project management tools and track engineer utilization over two years. Quarterly utilization results for the engineering staff were captured from January 2017 thru June 2020 and used to show resulting trends and statistical analysis of results. This research has shown clear and consistent improvement from the point of visual management implementation and has sustained improved performance over the last 1.5 years of the research period. Moreover, two statistical t-tests were used to show if the research rejects or accepts the null hypothesis that there was zero statistical difference to utilization or administrative time burdens before and after implementing the visual management tools. Lastly, survey results from the engineers included as participants provided the qualitative data needed to support the research conclusion and quantitative analysis.

Chapter 1 – Introduction

Background/Overview

Companies driven to customize their products to meet specific customer requirements are typically considered engineer-to-order (ETO) companies. An ETO product is defined as a product manufactured to specific customer requirements and unique specifications (Rahim & Baksh, 2003). Companies required to conduct business in this manner must have detailed processes and procedures and diligently follow them. Additionally, once the project is kicked off, any variation in the plan set forth will directly impact the gross profit margin promised to the company stakeholders. Ash (2009) states that "Global competition makes fast and effective management of mission-critical engineering projects essential for business survival and success" (p. 58).

This research studies how visual management (VM) tools can impact engineering resource utilization in a case study and referenced a US-based company located in central California. To maintain confidentiality, we will refer to the company only as *The Company*. The company manufactures engineer-to-order equipment and has seventeen engineers on staff for mechanical and electrical design. By nature, ETO projects have a great deal of uncertainty and risk because of the lack of historical design data and limited testing and evaluation time. Cutler (2009) states that "ETO is a manufacturing philosophy, not just an engineering process because finished goods are built to unique customer specifications" (p. 36). The study explored if VM used within an engineering department would maximize engineering resource utilization and reduce administrative time.

Statement of the Research Problem

This research addressed the problem that without clear communication of tasking within a project design team, the impact is reduced resource utilization and increased non-value-added time. Unplanned requests and distractions that engineers face daily are a real challenge and one that cannot be avoided altogether. As the days come and go throughout the project, precise alignment within the project team must be maintained. One method to maintain this alignment and communicate the day's priorities is through VM. This research will focus on VM used by the individual, at the team level, and visual metrics made available to the department and other project stakeholders. Eaidgah et al. (2016) stated that “Visual management can provide a simple and yet effective solution to enhance information flow in organizations. However, for visual management to yield its full benefit, it will need be part of a bigger plan.” (p. 187).

When ETO projects are being planned, the amount of work and time needed to complete the engineering design process is typically based on estimates from historically similar projects and input from subject matter experts. Each task is unique, and assessments can be built from past situations with comparative qualities (Lorincz, 2005). Once the contract details and engineering hour budgets are agreed upon, the limits are set, and the margin for error is unforgiving. Buffers can be built into the engineering time and scheduling estimates. However, those buffers should only be used when necessary.

Furthermore, it is common for the front-line engineers to be excluded from the initial planning discussions that drive the project schedule and budget targets. Once the project is handed off to the project team to execute, the plan must be communicated, milestones set, and deliverables agreed upon and tracked. Without a VM system and a process to maintain this communication, a new layer of complexity is introduced that will impact the team's chances of hitting their key deliverables. Visual management is the practice of visualizing information or displaying requirements to set directions (Eaidgah, et al., 2016).

Significance / Purpose of the Study

The research's significance is to demonstrate the value of using VM to enhance communication within an engineering design team, precisely when executing projects associated with ETO product lines. It is common for engineering managers to manage their staff tasking and project metrics using custom spreadsheet tools or Microsoft (MS) Project. Although the best intentions are in mind while attempting to use these tools, their accuracy and ability to be flexible are limited as projects progress and priorities change (Margea, 2011). As the research discussion progresses, the content is directed towards web-based project management (PM) software for team collaboration, visual management dashboards, and analytic metrics reporting. There are many software options on the market (see Appendix A). The research will not advocate for any specific one.

When choosing a web-based PM tool to be used within a design team, the software must allow quick adjustments to resources, schedules, and interfaces available in real-time to the individual task owners. Without real-time updates to the engineers when plans or resources are adjusted, the result is confusion, lost time, and a negative impact on utilization, schedule, and budgets (Margea, 2011). The purpose of the research is to present case study data from The Company that implemented a web-based, predictive PM tool that provided live project data to the users and visual management to all stakeholders. The researcher collected, analyzed, and prepared data to be presented following the research period that rejects or failed to reject the null hypothesis. The null hypothesis states that the PM tool and Visual Management outputs did not improve engineering resource utilization or reduce non-value-added administrative time. The research data was compiled and presented in Pareto charts, trend charts, and statistical t-test analysis to show the impact over two years. The end significance and purpose were to show that teams can achieve their best when organized in a collaborative, visual, and intuitive interface that minimizes confusion when priorities shift. When all members can view the project plan and their specific tasking, project success and enhanced efficiency are expected to be the result (Eaidgah, et al., 2016).

In Addition, the final result is an automated collection of VM metrics comprised of project interfaces, project analytics available to the managers, and dashboards published for all stakeholders to view. A major obstacle for organizations is the difficulty of making information flow effectively and efficiently. Therefore, stakeholders and decision-makers do not receive the right information at the right time to make the right decisions (Eaidgah, et al., 2016).

Research Questions

The research hypothesis is that before using VM within a product design team, resource utilization was negatively impacted due to team misalignment with project tasking and priority adjustments. Additionally, a second hypothesis is that, before implementing the tools, unnecessary non-value-added administrative time was a consequence. Even at a minor amount, reoccurring confusion resulted in non-value-added time. It took engineers off the value-added tasks that keep the project on schedule and budget. These non-values added hours are at risk of being charged in an admin-type bucket of time or are charged to the project impacting the project budget. For the research participants in this study, administrative time was defined as the time associated with general conversations with peers, reoccurring meetings, non-project correspondence, general meetings held with other departments, expense reports, or department meetings.

To address the purpose of the study, the researcher developed two research questions. First, was there a difference in engineering utilization after the implementation of the VM tools? Second, was there an associated reduction in administrative time charged during the research period? Utilization calculations will simply be the available capacity, divided into the recorded value-added hours charged to sold projects over the defined research period. The captured data from January 2017 thru July 2018 transitioned into the analysis after implementing the PM tools in August 2018. The data was prepared to show whether there was a difference in utilization and administrative time throughout the research period or zero impact. The study analyzed the collected data and presented statistical t-tests of quarterly utilization and total monthly administrative time.

Furthermore, a comparison of the before and after utilization and administrative time data was made available to report the analysis. Before and after comparisons will use an average of the data collection periods while taking the standard deviations of data points for each period into consideration. Two null hypotheses were developed to address the stated research questions. The first null hypothesis states that there was no statistical difference in resource utilization between the before and after data sets. The second null hypothesis states that there was no statistical difference in administrative time between the before and after data sets.

Assumptions, Limitations, and Delimitations

The assumptions that must be understood are that all team members were receptive to having this VM level required. It is a personality barrier that must be broken down, but assuming everyone was fully receptive is not realistic. It is common for an engineer to feel micro-managed when this type of visibility is put on their work and the reporting of progress being made daily. Another assumption is that the manager appropriately maintained the project tasking, task priority, budget, and milestone schedule. Without regular reviews, tasks being marked complete, and hours being charged appropriately, the tools and VM indicators could quickly trend towards being inaccurate. The managers' and supervisors' responsibility is to ensure the engineers are following the policies and procedures that are put into place to maintain the accuracy of visual project metrics. Additionally, it is the leadership's responsibility to ensure that the project tasking, task priority, and any changes directed from management are effectively communicated to the supervisors and engineers on the teams.

Chapter 2 – Review of Literature

The literature captured to support the research included content that references general VM principles and ETO manufacturers' challenges. Although the two concepts are not referenced in the same context, the challenges discussed with ETO manufacturers and the benefits mentioned of VM support the research questions appropriately. For engineering disciplines that work in an ETO environment, there are unique challenges that they are faced with regularly. In an article titled Leaning ETO Project Management, the author references the unique nature of ETO projects concerning challenges in estimating, contracts, relentless engineering changes, project management, and much more. Although the article is driven towards the proper use of Enterprise Resource Planning (ERP) tools, the content also supports the research by exposing what VM can improve communication. One particular piece of the article discusses how a project's profitability is directly related to recording and monitoring changes and maintaining accountability and the impact to cost or schedule (Lorincz, 2005).

The most relevant supporting literature discussed the challenges for the industrial engineer executing ETO projects. This article went into great detail about the unique nature of ETO projects and the result if they are not planned and organized correctly. Specifically, the article discusses the elements unique to engineering that supports the research claims. For instance, the author mentions how engineers face constant changes throughout a project cycle. The ability to manage these changes efficiently often will determine the project's success or failure (Cutler, 2009).

Additionally, points are made to the importance of timely sharing of data, drawings, information, and management of project metrics. These fundamental elements fit nicely into the research questions about how VM can provide value to engineering stakeholders and the project team as a whole. The author also discusses the importance of using Lean principles to improve communication in posting daily metrics for the other business functions. His focus is to manage the constant changes associated with ETO projects, with an end goal of minimizing the time required during the project's engineering scope. Cutler (2009) suggests that, "One common trait that is unique to all

ETO businesses is the need to deal with constant changes throughout the life of each project. Design changes, order changes, and delivery change all stall projects in engineering and directly affect the project duration and chance for success" (p. 37).

There is an abundance of literature that references the many types of VM tools available and how they can improve communication, quality, and efficiency. The first journal that is referenced is titled, Visual Project Management Tools and Their Application. This journal is focused on how students at Texas A&M used visual project management tools during their capstone design project. There is mention about the many visual management tools used over the years, and how many of them were not convenient for use weekly for status reviews (Zhan and Morgan, 2011). The content suggests that the students used visual management to communicate metrics such as percent completion, highlighted critical paths, duration of each task, project budget, and schedules. Traditional project management tools, such as MS Project, all have one common shortcoming. The shortcoming is that they require a project manager of some type to maintain regularly, and they do not have the level of customization that is sometimes required (Zhan and Morgan, 2011). The students attempted using various types and iterations of visual management during the course. The final comments mention that the students planned to consider web-based programs for generating these graphs for future work (Zhan and Morgan, 2011). These final comments support the research for how web-based visual management tools can effectively reduce administrative non-value-added time and improve engineering resource utilization. Whether referencing literature that is specific to challenges associated with ETO projects or the use of visual management in engineering, there is an understandable need for the two to be associated. How can VM be implemented and used in an ETO manufacturing environment effectively and efficiently? For ETO manufacturing companies, direct, constant, and collaborative VM tools that require minimal intervention to maintain should be the ultimate goal. Tezel, Koskela, and Tzortzopoulos (2016) states that, “VM strategy is independent of the production industry and production systems as it is a close-range visual (sensory) communication strategy” (p. 788).

There are numerous Lean tools available to leverage for supporting process improvements and using some form of VM is just one (Van & de Mast, 2019). Furthermore, visual management tools and processes will only complement other Lean practices and should be incorporated into a Lean infrastructure. In an article titled, Visual Performance Management as A Fitness Factor for Lean, the author writes about how Lean is a broad principle. VM is a bundle of practices where visual techniques are used to offer timely information (Van & de Mast, 2019). For the two research questions mentioned in this study, the VM tools were only able to achieve their full benefits once the tools were supported by Lean thinking and robust processes that ensure accountability and proper use of the shared information.   In conclusion, the article states that the research conducted further supported the stance that Lean should not be understood by studying its practices and tools in isolation (Van & de Mast, 2019). For the analysis conducted to address the stated research questions, emphasis on VM being only part of a larger plan and a Lean culture is highlighted.

Another exciting literature review discussed challenges experienced by schedulers when excessive time is spent interacting with external parties. The author suggests that schedulers spend excessive time searching for the information needed than scheduling work (Larco et al., 2018). The research observed seven schedulers for a total of nineteen eight-hour shifts to capture time data about their activities and time associated with interruptions. Although the research participants were not part of an engineering function, the challenge with having information available to improve time management largely overlaps and broadens the possibility of the analysis being valuable to a larger audience outside of engineering leaders. Larco et al. (2018) argued that a significant fraction of scheduled tasks were interrupted by disruptions and that time management is a critical skill for productivity. The research referenced in this literature further supports the engineering-specific research questions focused on improving resource utilization and reducing administrative distractions. Narayanan et al. (2020) contended that adopting well-designed task management policies can significantly improve engineer resource utilization in capacity-constrained settings.

Chapter 3 – Methodology

Research Design

The research method involved the collection and analysis of both qualitative and quantitative data. Specifically, the method could be classified as convergent parallel due to the data sets being collected concurrently for future integration and interpretation. The data was collected quantitatively through data collection embedded in the VM tool, and the study utilized a survey of the participants to collect the qualitative data. After the research time frame was concluded, the survey was conducted to support the quantitative analysis and the conclusion. After all the data was collected and analyzed, it was integrated to answer the research question. The time frame for which the research focused was over 3.5 years. Benchmark data was collected and organized to calculate historical utilization results and admin hours totals from January 2017 thru June 2018. The web-based Visual Management tools and processes were implemented in August 2018, and data was collected thru June 2020. The analysis's goal was to investigate whether there was a difference in engineering resource utilization and a difference in administrative time data that began in August 2018 and showed sustained improved performance through the research period's conclusion. The null hypothesis is that there was no impact in engineering resource utilization nor reduced administrative time data between the before and after data sets.

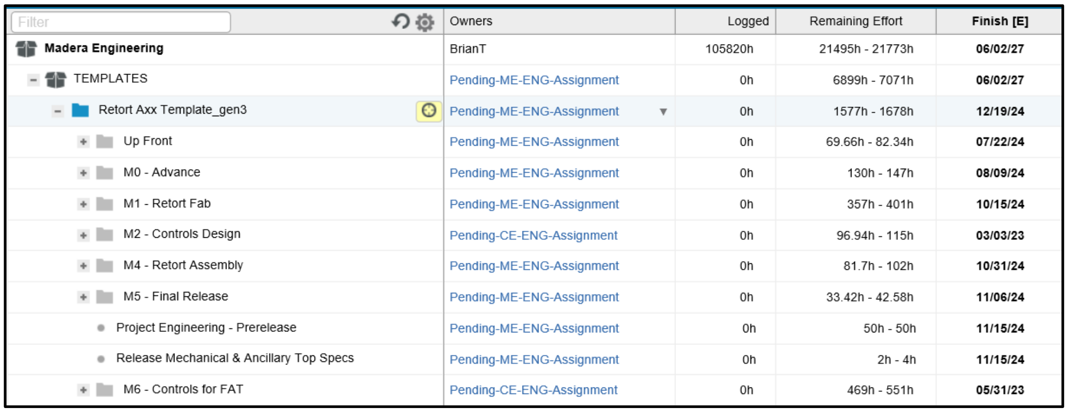
Participants and Data Sets

The research participants included sixteen engineering staff members composed of seven mechanical and five electrical Engineers, one associate designer, two supervisors, and one department manager. The company's business unit is located in California and had a history of shortcomings in the engineering department, including negative project margins, missed delivery targets, and a lack of project metric visibility required by senior management. In early 2018, a drastic reorganization of the business unit personnel and leadership was executed to improve operational performance and culture. The new engineering manager who was hired saw the value of visual project management tools in an engineering function. This engineering staff was identified for the research participants solely because of the need to improve department performance, and the opportunity presented itself to the incoming manager. The engineering staff was reasonably young, with the majority within five years from college graduation. The initial impression gathered from the existing staff was that they were uncertain of the business's future and frustrated about the historically ineffective planning and crossfunctional alignment when projects were inbounded. When presented with implementing a web-based predictive project management software that would provide the visual management and metrics desperately needed, the existing staff's response was very positive, setting the stage for this group to be the perfect participants to begin the research.

Once the web-based project management and VM tools are purchased, staff members were trained, and well-defined processes and procedures were developed. The data sets started to be collected from the engineers as they began executing projects and specific tasks that they were assigned. The hours logged to the assigned tasks began to populate the metrics and dashboards used in the key performance indicators (KPI). The logged time was also used as the data source for the required time entry into the business Enterprise Resource Planning (ERP) software, so accountability and risk of non-participants was not a concern.

Data Collection, Instruments, and Procedure

To understand the data collection process and instrumentation used, the reader must first understand how the web-based project management tool functions. The web-based PM software implemented for the research is a dynamic tool in which task lists are created specific to the project, engineering resources are assigned, and hour estimate ranges are applied to each task. An estimated completion date is calculated based on the resources' set availability (see Figure 1).



Filter	Owners	Logged	Remaining Effort	Finish [E]
Madera Engineering	BrianT	105820h	21495h - 21773h	06/02/27
TEMPLATES	Pending-ME-ENG-Assignment	0h	6899h - 7071h	06/02/27
Retort Axx Template_gen3	Pending-ME-ENG-Assignment	0h	1577h - 1678h	12/19/24
Up Front	Pending-ME-ENG-Assignment	0h	69.66h - 82.34h	07/22/24
M0 - Advance	Pending-ME-ENG-Assignment	0h	130h - 147h	08/09/24
M1 - Retort Fab	Pending-ME-ENG-Assignment	0h	357h - 401h	10/15/24
M2 - Controls Design	Pending-CE-ENG-Assignment	0h	96.94h - 115h	03/03/23
M4 - Retort Assembly	Pending-ME-ENG-Assignment	0h	81.7h - 102h	10/31/24
M5 - Final Release	Pending-ME-ENG-Assignment	0h	33.42h - 42.58h	11/06/24
Project Engineering - Prerelease	Pending-ME-ENG-Assignment	0h	50h - 50h	11/15/24
Release Mechanical & Ancillary Top Specs	Pending-ME-ENG-Assignment	0h	2h - 4h	11/15/24
M6 - Controls for FAT	Pending-CE-ENG-Assignment	0h	469h - 551h	05/31/23

Figure 1. Engineering project template prepared for task assignment, hour estimates, and calculated completion date estimates.

Each engineering resource has a web interface available and is a tool used daily to understand their tasking, email notifications when tasking changes, their impact on the project metrics, and the timesheet tool to capture the time data (see Figure 2). The time data is input by the engineers daily, and accountability is reviewed weekly by the department manager.

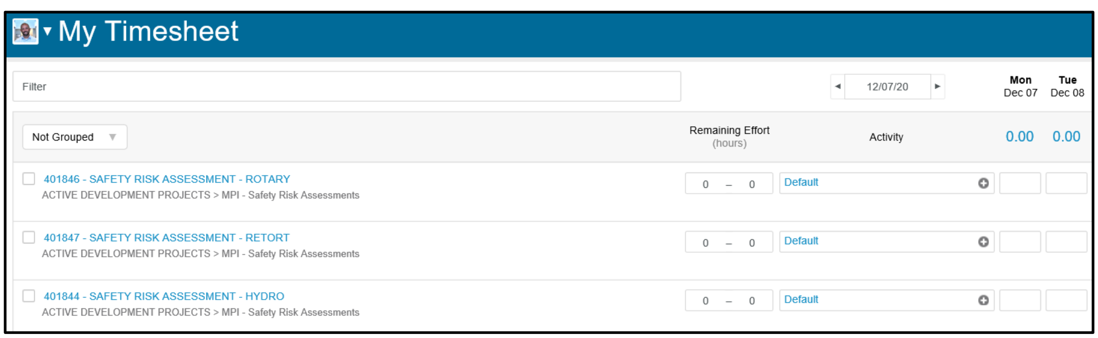


Figure 2. Engineer task assignments are available on the user timesheet for efficient and accurate time entry

Within the software, project dashboards were created and used on every project to show the live status of time charged, estimated time remaining, budget status, and schedule risk. These dashboards were one key piece of visual management used by the engineers and leadership to actively review project status and identified risk(s) as early as possible (see Figure 3). As schedule and budget risk were identified during weekly project reviews, immediate changes in engineer tasking could put into place to mitigate negative impact to the project.

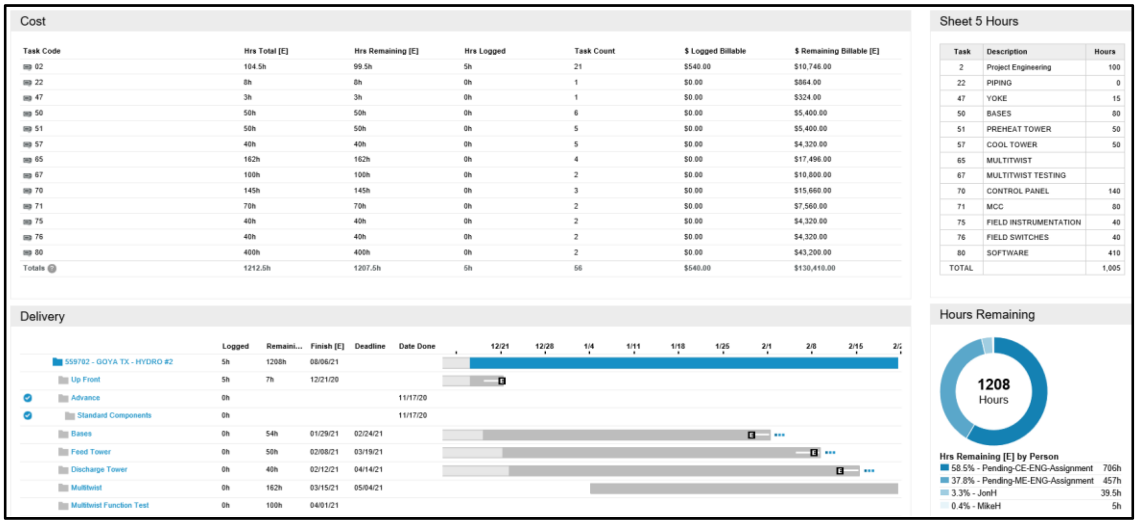


Figure 3. Standardized project dashboards are used for every project that is planned. The dashboards show live data and metrics to review total hours estimated, hours remaining, hours logged, pending tasks in priority order, deadline targets, and schedule status in the form of a Gantt chart. The table also converts hours to billable hours.

With the time data that was input daily and reviewed weekly, the department manager could export the data totals and calculate weekly utilization. Utilization is the KPI for how well the engineers can stay focused on value-added project work rather than non-value-added administrative burdens. Daily time management guidelines and a decision matrix were made available. The training provided to the staff ensured that the engineers were making the best decision for charging their time. The decision matrix was used to help the engineers identify the proper task to charge hours, whether it is a project, or a non-project task based on the work being planned (see Figure 4).

Task Description	ADMIN-ENG - WC: 709418	ADMIN-ENG MTES - WC: 709418	ADMIN-ENG JDE TRANSITION - WC: 709418	ADMIN-ENG TIMESHEETS - WC: 709418	401856 - TRAIN-ENG	XXXXXX - SOLD CUSTOMER PROJECT WITH ENGINEERING	525502 - PERIOD COST – ENG ASME COORDINATOR	540660 - PERIOD COST – ENG SUPPORT FOR CORPORATE	401796 - ENG-METHODS / OPS Support	401797 - ENG-SERV	401798 - ENG-AE	401799 - ENG-CS	401800 - ENG-RCI	531322 - PC - ENG SAFETY - GENERAL
General converstions with piers, non project coorespondence, general meetings held with other departments, expense reports, site or department quarterly meeting.	X													
Hours towards populating MTES with weekly LP Labor		X												
Hours towards delays associated with JDE transition			X											
Hours associated with populating daily LP timesheet hours				X										
Hours associated with safety stand-up meeting, DuPont safety training, in-person safety trainings, safety training for Interns/contractors / new employees, BBSO's and Near Miss Reporting.														X
Hours towards one-on-one, small group or formal classroom training					X									
Any work or correspondence associated with a sold project						X								
all non-project work that is done with regards to ASME coordination, documentation and distribution							X							
All hours associated with support towards the corporate sourcing initiatives								X						
Any work or correspondence associated with supporting the Service department										X				
Any work or correspondence associated with supporting Customer Care, direct customer support, or assisting purchasing on a non-project item.												X		
Any work or correspondence associated with supporting Sales or Application Engineering (e.g. Preparing / participating in 75%, 90% or KO meetings)											X			

Figure 4. Work order decision matrix ensures proper and accurate time data entry for utilization calculations.

It is expected that there is going to be a percentage of non-project work requested from the engineers, to include supporting other business functions, training, and administrative requirements such as emails and phone calls. The objective was to make information available to the engineers so time can be logged as accurately as possible towards what was being requested and accomplished. Procedures defined in the developed standard operating procedure (SOP) are that each engineer will log their time daily and submit timesheets weekly. Once submitted, the department manager was able to verify that the engineer had completed the time entry process and submitted it for review. Following a review to check quality and completeness, the manager then locked the timesheet tool preventing further manipulation (see Figure 5).

Person: 17 members From: 12/07/20

Legend: Not Ready | Needs Update | • Ready | Locked

Person▼	Week 50 379.70 h 12/07/20	Week 49 696.06 h 11/30/20	Week 48 602.14 h 11/23/20	Week 47 714.21 h 11/16/20	Week 46 740.36 h 11/09/20	Week 45 694.61 h 11/02/20
CoreyC	0.00 h	40.00 h	40.00 h	48.00 h	48.00 h	40.00 h
GarrettC	0.00 h	40.00 h	40.00 h	40.00 h	40.00 h	40.00 h
JeremiahS	32.50 h	40.00 h	0.00 h	40.00 h	40.00 h	40.00 h
JesusG	0.00 h	48.00 h	40.00 h	48.00 h	48.00 h	40.00 h
JonH	12.00 h	41.00 h	40.00 h	43.00 h	45.25 h	41.00 h
KevinC	0.00 h	40.00 h	40.00 h	40.00 h	40.00 h	40.00 h
LizethK	• 42.50 h	41.00 h	40.50 h	42.50 h	43.50 h	41.00 h
MichaelF	48.50 h	40.00 h	40.00 h	43.00 h	44.00 h	40.00 h
MikeH	25.50 h	40.00 h	40.00 h	40.00 h	40.00 h	40.00 h
RandyH	16.00 h	40.00 h	40.00 h	42.00 h	50.50 h	49.00 h
RichardR	• 40.00 h	40.00 h	40.00 h	40.00 h	40.00 h	40.00 h
RyanN	46.00 h	45.00 h	41.50 h	45.50 h	48.50 h	40.00 h
ThomasW	0.00 h	40.16 h	40.14 h	41.11 h	41.51 h	41.31 h
TracyS	• 40.70 h	40.90 h	40.00 h	41.10 h	41.10 h	41.30 h
TrevorS	26.00 h	40.00 h	40.00 h	40.00 h	50.00 h	41.00 h
TzelaY	40.00 h	40.00 h	0.00 h	40.00 h	40.00 h	40.00 h
WesW	10.00 h	40.00 h	40.00 h	40.00 h	40.00 h	40.00 h

Figure 5. Time data entry is submitted, verified, and locked by the manager weekly. Verification is quickly viewed using the timesheet status dashboard.

Coordination to ensure accurate and complete time data entry was critical to producing the accurate utilization calculation to address the research question. The time data captured was used to calculate utilization percentages weekly, and the results were made available to the engineering staff with a target set at ≥ 92% (see Figure 6). If the weekly percentage was less than the target, the manager analyzed the timesheet data to understand the root cause and react accordingly to bring the results back to the KPI target range. At this time, the manager would review non-value administrative time that drove the utilization decline and mitigate causes.

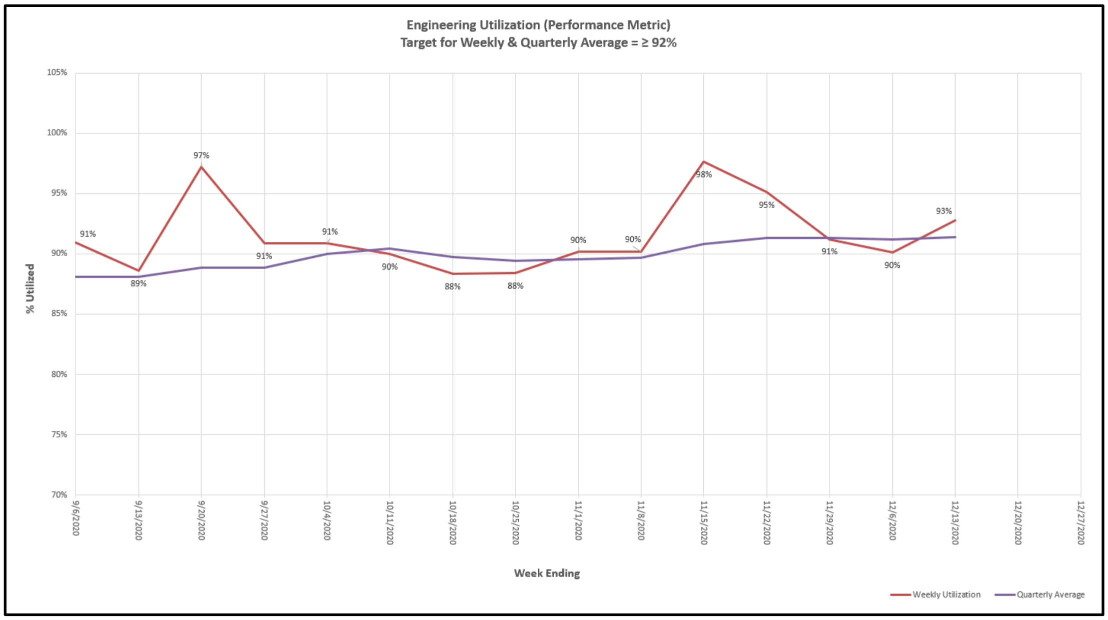


Figure 6. Weekly utilization results trend report

Data Analysis

Historical data was obtained so that a comparison could be measured and analyzed following the research period. Historical time entry data from January 2017 through June 2018 was obtained, and quarterly utilization was calculated. In addition, monthly admin time totals from that period were prepared. The utilization percentage was calculated by summing the total hours logged per quarter and dividing it into the total hours only associated with sold projects. In general, the numerator of the ratio is the total hours captured, minus the hours associated with defined administrative non-value-added time $(\frac{Total\ Hours - Admin\ Hours}{Total\ Hours}) * 100$. The same historical data set was leveraged to sum the hours charged to administrative tasks and populated to show monthly totals. Based on historical data, the results were used as a baseline that the new August 2018 through June 2020 results were measured against to accept or deny the research hypotheses. Quarters three and four of 2018 were the time frame of process/procedure development, training, and implementation of the web-based project management tools and visual management references.

Following the successful implementation, the data retrieved from the time entry tool was used to calculate utilization and capture admin hour totals using the same methodology as the historical baseline calculations. Once the historical and post VM time data was collected, the monthly and quarterly averages were used to populate Pareto charts signaling trends. For the utilization analysis, a comparison between seven data points (seven calendar quarters) before and after implementation was made to measure the relative change in utilization while accounting for the standard deviation of the two data sets. Finally, a statistical t-test was used to support the conclusion further and accept or reject the null hypothesis that there was zero impact on utilization due to the implementation of visual management tools and processes.

The second research question that the examination addressed was that non-value-added administrative time could be reduced following the VM tools' implementation. The data used to complete the second research question analysis was derived using the same methodology and used the same data set for the primary analysis for improving resource utilization. Monthly averages of administrative time charged were used to populate Pareto charts showing monthly trends. Moreover, a comparison between eighteen monthly averages before and after implementation measured relative change in administrative time charged while accounting for the two data sets' standard deviation. Finally, a statistical t-test was used to support further the conclusion that either accepts or rejects the null hypothesis that there was zero change in administrative time charged following the implementation of visual management tools and processes.

In addition to the quantitative analysis of the obtained data, qualitative analysis was also collected to be presented. The qualitative analysis includes survey results received from the engineers that were included as research participants. The survey questions were prepared to allow the engineers who used the new tools and visual management indicators to voice their input on whether improvements were realized. The research participants' qualitative results were essential to ensure that any researcher biases are negated, and assumptions do not influence the analysis. The complete analysis outcome has shown a statistically significant improvement in engineering utilization following the web-based project management tool and visual management indicators. In Addition, the analysis has shown reduced administrative non-value-added time due to improved communication and enhanced alignment across design teams when tasking and priority changes are imminent.

Threats to Validity

The threat or risk to validity for this research is minimal but not absent. The VM used by the engineers was web-based and provided real-time tasking based on priority. Therefore, the hours were being recorded as tasks were complete resulting in the validity of the data being irrefutable. However, one threat to be aware of is the sample size of the data following VM implementation. If the sample size was too small, the research results might be scrutinized as not sustainable. Merging the qualitative data collected from the survey supported the quantitative data and minimized the risk associated with the research validity threats.

Additionally, a threat to validity could be raised because the department's research participants were not fully absorbed with sold project hours to cover the engineers during the research period. Any gaps in sold project hours to cover the participant's capacity would impact the utilization and administrative time data calculation. The research participants were fully absorbed with sold project hours with zero under-absorption periods during this research period.

Chapter 4 – Results or Findings

The research objective was to study the impact on engineering resource utilization and associated non-value-added administrative time following the implementation of a web-based project management solution and associated visual management. The data collection plan was to leverage historical utilization results from January 2017 thru Q3 of 2018 as a baseline and then compare results following the software and visual management tools' implementation. Additionally, the same timesheet data was leveraged to prepare an analysis of the administrative non-value-added time charged during that period. The data collection period concluded at the end of Q3 2020, and at that time, the comparison was able to be made. The research hypothesis is that before using VM within an engineering team, resource utilization was impacted due to the time required for all members to be continuously aligned with the project tasking and priority adjustments. Similarly, a second hypothesis is that non-value-added administrative time could be reduced concurrently by leveraging the VM tools, which directly correlates to the improved resource utilization for the team.

During the third and fourth quarter of 2018, the implementation period included procuring the software, developing standard procedures for use, standardizing the visual management dashboards, and providing training to the engineers on how the tools were to be used daily. Once the new tools and processes were underway and integrated into the department, utilization and admin hour totals were closely monitored each week to track results against the ≥ 92% utilization target. The manager completed this review each Monday morning and referenced the prior week time data that the engineers input through the web-based tool. The utilization trend chart was populated and emailed to all the department engineers each week and ensured visibility of results and actions required if results were less than the set target. This visual management feedback loop was instrumental in ensuring that opportunities to improve existing processes were identified, and optimized utilization was always under review.

Following the period of utilization and admin time data collection that concluded at the end of quarter three, 2020, the results could be calculated and then compared to the baseline data set from January 2017 through quarter 3, 2018. The utilization results showed an average of 82.80% before the implementation and 89.85% across the post-implementation quarters (see Table 1, for utilization results).

Table 1

Quarterly Utilization Results Before & After VM Implementation

Quarter Number	Calendar Quarter	Average % Utilized
	Calendar Quarters Before Implementation	
1	2017-1	82.49%
2	2017-2	82.14%
3	2017-3	81.54%
4	2017-4	81.45%
5	2018-1	81.77%
6	2018-2	86.29%
7	2018-3	83.92%
	Calendar Quarters After Implementation	
1	2019-1	89.48%
2	2019-2	90.00%
3	2019-3	88.50%
4	2019-4	89.29%
5	2020-1	89.83%
6	2020-2	92.69%
7	2020-3	89.15%

Note. The table compares historical quarterly utilization results to quarters following web-based project management software and visual management tools.

Additionally, the results showed an average of 401 administrative hours per month before the implementation and an average of 246 hours across the post-implementation months (see Table 2, for monthly admin results). Standard deviation from the two periods was validated to be ≤ 1.75% for utilization and ≤ 106 hours of admin time charged (see Table 3, for the standard deviation of utilization %) (see Table 4, for the standard deviation of admin hours). This calculation was made to ensure that the averages did not include considerable variation from the mean value calculated during the period,

Table 2

Monthly Admin Time Results Before & After VM Implementation

Month Number	Calendar Months	Total Admin Charged
	Months Before Implementation	
Month Number	Year / Mo	Admin Hours
1	2017-1	618
2	2017-2	384
3	2017-3	546
4	2017-4	342
5	2017-5	428
6	2017-6	559
7	2017-7	396
8	2017-8	369
9	2017-9	319
10	2017-10	315
11	2017-11	321
12	2017-12	316
13	2018-1	546
14	2018-2	426
15	2018-3	207
16	2018-4	430
17	2018-5	363
18	2018-6	337
	Months After Implementation	
1	2019-1	288
2	2019-2	304
3	2019-3	271
4	2019-4	284
5	2019-5	225
6	2019-6	198
7	2019-7	250
8	2019-8	283
9	2019-9	259
10	2019-10	333
11	2019-11	177
12	2019-12	214

13	2020-1	280
14	2020-2	210
15	2020-3	278
16	2020-4	204
17	2020-5	133
18	2020-6	232

Note. The table compares historical admin hours results to the months following web-based project management software and visual management tools.

Table 3

Average Utilization Results with Standard Deviation

	Average	Sta dev
Before Implementation	82.80%	1.75%
After Implementation	89.85%	1.34%

Note. The table shows average utilization before and after implementation with standard deviation for each data set.

Table 4

Admin Hour Results with Standard Deviation

	Average / Month	Sta dev
Before Implementation	401	106
After Implementation	246	50

Note. The table shows the average administrative time charged before and after implementation with a standard deviation for each data set.

The tabulated results and comparisons from the two data sets representing the period before and after the implementation show a utilization improvement of 7% from the mean values and a 39% reduction in administrative time. To further investigate if there was a statistical difference between the two periods' mean values, a statistical t-test was used for both utilization and admin time results—specifically, a Two-Sample Assuming Unequal Variances t-test. The null hypothesis states that the difference in the mean utilization is zero for the two sample periods. The results showed that the calculated P(<=t) two-tail value is less than the stated P-value of 0.05 for both utilization and admin hour results. The results of the analysis indicate that the null hypothesis can be rejected. An alternate hypothesis is that the difference in means is not equal to zero and holds a 95% confidence interval (see Table 5, for utilization T-test results) (see Table 6, for administrative time T-test results).

Table 5

T-Test: Two-Sample Assuming Unequal Variances
Null Hypothesis: The difference in mean utilization is zero for the two sample periods

	Before VM	*After VM*
Mean	83%	90%
Variance	0.031%	0.018%
Observations	7	7
Hypothesized Mean Difference	0	
df	11	
Stated P-Value	0.05	
t Stat	-8.438387563	
P(T<=t) two-tail	3.91942E-06	
t Critical two-tail	2.20098516	

Note. The calculated P(<=t) two-tail value is less than the stated P-value of 0.05. Reject the Null Hypothesis that the difference in mean utilization is zero for the two sample periods.

Alternative hypothesis: True difference in means is not equal to zero with a 95% confidence interval

Table 6

t-Test: Two-Sample Assuming Unequal Variances
Null Hypothesis: The difference in mean administrative time is zero for the two sample periods

	Before VM	*After VM*
Mean	401.0	245.7
Variance	11294.8	2529.9
Observations	18	18
Hypothesized Mean Difference	0	
df	24	
Stated P-Value	0.05	
t Stat	5.605828436	
P(T<=t) two-tail	9.0484E-06	
t Critical two-tail	2.063898562	

Note. The calculated P(<=t) two-tail value is less than the stated P-value of 0.05. Reject the Null Hypothesis that the difference in admin time is zero for the two sample periods.

Alternative hypothesis: True difference in means is not equal to zero with a 95% confidence interval

Pareto charts were populated for each analysis to visually show trends throughout the two sample periods (see Figure 7-8). The two data samples are also shown in a side-by-side Pareto chart to validate further that the reference periods from the two data sets have consistent and sustained improvements over the seven quarter periods (see Figure 9-10). Utilization results over the research period showed a consistent improvement trend following the implementation period. Also, the admin hour results over the period showed a consistent reduction trend. The side-by-side Pareto chart for both utilization and admin hours allowed for comparing the periods before and after implementation.

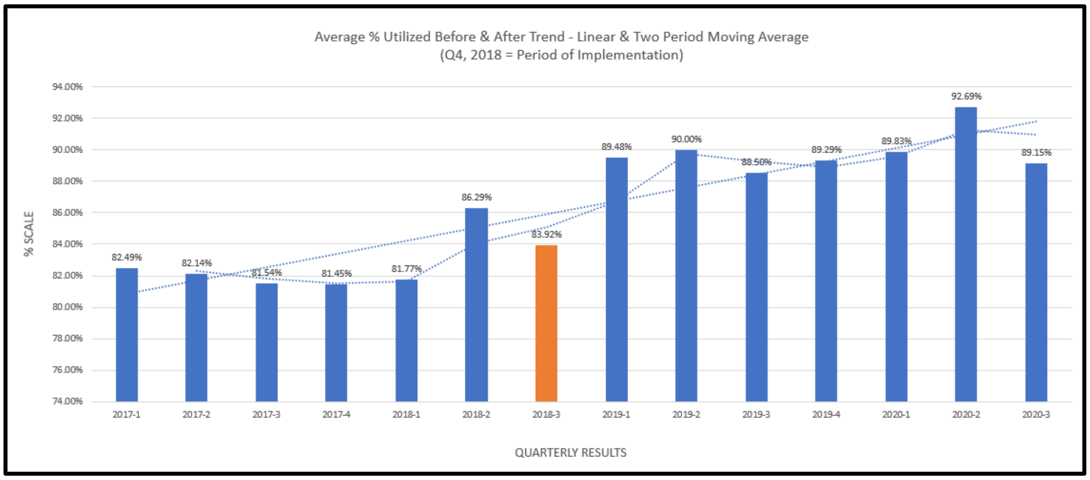


Figure 7. Pareto graphically depicts the change in utilization over time. Quarter 3 and 4 of 2018 was the implementation, training, and process/procedure development period.

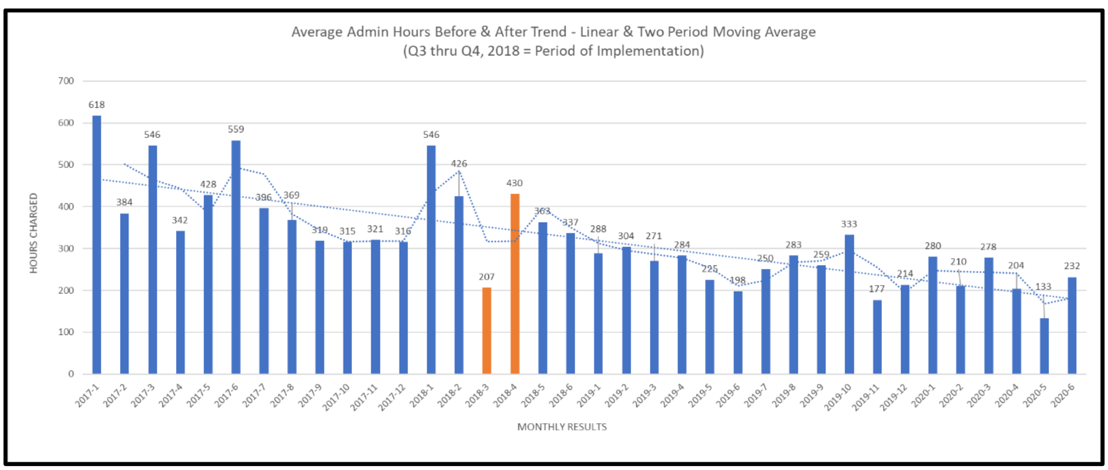


Figure 8. Pareto graphically depicts the change in admin hours charged over time. Quarter 3 thru 4 of 2018 was the period of implementation, training, and process/procedure development.

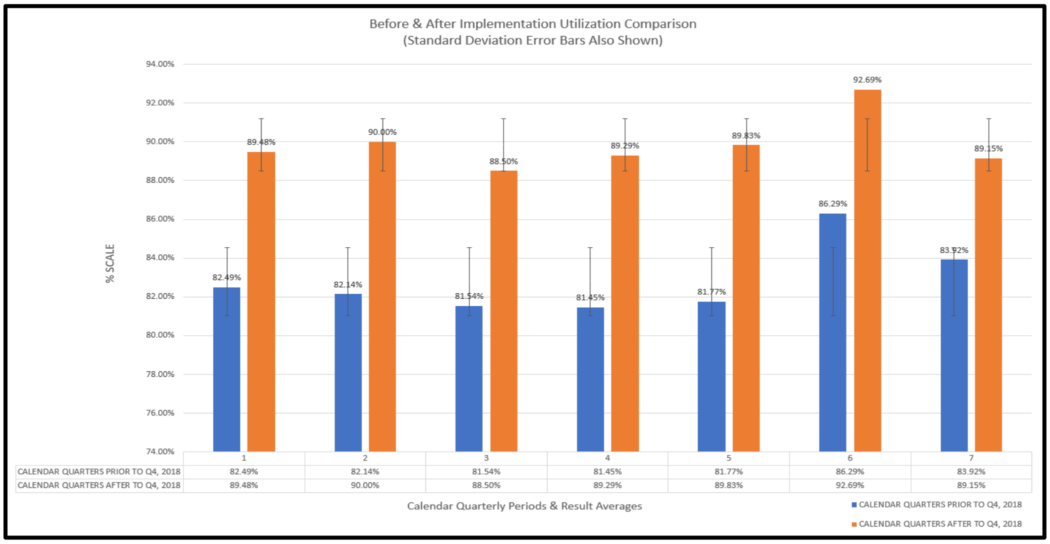


Figure 9. Pareto graphically depicts a side-to-side comparison of quarterly utilization results before and after visual management implementation. Standard errors are represented in the figure by the error bars attached to each column.

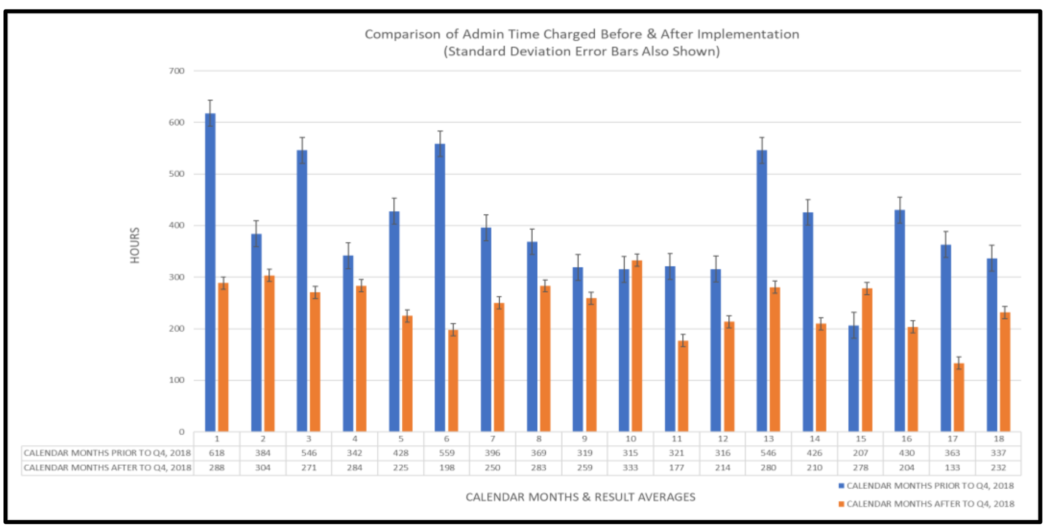


Figure 10. Pareto graphically depicts a side-to-side comparison of monthly admin time results before and after visual management implementation. Standard errors are represented in the figure by the error bars attached to each column.

The final investigation of the results that support the research hypothesis was a survey conducted with the participants that provided the qualitative data to support the research. The questions asked to the research participants were compiled to understand how the web-based project management software and the visual management tools impacted their daily work. The questions were directed towards visibility of changes in general project metrics, administrative burdens, team task alignment, overall visibility, the accuracy of KPIs, and some direct comments towards the good and bad of the new tools implemented. Eleven questions were asked, and responses were received from 65% of the participants. Responses indicate and support the quantitative results. The web-based predictive and dynamic project management and the implemented visual management tools reduced administrative time burdens and provided the visibility needed to drive improved utilization (see Appendices).

Chapter 5 – Conclusion

Once the research period concluded and the data was formatted for analysis, the opportunity to widen the lens and re-see the big picture was made available. As the opportunity to improve a known utilization issue within the engineering team was known, some assumptions were made to identify the suspected root cause. What was not an assumption was the challenges that existed to plan and execute the ETO project with the known uncertainty (Cutler, 2009). Planning and executing an ETO project's engineering scope requires detailed planning and alignment from all functional stakeholders. Without consistent alignment of project KPIs and engineer tasking, it is not unrealistic to assume that utilization would be negatively impacted. Once the VM tools were in place and the weekly utilization KPI reports were created and distributed, the manager saw the ability to maintain visibility and react accordingly. Utilization improvements and a reduction in administrative time burdens were the primary focus of the research, but a positive impact on budget and schedule attainment was also realized. Measuring the impact of these two critical metrics could be the focus of future research and would complement this thesis nicely.

The engineering staff that participated in this research are measured similarly to direct labor employees in a manufacturing environment. Similarly, the hours charged to sold projects are billable, and everything else is cost overhead. However, the engineers were not measured based on efficiencies but on how they were utilized over the project's life cycle. As long as the project's engineering scope was planned correctly, optimized utilization typically results in a higher success rate towards budget and schedule attainment (Lorincz, 2005). When engineers are not adequately utilized and non-value added time becomes excessive due to poor communication or misalignment, the project is negatively impacted. This research aimed to show how visual project management made available through web-based tools can positively impact if appropriately implemented. The quantitative data proved a 7% average utilization improvement and a 39% reduction in admin hours per month between the two periods. The qualitative survey results further supported that the improvement was realized.

As mentioned, the T-test results allowed the researcher to reject the null hypothesis that there was zero change in utilization or reduction in administrative time before or after implementing the VM tools. For both the utilization and admin data sets compared for the Two-Sample Assuming Unequal Variances T-test, the hypothesized mean difference was zero. In both cases, the resultant P $(T \leq t)$ value using the two-tail test was less than the stated P-value of 0.05. The T-test analysis indicated a less than a 5% chance that the null hypothesis was accurate and provided substantial evidence to reject the null hypothesis. The T-test results do not imply with 100% certainty that a research hypothesis was correct as there is still a 5% probability that the results happened by chance. However, the T-test results complement the Pareto trend results and comparison charts to support further the research question and rejection of the null hypothesis that zero improvements were realized.

The qualitative survey results captured from the research participants further supported the quantitative data and research analysis. The questions were formatted to allow the participants to directly input how the VM tools impacted their daily routines and visibility on project metrics and department KPIs. From the 16 participants that the survey was sent to, ten responses were received. Two participants were not part of the engineering staff during the period before implementation, so their input did not provide additional insight on the questions that required historical knowledge for a comparison to be possible. There were 11 questions asked, with nine being multiple choice and two requiring a typed answer. In all multiple-choice responses, the results were positive and indicated that improved project metric visibility was seen. Participants were overall satisfied with the VM tools and felt that daily administrative time was reduced following implementation. One particular question that was not anticipated was directed towards how the weekly utilization visual metric impacted their behavior. For this question, the results showed that 90% of the participants responded that their behavior was only sometimes changed when weekly utilization KPI was below the 92% target. This specific question's details could be a point of focus if the research continued to find further opportunities to improve. The final two questions requested a typed response towards what the participants liked most and least from the implemented web-based visual project management tools. There were nine responses, and their feedback provided input towards the many realized positive impact and opportunities to improve the way the tools are used.

It is important to note that in March of 2020, the US faced a pandemic with the COVID-19 virus. At that time, the company began redirecting the engineering staff to a work from their home posture. It would require a different research scope, but it is safe to assume that without the web-based visual project management and KPI reporting metrics in place, the transition to remote work would have negatively impacted utilization. This research demonstrated that even with engineers working in physically different remote locations, clear tasking, alignment, and tracking of KPIs could be successful. How the VM tools could impact a post-COVID workforce is an important additional point of knowledge that the audience can take away from the research.

In conclusion, managers should realize that implementing web-based visual project management software to improve engineering utilization will not be an easy plug-and-play solution. Time must be taken to study all the options available on the market, select the tool that meets the company's specific needs, then develop robust processes and procedures to ensure proper use. Gaining buy-in from the engineers on the staff is also an important piece. Requiring this level of visibility on an engineer’s use of time can be an obstacle. This obstacle can be mostly overcome by communicating the project's positive financial impact and making the engineer’s life and job less stressful. If the manager can gain trust from the engineering staff, then implementing the VM tools and processes can be made as easy as possible. There will always be those who reject change and resist the level of visibility that is made available. This resistance will fade over time, but with strong leadership and earned trust, the resistance curve can be minimized.

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Appendix A

Reference Web-Based Project Management Options and Their Capability

Product	TA Rating	Budget Tracking	Resource Management	Email Integration	Gantt Chart View
Monday.com	4.41/5	✔	✔	✔	✔
Smartsheet	4.32/5	✔	✔	✔	✔
Wrike	4.34/5	✔	✔	✔	✔
Workzone	4.5/5	✔	✔	✔	✔
Asana	4.21/5	✔	✔	✔	⊘
Jira	4.2/5	⊘	⊘	✔	⊘
LiquidPlanner	4.5/5	✔	✔	✔	✔

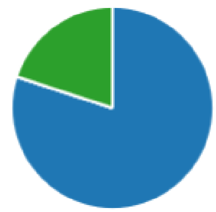
Appendix B

Qualitative Survey Results (Questions 1-2)

1. Do you personally feel like you have a higher level of project status visibility then before using this form of visual management?

More Details

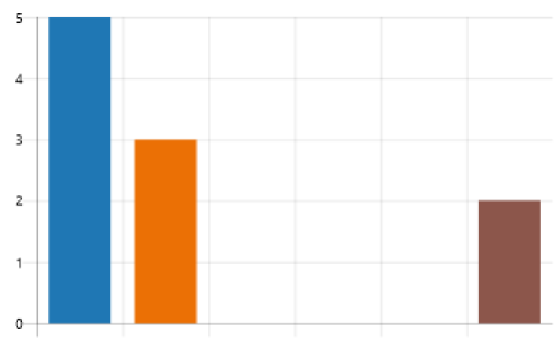
Yes	8
No	0
Maybe	2



2. Since on-boarding in 2018, how satisfied are you with using this form of visual management of our engineering projects?

More Details

Very satisfied	5
Somewhat satisfied	3
Neither satisfied nor dissatisfied	0
Somewhat dissatisfied	0
Very dissatisfied	0
Not employed with JBT prior t...	2



Appendix C

Qualitative Survey Results (Questions 3-5)

3. Do you feel like you have better visibility of current and near future project work assigned?

More Details

Yes	8
No	0
Maybe	0
Not employed with JBT prior t...	2

4. Do you feel that the time needed to align with project team has been reduced?

More Details

Yes	5
No	2
Maybe	1
Not employed with JBT prior t...	2

5. Do you have better visibility of project budget and schedule than before using web based visual management of projects?

More Details

Yes	6
No	0
Maybe	2
Not employed with JBT prior t...	2

Appendix D

Qualitative Survey Results (Questions 6-9)

6. Do you use the project dashboards to monitor hour budget status?

More Details

Yes	7
No	3
Maybe	0

7. Do you feel that time entry is less of a administrative burden than before using the visual management time sheet?

More Details

Yes	7
No	0
Maybe	1
Not employed with JBT prior t...	2

8. Do find that estimating project ENG hours and completion dates is more accurate than before using this tool?

More Details

Yes	6
No	0
Same level of uncertainty as b...	2
Not employed with JBT prior t...	2

9. When weekly utilization results are sent out, does that impact your behavior if results are below target?

More Details

Always	0
Sometimes	9
Frequently	1
Seldom	0
Rarely	0

Appendix E

Qualitative Survey Results (Question 10)

10. In one sentence, what do you like most about using this form of project visual management for daily project communication, planning, time keeping and tracking of project data?

9 Responses

ID ↑	Name	Responses
1	Mike Hoover	There are multiple benefits to LP, primary to me is project planning and resource management
2	Trevor Sanders	Provides high visibility of all the tasks needed for a given project and history of past projects to reference.
3	Rick Ri	Quick ease of use
4	Lizet ner	Helps to see future work load and determine who is available for the next project. .
5	Wes V	I do like the display of remaining hours on each task displayed on time sheet.
6	Core nsen	I like that I can see in detail how much effort is remaining in each project with minimal clicks.
7	Jonath	The interconnected real-time update of hours and tasks affecting other tasks is a vast improvement over the previous manual method.
8	Ryan Now	I like the ease of time tracking, ease and visibility of notes, visibility of total project hours when before I would rarely see the total, and I really like the checklists within a task.
9	Randy Harris	Keeps me organized!

Appendix F

Qualitative Survey Results (Question 11)

11. In one sentence, what do you like least about using this form of project visual management for daily project communication, planning, time keeping and tracking of project data?

9 Responses

1	Mike Hoover	The estimated completion dates are arbitrary due to the continuous shuffling of workload/tasks/requests, and necessary sharing of information/collaborating necessary to complete complex projects. This is understandable, just the nature of the beast, since LP can only plan based on the information available.
2	Trevor Sanders	Seems like every task is always red for all the projects; probably more a symptom of challenging deadlines though.
3	Rick Ripley	I rarely use it for multiple projects - so N/A for my unique role as developer.
4	Lize ner	LP helps me to keep on pace with project deadlines and budget.
5	Wes \	When going between project and time sheet while completing time for previous week it keeps going back to current week setting you up to enter in the wrong week.
6	Core ınsen	When projects are broken down into small buckets, it's difficult to remember what individual tasks you worked on during the week.
7	Jonatl	As a product line lead who is spending a majority of time assisting other engineers on my projects, my specific tasks/efforts are not captured very well and it can become difficult to find the next direct thing to work on (this Tuesday LP webinar recommendation to use personal dashboards may help with this).
8	Ryan Nov	The amount of tasks that projects have been broken out to is a little excessive to me and it make charging to the correct task sometimes difficult.
9	Randy Harris	I have yet to have a negative experience with the program.