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Visual Management Implementation at Primetals Technologies

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Visual Management Implementation at Primetals Technologies

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Table of Contents

Table of Figures

List of Tables

Abstract

Our project goal was to produce a visual management system for Primetals for the MMD-2 and VMC-5 machines. We first defined the relevant key process indicators (KPIs), produced a specification detailing the importance of specific KPIs and from where to collect relevant data. With this information we produced a visual design which was then modeled using the programming language python to make a functioning application. As our application is a mockup of the final product, we then performed market research and a business analysis to compare alternative visual management software's for Primetals. Our MQP deliverables are: KPI specification of important KPIs, a visual design of a screen to display these KPIs, an application mockup, market analysis of alternative software options, and a business analysis of the selected companies. After conducting qualitative, quantitative and business analysis we can conclude that Predator MDC is the preferred software alternative.

Acknowledgements

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Executive Summary

Introduction

The goal of this project was to design and research a visual management system for Primetals Technology. To meet this goal, we identified key process indicators (KPI's), arranged appropriately them to make a digital display, created a mock up using python, and performed market research on visual management services.

Methods and Results

Visual Design

Using the KPIs identified in dashboard stakeholder meetings, and conducting research, we developed a visual mockup design. The product is made to display complex information into simpler information, be intuitive and be easy for stakeholders to process the data.

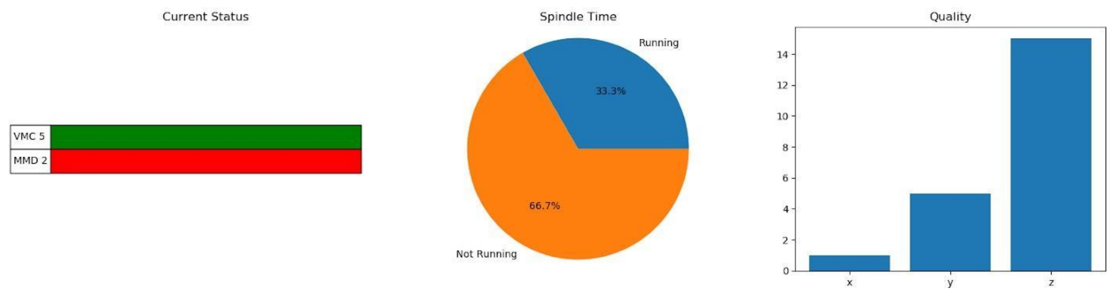
The end product contains 4 KPIs. The highest ranked KPI according to the dashboard's stakeholders is the production schedule. The schedule represented on the dashboard is meant to keep the old layout for ease of use for the dashboard users. The colors on the schedule displays the status of each parts on a specific machine. The next KPI is the machine status. This KPI displays the status of a machine, whether it is running, idle, off, or fail. Workers can quickly glance at this KPI to determine if a particular machine is running, or why it isn't running. The next KPI is spindle time. The pie chart compares run time against downtime for a given machine. The final KPI indicates the cause of the nonconformance so users can quickly obtain data as to why there is none conformity in the product.

Coded Mockup

Using the visual design, we used python to make a small applet that would take data from a spreadsheet and display it on a screen. To do this we used the matPlotLib library.

Schedule

	D/M	Part No.	Planned Strt	Planned Finsh	Actual Strt	Actual Finsh	% Done
Sched Hrs X Machene #	1	2	3	4	5	6	7
Sched Hrs X Machene #	8	9	10	a5.25	12	13	14
Sched Hrs X Machene #	5	5	5	5	5	5	5
Sched Hrs X Machene #	6	6	6	6	6	6	6



Coded Design

Primetals intends to use this applet to test the concept before investing in a larger system. While this screen does show the proper data values, the information does not automatically update and requires the scheduler to manually input data into the spreadsheet.

Market Research

The goal for market research part was to help Primetals select manufacturing software to purchase. The research was broken into two parts: quantitative and qualitative analysis. During the qualitative analysis, software information were compared through the use of reliable sources so Primetals could learn about strengths and weaknesses of each alternative software. The intent of quantitative analysis was to convert this information numerically and compare important criteria using user-defined preferences. We used two techniques from decision analysis, Analytic Hierarchy Process (AHP) and Simple Multi Attribute Rating Technique (SMART). The quantification of important criterion for each alternative simplifies the ranking and comparison of software alternatives. After both analyses were conducted, Predator MDC had the highest AHP score and the highest SMART score. The results indicated that Predator MDC was the preferred choice out of 6 alternative software's.

		Ranking	
Merlin Optime	0.154	4	
Predator MDC	0.293	1	preferred system
SAP MII	0.203	2	
ORACLE manufacturing intelligence	0.070	6	
Seiki SFDC	0.112	5	
SCYTEC data Xchange	0.167	3	

AHP Results

Merlin Optime	62.09
Predator MDC	87.81
SAP MII	74.27
ORACLE Manufacturing Intelligence	37.35
Seiki SFDC	51.26
SCYTEC Data Xchange	75.77

SMART Results

Business Analysis

By contacting the software providers and requesting a quote we were able to construct a cost table which considered both the one time and repeating costs associated with the software. We then found the value of the features each software provided and constructed a cost benefit chart. By comparing the value generated by each option with regards to the cost of the option. From this comparison we found that SAP MII was the preferred choice. However, since we did not hear back from all software providers, we were unable to compare all of the options from the market analysis.

1. Introduction

Primetals Technologies, located in Worcester, Massachusetts, specializes in manufacturing machinery used in the steel and wire rolling industry world-wide. The facility operates as a jobshop that manufactures a variety of custom products in smaller batches such as mini mills and long rolling (Primetals Technologies n.d.). Primetals partnered with Worcester Polytechnic Institute (WPI) to sponsor this MQP, which was completed in March 2019.

1.1 Problem Statement

In manufacturing, bottlenecks often stem from a lack of information (Kokemuller n.d.). In the past, many systems have been adopted to improve information flow in production. One example of an improved information system is companies using whiteboards to indicate the production stage of a project and its expected completed time (Specht, 2018). Today, companies are moving towards an "Industry 4.0" manufacturing style. Industry 4.0 is a standard in manufacturing focusing on "smart production" which includes processes such as automated machines and interoperability between machines and controller/monitoring systems (Horst 2015). These processes are tracked by Key Performance Indicators (KPIs) - performance metrics used by organizations to assess, analyze and track processes. KPIs are commonly used to measure process performance and evaluate success relative to an organization's goals and objectives.

Primetals is one of the many companies moving towards Industry 4.0. To achieve this standard, the organization needs to implement virtual visual management systems to monitor their shop floor functions. These functions include machine efficiency, work order progress, and job/production scheduling. Primetals is seeking is to implement a visual management system throughout their shop floor that will identify, display, and drive progress toward with the use of KPIs within the next two years. Prior work has been done internally to begin the process of identifying some of the KPIs Primetals needs to monitor. This MQP team is tasked with assisting Primetals to structure the display of the visual management system for machines VMC5 and MMD2, determine the necessary background information to drive the KPIs, determine how to process that information, and connect it to a comprehendible display system.

1.2 Project Goals and Objectives

The goal of this project was to produce a visual management system for Primetals to use with the MMD-2 and VMC-5 machines.

To achieve this goal, our team has the following objectives:

1. Define the relevant KPIs and how they will be measured.
2. Perform market research to attain both quantitative and qualitative data.
3. Develop a visual layout design.
4. Develop a functional mockup based on the market research and visual layout.
5. Perform a business analysis.

1.3 Project Deliverables

The primary project deliverable is to develop a mock-up of a visual management system for the VMC5 and MMD2 machines. The project scope is such that updates do not need to happen in real time; but the mockup should display all relevant information and design aspects. We are also going to perform market research to find the best way to implement the visual system in a scalable and repeatable way.

1.4 Project Timeline

The timeline for completing this MQP was from the beginning of A-Term, August 2018, to the end of C-Term, March 2019. As requested by Primetals, much of the project will be completed by December 2018, so that we may use the remainder of our time for analysis and our Sponsor Presentation.

2. Background

To understand the context of the project, the MQP team conducted research regarding the Primetals Technologies organization, previous MQPs completed by WPI Foisie Business School students at Primetals, KPIs, Industry 4.0, overall equipment effectiveness, visual management and controls, and machine shop floor monitoring to understand the problem completely and implement a solution. In what follows below we summarize our findings (Rodgers, 2018).

2.1 Primetals Technologies

Primetals Technologies located in Worcester, Massachusetts was founded in 1888 and originally owned by Morgan Construction Company. Morgan Construction specialized in manufacturing equipment used in steel mills and had a reputation for being innovative and producing high quality products (Primetals Technologies n.d.). Even though the company was regarded for their quality and innovation, they were dominated by a market with much larger organizations. In 2008 Morgan Construction was acquired by Siemens and the company became a part of Siemens VAI. In 2015 Siemens VAI partnered with Mitsubishi-Hitachi Metals Machinery and Primetals was then founded as a joint venture between the two (Primetals Technologies n.d.). The joint venture combined the strengths of the two partners and they became a global provider for products and services for iron, steel and nonferrous industries.

2.2 Key Performance Indicators

KPIs, are variables that organizations use to assess, analyze, and track a process. They are performance measurements used to evaluate the success of a project or process in relations to goals and objectives. KPIs can be applied to many different industries, such as customer service, information technology, finance, and for this project manufacturing (MRPEasy, 2017). Some common KPIs for the manufacturing industry are as follows:

1. Count

   The total number of parts or operations completed.

2. Reject Ratio

   The number of parts that failed to meet the quality specifications.

3. Rate

   The number of parts or operations completed over a length of time.

4. Target Takt Time

   The time allotted for each part to be completed.

5. Down Time

   The amount of time the machine spends running vs idle.

6. Overall Equipment Effectiveness

   A composite score of availability, performance and quality.

(Scoreboard, n.d.).

When KPI's are applied correctly they will improve processes, but they must be based on accurate and reliable data. Since KPI’s are usually recorded to improve processes, it is important to collect information that will be relevant to current strategic plans for improvements. (MRPEasy, 2017).

2.3 Industry 4.0

Industry 4.0 is a standard that Primetals strives to implement. Industry 4.0 is a system that makes it possible to gather and analyze data from across the production system to enable faster, flexible, and more efficient process to produce goods (Marr, 2016). For a system to be considered an Industry 4.0, it must broadly follow four principles. First, transparent information - a physical virtual copy of the physical world can be created through data from raw sensors attached to machines. Second, interoperability of components - a protocol for devices and sensors to communicate effectively with one another. Third, technical assistance - aiding humans in making informed decisions. Lastly, decentralized decision making - the ability of the system to make simple decisions and become as autonomous as possible (Gaskell, 2017). Our project with Primetals involved Industry 4.0 in such ways such as researching how to connect smart devices on the shop floor through Industry 4.0 gateways that make it possible to share data and information and using real-time KPI tracking and digital performance boards to accelerate response times.

2.4 Overall Equipment Effectiveness

Another aspect of this project is overall equipment effectiveness (OEE). OEE can be thought of as the best way to run your equipment so that you can avoid long downtimes for repairs (Stamatis, n.d.). OEE is measured on a score from 0-100%. OEE is composed of the amount of time the machine is running, the quality of the parts being made, the performance or speed, and the availability of the machine to start a new product (What is Overall Equipment Effectiveness, n.d.). The OEE calculation is (Availability)*(Performance)*(Quality) (What is Overall Equipment Effectiveness). OEE is the single best benchmarking metric and is often used to improve the overall productivity of machines (What is, n.d.). Operators and management should be keeping track of how many hours a machine is running and schedule maintenance accordingly so that the machine has a lower chance of breaking down or wearing out to the point where it affects quality (What is, n.d.).

2.5 Visual Management and Controls

Visual management is an essential part of practicing lean manufacturing, which is another aspect of this project that we aim to convey through our final product. Visual management enables operators or managers to manage everything in the factory succinctly without having to go through the data from many locations. A visual management system displays the status of the machine's performance or Key Performance Indicators (KPI) such as production status, delivery status, and machine status. Visual management is used as an indicator and summarizes manufacturing and operator status of the factory. Visual controls serve as visual instructions for operators and workers around the factory. Also, visual controls could instruct operators how areas work physically, where items are located, directions and safety protocols. Overall, visual controls benefit the factory because they help support and control the flow of production, which increases factory's efficiency (Wright, 2009).

For a visual management system to be successful, people involved must have the right attitude, company must establish clear performance standard, and company must determine essential measurements (Markovitz, 2016). A company's employees must have the right attitude toward new changes that will display their work for everybody to see so that everybody could accept and willing to adapt to these new changes (Markovitz, 2016). Each company must set their own performance standard either quantitative such as amount of product produced per day or qualitative such as safe work environment (5S compliant). Lastly, each company must determine essential specifications or measurement to be put up on the screen or board so that it reflects on the overall performance of the entire factory.

2.6 Machine Shop Floor Monitoring

Machine shop floor monitoring can be broadly categorized into two different types: "smart" and "dumb" (Horst, 2015). Smart machine monitoring delivers process or product quality information to the operator during the process, allowing any defects or issues to be rectified. In contrast, dumb machine monitoring is static, and does not provide real time, or near real time, process feedback to the operator. Quality feedback is received through quality checks or customer reports well after the product is manufactured (Horst, 2015). Techniques used in smart machine monitoring include visual cues attached to machines, dashboards that provide real time data and reporting solutions that analyze data from the machine.

2.7 Machine Descriptions

The machines we will be working for this project are Dmg Mori's VMC-5 and MMD-2 machines. They are both 5-axis milling machines. VMC-5 is Dmg Mori's DMU monoBLOCK 105 machine and MMD-2 is Dmg Mori's DMU 50 machine. The DMU 105 monoBLOCK is equipped with a swivel rotary table, allowing high-productivity by simultaneous 5-axis machining. It has 180 tool pockets and technically stands out due to its precision and continuous 5-axis processing. By using two different tables, the VMC-5 can work on objects as large as 1.240 mm x 690 mm weighing up to 2.000 kg with swivel rotary table and 1.400 × 1.240 × 690 mm and max. 2.500 kg with rigid table. The monoBLOCK series models are 5-axis machining centers suited to workpieces in various fields such as the aerospace, energy, medical component and automotive industries such as car radiator grills, tire mold, engine block and planet carriers (Figure 1).

The DMU 50 is compact entry-level model for 5-axis machining with the integrated swivel rotary table which employs large-diameter bearings on the rotary axes achieves high accuracy machining of heavy workpieces with high spindle cutting speed. It is equipped with an φ 630mm x 500mm NC swivel rotary table and has up to 60 tool pockets. It is capable of milling smaller designs such as magazine disc, pump housing for oil and gas, housing cover for consumer electronics, valve blocks and hydraulic components for automotive industry (Figure 2). Both machines have built-in operating system called CELOS, which can be used for job scheduling, tool handling, production planning and more. CELOS built-in machines are built with up to 60 sensors for monitoring and supervision of machine and process which are crucial for data collection to maximize the digital workflow efficiency on the shop floor.

Figure 1 DMU 105 monoBLOCK machine

Figure 2 DMU 50 machine

3. Methods

3.1 Specification

Within the specification we defined the relevant KPIs and how they are to be measured. Possible KPIs were determined through interviews with Primetals stakeholders, analysis of current Primetals KPI tracking techniques and research of industry standards. Once the possible KPIs were determined, the WPI team conducted further research and engaged in team discussion to select the final KPIs.

Along with the KPIs, the final specification included implementation details, product functions and features relating to the KPIs. The implementation details consisted of the separation of requirements for a WPI dashboard mockup. The product functions consisted of all required functions for the both the WPI mockup and the final product. Lastly, the features relating to the

KPIs consisted of information that can be provided for the KPIs to assist developers with designing the final product. This information indicated how each KPI is calculated and where developers can find the data.

3.2 Market Research

The selection of alternative visual management software programs was conducted through WPI library resources and information from Primetals. The process of elimination comprised of adopting decision making methods and conducting thorough research. For example, Hoover and IBISworld would be used to search for industry reports and Science Direct and ACM digital library were used to search for software's specifics. After that, we conducted quantitative and qualitative analysis on these alternatives to select the best program that fit the required specifications.

To have both quantitative and qualitative data to recommend a VMS software, we decided to use Simple Multi-Attribute Rating Technique (SMART), Analytic Hierarchy Process (AHP), and business analysis for the programs. SMART is a multi-criteria decision-making theory similar to and derived from cost/benefit analysis but considers many other factors defined to be important by the users and decision-makers (Edwards, 1997). Working with our sponsor we identified attributes using a Value Tree - a tree comprised of attribute branches ranging from more general attributes at the top to more specific attributes at the bottom. After that the weights were assigned for each attribute and combined with the values to get the benefits score.

AHP is a method for ranking several decision alternatives that involve using pairwise comparison (Golden, 1989). The weights were determined through pairwise comparisons and each criterion was assigned a weight. Weighted criteria will be combined for a total score which reflects a decision- makers ranks of software. For SMART and AHP analysis, the process of obtaining decision-maker and user input to identify decision objectives, weights and attributes were essential. We interviewed four stakeholders such as Head of Environment, Health and Safety Management and our coordinator, Daniel K. Gilbreath, regarding their perspective on prioritizing the criteria and attribute of the two methods. After that, we averaged the scores provided by the stakeholders to consider each stakeholder's opinion equally.

To have qualitative data to support the numbers from the previous methods, we decided to conduct a competitive analysis- a method to analyze the strengths and weakness of each visual management software to evaluate each software (Tighe, 2017). This evaluation could be done by comparing the capabilities of the programs to set a standard for each attribute and see which one is below or above the standard. A standard measurement is determined by the required specifications that the visual management software should have to deliver the objectives.

3.3 Visual Mockup

To come up with an effective visual layout design for the monitors, we must recognize the priority of each KPI and its placement on the screen. To achieve this, we conducted a meeting with Professor Eleanor T. Loiacono, a management information science professor at WPI, on October 8th, 2018 to understand the optimal placement positions of each KPI. Furthermore, the dashboard's shareholders at Primetals were asked to rank each of the proposed KPIs to quantify the placement priorities of each KPIs. As each shareholder indicated that their KPIs are the most important, we used our judgement and information obtained from various background reading about dashboard design, to find the best placement for the KPI on the board. A good visual management system must be able to display complex information into simpler information, in which also makes it easy for stakeholders to utilize the data (Hertz, 2017). Since the dashboard must be intuitive for the user, the highest priority KPI will be placed on the top of the screen since majority of people read from left to right- the same way we read sentences (Fessenden, 2017). Consensus from our stakeholder meetings indicated that scheduling was the most important KPI and should be placed on top of the screen. Furthermore, KPIs that are directly related to the highest priority KPI will be contiguously placed to the right of it to make the flow of information as intuitive as possible. To make the transition towards a digital visual management system as easy as possible we used the same, or minutely changed, layouts of preexisting visual KPIs. In addition, KPIs that are categorizable, such as machine status, were color coded for a more effective and efficient way of communication. Lastly, we continually asked various stakeholders' input on the visual layout design to produce a system that is most effective for the users.

3.4 Functional Mockup

3.4.1 Data collection from MTConnect

MTConnect is an open-source, royalty-free, read-only, and XML-based protocol that allows data to be collected from CNC Manufacturing machines (Parto, 2017, p. 12). Understanding MTConnect is crucial for our project at Primetals, in terms of, being proficient in our data collection process for our visual management system development and for further research purposes to find visual management software's in the market. MTConnect system is composed of three components which are machines, adapter and agent. The system starts with the machines which are the machine tools or manufacturing equipment which has data source. In our case, the machines are the DMG Mori – VMC-5 and MMD-2. The adapter is a device which is required to change the machine data to MTConnect data type. The sensors from the two machines sends the real-time data to the adapter. Second, the adapter will, in turn, bring the data to the agent. The agent is a software that collects and formats the data from the adapter. The agent hosts the data in a TCP server and provides a REST interface, meaning that the data can be retrieved via HTTP request-reply (Parto, 2017, p. 13). Therefore, the client can extract the real-time data that are collected by the machines (Figure 3).

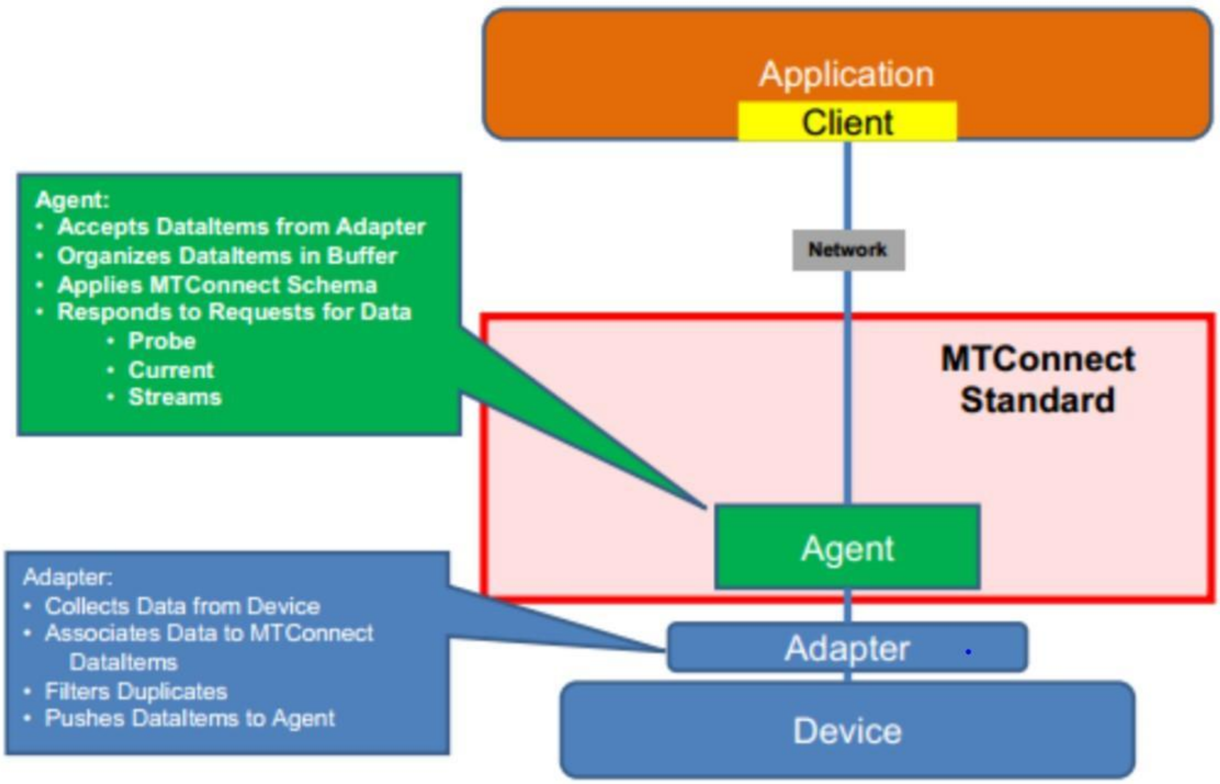


Figure 3 The architecture of MTConnect system (Pezzullo, 2014)

The data type from MTConnect is the XML output which is a common language used in transporting and storing data. The advantages of using MTConnect is that the XML data type readable by humans and machines, making it customizable for any data representation or software platform integrations. Data is transferred using the HTTP - HyperText Transfer Protocol with the TCP/IP - Transmission Control Protocol, which is a standard procedure in data transfer protocols. This standard procedure creates a user-friendly environment and enables “plug-and-play” interoperability between devices due to common data transfer protocols, meaning that it is easy to install with limited setup procedures and applications can simply “plug into it” and have access to the information without any additional procedures (Pezzullo, 2014).

There can be a slight delay (about 1 second) between the adapter and the agent to collect data, which is then buffered and stored in the agent for a certain length of time. The data acquired by the agent is stored in an adjustable size buffer capacity. When the buffer capacity limit is exceeded, the new data is being replaced by the oldest ones. However, the delays are not significant enough to affect the data collection process and application. Real-time data is collected while using MTConnect.

3.4.2 Programming

In this project we used Python to create a graphical user interface. This dictates the layout of the screen and allows the elements to update depending on input information. For this prototype, the data will be inputted manually using an excel sheet by the scheduler (Figure 4).

	A	B	C	D	E	F	G	H
1	30							
2	15							
3	1	3						
4	1	5	15					
5	1	2	cat	4	5	6	7	
6	8	9	10	11	12	13	14	
7								
8								

Figure 4 The architecture of the Data Entry System

The code relies on the matplotlib library which is commonly used to make simple applications and can be dynamically updated.

3.5 Business Analysis

To determine the best visual management system for Primetals we conducted a business analysis. To do this, we considered the possible alternatives from our market research. The following factors: feasibility, available funds, return on investment, and the ability to implement the visual management system throughout the shop floor were used to select an alternative. We then conducted a cost-benefit analysis and sensitivity analysis. The cost benefit analysis will "observe the cost of pursuing an action and the benefits of that action" (Prakash, n.d.) To obtain these costs we reached out to the providers the visual management system in question and requested prices quotes for each of their services to compare with our mock-up. For each alternative, we incorporated an additional machine into the visual management system after Year One. The additional machines were added to consider the future scenario of expanding the visual management throughout Primetals facility. For each analysis we considered all one-time costs such as account activation costs to purchase the visual management software and a PC and monitor to display the software. In our analysis a PC and monitor are purchased every 2 years so that the visual management boards are not overly cluttered with each machine integrated. We also considered recurring costs such as annual software fees and eLearning subscriptions. For both the one-time and recurring costs we calculated the totals that are required to calculate the benefits and savings for each visual management system. The benefits will be obtained after calculating the costs and the return on investment. The resulting benefits weigh each of the investment opportunities, quantify the effects on stakeholders, and determine which visual management system should be pursued.

4. Results

4.1 Specification

The research into relevant KPIs identified seven distinct KPIs: . Machine Status, Parts Status, Schedule, and Non T conformance/Complaints, Daily Targets, OEE and OLE. These KPIs were then divided into High, Medium and Low priority groups with the assistance of the Primetals stakeholders (Table 1).

High	**Medium**	**Low**
Schedule	Non-Conformance/Complaints	OEE
Part Status	Daily Targets	OLE
Machine Status		

Table 1 Stakeholder priorities

KPI definitions:

1. Machine Status: This KPI shows what the machine is doing at the current time. The

possible statuses are running or not running. If the option is not running then a reason, such as no operator, will be displayed with it.

2. Part Status: This KPI shows the progress on the current part and how much time is left in the job as a percentage complete.

3. Schedule: This KPI is a breakdown of the scheduled work for this machine. It includes the parts scheduled and the target and actual start/finish dates.

4. Non-Conformance/Complaints: This KPI is a measurement of the percentile of nonconformance/complains of parts versus. total parts coming off the machine for a time period of Primetals choosing.

5. Daily Targets: This KPI shows the daily target number of parts and how many were actually made over a past time period to be determined by Primetals.

6. OEE: Overall Equipment Effectiveness is defined in Section 2.4. This KPI would display the OEE score of the machine.

7. OLE: Overall Labor Effectiveness is a similar metric to OEE but to measure the efficiency of labor instead of a machine. This KPI would display the average OLE of the operator of the machine.

Of these seven KPIs, four were included in the final WPI Mockup: Machine Status, Schedule, Non-conformance/Complaints and Part Status. Daily targets, OEE and OLE were not included in the final WPI Mockup due to concerns over oversaturation of information and relevance to users of this screen.

4.2 Market Research

We provide a general overview of each of the six software that we chose from our market research. Table 2 summarizes the pros and cons of each software and compares good choices for shop floor data visualization software at Primetals Technologies. In what follows, we summarize our findings regarding each of the six software.

Merlin Optime[1] is a software used to link with MTConnect to provide feedback on machine states such as uptime and downtime. This feedback could be used to identify machine problems and potential bottlenecks of the system. The reports on utilization were presented in percentages of uptime and downtime. The essential features include simple installation, real-time utilization gauge, capacity to add and display multiple devices, and 8-hour rolling utilization chart. The strengths of this software were its accessibility to operational and process information, and real time visibility of machine assets which enables fast response to machine issues. The weakness of Merlin Optime is its compatibility with other software's, since it could only be connected to MTConnect.

Oracle Manufacturing Intelligence[2] is a software which aims to maximize profit margins and optimize productivity through the use of real-time performance data. Its main functions are plant floor data analysis, strategic cost management, manufacturing analytics and manufacturing operational costs. Plant floor data analysis allows user to continuously collect data from shop floor and monitor production performance in real time through prebuilt analytical dashboards. Strategic

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[1] http://www.memexoee.com/products/software/merlinoptime/

[2] https://www.oracle.com/applications/supply-chain-management/solutions/manufacturing/manufacturingintelligence.html

cost management aims to maximize profit margins by allowing the user to run real-time simulations of all cost factors to. Manufacturing analytics and operation cost enable users to monitor production plan through its correlation with work order data and allow users to gain a realtime view of shop floor status. Even though ORACLE's software has many functions to analyzing costs, the functionality to track the spindle time and locate the bottleneck is limited.

SAP MII[3] is a software that has centralized plant information, which means through data collected, users can gain a clear view of plant resources and incorporate information from sensors and business users. The strengths of SAP MII are its easy to use function and connectivity. SAP MII simplifies plant monitoring process and data analysis into user's desktop or mobile device with user-definable dashboards, which are simple and easy to use. There is also an in-memory platform that supports cross-data store analysis and provide big data storage. These features allow users to easily identify the root causes of equipment downtime and bottlenecks. Even though SAP MII is compatible with many software's, the variety of displays is considered weak compared to other alternative software's.

Scytec Data Xchange[4] is a software that runs on cloud and on premise machine data analytics software which measures current status of the equipment, part counts, target utilization, overall equipment effectiveness metrics, downtime Pareto's, downtime summaries, timeline views, and shop floor layouts. The software increases OEE and shop floor productivity through automatic data collection through MTConnect and analyses the data. It can be connected through wire or

[3] https://www.sap.com/products/manufacturing-intelligence-integration/features.html

[4] https://scytec.com/dataxchange-overview/

wireless through MTConnect, Fanuc FOCAS and OPC UA feeds the data analysis through the software. The software is compatible for all capacities of manufacturing plants from small facilities to large factory level operations. The return of investment can be seen just by observing 30 minutes of machine uptime increment for using Scytec Data Xchange.

Seiki Shop Floor Data Collection (SFDC)[5] features collecting job status data – start/finish/pause, automatic and manual part counting, enter scrap code numbers and reasons, integrated with work queues, graphical reports of individual job performance, export data as .csv, .bmp or HTML format for easy distribution and integrates to an ERP system for automatic updating of inventory levels. SFDC enables the data collection designed specifically for the shop floor environment. Benefits include improved visibility of work order status and material traceability, greater data accuracy and on-time delivery, optimized work order performance, W.I.P tracking, supported job costing. SFDC is a great software to portray the true capacity for planning and scheduling work throughput through the shop floor showing work in progress status which can also be updated into an ERP/MRP system. The software also provides graphical reports and detailed analysis of all the machine operations for work orders enabling the users to make better decisions to reduce cost and downtime.

Predator MDC[6] (Machine Data Collection) is a real-time machine data monitoring software which supports data collection, monitors CNC machines, real-time machine job and part dashboards, slideshows for digital signage, multi-plant support, a wide variety of reports and

[5] https://www.seikisystems.co.uk/product/shop-floor-data-collection/

[6] https://www.predator-software.com/Predator_MDC_Software.htm

charts, and OEE indicators. It is widely compatible with industry standard connections such as Wireless, Ethernet, RS-232, Parallel, RFID, Digital I/O and Analog I/O and easily integrates in to any ERP and MES software's the user is using. The data collection can be through MTConnect, Fanuc Focus, Fanuc Robot, Okuma THINC, Modbus, OPC, Haas and XML. 20 which provides enough flexibility to be compatible with every machine on the shop floor. Predator MDC improves machine uptime by supplying accurate shop floor productivity KPIs and metrics to improve faster machine processing time and job scheduling.

Software	Display	Function & Usage	Pros	Cons
Merlin Optime	- Utilization trends in terms of uptime and downtime percentages	- Execution, controller mode, overrides, part program name and parts made - Machine status Real-time Utilization gauge for up to 8 hours - Capacity to add and display multiple devices and agents	- Free software to implement with MTConnect	- Limited data storage time and functionality

Predator MDC	- 18 Real-time Dashboards - 100+ KPIs and Metrics - 30,000+ Reports and Charts	- Unlimited number of data collection events - Automatic and manual data collection - 1 Network to monitor all CNC machines	- Wide range of KPIs for shop floor data visualization	
SAP MII	- User definable dashboards on desktop or mobile device	- OEE, equipment downtime, efficiency loss, and poor quality on various hierarchy levels	- Data analytics function - More familiar user friendliness as Primetals uses	- Expensive for shop floor data visualization software - More for management application than
		- Cross-data store analysis, statistical process control, predictive analytics, and storage for Big Data	SAP ERP system	shop floor application

Oracle MI	- Production performance in real time through prebuilt analytical dashboards and reports	- Plant Floor Data Analysis - Continuously collect data from the shop floor and synchronize it with data from your ERP system. - Collect, cleanse, and process data from disparate sources and store it in a single, secure repository - Collect shop floor data from a range of control systems and sensors	- Plant floor data analysis function	- Expensive for shop floor data visualization software - More for management application than shop floor application
Seiki SFDC	- Graphical reporting and detailed historical analysis of the progress and times of operations for individual works orders, including a comparison of planned versus actual job times and costs.	- Collect job status data – start/finish/pause - Automatic and manual part counting - Enter scrap code numbers and reasons Integrated with work queues	- Job performance reports function	- Data entry only by manual and barcode - More for job planning than shop floor data visualization

		- Graphical reports of individual job performance - Export data as .csv, .bmp or HTML format for easy distribution - Integrates to your ERP system for automatic updating of inventory levels		
Scytec DataXchange	- On cloud and on premise machine data analytics graphs board	- Current status of the equipment, part counts, target utilization, OEE metrics, downtime Pareto's, downtime summaries, timeline views, shop floor layouts, Caron TMAC status	- The only software with cloud function among the 6 - great selection of functions for shop floor data visualization	

Table 2 Market research analysis results

In comparing six software, we focused on the software which would provide the greatest advantage for the shop floor data visualization at Primetals Technologies. Predator MDC and Scytec DataXchange provide the most functions for machine data visualization, but Scytec has an edge over Predator with its cloud function. From our business analysis section (See Section 4.5), over a 5 year period, Predator MDC would cost around $14,000 whereas, Scytec would cost around $30,000. While Scytec offers a cloud function, it is double the cost of Predator and all over functions are the same. Merlin Optime is a good choice for an entry level data visualization software as it is a free software to use. SAP MII would give users at Primetals familiar user friendliness as SAP ERP software is currently used at Primetals. If we compare the software based on shop floor data visualization, Predator MDC would be a good choice due to its functionality and cost benefits.

4.2.1 AHP Analysis

The criteria were identified following discussions with stakeholders. The criteria identified are: price, display, function and usage. *Price* was the cost of the software, which included any setup cost or maintenance cost. *Displa*y was the ability of the information to be displayed on the screen clearly with variety of formats to choose from. *Function* was the ability to collect data, large storage capacity and perform with minimal errors. *Usage* measured how compatible the software is when connecting to other software systems and how easy is it to use by operators. The weights of AHP criteria were found by conducting interviews with four stakeholders and then finding the average weights of collected data to combine all four perspectives from the stakeholders. The Consistency Index (CI) and Consistency Ratio (CR) were calculated by using Equation 1, and Equation 2 where RI was random-like matrix.

Equation 1

$$\text{C.I.} = (\lambda_{\max} - n)/(n-1)$$

Equation 2

$$\text{CR} = \text{CI}/\text{RI}$$

The purpose of the CI and CR was to check whether the information obtained during the interview is logical and compatible with each other, where the CR value could not exceed 0.1. Table 3 below summarizes the result from one of the stakeholders. Appendix #3 contains the other stakeholder results.

Criterion	Price	Display	Function	Usage
Price	1	1/5	1/7	1/6
Display	5	1	1/5	1/4
Function	7	5	1	2
Usage	6	4	1/2	1
sum	19	10.20	1.84	3.42

Criterion	Price	Display	Function	Usage	Priority
Price	0.05	0.02	0.08	0.05	0.05
Display	0.26	0.10	0.11	0.07	0.14
Function	0.37	0.49	0.54	0.59	0.50
Usage	0.32	0.39	0.27	0.29	0.32

Criterion	Price	Display	Function	Usage	Sum
Price	0.05	0.03	0.07	0.05	0.20
Display	0.25	0.14	0.10	0.08	0.56
Function	0.35	0.68	0.50	0.64	2.16
Usage	0.30	0.54	0.25	0.32	1.41
Price	4.04				
Display	4.15				
Function	4.35				
Usage	4.42				
Average	4.24				
CI	0.08				
CR	0.09	must be lower than 0.1			

Table 3 A Stakeholder's AHP Criteria Weights (Jared)

Based on the average weights, usage was found to be the most important criteria followed by function, display and price. See Table 4, summarizes the average priority score of each criterion.

Criterion	Price	Display	Function	Usage
Price	1	1/4	1/6	1/7
Display	4	1	1/2	1/3
Function	6	2	1	1
Usage	7	3	1	1
sum	18	6.25	2.67	2.48

Criterion	Price	Display	Function	Usage	Priority
Price	0.06	0.04	0.06	0.06	0.05
Display	0.22	0.16	0.19	0.13	0.18
Function	0.33	0.32	0.38	0.40	0.36
Usage	0.39	0.48	0.38	0.40	0.41

Criterion	Price	Display	Function	Usage	Sum
Price	0.05	0.04	0.06	0.06	0.22
Display	0.22	0.18	0.18	0.14	0.71
Function	0.32	0.35	0.36	0.41	1.45
Usage	0.38	0.53	0.36	0.41	1.68
Price	4.01				
Display	4.02				
Function	4.04				
Usage	4.07				
Average	4.04				
CI	0.01				
CR	0.01	must be lower than 0.1			

Table 4 Average Weights of AHP

After we had the required weights for criterion, we conducted research to compare the six alternatives software's based on the criterion. The last step was to combine the weights of criteria with the comparison of the software's. As a result, Table 5 indicated that the top three software's are SCYTEC data Xchange, Predator MDC and SAP MII respectively.

Candidate	Price priority	Display priority	Function priority	Usage priority
Merlin Optime	0.46	0.12	0.03	0.24
Predator MDC	0.08	0.25	0.43	0.22
SAP MII	0.07	0.09	0.09	0.37
ORACLE manufacturing intelligence	0.06	0.15	0.07	0.03
Seiki SFDC	0.19	0.03	0.17	0.08
SCYTEC data Xchange	0.14	0.36	0.20	0.06

		Ranking	
Merlin Optime	0.154	4	
Predator MDC	0.293	1	preferred system
SAP MII	0.203	2	
ORACLE manufacturing intelligence	0.070	6	
Seiki SFDC	0.112	5	
SCYTEC data Xchange	0.167	3	

Table 5 AHP Scores of Software Alternatives

4.2.2 SMART Analysis

The weights of each attribute were found by conducting interview with four stakeholders and then finding the average weights of both original and normalized of collected data to combine all four perspectives from the stakeholders. Table 6 provides an example of one of the stakeholders' SMART scores.

Attribute	Original Weights	Normalized weights
Price	30	9.84
Display	100	32.79
Function	90	29.51
Usage	85	27.87
sum	305	100

Table 6 A Stakeholder's SMART Attribute Weights (Phil)

Surprisingly, when we conducted the SMART analysis, stakeholders prioritized function followed by usage, display and price. After collecting the information from all stakeholders, the weights of the attribute from all stakeholders were combined to find the average, which is shown in Table 7.

Attribute	Original Weights	Normalized weights
Price	32.5	12.09
Display	62.5	23.26
Function	90	33.49
Usage	83.75	31.16
sum	268.75	100

Table 7 Average Weights of SMART

After the average weights of SMART were obtained, data regarding the six alternative software's was researched. In contrast to AHP, the SMART technique scores were given independently without having to compare one alternative against another. Eventually, the average normalized weights are multiplied with values from each software alternative to determine final score. The results from the SMART analysis found that that Predator MDC had the highest score, and therefore we conclude that it is the preferred choice according to stakeholder preferences. Table 8 summarizes the scores for each software alternative.

Merlin Optime			
Attribute	Values	Normalized weights	Value*Weight
Price	100	12.09	1209.30
Display	80	23.26	1860.47
Function	10	33.49	334.88
Usage	90	31.16	2804.65
score			62.09

Predator MDC			
Attribute	Values	Normalized weights	Value*Weight
Price	70	12.09	846.51
Display	90	23.26	2093.02
Function	100	33.49	3348.84
Usage	80	31.16	2493.02
score			87.81

SAP MII			
Attribute	Values	Normalized weights	Value*Weight
Price	50	12.09	604.65
Display	60	23.26	1395.35
Function	69	33.49	2310.70
Usage	100	31.16	3116.28
score			74.27

ORACLE manufacturing intelligence			
Attribute	Values	Normalized weights	Value*Weight
Price	10	12.09	120.93
Display	70	23.26	1627.91
Function	50	33.49	1674.42
Usage	10	31.16	311.63
score			37.35

Seiki SFDC			
Attribute	Values	Normalized weights	Value*Weight
Price	80	12.09	967.44
Display	10	23.26	232.56
Function	80	33.49	2679.07
Usage	40	31.16	1246.51
score			51.26

SCYTEC data Xchange			
Attribute	Values	Normalized weights	Value*Weight
Price	60	12.09	725.58
Display	100	23.26	2325.58
Function	70	33.49	2344.19
Usage	70	31.16	2181.40
score			75.77

Table 8 SMART Scores of SMART Software Alternatives

4.3 Visual Mockup

In the visual mockup aspect of this project, the result can be seen in Figure 5. The highest ranked KPI according to Primetals and our team is scheduling. Scheduling, Figure 6, was designed to replicate, with minor modifications, the schedule board currently being used at Primetals. Since the dashboard will be piloted and will be used with two machines, we removed data from the scheduling board deemed irrelevant, such as tooling. According to Primetals schedule manager, the tools that are used with the machines VMC-5 and MMD-2 are stationary (tools are not removed from the machines); therefore, the tooling aspect of the schedule was excluded from the design.

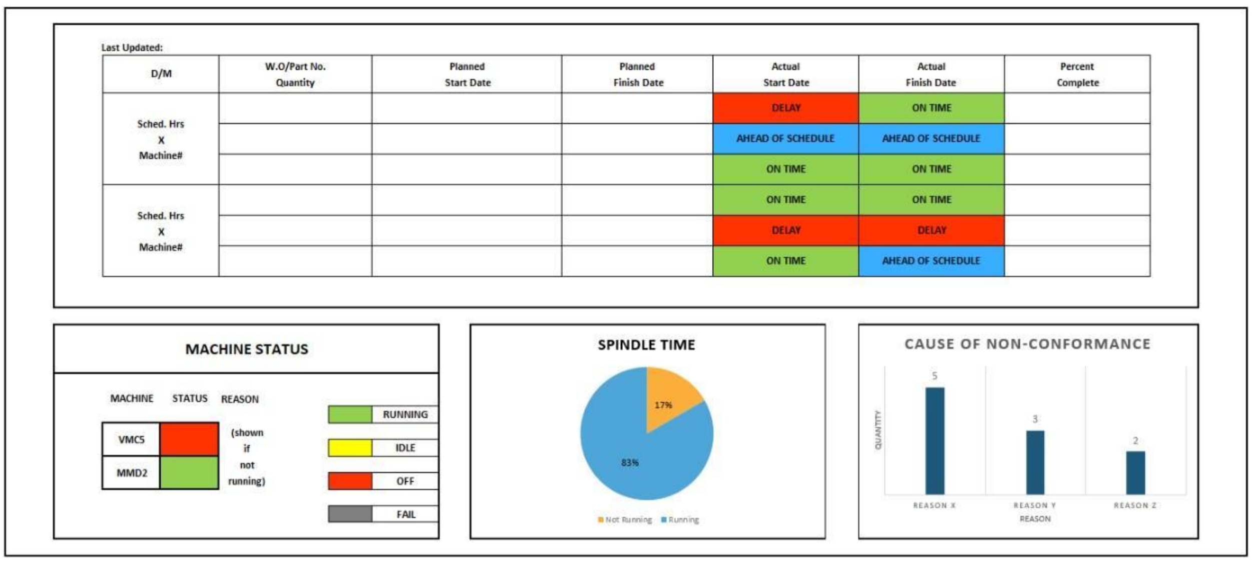

Figure 5 Final Revision Dashboard Design

The final revision, Figure 5, of the visual mockup contains a more compact version of Revision 1 (Figure 8). The new schedule module (Figure 6), compared to revision 1’s schedule module contains less columns of data. The final revision’s schedule module does not contain *Program Ready* and *Quantity Hold* columns. Since both newer machines operate on their own programs, operators would not need to prepare programs to run the machines.

Furthermore, one major difference between the first revision and the second revision is the missing part status. In the final revision, the schedule module and part status module were combined to reduce the space needed to efficiently display the data. The new schedule now changes colors depending on the differences in planned and actual columns. For example, if production of the part has started later than anticipated, or the actual start date is after the planned start date, the *actual start date* column will change color to red as production is delayed. If production on the part began on time, or earlier than planned, the colors would then change to display green or blue respectively.

Last Updated:

D/M	W.O/Part No. Quantity	Planned Start Date	Planned Finish Date	Actual Start Date	Actual Finish Date	Percent Complete
Sched. Hrs X Machine#						
Sched. Hrs X Machine#						

Figure 6 Final Revision Schedule

Machine status, Figure 7, shows which machines are currently running and is similar to the part status which uses a color coded system. The module comprises of two machines - VMC5 and MMD-2. Through choosing the colors to be as intuitive as possible, green, yellow and red, the dashboard users shouldn’t have difficulty understanding and utilizing the module. We also added a machine failure, which is color coded as grey, to indicate that the machine will need fixing and will out of production for a while.

Another addition to the final revision dashboard design is the cause of non-conformance (Figure 7). This module was added to provide workers on the floor an insight on what is causing their products to not pass quality check, if it happens to be caused by a human error.

The last module revised is the l conformance pie chart for spindle time (Figure 7). Spindle time was designed as a pie chart to effectively display the information of machine run time. Floor workers can quickly gauge how long the machine is running over the total time planned.

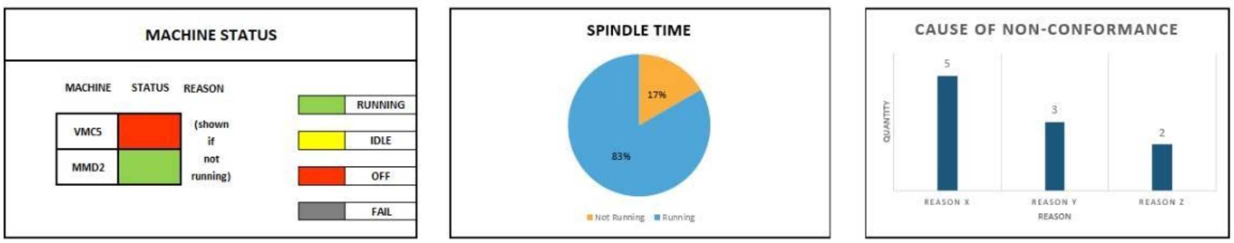

Figure 7 Final Revision Conformance module and Spindle Time Module

4.4 Functional Mockup

The programmed mockup can be seen in Figure 8.

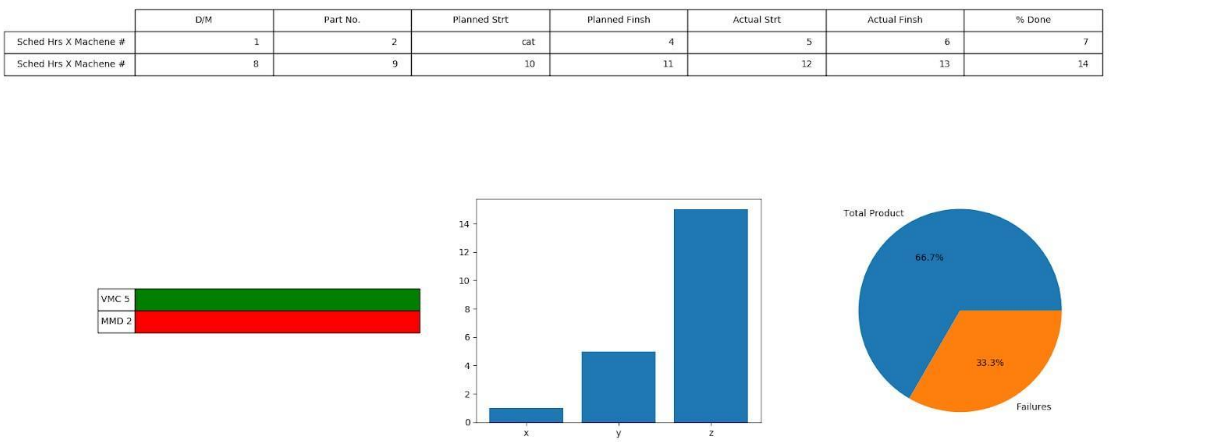

Figure 8 Mockup Display

This mockup is driven by the visual mockup, coded in Python, and is manually updatable using Microsoft Excel. The code is available in Appendix 1

4.5 Business Analysis

Using Microsoft Excel, we calculated the cost benefit for each year over a five-year period for each of the products considered in the market analysis (Table 9).

PROJECT COSTS						
DESCRIPTION	**YEAR 1**	**YEAR 2**	**YEAR 3**	**YEAR 4**	**YEAR 5**	**TOTAL**
ONE-TIME COSTS						
PC	$ 733	$ -	$ 733	$ -	$ 733	$ 2,199
Moniter	$ 1,265	$ -	$ 1,265	$ -	$ 1,265	$ 3,795
MT Connect	$ 1,000	$ -	$ -	$ -	$ -	$ 1,000
JavaFX	$ -	$ -	$ -	$ -	$ -	$ -
Installation	$ -	$ -	$ -	$ -	$ -	$ -
Training (initial)	$ -	$ -	$ -	$ -	$ -	$ -
TOTAL ONE-TIME COSTS	$ 2,998	$ -	$ 1,998	$ -	$ 1,998	$ 6,994
RECURRING COSTS						
Software Maintenace & Upgrades	$ -	$ -	$ -	$ -	$ -	$ -
IT Staff Cost	$ -	$ -	$ -	$ -	$ -	$ -
Training (new users)	$ -	$ -	$ -	$ -	$ -	$ -
TOTAL RECURRING COSTS	$ -	$ -	$ -	$ -	$ -	$ -
TOTAL COSTS	$ 2,998	$ -	$ 1,998	$ -	$ 1,998	$ 6,994

Table 9 Cost Benefit Analysis Total

The benefits and savings measure the gain or loss generated on an investment relative to the amount of money invested. The total annual price, the annual savings, cumulative savings and costs, and the cumulative total net savings are needed to calculate the benefits and savings. The calculations are completed for each of the 5 years, and total for the 5 year for each calculation (Table 10).

BENEFITS / SAVINGS						
PROCESS	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	TOTAL
CURRENT						
TOTAL ANNUAL PRICE	$ 2,998	$ -	$ 1,998	$ -	$ 1,998	$ 6,994
NEW						
TOTAL ANNUAL PRICE	$ -	$ 1,998	$ -	$ 1,998		$ 3,996
ANNUAL SAVINGS	$ 2,998	$ (1,998)	$ 1,998	$ (1,998)	$ 1,998	$ 2,998
CUMULATIVE SAVINGS	$ 2,998	$ 1,000	$ 2,998	$ 1,000	$ 2,998	$ 5,996
CUMULATIVE COSTS	$ 2,998	$ 2,998	$ 4,996	$ 4,996	$ 6,994	$ 13,988
CUMULATIVE TOTAL NET SAVINGS	$ -	$ (1,998)	$ (1,998)	$ (3,996)	$ (3,996)	$ (7,992)

Table 10 Cost-Benefit Analysis, Benefits and Savings

5 Conclusions

5.1 Market Research

We researched software alternatives that Primetals should consider, which included Industry 4.0 standards for data collection and visualization with key performance indicators and machine shop monitoring. We completed both the qualitative analysis and quantitative analysis for six software's which are Merlin Optime, Oracle Manufacturing Intelligence, SAP MII, Scytec DataXchange, Seiki Shop Floor Data Collection (SFDC) and Predator MDC (Machine Data Collection). From our qualitative analysis, we focused on the software selection which would give the best visual management display system for Primetals' shop floor data which resulted in Predator MDC as the best choice because of functions on data visualization and cost benefits.

From the quantitative analysis, we used both AHP and SMART decision making tools to rank criterion deemed to be important to arrive at a final selection consistent with user preferences. The ranking of the criteria was done by the stakeholders from Primetals. The results from our quantitative analysis indicated that Predator MDC is the most favored software for Primetals and followed by SAP MII, Scytec DataXchange, Merlin4 Optime, Seiki SFDC and Oracle manufacturing intelligence.

5.2 Business Analysis

Using the data obtained from software vendors we were able to construct cost estimate tables for three alternatives: the mockup, Scytec DataXchange, and SAP MII. From the cost benefit tables we found that SAP MII was the most preferable, while the mockup was the least desirable with Scytec DataXchange falling in between them. However, this is not a complete dataset as we were unable to get a quote for all the software alternatives.

6. Recommendations

After obtaining the information regarding the criteria preference from four stakeholders and essential information through thorough research, we were able to identify the software that met all requirements. Qualitative analysis resulted in Predator MDC as a recommended software because of its data visualization functions and cost benefits. The results from the quantitative analysis indicated that, according to stakeholders' preferences, Predator MDC was the best software to purchase. It had the highest AHP and SMART score among the six alternative software's and its strengths in function and usage matched the preferred requirements from Primetals.

By comparing the results of the business analysis, we found the cost benefit analysis for each alternative. By comparing these values, we found that the most preferable option for Primetals would be the SAP MII to be the most preferable option as it had the highest value per dollar spent.

7. IE Reflection

In this project we designed a visual management system for Primetals for their VMC-5 and MMD-2 machines. The goals of the project were to:

- Define relevant KPIs:
- Perform market research on potential alternatives;
- Develop a visual layout design; ● Develop a functional mockup, ● Perform a business analysis.

The measurement of the completion of these goals was the successful completion of the project deliverables, a working mockup and market/business research into what visualization software would best fit Primetals. The mockup went through several rounds of iteration with Primetals, both in visual design and the code behind it. The final mockup was reviewed and approved by Primetals alongside the submission of our recommendations on what visualization software would best suit Primetals.

Visual design

In designing the visual design of the dashboard, we created a template for what the final dashboard will look like. This is an important step in turning abstract idea into a physical product through coding to achieve a usable dashboard for on floor workers.

In this project we used python with the matPlotLib library to produce a functional mockup of the visual design. This is important as it serves to take the idea of the visual design and turn it into a physical product that can be displayed on a screen. This physical product is the result of our design and one of the final products of our project

To approach our market research problems efficiently, we have to design our solutions using what we learned as Industrial Engineers. As engineers we specialize in converting facts, evidence and information into comparable numbers. As a result, the goal for market research approach was to present the sponsor with measurable solutions that they could be part of and related to. Therefore, we decided to adopt decision-making methods into our design process. The design process for market research solutions included two parts, which were qualitative analysis and quantitative analysis. Qualitative analysis was the beginning stage of our research where we gather relevant information from reliable sources to proceed onto the quantitative analysis. Quantitative analysis involves decision making methods such as Analytic Hierarchy Process (AHP) and Simple Multi-Attribute Rating Technique (SMART) to convert the informative we gathered into numbers. This part of the process also deployed our stakeholders' opinions into the calculation. Based on our process design, we were able to come up with measurable solutions based on the combination of thorough research and decision makers' (stakeholders at Primetals) perspectives. We also added financial methods into the design process by conducting business analysis. This addition provided another essential dimension to our approach.

The constraints that were found in this project include coding, program compatibility, and the selection of KPIs on the screen. Since our visual mockup required coding and most members of our team lack the understanding or ability to code, one limitation was the group's understanding of computer programming. This affected the project as we were unable to use any more advanced languages or techniques. For example, we were unable to program the mockup to automatically update.

In addition, another constraint that we found while working in the project is the compatibility of software's with MTConnect, a protocol designed for the exchange of data between shop floor equipment and software applications used for monitoring and data analysis. We were supposed to extract machine data from the machines via MTConnect and create a functional mockup for data visualization but the lack of MTConnect at Primetals made us change the direction to just creating a functional mockup for the machine data with manual data entry.

Lastly, the final constraint is the amount of KPIs that could be placed on the dashboard screen. The specifications sheet defined a total amount of seven KPIs. However, on the screen, only four of the 7 KPIs are displayed. The KPIs that were excluded are OEE, OLE, and Daily Target. The two main reasons why these KPIs were not displayed on the dashboard is due to the concern of oversaturation of the dashboard, which can diminish the effectiveness of the dashboard, and its relevance to on-floor shop workers.

Solomon Ortega

For me, the most impactful part of this project was to see how nonstandard problems can be in industry. In my classes, many Industrial Engineering problems had a simple and standard solution. This was not the case during most of this project. We encountered several problems during this project such as shifting goals for the project, the primary contact for the project changing jobs a third of the way into the project, and not having accurate or correct data for what we wanted to do. However, we also found how to work in suboptimal conditions and how to adapt the project so that it still produces a useful product.

At the beginning of this project, the project goal was to create a visual design for the factory floor and develop a plan to reduce the spindle change time for operators. After a few weeks of project definition, the goal of the project changed to just developing the screen and producing a physical mockup. Since this new goal wasn't enough to justify an MQP, we added the market and business analysis to the project. Over the project, these sections grew to be a main part of the project and they became some of our deliverables.

While losing our primary contact was a setback, we learned about how to transfer a project from one group to another. I think this is a valuable skill as it ties into working well in a group and understanding how to efficiently convey your work and goals to an outsider in a way that makes them an active participant.

Another lesion I learned from this project was that there is rarely ideal data. For the early part of the project we thought that we would have access to the information directly output by the machines. However, Primetals did not yet have the software to access it. To accommodate for this, we changed the goal for the mockup to require manual data entry.

Overall, I learned several lessons from this project. I feel the most important thing I learned was that things are often more complicated in industry, but with effort, I can still provide a successful product.

Adam Maier

This project was a learning experience throughout the entire thing. In the beginning we spent our time researching manufacturing and how machines are monitored. After that we learned about Key Process Indicators (KPIs) and what makes a good one. During the entire project we were learning about the Primetals and how they operated. For specific, non-coursework items I have learned the top two were adapting to the changing contacts within Primetals and learning how Primetals prioritized the different functions of the Mockup.

We went through several contacts with Primetals due to roles shifting about in the company. This led to a need to adapt to what a new contact could provide. Through this I learned how to quickly bring a new contact up to speed on what we were doing. This is a valuable tool and one not needed much at WPI due to the heavily structured nature of courses.

Learning about the Primetals' priorities was a completely different story. The main thing I learned was how to know when there is too much information to be useful. I was very surprised when complex measures of performance such as OEE and OLE were passed over in favor of more basic measures such as part status and scheduling. The most valuable takeaway I got from this was that if data is displayed to drive certain actions then that data needs to be easily understood to allow for the quickest response to that data.

In order to continue my learning experience, I will take this knowledge and, more importantly, the experience of how I learned these things to maintain an open mindset into the future. The engineers, operators, supervisors and management all had fantastic lessons to teach and if I can maintain the ability to learn from those like them then I can continue growing as an engineer.

Passavich Nalamlieng

The project at Primetals has given me so much valuable experiences. This MQP project gave me a real-life working experience in teams that have to coordinate with each other in order to achieve a common goal. Through a real-life working experience for a long term project, I had encounter many spontaneous problems. The problems related to market research that I mainly responsible for were able to be solved with knowledge from courses taken at WPI. This MQP gave me a direct experience on how we could adapt our knowledge in classroom to be used to find the right solutions to work related problems. I was able to recognize the benefits of decision-making methods that were taught in WPI, such as AHP and SMART, and use them to strengthen our market research. This experience proved to be a transitioning from learning inside a classroom to working in a real world.

Aside from work related problems that could be solved with adapting prior knowledge, I also learned to cope with spontaneous problems outside of classroom. The path of this project was not smooth due to internal and external conflicts. We had to change the scope of our project at the beginning of A term and had to change a coordinator every term. These myriad obstacles taught us to be adaptable to the changes and learned to plan for any uncertainties. I learned the importance of communication, teamwork and responsibilities from overcoming these conflicts that I couldn't find in coursework or classroom.

I would continue the learning endeavor by experimenting on different approaches to upcoming problems in my career path. I believe that if I continue to progress with my career and pursue my passion, I will always get to learn from the mistakes that I made and the success that I earned. I sincerely believe that the hands-on experience that MQP gave me and engineering ideals that WPI embedded in me will be great benefits in the future.

Panuwat Kongpornjaras

My overall experience with this project has been insightful to me in terms of uncertainty and in terms of completing new tasks without any prior knowledge. Within the weeks working with Primetals, multiple changes have been made to the project and to the people. Our goal at the beginning of the project was to only define a prototype dashboard that will help assist on floor workers to increase productivity and reflect their achievements. However, as a six-person team, the project wasn't going to effectively challenge all members; therefore, another segment of business analysis and market research was created. I originally thought the project outcome would totally be defined, but major adaptations could still be implemented later. In addition to the project itself, Primetals had multiple role changes that had affected the progress of the project. In the beginning, our project representative from Primetals was Bonnie Specht, however, a few weeks' later roles were changed, and Dan would be our project representative instead. Each role transfer slowed the progress of our project, but we were quick to respond and fill Dan in.

Another aspect was having to learn to create a dashboard from scratch, something that I had never done before. I was expected to create an effective solution to a problem that I have little experience at. This was an interesting experience since I had to continually report and adjust the design to Primetals needs. This resulted in a continuous back-and-forth communication and adjustment between Primetals and me, something that I seldom experience.

I would continue the learning endeavor through trying new things that I haven't done before. By creating a visual design mockup, starting from not knowing anything about dashboards, I believe that I can achieve and obtain new learning experiences directly from jumping into new and challenging situations.

Hein Htet Hlyan

The 3-term MQP project at Primetals Technologies gave me experiences which are very beneficial for my future endeavors. It gave me not only the understanding of an American hierarchical organizational structure of industry, but also the engineering knowledge of the industry and how it is going towards.

One of the most beneficial experiences from this project was dealing with multiple working professionals on every level at Primetals. It gave me a lot of insights on how an organization or a factory operates with the coordination of working professionals on every level at Primetals. During the project, I interacted with professionals ranging from shop floor machine coordinator to the plant management level director and I had a chance to interview their thoughts on the market research criterion. The interviews gave me an insight on how professionals think according to their respective position and how the combination of all professionals keeps business thriving at Primetals.

The other advantageous experience I had from the project experience was gaining a lot of manufacturing industry knowledge. For our project, we delivered a functional mockup for data visualization on the shop floor at Primetals. Through the project, I had the chance to research through specifically data collection methods and data visualization and analytics software's through the machines at Primetals. It gave me a view on how the manufacturing industry is going towards Industry 4.0 and how the machine data analytics can give a competitive edge for a manufacturing factory for greater profit, quality and quantity of products.

The real-life working experience at Primetals gave me the energy and the industry experience for starting my own manufacturing business in the future. I would keep on researching and learning for the manufacturing industry technology and operational procedures as they all would, one day, pile up in one place in my future business endeavors.

Alexandra Barber

My experience working on the project was very eye opening to how industry works. Projects in industry are constantly going through changes such as the management of the project and projects goals in objectives. I experienced both of these changes well working on the project. Our original contact with Primetals ended up leaving the company at the end of A-term, which caught us all by surprise. We had to quickly formulate a plan to move forward with the project and start communicating with a new contact. In industry people are constantly moving around to a new position or a new company which can affect working on a project. This taught me to adapt quickly to unavoidable changes and keep moving forward no matter the situation.

Our project objective at the begging of A-term was nothing like the end of C-term. At the beginning of the term we were supposed to be two teams of three people working on two separate projects at Primetals. That changed pretty quickly, and we ended up working as one team of 6 people on one project for Primetals. One of the projects we were going to do was dropped because the company would be moving to a new location and it would no longer be an effective use of our time. It was very interesting to see our project evolve over the course of three terms and a great learning experience. In industry new things happen all the time and priorities can be made for different aspects of a project or a project as a whole. Teams working on these projects have to adapt quickly can come up with unique solutions.

The most important skills I learned while completing this project that were not covered in my prior coursework, were adaptability skills. In my past classes the coursework is always structured, they follow a strict schedule and have basic guidelines to reference. When working on this project everything was subject to change from our project objectives to our project contact. We created a timeline and set deadlines for the project, but as with most projects there were plenty of bumps in the road. Being able to adapt quickly was import to the project being a success and is not covered in most coursework.

To continue my learning endeavor I will make learning a priority in my life and not just wait for learning to find me. There are many opportunities to continue learning after college from online courses, company mentorships, and certification programs. I'm very fortunate that the job I received an offer for supplies all of these opportunities to their employees. I plan to take advantage of all of them as well as the people I will be working with. The people at Primetals were very accommodating and educated us about the company and their processes whenever we asked. I will continue to take advantage of all of my educational opportunities after college to better myself and my future career.

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10. Appendices

Appendix 1: Mockup

import matplotlib.pyplot as plt

import numpy as np import csv

#init fig = plt.figure() tableAxes =

fig.add_subplot(211) otherAxes1 =

fig.add_subplot(234) otherAxes2 =

fig.add_subplot(235) otherAxes3 =

fig.add_subplot(236)

#Data

running = 0;

nrunning = 0;

num = []

status = [] i =

0

data = [['1','2','3','4','5','6','7'],['8','9','10','11','12','13','14']] with

open('MQP.csv') as csvfile:

reader = csv.reader(csvfile,delimiter=',',

quotechar='|') for row in reader: if (i==0):

running = int(row[0])

i = i+1 elif (i==1):

nrunning = int(row[0])

i = i+1 elif (i==2):

status = [int(row[0]),int(row[1])]

i = i+1 elif (i==3):

num = [int(row[0]),int(row[1]),int(row[2])]

i = i+1 else:

```
            data[i-4] = row
i = i+1
#Table


colLabels = ['D/M','Part No.','Planned Strt','Planned Finsh','Actual Strt','Actual Finsh', '% Done']
rowLabels = [] for index in range(len(data)):
            rowLabels.append('Sched Hrs X Machene #'),
tableAxes.axis('tight')
tableAxes.axis('off') tb
= tableAxes.table(
            cellText=data,
rowLabels=rowLabels,
colLabels=colLabels,     loc='center'
)
#Pie Chart
labels = 'Total Product', 'Failures' sizes
= [running, nrunning]
otherAxes3.pie(sizes, labels=labels, autopct='%1.1f%%', startangle=0) otherAxes3.axis('equal')
#Bar Chart x =
np.arange(3)
otherAxes2.bar(x, num,tick_label= ('x','y','z'))
#on/off working
= ['','']
text = ['','','','','','',''] for index in
range(len(status)):          if
(status[index] == 1):
working[index] = 'g'
text[index] = 'Running'  elif
(status[index]==2):
```

```
working[index] = 'y'
text[index] = 'Idle'          elif
(status[index]==3):
working[index] = 'r'
text[index] = 'Off'           else:
            working[index] = 'tab:gray'
text[index] = 'Fail'

otherAxes1.axis('tight')
otherAxes1.axis('off')
tb2 = otherAxes1.table(rowLabels = ['VMC 5', 'MMD 2'], cellColours = working, loc = 'center')
#show
mng = plt.get_current_fig_manager()
mng.window.state('zoomed')
plt.show()
```

Appendix 2: Mockup Visual Design Revision 1

Figure 9 Dashboard Design.

Figure 10 Schedule Module

The part status, Figure 11, was designed so that Primetals could effectively consume the visual data through color coding. Since some jobs require multiple machines, it is critical to acknowledge which parts are on time, delayed, or ahead of schedule in order to produce the product in time for the customer. The part status module is comprised of part name, part status, and a legend for the colors. The design is streamlined as much as possible in order to effectively depict the status of the KPI.

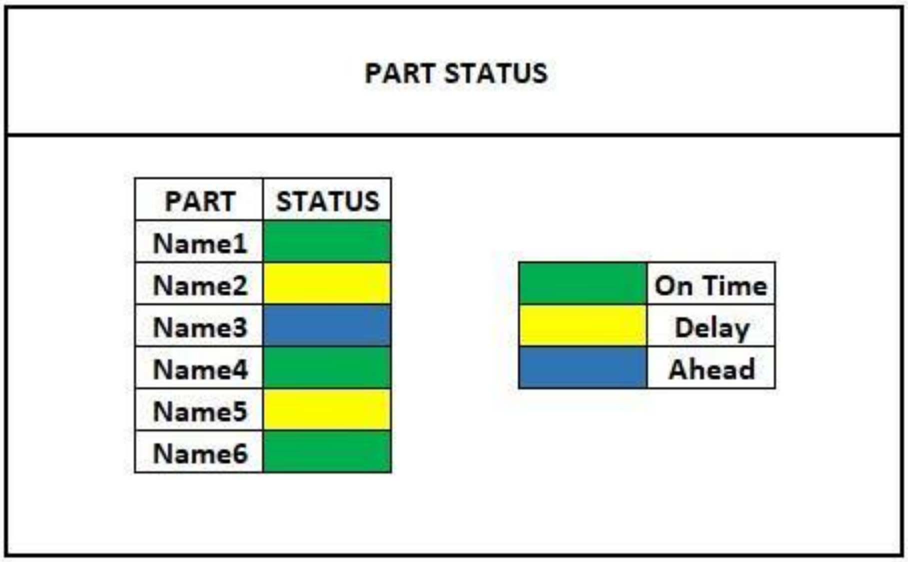

Figure 11 Part Status Module

The non-compliance module, Figure 12, is used as a brief summary for quality checking. Quality checking is important since products have to meet or exceed the customer's expectations. Within the module, the unit of time can be used from day to week to month, in accordance with Primetals specific design. Through using a pi-chart and contrasting colors, users can quickly gauge, as a whole, what the quality of the products is.

Figure 12 Non-Compliance Module

Appendix 3: Market Research Quantitative Analysis

Criterion	Price	Display	Function	Usage
Price	1	1/5	1/7	1/6
Display	5	1	1/5	1/4
Function	7	5	1	2
Usage	6	4	1/2	1
sum	19	10.20	1.84	3.42

Scale	1-9
	9 being more preferable

Criterion	Price	Display	Function	Usage	Priority
Price	0.05	0.02	0.08	0.05	0.05
Display	0.26	0.10	0.11	0.07	0.14
Function	0.37	0.49	0.54	0.59	0.50
Usage	0.32	0.39	0.27	0.29	0.32

Criterion	Price	Display	Function	Usage	Sum
Price	0.05	0.03	0.07	0.05	0.20
Display	0.25	0.14	0.10	0.08	0.56
Function	0.35	0.68	0.50	0.64	2.16
Usage	0.30	0.54	0.25	0.32	1.41
Price	4.04				
Display	4.15				
Function	4.35				
Usage	4.42				
Average	4.24				
CI	0.08				
CR	0.09	must be lower than 0.1			

Table 11 Jared's AHP Criteria

Criterion	Price	Display	Function	Usage
Price	1	1/8	1/7	1/9
Display	8	1	3	1
Function	7	1/3	1	1/4
Usage	9	1	4	1
sum	25	2.46	8.14	2.36

Criterion	Price	Display	Function	Usage	Priority
Price	0.04	0.05	0.02	0.05	0.04
Display	0.32	0.41	0.37	0.42	0.38
Function	0.28	0.14	0.12	0.11	0.16
Usage	0.36	0.41	0.49	0.42	0.42

Criterion	Price	Display	Function	Usage	Sum
Price	0.04	0.05	0.02	0.05	0.16
Display	0.31	0.38	0.48	0.42	1.59
Function	0.27	0.13	0.16	0.11	0.66
Usage	0.35	0.38	0.64	0.42	1.79
					0.00
Price	4.02				
Display	4.20				
Function	4.13				
Usage	4.27				
Average	4.15				
CI	0.05				
CR	0.06	must be lower than 0.1			

Table 12 Phil’s AHP Criteria

Criterion	Price	Display	Function	Usage
Price	1	1/6	1/5	1/9
Display	6	1	2	1/3
Function	5	1/2	1	1/3
Usage	9	3	3	1
sum	21.00	4.67	6.20	1.78

Criterion	Price	Display	Function	Usage	Priority
Price	0.05	0.04	0.03	0.06	0.04
Display	0.29	0.21	0.32	0.19	0.25
Function	0.24	0.11	0.16	0.19	0.17
Usage	0.43	0.64	0.48	0.56	0.53

Criterion	Price	Display	Function	Usage	Sum
Price	0.04	0.04	0.03	0.06	0.18
Display	0.27	0.25	0.35	0.18	1.04
Function	0.22	0.13	0.17	0.18	0.70
Usage	0.40	0.76	0.52	0.53	2.21

Price	4.05		
Display	4.13		
Function	4.03		
Usage	4.17		
Average	4.09		
CI	0.03		
CR	0.03	must be lower than 0.1	

Table 13 Bill's AHP Criteria

Criterion	Price	Display	Function	Usage
Price	1	3	1/4	1/3
Display	1/3	1	1/6	1/4
Function	4	6	1	3
Usage	3	4	1/3	1
sum	8.33	14.00	1.75	4.58

Criterion	Price	Display	Function	Usage	Priority
Price	0.12	0.21	0.14	0.07	0.14
Display	0.04	0.07	0.10	0.05	0.07
Function	0.48	0.43	0.57	0.65	0.53
Usage	0.36	0.29	0.19	0.22	0.26

Criterion	Price	Display	Function	Usage	Sum
Price	0.14	0.20	0.13	0.09	0.55
Display	0.05	0.07	0.09	0.07	0.27
Function	0.55	0.39	0.53	0.79	2.27
Usage	0.41	0.26	0.18	0.26	1.12
Price	4.03				
Display	4.07				
Function	4.25				
Usage	4.23				
Average	4.15				
CI	0.05				
CR	0.05	must be higher than 0.1			

Table 14 Dan's AHP criteria

Criterion	Price	Display	Function	Usage
Price	1	1/4	1/6	1/7
Display	4	1	1/2	1/3
Function	6	2	1	1
Usage	7	3	1	1
sum	18	6.25	2.67	2.48

Criterion	Price	Display	Function	Usage	Priority
Price	0.06	0.04	0.06	0.06	0.05
Display	0.22	0.16	0.19	0.13	0.18
Function	0.33	0.32	0.38	0.40	0.36
Usage	0.39	0.48	0.38	0.40	0.41

Criterion	Price	Display	Function	Usage	Sum
Price	0.05	0.04	0.06	0.06	0.22
Display	0.22	0.18	0.18	0.14	0.71
Function	0.32	0.35	0.36	0.41	1.45
Usage	0.38	0.53	0.36	0.41	1.68
Price	4.01				
Display	4.02				
Function	4.04				
Usage	4.07				
Average	4.04				
CI	0.01				
CR	0.01	must be lower than 0.1			

Table 15 Average AHP Criteria

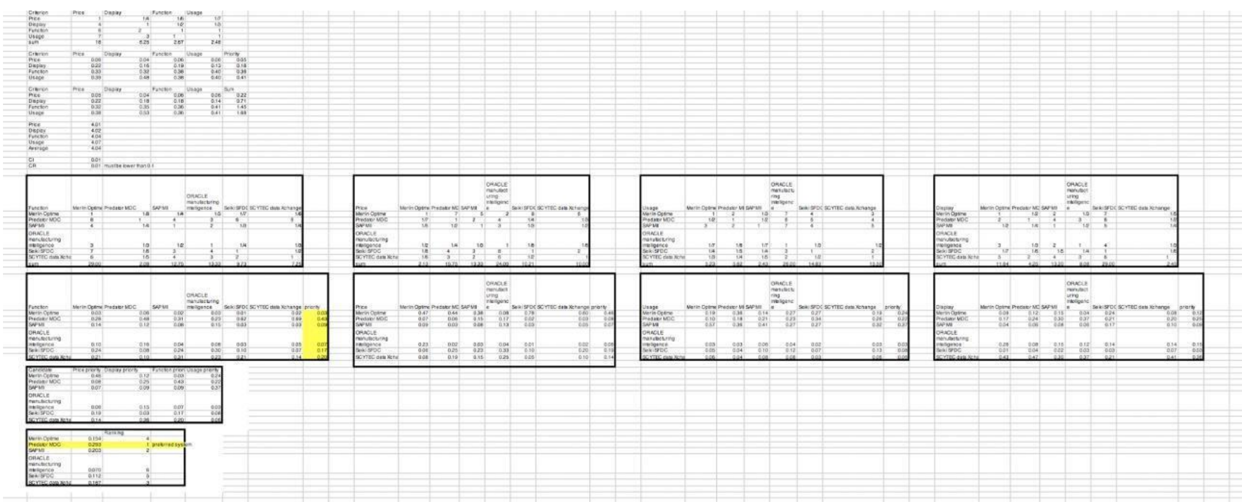

Table 16 Software's AHP Results

Attribute	Original Weights	Normalized weights
Price	30	12
Display	50	20
Function	100	40
Usage	70	28
sum	250	100

Table 17 Jared's SMART Attribute

Attribute	Original Weights	Normalized weights
Price	30	9.84
Display	100	32.79
Function	90	29.51
Usage	85	27.87
sum	305	100

Table 18 Phil's SMART Attribute

Attribute	Original Weights	Normalized weights
Price	30	10.71
Display	80	28.57
Function	70	25.00
Usage	100	35.71
sum	280	100

Table 19 Bill's SMART Attribute

Attribute	Original Weights	Normalized weights
Price	40	16.67
Display	20	8.33
Function	100	41.67
Usage	80	33.33
sum	240	100

Table 20 Dan's SMART Attribute

Attribute	Original Weights	Normalized weights
Price	32.5	12.09
Display	62.5	23.26
Function	90	33.49
Usage	83.75	31.16
sum	268.75	100

Table 21 Average SMART Score

Attribute	Original Weights	Normalized weights
Price	32.5	12.09
Display	62.5	23.26
Function	90	33.49
Usage	83.75	31.16
sum	268.75	100

Merlin Optime

Attribute	Values	Normalized weights	Value*Weight
Price	100	12.09	1209.30
Display	80	23.26	1860.47
Function	10	33.49	334.88
Usage	90	31.16	2804.65
score			62.09

Predator MDC

Attribute	Values	Normalized weights	Value*Weight
Price	70	12.09	846.51
Display	90	23.26	2093.02
Function	100	33.49	3348.84
Usage	80	31.16	2493.02
score			87.81

SAP MII

Attribute	Values	Normalized weights	Value*Weight
Price	50	12.09	604.65
Display	60	23.26	1395.35
Function	69	33.49	2310.70
Usage	100	31.16	3116.28
score			74.27

ORACLE manufacturing intelligence

Attribute	Values	Normalized weights	Value*Weight
Price	10	12.09	120.9302326
Display	70	23.26	1627.906977
Function	50	33.49	1674.418605
Usage	10	31.16	311.627907
score			37.35

Seiki SFDC

Attribute	Values	Normalized weights	Value*Weight
Price	80	12.09	967.4418605
Display	10	23.26	232.5581395
Function	80	33.49	2679.069767
Usage	40	31.16	1246.511628
score			51.26

SCYTEC data Xchange

Attribute	Values	Normalized weights	Value*Weight
Price	60	12.09	725.5813953
Display	100	23.26	2325.581395
Function	70	33.49	2344.186047
Usage	70	31.16	2181.395349
score			75.77

Table 22 Software's SMART Results

Appendix 4: Cost-Benefit Analysis Tables

PROJECT COSTS						
DESCRIPTION	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	TOTAL
ONE-TIME COSTS						
PC	$ 733	$ -	$ 733	$ -	$ 733	$ 2,199
Moniter	$ 1,265	$ -	$ 1,265	$ -	$ 1,265	$ 3,795
MT Connect	$ 1,000	$ -	$ -	$ -	$ -	$ 1,000
JavaFX	$ -	$ -	$ -	$ -	$ -	$ -
Installation	$ -	$ -	$ -	$ -	$ -	$ -
Training (initial)	$ -	$ -	$ -	$ -	$ -	$ -
TOTAL ONE-TIME COSTS	$ 2,998	$ -	$ 1,998	$ -	$ 1,998	$ 6,994
RECURRING COSTS						
Software Maintenace & Upgrades	$ -	$ -	$ -	$ -	$ -	$ -
IT Staff Cost	$ -	$ -	$ -	$ -	$ -	$ -
Training (new users)	$ -	$ -	$ -	$ -	$ -	$ -
TOTAL RECURRING COSTS	$ -	$ -	$ -	$ -	$ -	$ -
TOTAL COSTS	$ 2,998	$ -	$ 1,998	$ -	$ 1,998	$ 6,994

BENEFITS / SAVINGS						
PROCESS	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	TOTAL
CURRENT						
TOTAL ANNUAL PRICE	$ 2,998	$ -	$ 1,998	$ -	$ 1,998	$ 6,994
NEW						
TOTAL ANNUAL PRICE	$ -	$ 1,998	$ -	$ 1,998		$ 3,996
ANNUAL SAVINGS	$ 2,998	$ (1,998)	$ 1,998	$ (1,998)	$ 1,998	$ 2,998
CUMULATIVE SAVINGS	$ 2,998	$ 1,000	$ 2,998	$ 1,000	$ 2,998	$ 5,996
CUMULATIVE COSTS	$ 2,998	$ 2,998	$ 4,996	$ 4,996	$ 6,994	$ 13,988
CUMULATIVE TOTAL NET SAVINGS	$ -	$ (1,998)	$ (1,998)	$ (3,996)	$ (3,996)	$ (7,992)

Table 23 Cost-Benefit Analysis for Functional Mockup

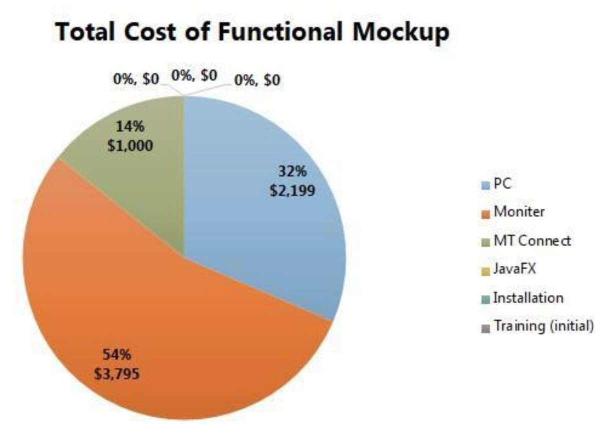

Figure 13 Cost – Benefit Summary for Functional Mockup

PROJECT COSTS						
DESCRIPTION	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	TOTAL
ONE-TIME COSTS						
PC	$ 733	$ -	$ 733	$ -	$ 733	$ 2,199
Moniter	$ 1,265	$ -	$ 1,265	$ -	$ 1,265	$ 3,795
License	$ 2,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 6,000
Adaptor	$ 800	$ 400	$ 400	$ 400	$ 400	$ 2,400
TOTAL ONE-TIME COSTS	$ 4,798	$ 1,400	$ 3,398	$ 1,400	$ 3,398	$ 14,394
RECURRING COSTS						
None	$ -	$ -	$ -	$ -	$ -	$ -
TOTAL RECURRING COSTS	$ -	$ -	$ -	$ -	$ -	$ -
TOTAL COSTS	$ 4,798	$ 1,400	$ 3,398	$ 1,400	$ 3,398	$ 14,394
BENEFITS / SAVINGS						
PROCESS	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	TOTAL
CURRENT						
TOTAL ANNUAL PRICE	$ 4,798	$ 1,400	$ 3,398	$ 1,400	$ 3,398	$ 14,394
NEW						
TOTAL ANNUAL PRICE	$ 1,400	$ 3,398	$ 1,400	$ 3,398		$ 9,596
ANNUAL SAVINGS	$ 3,398	$ (1,998)	$ 1,998	$ (1,998)	$ 3,398	$ 4,798
CUMULATIVE SAVINGS	$ 3,398	$ 1,400	$ 3,398	$ 1,400	$ 4,798	$ 9,596
CUMULATIVE COSTS	$ 4,798	$ 6,198	$ 9,596	$ 10,996	$ 14,394	$ 28,788
CUMULATIVE TOTAL NET SAVINGS	$ (1,400)	$ (4,798)	$ (6,198)	$ (9,596)	$ (9,596)	$ (19,192)

Table 24 Cost-Benefit Analysis for Predator MDC

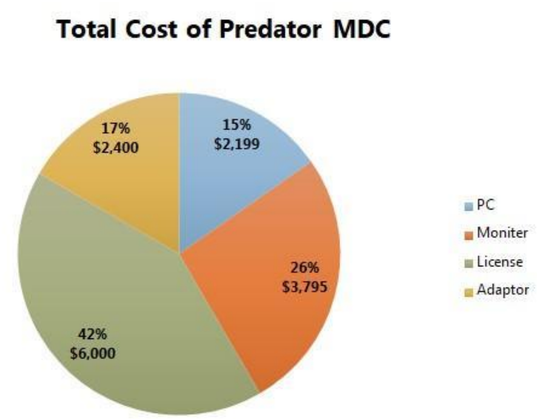

Figure 14 Cost-Benefit Summary for Predator MDC

PROJECT COSTS						
DESCRIPTION	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	TOTAL
ONE-TIME COSTS						
PC	$ 733	$ -	$ 733	$ -	$ 733	$ 2,199
Moniter	$ 1,265	$ -	$ 1,265	$ -	$ 1,265	$ 3,795
Account Activation	$ 2,000	$ -	$ -	$ -	$ -	$ 2,000
TOTAL ONE-TIME COSTS	$ 3,998	$ -	$ 1,998	$ -	$ 1,998	$ 7,994
RECURRING COSTS						
Annual Fee (per machine)	$ 2,040	$ 3,060	$ 4,080	$ 5,100	$ 6,120	$ 20,400
eLearning Annusl Subscription	$ 500	$ 500	$ 500	$ 500	$ 500	$ 2,500
TOTAL RECURRING COSTS	$ 2,540	$ 3,560	$ 4,580	$ 5,600	$ 6,620	$ 22,900
TOTAL COSTS	$ 6,538	$ 3,560	$ 6,578	$ 5,600	$ 8,618	$ 30,894
BENEFITS / SAVINGS						
PROCESS	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	TOTAL
CURRENT						
TOTAL ANNUAL PRICE	$ 6,538	$ 3,560	$ 6,578	$ 5,600	$ 8,618	$ 30,894
NEW						
TOTAL ANNUAL PRICE	$ 3,560	$ 6,578	$ 5,600	$ 8,618		$ 24,356
ANNUAL SAVINGS	$ 2,978	$ (3,018)	$ 978	$ (3,018)	$ 8,618	$ 6,538
CUMULATIVE SAVINGS	$ 2,978	$ (40)	$ 938	$ (2,080)	$ 6,538	$ 13,076
CUMULATIVE COSTS	$ 6,538	$ 10,098	$ 16,676	$ 22,276	$ 30,894	$ 61,788
CUMULATIVE TOTAL NET SAVINGS	$ (3,560)	$ (10,138)	$ (15,738)	$ (24,356)	$ (24,356)	$ (48,712)

Table 25 Cost-Benefit Analysis for SCYTEC data Xchange

Figure 15 Cost-Benefit Summary for SCYTEC data Xchange

PROJECT COSTS						
DESCRIPTION	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	TOTAL
ONE-TIME COSTS						
PC	$ 733	$ -	$ 733	$ -	$ 733	$ 2,199
Moniter	$ 1,265	$ -	$ 1,265	$ -	$ 1,265	$ 3,795
SAP ERP License	$ -	$ -	$ -	$ -	$ -	$ -
TOTAL ONE-TIME COSTS	$ 1,998	$ -	$ 1,998	$ -	$ 1,998	$ 5,994
RECURRING COSTS						
License for Manufacturing, Inventory, and Cost Management	$ 8,400	$ 12,600	$ 16,800	$ 21,000	$ 25,200	$ 84,000
License for Quality Management	$ 902	$ 2,700	$ 3,600	$ 4,500	$ 5,400	$ 17,102
TOTAL RECURRING COSTS	$ 9,302	$ 15,300	$ 20,400	$ 25,500	$ 30,600	$ 101,102
TOTAL COSTS	$ 11,300	$ 15,300	$ 22,398	$ 25,500	$ 32,598	$ 107,096

BENEFITS / SAVINGS						
PROCESS	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	TOTAL
CURRENT						
TOTAL ANNUAL PRICE	$ 11,300	$ 15,300	$ 22,398	$ 25,500	$ 32,598	$ 107,096
NEW						
TOTAL ANNUAL PRICE	$ 15,300	$ 22,398	$ 25,500	32,598		$ 95,796
ANNUAL SAVINGS	$ (4,000)	$ (7,098)	$ (3,102)	$ (7,098)	$ 32,598	$ 11,300
CUMULATIVE SAVINGS	$ (4,000)	$ (11,098)	$ (14,200)	$ (21,298)	$ 11,300	$ 22,600
CUMULATIVE COSTS	$ 11,300	$ 26,600	$ 48,998	$ 74,498	$ 107,096	$ 214,192
CUMULATIVE TOTAL NET SAVINGS	$ (15,300)	$ (37,698)	$ (63,198)	$ (95,796)	$ (95,796)	$ (191,592)

Table 26 Cost-Benefit Analysis for SAP MII

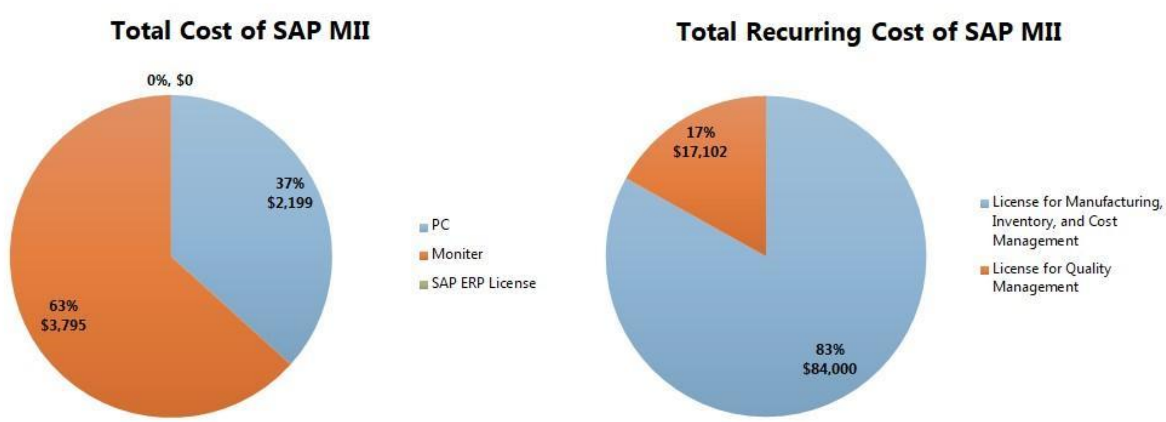

Figure 16 Cost-Benefit Summary for SAP MII

Appendix 5: Specification

Specification for the Primetals Worcester Visual Management System

Purpose

The purpose of this specification is to provide guidelines for creation of a prototype Visual Management System for Primetals and to provide goals for future states of the system.

Definitions

KPI - A measurable value that demonstrates how effectively a target is being met.

OEE – A qualitative measurement of machine performance.

OLE – A qualitative measurement of labor performance.

Product Functions

1) Display KPIs on a screen near the machine
    a. This information will be displayed in such a way that it is easy for users to understand.
2) Include manual data entry. Automatic data feeds are beyond the scope of this project 3) The layout of the system should be customizable as to allow for the most relevant information to be displayed at each location.
    a. This should include a modular display and that ability to add color coded indicators.
4) The system should have the future goal of being able to connect with a system such as MTConnect for automatic updates. **Implementation**

The implementation of this system will have two distinct stages:

1) WPI MQP team mockup
    a. Will have all relevant KPIs displayed
    b. Will include visual functionality such as color coding and different ways to display information
    c. Will require manual data entry
    d. Will include a market research of commercially available software packages
2) Final Design
    a. Built either in-house with Primetals IT or implement a commercial package for VMS
    b. Will automatically update using a system such as MTConnect

System Features

Seven relevant KPIs have been identified by the WPI MQP team. These KPIs are ranked in conjunction with Primetals in high to low priority based off of what activities they drive, who uses them and Primetals ability to capture the relevant data.

High Priority Features:

1) Machine Status
2) Part Status
3) Schedule

Medium Priority Features:

1) Non-Conformance/Complaints
2) Daily Targets

Low Priority Features:

1) OEE and OLE