Schauf, Maureen A. *Real Time Raw Material Processing*

**Abstract**

Access to real time material use data can provide opportunities for focused process improvement efforts that reduce overall costs. The purpose of this project was to provide an automated material handling system that provided real time data to Company XYZ through reporting elements that allowed the organization to focus on targeted continuous improvement efforts that would reduce production costs. Utilizing the DMAIC process, the goal was to replace the existing manual process with built in time delays with a system that communicated in real time material use and corresponding scrap rates. Through access to this real time raw material processing data, Company XYZ would have the ability to improve inventory management, problem solve in real time, and reallocate human resources to added value roles.
Acknowledgments

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Chapter I: Introduction

Company XYZ, whose organizational name was withheld to ensure confidentiality, is a custom manufacturer located in south central Wisconsin. This family owned organization operates three facilities with each facility manufacturing unique product lines: plastic extrusion, laboratory sampling bags, and extruded wood fibers. Company XYZ employs 250 people with 80% working in the production environment.

To maintain their competitive edge, XYZ focuses on utilizing lean six sigma methods of continuous improvement in the manufacturing environment throughout their facilities. This continuous improvement methodology relies heavily on timely cost information for process improvements to ensure that focused efforts to implement change can be deployed at the time of an event and impact real time scrap and financial results. One of the most significant challenges to the organization, within the process of implementing impactful improvements, was a lack of access to real time raw material usage reporting and that corresponding cost impact during the production process. With raw material costs representing up to 70% of the product cost within the extrusion facility, access to real time raw material reporting and costing was critical to any potential improvement analysis and solution implementation. XYZ’s previous material handling process, for their extrusion facility, had been in place since 2005 with no process changes implemented in over 13 years which meant that material usage and cost was not recorded at the time of use. The process required inventory tickets to be completed manually by the material handling team for each raw material taken to, and returned from, the production lines. The material handler then manually entered each of these tickets into their enterprise resource planning (ERP) system, at the end of their shift resulting in a maximum of an eight hour delay in data availability for production performance. The result was an inefficient system that required
multiple, manual-processing element steps to report material usage and incomplete financial results due to the inaccurate costing of products during production.

In an effort to improve the timely gathering of material usage data, XYZ was looking to implement a real time material handling system in their extrusion division. The goals of the system included improved inventory management, reduction of clerical work for key personnel, and real time scrap reporting for management use. Due to the significant impact raw materials costs had on the final product cost production variances were heavily driven by material scrap within the production process. As a result, the real time scrap-reporting element of a new material handling process was especially critical to the continuous improvement efforts of the production team, as this would drive enhanced visibility to issues as they occur allowing quick response and real time problem solving opportunities.

Statement of the Problem

Company XYZ’s extrusion division did not record raw materials being processed at the time of use. As a result, the organization did not have an accurate way of measuring and reporting material usage, scrap, and costs in real time. Without real time information, the organizations leadership is unable to identify, address, and correct issues efficiently reducing scrap and improving profitability.

Purpose of the Study

The purpose of this project was to develop and implement an automated, real time material handling system with report elements for Company XYZ’s extrusion facility. Through a collaborative effort between the manufacturing, engineering, maintenance, and information technology teams, the organization completed the objectives outlined below.
The first step in moving to an automated process required the organization to identify the available technologies that would enable equipment communication throughout the plant with a primary focus on the critical pieces of equipment within the material handling process. This was especially challenging due to the variety of equipment in use and the fact that there was not a marketed solution that the organization could implement. As a result, the company had to define and develop the communication methods within the existing technologies available on the market and within the existing equipment limitations. Clearly defining the parameters, goals, and what success would look like was the first step in identifying the appropriate solution for the equipment upgrades.

In order to support the expanded equipment communications, and the resulting drain on the exiting intranet, Company XYZ was required to complete an upgrade and expanded hardwiring of the production facilities. This would enable the equipment to be connected and communicate as outlined within the project goals while not overburdening the system and resulting in inefficiencies in other areas.

Again, since there was not a marketed solution that the company could implement off the shelf, this project required that the team identify a technological solution that would enable the equipment in use to process raw materials (blenders), to communicate with the network. Understanding available technology, its potential and limitations, was critical to the success of the project. The solution identified required Company ZYX to invest in the identified upgrades to the online raw material processing equipment enabling it to record and communicate material usage. When implemented these upgrades required extensive accuracy testing that the organization was required to complete within the confines of their manufacturing environment.
Upon completion of the facility and equipment upgrades, Company XYZ was tasked with developing a programmed solution to automate material handling in real time. The key to the programming was to build the link between the equipment data now being collected and the ERP system utilized to automate the issuing of material used in real time into the cost structure of the computer system. Within this project, the program needed to connect to, and then translate, the data collected into real time usage that could be pushed into the company’s ERP system at the time of use automatically. Completing this element would deliver real time reporting elements to the management team and enable the project team to develop systems to utilize the real time data collected online to communicate to production employees and leadership the real time results on line.

**Assumptions of the Study**

This project included multiple assumptions that relied on the company, the process, and technology coming together to create a unique and fully custom solution. The first assumption for successful implementation of the project was that Company XYZ would support this project by implementing necessary infrastructure upgrades and allowing the use of internal resources throughout the development process. In addition, there was the assumption that XYZ’s extrusion manufacturing facility had the infrastructure to support the addition of hard wired cabling to each production line to enable equipment communication through the addition of communication ports at each production line.

In addition to the facility requirements, there was the assumption that the material processing equipment, primarily blenders, currently in place in the production environment could be modified through programmable logic controller (PLC) upgrades to communicate through the network. Given the variety of brands and age of the units in use, success within this assumption
was vital to the projects continued development as purchasing new equipment would require a capital investment that would result in a staged project launch as the company staggered the purchases out over five years.

Once the hardware element assumptions were overcome, the project also assumed that a software solution could be developed to both pull data and also push instructions to the equipment. The project assumed that programming elements would be developed internally that would allowed the data collected electronically to be utilized and communicated to the company’s enterprise resource planning (ERP) system. In addition, once the data was being transmitted, it was assumed that the infrastructure of the company servers and the ERP system could support the additional transactions that would be sent into the system, which was expected to quadruple in volume as a result of implementation.

Definition of Terms

The terms utilized throughout the research and project implementation were focused on the solution development process and technology advances required for successful implementation of technological upgrade including:

**Demand, Measure, Analyze, Improve, Control (DMAIC).** Acronym utilized within the lean six sigma tool box and is a mix of qualitative and quantitative tools utilized to identify the root cause of a problem (Uluskan, 2016).

**Enterprise resource planning (ERP).** Modular database system that creates a comprehensive software database that connects separated organizational functions including material planning, scheduling, and accounting (Kim & Mourtisen, 2013).

**Industry 4.0 (IND4.0).** The fourth industrial revolution which focuses automation and data exchange within a manufacturing environment. The main objective is to create a smart
facility with automated elements of preventive maintenance, physical processing, and decision-making (Lasi, Fettke, Kemper, Feld, & Hoffman, 2014).

**Internet of things (IoT).** A network physical devices with embedded connectivity which allows them to exchange data. Allows equipment to be identified and controlled remotely through the network infrastructure (Lee & Lee, 2015).

**Lean Six Sigma.** Combination of two methodologies that ensures a process becomes lean while also increasing sigma resulting in increased efficiency and quality (Atmaca & Girenes, 2013).

**Machine to machine (M2M).** Communication is the element within IND4.0 that removes the human element of communication and allows equipment to communicate and respond to results without intervention from a human (Jacobson, Spence, & Pan-Wei, 2017).

**Programmable logic controller (PLC).** A computer used for automation within manufacturing equipment. The element within the equipment that allows the equipment to communicate and receive instructions from software solutions (Diego, Rodilla, Carames, Moran, & Santos, 2010).

**Limitations of the Study**

The results of this project were limited to Company XYZ’s extrusion facility and products produced in the extrusion process only. The remaining facilities and products produced utilized different raw materials, material handling systems, and processing equipment so were not considered a part of the project.

The material reporting elements were limited to production lines utilizing blenders for material handling. This limited the raw materials to resins and additives or elements introduced to the process at the extruder. Raw materials introduced later in the process, tape and packaging,
would be issued in real time utilizing the ERP system settings rather than the equipment readings.

Furthermore, only materials processed through the blenders would be reporting in real time. As a result, extrusion lines that do not utilize a blender, or utilize it for only a portion of the total materials processed at the extruder, would have some elements that are not included in the real time equipment material use data. These materials required processing under the manual process.

**Methodology**

The methodology utilized to complete this study is the DMAIC process of project management to develop and implement a real time reporting element for Company XYZ. Utilizing this methodology, the organization’s needs and current capabilities were identified to understand what improvements were required to fully implement a real time material handling process for the organization.

Throughout the define stage the team utilized the voice of the customer to clearly establish the goals of the project and define what success looked like for the project upon closure. This included the development of a detailed project charter to establish primary and secondary metrics while also outlining the resource and time commitment that Company XYZ was required to support throughout the project.

The measure phase of the project was largely focused on identifying and monitoring the key performance indicators to understand the items that were critical to quality. These critical elements were then the foundation for equipment upgrade identification and software development requirements. This stage was also critical in identifying the infrastructure capabilities and limitations so that the organization was able to implement the improvements
necessary to support the access points required and the volume of data processing that the real
time collection system would generate.

Data collected was analyzed and tested both on the hardware and software prior to
launch. Utilizing process maps, the existing process for both the physical material movement
and data movement within the ERP system was outlined to ensure that the real time material
system supported both elements of the process. Equipment upgrades were tested for accuracy to
ensure that material usage measurements met, or improved upon, historic accuracies. Software
was tested in both a development and live environment to identify potential failures and trouble
shoot prior to the full product launch. A focus team was utilized to understand end user needs
and ensure that all potential issues were addressed in development to allow for a successful
product launch.

Improvements were kicked off with a marketing campaign to inform the team members
of the changes coming, why they were needed, and how they could be leaders through the
process. Knowing that there would be challenges, that all potential issues could not be tested
prior to launch, team members were selected and trained to be experts within the new process to
ensure that each shift had resources available to them throughout the launch. As a part of the
failure mode and effect analysis (FEMA) process, system monitoring tools were developed to
ensure that the improve phase of the project was successful at both the hardware and software
level. These reporting tools also brought with them a level of comfort for the executives of
Company XYZ as it enabled them to monitor equipment usage, data trends, and validate the
accuracy of the system.

The control phases for this project focused on use of the control plan to ensure that all
elements of success were met and organizational standards were maintained throughout the
process. Reporting was developed within this phase to focus the extrusion team on utilizing the new data in a proactive way, to drive improvements in a focused, efficient way so that they could have an immediate impact. Through the use of the real time data collected, the organization was be able to utilize the tools to drive better decisions reducing scrap and increasing profitability.

**Summary**

The focus of this project was to implement a real time raw material handling system that linked in with reporting functions allowing for Company XYZ to reduce manual transactions while increasing reporting accuracy in real time. The developed reporting was utilized to facilitate real time trouble shooting and problem solving with in the manufacturing environment. Determining the needs of the organization and available technology was the foundation of the projects while developing a custom solution was challenge as both equipment and technological improvements were required in order to implement the solution.
Chapter II: Literature Review

Without a real time material handling process, Company XYZ’s extrusion business was unable to identify, address, and correct issues efficiently reducing scrap and improving profitability. In search of a solution, the organization became part of a new industrial revolution known as Industry 4.0. This revolution utilizes emerging technologies to transition equipment into communication tools which was needed for Company XYZ to transition to a real time reporting environment.

This literature review is focused on Industry 4.0 technology and the opportunities and challenges this industrial revolution brings to data management, security, and personnel when implementing real time reporting elements within a manufacturing environment.

Industry 4.0

The term industrial revolution is not new to business or manufacturing. In fact, there have been three industrial revolutions over the last two hundred years. The first revolution occurred with the introduction of mechanical production, the second revolution introduced mass production, and the third launched with automated production (Fuchs, 2018). Today the fourth industrial revolution, often referenced as Industry 4.0, is underway. While industrial revolutions date back centuries, Industry 4.0 is relatively new concept having originated in Germany in 2011 (Roblek, Mesko, & Krapez, 2016). In a perfect scenario, Industry 4.0 would mean that a product exists in a fully automatic processes, without human interaction in any step of the product’s life cycle including production, delivery, use, repair, and recycling (Fuchs, 2018).

According to Fuchs (2018), the ultimate goal of a product life cycle within Industry 4.0 is to completely eliminate human interaction, the first step on that journey is the use of technology to automate the exchange of information utilizing the Internet of things (IoT). By 2020 it is...
projected that IoT will reach 50 billion connected devices globally and that the connectivity
gains through IoT will add $3.9 trillion to $11.1 trillion a year in new economic value to
manufactures by 2025 (Toensmeier, 2017).

There are four key elements required within an Industry 4.0 model that allow an
organization to interlink their processes into an autonomous system. These elements include
data, devices, connectivity, and services, which incorporate analytics, networks, machines, and
security under the umbrella of Industry 4.0 (Harrison, Vera, & Bilal, 2016). These four elements
are the underlying elements required to make the transition to Industry 4.0.

**Data Management**

The element of data use within Industry 4.0 is a double edged sword. While there are
significant gains to be made from the effective use of the data now available, there are significant
challenges in managing the data itself.

**Data collection and use.** Within the real time reporting elements of Industry 4.0 there is
the data that will be utilized by managers and leaders to make effective business decisions. For
this element, Industry 4.0 data collection focuses on timely collection of data and dissemination
through visual elements to drive action and advanced analytics (Toensmeier, 2017).

However, collecting and managing data is an ever increasing challenge for organizations.
In 1997 NASA researchers Micheal Cox and David Ellsworth coined the term big data when
discussing the volume of data becoming available and the lack of processing capabilities to
handle it (Geng, 2017). Since the term big data is vague, we can further broken down the term
into four categories including volume, variety, velocity, and value (Geng, 2017).

Volume is easily the biggest challenge to an organizations Information Technology
department due to the complexity of collecting, storing, and sorting the sheer volume of data
now available. As the volume increases, the variety of sources and types of data being collected is also increasing bringing with it additional complexities in managing the data. Storing the increased volume of data will be unrealistic for many organizations resulting in the preservation of data based on need and value (Lee & Lee, 2015).

We utilize data every day in email, videos, webpages, and messaging which we would now consider traditional data but with Industry 4.0 data collected extends beyond these familiar tools to include equipment monitoring data from multiple pieces of equipment, in varying frequency, and coming at different intervals which leads to velocity of data issues and challenges in how it can be processed. With the increased velocity, and variety, of data advanced data mining tools will be required to translate that data into action (Lee & Lee, 2015).

The velocity of data analysis often varies depending on what is being reviewed but, for an organization to transition to Industry 4.0, response time is measured in milliseconds. As manufacturing transitions to an environment in which equipment to make it’s own corrections, it needs to gather, analyze, and respond to the data almost instantaneously.

Finally, the value of the data is essential to the process as the sheer volume of data alone can be almost crippling for an organization infrastructure so it is essential to ensure that the data collected and retained has a value to the organization and is driving decisions. Data for the sake of data will not lead an organization into a productive Industry 4.0 environment.

Data collection and dissemination to the right people, and at the right time, is often a focus of organizational leadership as it is a critical element in effective management and decision-making yet data alone is not enough for leadership to be successful (Toensmeier, 2017). As we have already reviewed that data in and of itself can be a challenge due to the volume, variety, velocity, and value challenges it presents, ensuring that the data we are utilizing the data
to drive decisions is how an organization makes the transition to an Industry 4.0 manufacturing environment. Data challenges facing organizations expand well beyond simply managing the data as they also have to define what data is valuable, who will get information from the data, how they will utilize the data, and how will they use it to make the right decisions (Albert, 2015).

Within Industry 4.0, the process of data collection and use is not only increased in volume and speed, but automation elements within the components allows for machines to make decisions based on the data immediately rather than waiting for a human analysis and response. While increasing response times this process, which is often referred to as on the fly analytics or edge computing, can also be beneficial in reducing the volume of data being transmitted and stored (Thompson, 2015).

The process of pulling, or converting, meaningful information from the data collected is a key element of Industry 4.0 and, in recent years, this element is being completed through the use of detailed algorithms that can utilize the data collected to provide predictive results (Lee, Bagheri, & Kao, 2015). This is where manufacturers see the most gains with the transition to Industry 4.0, decisions being made are better and faster due to data available and speed with which it is delivered. These decisions are now based on facts and results rather than theory or tribal knowledge which means less waste leading to increased profitability (Albert, 2015).

**Devices.** Devices are the tools used to create the network of intelligent equipment within Industry 4.0. Sensors are the tools utilized to detect and measure the processing condition or physical attributes of a product and are key to detection, intervention, and prevention within Industry 4.0 (Albert, 2015). Historically sensors looked for symptoms and would trigger a warning if they detected an issue but with Industry 4.0 there is a transition to an intelligent sensor that identifies the defect and then analyzes the data as a result of the issue and makes a correction
based on the results. As we look for sensors to make decisions, there are some vital questions that must first be asked to ensure the system is set up properly to operate indignantly. Defining what process changes require reaction, what decisions do we allow the sensor data to influence, and what is the value realized from this process are essential first steps to ensuring sensors are utilized in the correct manner for the business (Albert, 2015).

While communication between humans, and between humans and machines, has been common practice for centuries, the focus of Industry 4.0 is adding machine-to-machine (M2M) communication to the mix (Roblek et al., 2016). Utilizing M2M communication to automate processes and data exchange is a fundamental element in implementing an Industry 4.0 strategy within an organization. Through this automated exchange, the equipment without a human interface, directly manages various elements ranging from preventive equipment maintenance to supplier integration.

As Fuchs (2018) pointed out, the removal of the human factor is the key to transitioning to an Industry 4.0 platform. The introduction of machine-to-machine communication is the driving force behind the development of a smart factory, which includes integration of equipment maintenance, supply management, and optimized efficiencies (Pinkham, 2017). Looking at this process in a practical example, a machine utilizing Industry 4.0 technology will monitor hours of use and plan preventative maintenance when required including scheduling the technician and ordering the replacement parts via the internet with no interaction from human resources. This all inclusive process, removing the human factor historically required, is fundamental in making the transition to an Industry 4.0 process (Fuchs, 2018).

**Connectivity.** Connectivity is vital for Industry 4.0 to be effective within a smart factory as it is the link between the device and the data collected (Thompson, 2015). Independent
elements do not allow for the automation of response or the elimination of the human inputs historically required. Equipment must be connected through network systems and wiring to allow for the automation of processes and the dissemination of data collected into decision driving elements. Equipment that has the ability to monitor and record data is limited in value until it is connected to the factory network allowing data to be pulled and pushed electronically. This ability is when the smart element comes into play within the process and the equipment is able to transition to self-contained management. The ability for technology to monitor, control, and even predict outcomes is the path to lower costs and increased productivity within the manufacturing environment (Lee & Lee, 2015).

The smart factory, developed through connectivity, is a key feature of an Industry 4.0 initiative that focuses on the integration and networking of manufacturing systems for smart production. Without connecting the physical equipment like extruders, blenders, and hoppers with the online elements including the ERP system there is a disconnect in the process and an organization is unable to establish a truly smart factory under their Industry 4.0 umbrella (Wang, Wan, Zhang, Li, & Zhang, 2016). Linking the data collected with the devices monitored through a connected facility is how an organization pulls the process together and closes the communication loop on their path to real time information.

**Services.** The term services, within the context of the Industry 4.0, encompasses elements of data access, security, and collaboration. While the three other elements, data, connectivity, and devices, are focused more closely on the way the data is identified and collected with services we focus on how we provide these features to our users (Harrison et al., 2016). This element is much less glamorous than its predecessors but is essential to completing the development of a smart factory in the Industry 4.0 plan.
Team member access to data and ensuring security of the systems is the link that brings the elements together and provides a cohesive system to utilize and build on from a real time reporting standpoint. The services element of completing Industry 4.0 is often behind the scenes so has the potential to be ignored or underappreciated in the process of developing a comprehensive system. However, it is not optional for an organization as failure to complete the services element will break the entire process. In the information driven society there is an evolution leading to dependence on systems and data is only increasing so ensuring access and preventing interruptions is vital to an organizations success.

**Security**

As with any change, there are risks and the greatest risks within Industry 4.0 is to trade secrets, intellectual property, process control, and the potential for data breaches (Albert, 2015). As we become more connected, our challenges change and new threats develop. The Internet of Things (IoT), which refers to the multitude of smart connected devices being utilized, is expected to see market growth to from $655.8 billion in 2014 to $1.7 trillion in 2020 (Wylie, 2016). Transitioning to a highly technical system requires businesses to depend on connectivity services like the internet or other web based systems that open the organization to new risks. As a result, an organization must pay more attention to their cyber security as they increase connectivity within their manufacturing process or face grave consequences that reach far beyond system down time (Wylie, 2016).

Cyber attacks are ever present and organizations must be prepared to defend their systems while still allowing the level of data access required for their systems to operate as intended. While there are risks with these new services required for functionality, there are also benefits as they open up opportunities for data exchanges with customers and vendors previously
limited. Data sharing through online services further automate the process and allow for additional opportunities to remove the dependence on human interaction for structured, predictable elements.

There are a multitude of risks to an IoT system due to the variety of components making up the system including applications, network components, software, firmware and the machines utilized to support the system (Khan & Salah, 2018). As a result, an organization must have a multi-pronged approach to security to support their IoT system and ensure no disruptions within their organization.

Technological advances are often discussed in relation to how people are impacted, the ease with which we are able to connect with people, access data, and expand our understanding of our world. Industry 4.0 utilizes those same advantages and applies them to equipment creating an environment where machines are self-sufficient and interlinked with other equipment creating an all-inclusive communication circle that allows for automation and instant data application without the human interaction historically required. While this is often what we see on the front end of a process, what is happening behind the scenes to ensure security is critical to ensuring an Industry 4.0 environment that is sustainable.

As we become more dependent on our information we become more vulnerable as well. This is a significant challenge for manufacturers making the transition to an Industry 4.0 environment as you must invest in the the equipment and infrastructure to support the system but can not forget the personnel required to ensure security.

**Personnel**

Empowering people is an essential element of success within an Industry 4.0 environment. While removing the human factor from the process is an element within Industry
4.0 that is not to say that human beings won’t be critical to the overall success of the organization as it transitions under this new industrial revolution. The truth is that humans will continue to be key elements with the manufacturing environment, just in different ways than historically seen as the job changes as the workflow changes (Albert, 2015).

As manufacturing moves forward with increases automation the roles of personnel will change and evolve into roles that focus on analytics and programming rather than direct labor tasks. It is estimated that the United States would require an additional 1.5 million employees with analytical skills to process the data and make data driven decisions (Lee & Lee, 2015). This is not a new concept to industrial revolutions as we’ve seen changes in the role people play in production throughout the previous industrial revolutions. However, as we transition from an industrial to an informational society we will see a significant evolution in the expectations for employees (Kiesel & Wolpers, 2015).

In the new age of data three skills are increasingly in demand for employees: communication, problem-solving, and team work. Throughout the transition to Industry 4.0 these skills become a greater emphasis as roles transition to analytics and away from specific task oriented roles within manufacturing. This is not only true at the production level but is also seen in management roles and expands the desired skills to include collaboration, creativity, self-regulation, and reflective learning (Kiesel & Wolpers, 2015). As personnel transition within the data heavy environment of Industry 4.0 the need for enhanced education and evolving skills will continue to develop in order to ensure the data collected is making the transition to better decisions leading to cost savings for an organization.

Utilizing this revolution, and the newly acquired access to real time data, opens the door to new real time costing models. Many manufacturing businesses are used to a backwards looking
cost analysis that utilizes variance and historic data to evaluate performance. However, with data gathered in real time, pushed from the equipment processing, the potential to transition to a reactive costing model is not available for businesses to utilize. Reviewing costs in real time allows for quick response, corrective action, and improved results that post mortem reviews do not allow. Given the increasing competitive marketplace, understanding and controlling costs, is critical to an organization’s long term success (Dragoo & Letendre, 1994). Traditional cost accounting systems do not provide a direct link to production metrics as they are also often post mortem reviews after costs have been incurred and do not provide a real time look into live data (Wouters & Stecher, 2017).

Real time costing for a manufacturing organization can provide up to the minute information on scrap, material availability, labor demand, equipment utilization, and inventory turns. Utilizing this data the organization can reduce their investment in finished goods and raw materials while also being proactive should issues arise. Knowing that a line is experiencing increased scrap in real time allows for focused engineering support and responsiveness from support functions as well. While standards estimate material, equipment, and labor demand, real time data allows for actual, live data to be available and driving the decisions enabling the organization to reduce unplanned down time or inefficient uses of labor and raw materials.

The ultimate goal of all data collection is to ensure that the right information is with the right person at the right time so that the best decisions can be made, and quickly (Zhang, et al., 2012). Data for the sake of data will not drive down costs, improve supply management, or increase profitability so linking available data to metrics to monitor and improve results is a vital element to incorporate within a data collection plan. Having these items in real time is what
enables managers to link the data to metrics and allows for impactful decisions that influence the metric results immediately.

However, simply burying users with numbers and data is not an effective way to utilize the volume of data now available. Teams must identify the relevant data and then prepare and present it in a intuitive manner. Dashboards are a quick means to display a significant amount of data in a clear and visual manner. Enabling users to visually monitor results in a concise manner allows for them to focus on the implementation of improvements rather than the dissection of data. Creating a process that simply overruns the users with data is counterintuitive to the goal of increased efficiencies. Effective data is key to linking results with metrics and driving decisions that generate results immediately impacting performance.

Given that this is a new approach, only made available with the implementation of Industry 4.0 elements of communication and connecting, change management is a critical element of the data collection and use process. Removing the human interaction from a process can, and will, cause discomfort for employees which is why a strategic approach to change management when identifying and utilizing the data collected for real time analysis is critical to the long term success of the process (Dragoo & Letendre, 1994). While there will be a reduction, or elimination, in human inputs, a new role will develop for employees under Industry 4.0 that focuses on different, value added activities, that will lead to a significant increases in workplace learning (Kiesel & Wolpers, 2015). The development of increased analytic roles for employees, with greater demand for critical thinking, will offer new opportunities as an organization makes the transition.
Summary

Industry 4.0, and the link it provides to real time data, will continue to be a driver in business success. As the global marketplace becomes more competitive it will become increasingly more important for organization to understand their performance and be able to influence results in real time. How each organization accomplishes this may vary but the end result will be the same, connected technology that reduces human inputs and enables proactive data to drive activities in real time impacting results immediately. Developing the skills to support this new environment will be essential for an organization going forward and involves much more than installing a piece of equipment.

Beyond the equipment, or devices, required to gather data there needs to be significant focus on managing the data collected ensuring value added data is in use, that data is secure, and that the data is accessible to users in a meaningful way. Adding to the complexity of the issue is the fact that all elements must be secure from outside threats which is a unique challenge for organizations, making system accessible but also ensuring security is a complex challenge.

As organizations move to Industry 4.0 there work force will evolve to meet these challenges as well and being prepared on all front of this fourth industrial revolution is challenging for any organization. With technology developing each day, predicting where the next opportunity or challenge will arise is now a critical element within developing and maintaining a comprehensive Industry 4.0 platform.
Chapter III: Methodology

Without a real time material handling process, Company XYZ’s extrusion was unable to identify, address, and correct issues efficiently reducing scrap and improving profitability. However, with the introduction of Industry 4.0 elements there are opportunities for the company to move forward with real time material management that would allow the organization to improve scrap results driving the desired profitability gains. This chapter reviews how that transition took place for the organization and lays out the process utilizing the DMAIC (define, measure, analyze, improve, and control) approach.

Selection and Description

Company XYZ made the decision to begin making the transition to Industry 4.0 and defined step one of that process as implementation of a real time material handling system. The objective for the company is to capture material volume use in real time, during live production, and utilize that information to calculate accurate, current costs to produce, material scrap percentages, and material stock levels.

The DMAIC process was utilized by the organization to define, measure, analyze, improve, and control the launch of the real time material reporting project within the production environment and ensure that the process yielded the desired outcomes for the organization.

Define

Company XYZ did not have a real time material use process as their previous system depended on manual data collection and entry into their ERP system after the fact. Utilizing available technology, the organization was looking to automate the recording and issuing of material used in real time. The recorded data would report real time material inventory management, scrap reporting, and cost reporting within their extrusion facility. The objective of
this project was to define available technology to capture and record the live data, update
equipment to the required Industry 4.0 standard, and develop software that would record the
data, manage inventory, and report performance metrics.

**Measure**

Inventory accuracy was identified as the primarily critical element within the process.
An automated system, to record and process material transactions, must be accurate to ensure
inventory accuracy throughout the plant. Errors within the system would result in stock
shortages or an abundance that would effect on-time deliveries, production execution, and
inventory control. Understanding this requirement, it was necessary to first understand current
capabilities as the equipment used to weigh and track material use would not be changing. The
organizations current blenders would remain in use, simply be upgraded to an Industry 4.0
standard that would allow them to communicate out and receive data in. To ensure that the
equipment was capable of managing an automated process analysis was done on the current
process accuracy. For this analysis, the focus was on current weight readings and the margin of
error within the scale readings to ensure that changes would yield similar results or, if that was
not possible, to document and understand the differences. This was accomplished by manually
feeding material through the system and comparing recorded weights at the beginning and end
with the objective being to document the margin of error within the existing process.
Understanding that errors identified would be consistent with errors previously present, the team
still needed to define the error factor as automation would remove the human interaction that had
previously identified and adjusted for errors.
Analyze

The first step in making the Industry 4.0 transition in material handling was to identify the technology available to determine if the existing equipment could be retrofit to be intelligent enough to receive and transmit data. Through online research, and discussions with equipment manufacturers, the team identified an add-on through Anybus that would enable the blenders to be upgraded as needed to accomplish the requirements of this project.

However, prior to upgrading the equipment the team did additional analysis on blender accuracy. These trials consisted of manually feeding fixed pounds of material through the blenders and recording their readings to ensure that the pounds entered equaled those measured. Initial trials consisted of ten small 50 pound test with varying materials and densities. Once these were completed, and demonstrated sufficient accuracy, the trials expanded to larger scale in which 800 pounds of the top three materials; polyethylene, polystyrene, and ABS, were fed through the blenders and the recorded pounds were monitored throughout the process. The results of each trial were documented and the material processed re-weighed upon completion for a final verification of the pounds in as compared to the actual pounds out. Once the equipment was verified and deemed acceptable, at a .005% error rate, the equipment was upgraded.

Improve

Once the equipment was upgraded and able to communicate, it was time to improve the process through the development of software that would enable the automation of material pounds process and the action of recording, issuing, to the work order in real time. This technology did not exist so needed to be developed internally by the team. Utilizing the current
process experts which included production personnel, material handling team members, and the business systems team it was identified that the process was a three step system.

The first step was to develop an electronic set up sheet that enabled the production team to assign the blender and material in use to a work order. Set up sheets for each work order were printed pieces of paper on which production personnel would manually document parameters in writing. These forms would be reviewed by team leaders at the close of the work order to ensure any updates were completed and then filed. In order to ensure an electronic system could operate it was determined that the paper forms had to be replaced with an electronic system that could be accessed by the software to identify the blender in use on a specific order to ensure accurate material monitoring and issuing.

![Figure 1. Example of electronic set up sheet.](image)

The second phase was to create the programming process that would read the blender data, issue it to the work order running, and clear the blender at planned intervals to ensure inventory accuracy. Software was developed that linked the ERP system with the online data to record and process transactions from the blenders utilizing the set up sheet data. Due to the custom nature of the business this was a completely unique and specific system designed for
Company XYZ by their internal Business Systems team. The system recorded the pounds processed and issued it to the work order twice a day or at the close of the work order. Given the length of some orders it was important that the system have periodic work in process issues to ensure inventory accuracy on the demand side so that the purchasing team could monitor use versus stock to avoid stock out situations. In addition to monitoring and issuing the material used the system also cleared the blenders and re-set them after each issue so two way communication to the equipment was essential to an all-inclusive data solution. Testing was completed in a test environment to ensure that the software could receive data from the equipment and that the equipment could receive instructions from the software accurately. Once success was documented within the test environment, the system was tested, in limited release, in the live environment. During the transition to the live environment challenges with firewall and IP addresses were encountered and overcome through testing and retesting at various user stations. Upon completion of testing, the system was launched plant wide and monitored to ensure continued accuracy and a successful launch.

Finally, in the third step, it was critical to develop the tools necessary to monitor the system and process to ensure the control phase was successful. When transitioning to a new process, change control is essential to ensure users have confidence in the new process and understand their impact within the process. Making the transition to electronic material system would require checkpoints in both the manufacturing and office environment. These tools would be the base for the control phase of the system.

**Control**

To ensure the system accuracy and continued success tools were developed with in the software to allow for constant monitoring and alerts should systems error out. The control
measures implemented included manual, automated, and monitored reporting. The manual process required online visual checks for material pounds being used and the material assigned within the set up sheet. These checks relied heavily on personnel from both the production environment and the material handling team to ensure accuracy.

Automated elements to the system and reporting focused on pushing information to users. In the production environment, to add a level of control beyond a visual check, the team implemented a computer program element that enabled them to lock down the manufacturing team’s ability to report product without accurately completing the set up sheet as required to monitor and issue material. The system required the material selection and equipment use be completed on the production set up sheet prior to production employees being allowed to scan product to inventory or generate a label. Taking away the ability to report finished goods was a more controlled method for ensuring the required elements were completed than a visual check.

To ensure that equipment malfunctions were identified and addressed immediately, emailed alerts were developed and automatically distributed to the both the engineering and manufacturing teams impacted if blenders were offline but recording material and/or the line status was in production. In addition, issue verification emails to the system management team were implemented when material issues were processed at the close of a work order and during the automated times, 9 am and 3 pm, for work in process transactions. These emails allowed the team to quickly identify potential errors and investigate immediately rather than at the close of a work order which increased the effectiveness of the review.
Figure 2. Example of data distributed for errors in material issues.

Control methods that required monitoring were also developed to allow for enhanced management of the system and review of data processed to ensure accuracy. These tools focused on quick identification of issues and aided in troubleshooting potential issues as they arise in the live environment. An online blender monitoring page that included the blender identification, where assigned, last communication, and allowed for a reset should the communication module go offline were developed for leadership use to ensure the team could quickly troubleshoot any blender communication issues. In addition, a material handling website was developed that allowed the material handling and purchasing teams to monitor material online and work orders that closed to quickly identify potential issues, specifically over or under issues of raw materials.

Utilizing these many tools team members were able to monitor and validate the system throughout the launch phase and into the maintenance phase. The system was audited quarterly for materials as a part of the cycle count system as well to ensure continued accuracy. In addition, audits are regularly planned to identify areas for continuous improvement as a part of the project management process.

Summary

Industry 4.0, the fourth industrial revolution, focuses on the use of technology to transition equipment into self-sufficient units that are able to process and receive data automating previously manual tasks. Company XYZ has identified the automation of their material processing as their first step in implementing an Industry 4.0 system within their extrusion
facility. Key elements within that process included equipment upgrades, software development, and system monitoring tools to ensure accuracy when removing the human element. Utilizing the DMAIC process a cross-functional team upgraded equipment and developed custom software to automate material use tracking and the issuing of raw materials. Removing the human transaction element provided the organization with real time use to track in process scrap rates and production costs. Utilizing this new information the organization developed a proactive corrective action team to address production issues in real time allowing them to reduce scrap and increase profitability plant wide.
Chapter IV: Results

The focus of this project was to develop a real time material handling process for Company XYZ’s extrusion facility as this would enable the organization to identify, address and correct issues in real time thus reducing scrap and improving profitability. The historically utilized material handling process required manual entry which caused significant delays in data collection and challenges in dissemination of the data. Given that developing an automated process would require new technology and software development the DMAIC process was utilized to define, measure, analyze, improve, and control the development of a new material handling process. This chapter will review the results of each step on the analyze, improve, and control elements of the DMAIC process outlining how they were utilized in the development of an automated material handling process.

Analyze

Inventory accuracy was a critical element within the material issuing process and moving to an automated system presented concerns in the form of potential errors that would be compounded with the removal of the manual checks in place. To ensure that the equipment scheduled to be upgraded, which would allow for automated communication, met the accuracy requirements of the business, manual tests were completed to compare pounds physically processed through the blenders and the readings recorded by the system. These weight tests were completed by manually feeding fixed amounts through the blenders and recording the results to determine the level of error. In Table 1, the results of 50 pound material tests were recorded to form the basis of the accuracy.
Table 1

*Blender 50 Pound Material Weights Recorded by Resin*

<table>
<thead>
<tr>
<th>Trial Number</th>
<th>Polyethylene</th>
<th>Polystyrene</th>
<th>ABS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>50.01</td>
<td>50.01</td>
<td>50.00</td>
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<tr>
<td>2</td>
<td>50.00</td>
<td>50.00</td>
<td>49.95</td>
</tr>
<tr>
<td>3</td>
<td>49.98</td>
<td>49.95</td>
<td>50.02</td>
</tr>
<tr>
<td>4</td>
<td>50.05</td>
<td>50.05</td>
<td>50.05</td>
</tr>
<tr>
<td>5</td>
<td>49.99</td>
<td>50.00</td>
<td>50.06</td>
</tr>
<tr>
<td>6</td>
<td>50.00</td>
<td>50.01</td>
<td>49.95</td>
</tr>
<tr>
<td>7</td>
<td>50.01</td>
<td>50.00</td>
<td>49.98</td>
</tr>
<tr>
<td>8</td>
<td>49.98</td>
<td>49.97</td>
<td>49.97</td>
</tr>
<tr>
<td>9</td>
<td>50.00</td>
<td>50.04</td>
<td>50.05</td>
</tr>
<tr>
<td>10</td>
<td>50.00</td>
<td>49.99</td>
<td>49.98</td>
</tr>
</tbody>
</table>

Upon completion of the 50 pound tests it was determined that the accuracy level appeared adequate for automation. Prior to upgrading, to ensure that the accuracy would carry through to production volume material transactions, the decision was made to expand the test to larger amounts of material processing to ensure the accuracy was maintained as larger quantities were measured and recorded by the equipment. In Table 2 the results of 800 pound tests are presented.
Table 2

*Blender 800 Pound Material Weights Recorded by Resin*

<table>
<thead>
<tr>
<th>Trial Number</th>
<th>Polyethylene</th>
<th>Polystyrene</th>
<th>ABS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>800.20</td>
<td>800.00</td>
<td>800.10</td>
</tr>
<tr>
<td>2</td>
<td>800.00</td>
<td>800.10</td>
<td>800.10</td>
</tr>
<tr>
<td>3</td>
<td>799.85</td>
<td>799.90</td>
<td>800.20</td>
</tr>
<tr>
<td>4</td>
<td>800.15</td>
<td>799.80</td>
<td>799.80</td>
</tr>
<tr>
<td>5</td>
<td>800.00</td>
<td>800.35</td>
<td>799.90</td>
</tr>
</tbody>
</table>

With an accuracy level of .005% or better, as demonstrated in Table 2, the organization determined that the blender accuracy level was sufficient to support an automated process at production volumes. This allowed for the removal of the human element within the manual material issue process and enabled for the automation of the material transactions within the ERP system. As a result, the blender upgrades were approved which allowed for two way communication with the blender systems from the software solution. This communication would enable the system to read material use in real time, issue material as processed to the work order, and zero blenders after issuing the material. This communication element was the foundation of the automated transactional process within real time reporting. Upon completion of this element of the project, focus shifted to software development, or the improve portion of the DMAIC process utilized throughout the project.
Table 3

Percent Error within Blender Weighing System

<table>
<thead>
<tr>
<th>Material</th>
<th>Total In</th>
<th>Total Out</th>
<th>Percent Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyethylene</td>
<td>500.00</td>
<td>500.02</td>
<td>0.004%</td>
</tr>
<tr>
<td>Polyethylene</td>
<td>4000.00</td>
<td>4000.00</td>
<td>0.005%</td>
</tr>
<tr>
<td>Polystyrene</td>
<td>500.00</td>
<td>500.00</td>
<td>0.004%</td>
</tr>
<tr>
<td>Polystyrene</td>
<td>4000.00</td>
<td>4000.00</td>
<td>0.004%</td>
</tr>
<tr>
<td>ABS</td>
<td>500.00</td>
<td>500.00</td>
<td>0.002%</td>
</tr>
<tr>
<td>ABS</td>
<td>4000.00</td>
<td>4000.00</td>
<td>0.002%</td>
</tr>
</tbody>
</table>

Improve

Due to the unique nature of both the business processes, and the reporting needs of the business, software was not readily available on the market that would allow for Company XYZ to transition to an automated material handling process. As a result, the team was required to develop software that could communicate with the online material handling blenders in a manner that allowed for material to be pulled from the equipment while also pushing information to the equipment. The first step in the process was the development of electronic set up sheets as these would accurately identify which blender was in use on each individual line and allow for identification of the materials within the blender hoppers as well. Figure 3 shows the set up sheet equipment detail at a high level outlining the equipment identification, including the blender as BLM06, which is utilized by the software to ensure that readings from BLM06 are transferred to the work order, 20758, as linked within the set up sheet.
Figure 3. Sample electronic set up sheet equipment master page.

Due to the complexity of the business, multiple materials were utilized at the same time and processed through the same blender. However, each material was processed through an individual hopper within the blender so it was ensured that each hopper weight was recorded and managed through the software. To ensure that each material utilized was issued correctly, the electronic set up sheet system developed required that the materials be assigned the hoppers with in the set up sheet. In Figure 4 the material source options are identified by the material, BL505PEL, under the title hopper and the actual hopper. Figure 4 also demonstrates the integrated error checking process that highlights items not matching and requiring production attention.
Figure 4. Example of hopper assignment within the set up sheet process.

Each material listed required a hopper be assigned with in the set up but also required material location identification to ensure inventory accuracy within the physical locations. Materials could be sourced from two locations; direct feed from a silo or from the production line. Each silo and production line was set up as a unique inventory location to ensure that the system could clearly track where the material was originating from, Figure 5. For ease of use within the software it was established that if a silo was not identified the system would look for the material within the production line location. This information was also added to the parameters within the set up sheet to ensure that the software knew not only what was being used but the location of the material. This element was critical to ensure that the system issued the correct pounds of each material used to the correct work order and from the correct location.
**Figure 5.** Unique ERP warehouse locations for each production line and silo.

Tracking material usage by location was also completed to ensure that material lot trace was maintained as material lots were tracked through the location of the material within the ERP system. Maintaining the lot trace was a critical quality element of the process as customer product certifications required this information to ensure that issues could be traced back to their origins and properly addressed should recalls be required.

Upon completion of the electronic set up sheets, the software team transitioned to programming the required elements to push and pull information from the blenders. To be successful the software needed to pull the pounds used, in real time, and issue them to the work order in production while relieving the inventory from the correct location and lot. The system also needed to push a reset to the equipment so that it could start recording again from zero upon issuing a reading. Programming was written to complete both these functions within the production software with the addition of monitoring tools that allowed the production leadership...
and online team to monitor both the system and their data entry accuracy since the system relied so heavily on the set up sheet inputs.

Given that the majority of the data was utilized online to assist the production team with effective decision making it was critical that the team have the monitoring tools to ensure success within the system. As a result, additions to the production software elements were developed and implemented that allowed for visual monitoring of the set up sheet choices and material issues taking place. These elements were placed on the work order home page to ensure visibility and monitoring by the production team. An example of this is demonstrated in Figure 6.

![Figure 6](image-url)

**Figure 6.** Enhancements to production page outlining set up sheet selections and material issues.

Within the visibility on the home page, as outlined in Figure 6, blender tools were added that included a manual clear feature, the ability to change materials during the work order, and an option to start recording should the system go offline and require a manual reset. These features are demonstrated in Figure 7.
Figure 7. Example of production material use within the blender and hopper.

Expanding on the enhancements to production data, tools were developed within the production tracking software that provided visibility into the system and that also provided hard stops should critical information be missing. In Figure 8 and Figure 9, potential errors are identified, called out to the production personnel, and do not allow for product to be reported to inventory until they are corrected on the set up sheet. By implementing this level of control it was ensured that equipment and material in use were both accurate prior to production starting which eliminated the potential for errors in material issues and cost reporting.

Figure 8. Example of material BL392 error on the set up sheet disabling scanning of finished goods.
The hopper and silo information available online, as demonstrated in Figure 9, also provided a direct link to the set up sheet system which allowed for quick access to make the required changes without overburdening the production team with data tracking tasks. While accurate data was essential to the success of the automated process, ensuring that the required identification and maintenance of the system was not a burden to the personnel operating the production line was critical to the long term success of the project.

![Figure 9. Example of duplicate hoppers identified on the set up sheet.](image)

Monitoring the systems push and pull process was the key element within the control phase to ensure accuracy was maintained and that any issues were quickly identified and corrected as production was continuing in a live environment. However, that burden did not only fall to the on line personnel so additional control elements were developed that allowed management, engineering, and procurement to monitor the system and address any identified issues quickly.

**Control**

Completing the transition to a fully automated material issuing process required the removal of the human transactions previously utilized in the process. These human transactions were also viewed as review opportunities by the organization so developing control methods that
provided continued monitoring and review were critical to the leadership team prior to making the finalizing the transition and removing the human control element of the material handling process.

Due to the reliance on the blenders, for the overall success of the system, the first element developed to ensure control was a device monitoring website. This allowed for engineering to identify which equipment was in use and when it last communicated with the software. In Figure 10 an example of the monitor in real time identifies the information engineering would utilize to quickly identify potential issues if concerns were raised by the production team.

![Device Monitor](image)

**Figure 10.** Example of device monitor website for engineering analysis.

While the device monitor was an excellent resource for the engineering team it was also determined that control features should push data to the users to ensure quickly responses. To meet this requirement the programming generated an automated email that outlined the lines in production and their status through color coding. Work order numbers that were highlighted in green were in a run status while yellow meant that they were in delay. Work orders in delay were most likely not processing material so allowed for the team to quickly focus on work orders running production that were having an issue. In the example in Figure 11, the production line
H06 is running work order number 20450 and the blender is not communicating. This email would trigger the engineering team to quickly address the issue on the production line or within the software to ensure communication is established as soon as possible.

<table>
<thead>
<tr>
<th>Attention Required</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>This message was sent from: AutoRun</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Blender</th>
<th>Material</th>
<th>Quantity</th>
<th>Location</th>
<th>Lot</th>
</tr>
</thead>
<tbody>
<tr>
<td>BLM04</td>
<td>Un-Assigned</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BLM05</td>
<td>H07</td>
<td>(20108$1$0$0$10)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BLM06</td>
<td>H06</td>
<td>(20450$1$0$0$10)</td>
<td><strong>Blender Not Communicating</strong></td>
<td>3/29/2018 8:51:50 PM</td>
</tr>
<tr>
<td>BLM07</td>
<td>H06</td>
<td>(20428$1$0$0$30)</td>
<td></td>
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</tr>
<tr>
<td>BLM08</td>
<td>H08</td>
<td>(20427$1$0$0$30)</td>
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<td>Un-Assigned</td>
<td></td>
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<tr>
<td>BLM22</td>
<td>I12</td>
<td>(20291$1$0$0$10)</td>
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<td>BLM23</td>
<td>I13</td>
<td>(20700$1$0$0$30)</td>
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<td></td>
</tr>
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<td>BLM24</td>
<td>H04</td>
<td>(20593$1$0$0$30)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 11.** Automated email outlining blender assignments and status in real time.

The second element required in control, to ensure accuracy of the system, was focused on the material issued to the work orders. Accuracy in both quantity and lot trace were critical to the costing, inventory, and quality elements of the system. To add a level of control within this process automated emails were developed that triggered when issues occurred so the quality and inventory management team had an opportunity to review and track any issues identified. In Figure 12, the automated email for BL21 outlined the material, quantity, location, and lot issued to work order number 20422.
Finally, to assist in work order review at close, and to assist the material handling team in material location monitoring, a website was developed that identified the material on each line, the work orders running, and allowed for the team to quickly transfer material to and from lines in real time. For researching any inventory in accuracies the page also included a summary of closed work orders with a comparison of the material quantity required and the quantity issued. With material costs representing up to 70% of the product cost this element allowed for quick analysis of over and under issues. The production team utilized this information when reviewing closed work orders to understand what costs drove the financial results. Figure 13 is an example of this page that was developed as the interface that the materials management and production team would utilize for inventory control and work order analysis.
Summary

The manual material issue process, previously in place at Company XYZ, did not allow for real time data collection, analysis, or corrective responses. The DMAIC process was utilized to analyze the current process and improve upon the process through the development of a material issuing process that utilized automated machine communication and software developments to automate the material issuing process. To ensure control of the system, additional modules were developed that provided opportunities for the production support team to pull equipment and material information while also pushing, through automation, information to the team for review. These tools were a critical part of the last step in the DMAIC process; control. Ensuring that the automated system was functioning accurately was the final requirement prior to removing the human transactional element of the previous system and key to the automated systems successful launch.

Figure 13. Material management website.
Chapter V: Discussion, Conclusion, and Recommendation

This project developed and implemented an automated, real time material handling system with report elements for Company XYZ’s extrusion facility. Utilizing the DMAIC process an automated material handling process was designed and developed to replace the manual process previously in place. The new system utilized equipment communication, rather than human inputs, to push and pull data from the live production environment and report that activity to the ERP system resulting in real time inventory and cost reporting for the leadership team to utilize in the reduction of overall costs.

Chapter I discussed the technological advances that would need to be achieved in order for the project to move forward. These challenges included equipment upgrades that would support two-way data communication, facilities upgrades to support the volume of data exchanges, and the development of a custom software solution that could translate the data collected to the ERP system. With the introduction of Industry 4.0 new technological advances were now available that would allow for the organization to develop smart equipment. In addition, improvements to the intranet would allow the organization to continue developing Industry 4.0 technologies beyond the material handling system. Finally, the development of the custom software allowed for a fully integrated and completely custom solution. The team utilized the DMAIC process to manage the process and ensure a comprehensive solution was put in place meeting all of the project objectives upon completion.

Chapter II reviewed the literature related Industry 4.0 and both the opportunities, as well as, challenges that the fourth industrial revolution represents for data management, data security, and personnel. Within data management, challenges to overcome went beyond how to collect and use that data to include how to manage and store the volume of data now available. Sorting
through the multitude of data points to find the relevant ones and utilize them in a meaningful way is the key to successfully managing the data. Once collected, securely disseminating the data within the network was critical due to the organization’s competitive environment. Finally, transitioning personnel from transactional to analytical is a vital part of transitioning to an automated environment. Understanding these essential tasks within Industry 4.0 established the project’s basis for transition.

The focus of Chapter III was the use of the DMAIC process in the development of an automated material handling system. Defining success was the first element in the design of the final product and the define stage was utilized to clearly establish the objectives and timelines which were the basis for the project launch. As the team transitioned into the measure phase of the project, the focus transitioned to the maintenance of inventory accuracy throughout the process. The development of a standard, based on the current equipment capabilities, and the impact equipment upgrades would have on that standard, was the primary goal of this step of the measure phase. Upon completion of the foundation steps, define and measure, the focus shifted to the analysis of needs, improvement of processes, and control measures required within the new material handling system. These three elements included the development of a supporting software foundation, integration of data within the ERP system, and the creation of reporting tools that the production and support teams would need to utilize the data and drive the projected improvements in real time.

Chapter IV outlined that particular emphasis was placed on the analyze, improve, and control phases of the DMAIC process to ensure that the real-time material handling process allowed the organization to identify, address, and correct issues in the live production environment thus reducing material scrap and improving profitability. Development of
improved system reporting functions bridged the gap between data and action by clearly presenting the material use and scrap data to personnel in a meaningful manner. The elimination of the human transactional process meant also eliminating built-in check points so it was essential that the system developed control checks that forced the required inputs to be completed to ensure accuracy. Examples of the software solutions, both automated and manual, were outlined to demonstrate the checks and balances developed within the new automated material handling process.

Finally, in Chapter V, the limitations of the project were revisited while both conclusions and recommendations are discussed to outline what further enhancements or system developments could be implemented now that the foundation has been developed.

**Limitations**

The results of this project were limited to Company XYZ’s extrusion facility and products produced in the extrusion process only. As the remaining facilities utilized different raw materials, material handling systems, and processing equipment this limitation had no impact on the projects timeline or success.

The material reporting elements were limited to production lines utilizing blenders for material handling. This limits the raw materials to resins and additives or elements introduced to the process at the extruder. Due to this limitation the team had to address the other materials to ensure real time costing was accurate. As a result, raw materials introduced later in the process, tape and packaging, were issued in real time utilizing the ERP system settings rather than the equipment readings.

Finally, only materials processed through the blenders would be reporting in real time. As a result, extrusion lines that do not utilize a blender, or utilize it for only a portion of the total
materials processed at the extruder, would have some elements that are not included in the real
time equipment material use data. These materials required processing under the manual
process. To clearly identify these lines to the team, so that data integrity was not compromised,
online scrap tools outlined the pounds issued by each material so that unissued materials were
clearly identified during process reviews.

**Conclusions**

Through the literature review, technological changes brought forth by Industry 4.0
highlighted opportunities to develop real time reporting elements while also outlining potential
challenges within the technological advances. Identifying potential equipment upgrades that
would create smart elements, which could send and receive data, was essential in making the
transition to an automated material handling system. However, ensuring that the developed
software could narrow the data scope to relevant information and then apply that information in a
secure and meaningful way for personnel to utilize was the link that changed data into action.

While developing an accurate and efficient automated process was the primary focus of
the project, managing the affected personnel through the change was essential to ensuring the
process was sustained beyond launch. Including affected personnel in the DMAIC process
ensured that the process was clearly defined while also building advocates for the change
planned. Testing in the live environment provided opportunities for the extended team to have
hands on experience with the software prior to launch and to take ownership in development
elements. Developing additional systems experts was an added advantage during both the
development and launch of the software. Demonstrating the advantages of the new process, and
laying out additional value added activities that impacted personnel would be taking on, assisted
a successful launch of the system.
Collecting and utilizing real time material use data enabled the organization to identify issues and troubleshoot in real time, improved management of inventory levels, and allowed for the repurpose of team members to new value added roles. Through internally developed software the organization was able to focus support efforts and drive improvements. Identifying issues with material use, primarily increased scrap, allowed for engineering and production personnel to narrow their scope and focus attention on specific products and processes. Doing so in real time allowed for in-process trouble shooting to ensure issues were addressed immediately and solutions were documented for future use. Improved management of inventory allowed for the procurement team to better manage inventory space and ensured that work orders with higher than planned scrap were supported with additional material allocations. Finally, redirecting personnel, previously performing manual material transactions, allowed for additional analytical review and professional development of the team.

**Recommendations**

Building off the success of this projects ability to implement real time equipment communication opens up limitless possibilities for Company XYZ. With the infrastructure in place to support continued data growth the organization is positioned well to continue the focus on Industry 4.0 development. Continuing to automate information and processes will open up new opportunities for cost reductions, employee development, and modernization of the facilities.

In order support the continued development of data collection and dissemination it is recommended that Company XYZ ensure that equipment upgrades are a focus for capital investments. Continue to expand on Industry 4.0 efforts by upgrading additional equipment within the extrusion facility as these efforts will further assist in controlling the processes.
Extruders should be a primary focus due to the direct impact on the overall process and quality of the products. Improving the control at the extruder level will improve the consistency in finished goods and allow for better management of the process thus reducing variability.

As Company XYZ continues to grow and expand it is likely to replace existing equipment or purchase new equipment. To aid in this process it is recommended that a checklist be developed to ensure that all equipment purchased has the Industry 4.0 elements to support communications and is compatible with their systems. Utilizing a cross functional team from procurement, engineering, and information technology team will ensure that new equipment meets the needs of the organization in a functional and technological manner.

Company XYZ needs to continue to build on the success of automating the material handling system by continuing to automate processes within the organization. Identify other processes within the organization that rely heavily on human transactions and work to streamline and automate those systems as well. For example, the shipping and receiving process continues to be manual with significant opportunities to automate and reduce the human transactional elements.

As the organization continues to develop new processes and system improvements it is recommended that they develop marketing tools for each launch to assist in managing through the change. Clearly communicate to impacted team members on how, when, where, and why so ensure that obstacles are addressed early and the change is managed appropriately. Include team members throughout the DMAIC process to build advocates for the changes which will assist in successful launches.

Going forward it is also recommended that Company XYZ utilize the systems and knowledge gained through this project to expand the automated real time material handling
process to other facilities. Each facility has different materials and processes but would benefit from real time data so, while the solution may need to be modified, the benefit remains.

Finally, the organization should implement an internal audit system to verify the material handling process, and all other developed automated processes, continue to operate as planned and ensure that they are upgraded as the needs of the business change. Maintaining strong systems that support the business needs is critical to the continued success of the organization in the competitive manufacturing environment.


Toensmeier, P. (2017). The industrial Internet of Things is enhancing productivity & profitability: In the digital age, nothing seems impossible, especially when it comes to improving operations with cyber-physical systems such as IIoT. *Plastics Engineering*, 73(7), 54-58.


