The Value of Digitizing Manufacturing Environments

by

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Abstract

There is significant variability and dispute around the value of digitally transformed manufacturing environments and no single methodology is broadly accepted. The variability stems from time-dependencies, implementation effectiveness, and the dynamic environments digital solutions are deployed in. However, an accurate accounting of this value is essential to company strategic planning. The research outlines how to approach this variability, cost parameters to consider, primary sources of value generation, and best practices for implementing Smart Factories. A tool that addresses these issues was successfully developed and deployed at Stanley Black & Decker, helping the company to assess performance of the digitization efforts and tailor the delivered solution to optimize manufacturing performance. Results from this tool showed a positive expected return on investment and are provided to contextualize efforts in similar areas.

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Table of Contents

List of Figures

List of Tables

List of Equations

List of Acronyms

Table 1: List of Acronyms

AI	Artificial Intelligence	RIP	Raw Inventory
APM	Asset Productivity Management	ROI	Return on Investment
APV	Adjusted Present Value	SBD	Stanley Black & Decker
CCMS	Company Compass	SEK	Swedish Krona
CDO	Chief Digital Officer	TAM	Total Addressable Market
CI	Continuous Improvement	WIP	Work in Progress
COPQ	Cost of Poor Quality	USD	United States Dollar
COT	Cost of Transfer	OT	Operational Technology
CPS	Cyber-Physical Systems	POD	Production Overview Dashboard
CSCO	Chief Supply Chain Officer		
DF	Decision Frequency		
DCRR	Discounted Rate of Return		
EUR	Euro		
ICS	Internal Clock Speed		
IIoT	Industrial Internet of Things		
KPI	Key Performance Indicator		
M2DDM	Maturity Model for Data-Driven Manufacturing		
NPV	Net Present Value		
OEE	Overall Equipment Effectiveness		
OpX	Operational Excellence		
OT	Operational Technology		
OxT	Operational Excellence Technology		
PLC	Programmable Logic Controller		
POD	Production Overview Dashboard		

1 Introduction

1.1 Problem Statement

Stanley Black & Decker (SBD) is in the midst of a supply chain transformation and focused on instilling operational excellence into the global network of diverse manufacturing environments. The company is attempting to drive operational improvements to the flow and processes within sites by investing in digital and connected factory (Industrial Internet of Things – IIoT) technology. The goal is to improve the fundamental operating systems and capabilities for lean and continuous improvement.

To appropriately guide investment and development strategy, the team requires a method to quantify the value generated from the implementation of digital tools in the manufacturing environment. The approach must be applicable to the large portfolio of digital tools employed and variety of production environments at SBD (100+ sites, 150k+ SKUs, 50k+ employees). Additionally, the methodology must account for changing acquisition methods, people and time-dependent results, and simultaneous ongoing change initiatives.

1.2 Business Implications

The digital transformation effort at SBD is capital-intensive and requires justification for continued investment while the manufacturing leadership needs to understand the risks and opportunities of the technology embedded into critical processes. Additionally, major problems occur during implementation of digitization efforts without monitoring systems to assess progress [1]. By quantifying the value generation and costs from this digital push, SBD can optimize the delivered solution to maximize value and minimize costs for each site and value stream. These solutions generate different ROI depending on the application, so mapping best practices and guiding the development and deployment strategy will dramatically improve the chance of success for this digital transformation at SBD. Unfortunately, there is currently no industry approved method for calculating the value created by digitizing manufacturing environments which prevents presenting a business case through a traditional approach.

The wide spectrum of manufacturing environments, variety of digital tools, and dependency of results on time, culture, and people cause assessments to be ephemeral. Therefore, assessment workload will be inversely correlated with the applicability towards strategic insights. If it is too slow or cumbersome such that it can get very precise results, those results will be incorrect by the time the assessment is complete and the assessment will be done infrequently, limiting the impact on digital strategy. Consequently, efficiency is a key aspect of assessment methodology.

2 SBD Background

Stanley Black & Decker is a long-standing, distinguished company built through a combination of natural growth and acquisitions. Currently, there are over 50 thousand employees at over 100 manufacturing and distribution facilities that support the production of hundreds of thousands of different SKUs across 24 different brands. Those brands range from common household names to small, specific product-oriented brands. The brands target different customers from corporations to professional tradespeople to casual users, but they all primarily focus on tools (indoor and outdoor) and industrial applications. The brands include DEWALT, CRAFTSMAN, STANLEY, BLACK+DECKER, Lenox, Irwin, Bostitch, Facom, Mac Tools, Porter-Cable, Proto, Sidchrome, USAG, Cub Cadet, Hustler, Troy-Bilt, Rover, Wolf-Garten, CAM, CribMaster, Lista, Vidmar [2].

Due to the size, diversity, and acquisitions, there is significant variety in the people, products, and processes across the company. Individual manufacturing sites enjoy significant autonomy to tailor the processes to the unique products they produce. Section 2.1 provides an overview of the industry SBD competes in while Section 2.3 provides an overview of the organizational structure within the company.

Despite the long years of success as a company, SBD is a company in transition. Recent years of leadership challenges and supply chain bullwhip from the COVID-19 pandemic hit SBD particularly hard. In 2022, after 23 years at the company, the CEO James Loree was replaced by CFO Don Allan and a new wave of leadership [3]. The new leadership started focusing heavily on growth and supply chain problems. To counteract those challenges, SBD has been focused heavily on supply chain optimization through operational excellence initiatives, site consolidation, and supply chain localization (partially due to changing tariff policies).

2.1 Industry Overview

To understand the context around the digital strategy implementation, it is important to characterize the industry SBD competes in. While SBD is a part of a variety of industries, this analysis pertains specifically to the power tool industry, as it is one of the biggest areas of focus for SBD and the primary industry the Jackson and Monterrey site compete in. The power tool industry was valued around 27.5B (USD) in 2023 and is exhibiting a compound annual growth rate (CAGR) of 4.4% [4]. A majority of the tool brands have consolidated into a single company through acquisitions, just as with SBD. Figure 1 below displays some of the major competitors and their brand ownership. Note, these brands enable differentiation of the diverse customer base. These customers can be delineated between tradespeople who are professionals with high quality and performance requirements, casual users who are primarily driven by price point, and "weekend warriors" who periodically use tools for personal projects. Many of the brands specifically target one group of customers, such as DEWALT and Milwaukee targeting the tradespeople.

Figure 1: Tool Brand Ownership [5]

Despite the high levels of competition, this industry enjoys relatively high gross profits and projected future growth. Table 2 below shows SBD key financial metrics with a few major competitors. Note, many of these competitors have branches outside of the power tool industry, which accounts for the high sales volume relative to the industry size. However, SBD is experiencing slightly slower growth and lower gross profit than many of the competitors. This, when added to the bullwhip impacts from the COVID-19 pandemic, heightens the importance of improving SBD performance.

Table 2: Company Financial Performance [6] [7] [8] [9] [10] [11] [12] [13] [14] [15]

	Company Metrics (as of 12/31/2023)			
	Employees	Revenue	Gross Profit	Revenue CAGR[1]
Company	[people]	[M USD]	[%]	[%]
Stanley Black & Decker	50,500	$15,781	25%	4.5%
Bosch[2]	429,416	$101,287	31%	3.3%
Chervon	6,173	$1,375	28%	Unknown
TTI	47,224	$13,731	40%	12.4%
Makita[3]	20,233	$5,422	Unknown	8.8%
Husqvarna Group[4]	13,755	$5,289	30%	5.8%
Snap-On Inc	13,200	$4,730	50%	4.7%

Note 1: Compound Annual Growth Rate (CAGR) calculated over period from 2016-2023
Note 2: Annual report values translated from Euro to USD through 1/1/2024 exchange rate (1.1058)
Note 3: Annual report values translated from Yen to USD through 1/1/2024 exchange rate (0.007090)
Note 4: Annual report values translated from SEK to USD through 1/1/2024 exchange rate (0.099299)

2.2 Site Overview

In 2024, the SBD sites in Jackson, Tennessee and Monterrey, Mexico received end-to-end digital connectivity solutions. These sites demonstrate the diversity of the SBD portfolio and provided insights to deploying similar solutions in very different environments. As Table 3 summarizes, the Jackson site is much older and smaller, primarily producing products for internal customers (SBD assembly sites). As a product of the work statement, the ratio of assets per employee is high (greater than 5:1). The site has been in operation for a long time and seen different strategic initiatives over the years, including the Industry 4.0 push and Plantstar deployment, which led to more cultural resistance. Monterrey, on the other hand, is a very new site and completes final assembly of products before shipping them to external customers and distribution centers. There are less industrial assets per capita since the assembly lines consist of more manual processes. The site age and employee tenure are much lower than Jackson, resulting in a more dynamic environment and culture more open to new approaches.

Table 3: Site Comparison

Parameter	Jackson, TN	Monterrey, MX
Year Established	1965	2020
Headcount	~400	~2,000
Value Streams	8	16
SKUs	1,104	3,543
Customers	Primarily Internal (SBD)	Primarily External (DCs)
Core Competency	Tank Fabrication, Steel Machining, Gear Cutting, Assembly, Heat Treatment	Assembly, Batteries, Motor Winding
Products		

2.3 Team Structure

SBD is a matrix organization with two distinct groups of teams supporting manufacturing. Each site consists of Makers (operators, machinists, assemblers, etc.), Team Leads who oversee around 10 Makers, and Supervisors who oversee and manage around 20 Makers and 2 Team Leads. These supervisors are supported by teams categorically organized: value streams, maintenance, material handling, quality, engineering, continuous improvement (CI), janitorial, buyers, finance, and planners. Each of these supporting teams and the supervisors themselves are led by managers at the site who report to the plant manager. This plant manager is responsible for the site-wide performance and financial health and has autonomy to make almost all decisions about the plant. They eventually tree up through increasing levels of regional leadership to the Chief Supply Chain Officer (CSCO).

The second organization that supports manufacturing is the Operational Excellence (OpX) group led by a VP directly under the CSCO. This team is not associated with specific sites, but instead works to improve manufacturing capabilities across the company by implementing standards, swarming critical sites to provide support, and developing critical capabilities that help all sites. Within OpX is the Operational Excellence Technology (OxT) team, a group of about 30 people with a technology heavy skillset (IIoT, application development, digital manufacturing). They focus on developing digital innovations that can push SBD operational capabilities forward. The budget of the OxT team is justified through performance and improvements implemented at the site level. This team was the primary point of contact during the project.

2.4 Stakeholder Analysis

The development and deployment of digital tools is executed by the OxT team, but is funded by SBD corporate leadership, guided and approved by individual site leadership, and used by Makers on the floor. Consequently, there are three primary customers, all with slightly different objectives that complicates the political environment. Figure 2 provides a depiction of these groups and the targeted area of overlapping interests.

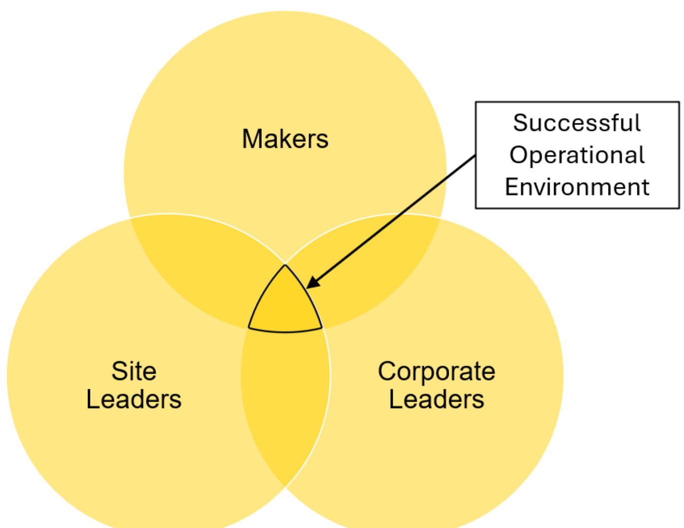

Figure 2: Stakeholder Groupings

If the Makers don't employ the digital solutions delivered, they will generate no value for SBD. Previous digitalization efforts in the past have failed and left them in worse shape, so they see the recent efforts as the "flavor of the month". Also, these employees are only incentivized to utilize the solutions if it either saves them time or makes their job easier, so the delivered result must meet those criteria to be successful. Similarly, the site leaders are somewhat scarred by the previous failed attempts at digitization which cost their site money and time. However, the two leaders of Jackson and Monterrey are strong proponents of improvement efforts and volunteered their sites to be the "guinea pigs" for the first year. As such, they are cautiously optimistic that the digitization effort will deliver significant value. The final group of corporate leaders consists of both the CSCO who funds the initiatives and the other groups working to optimize SBD supply chain as a whole. They hope this results in a more agile and flexible business model, with reporting transparency that delivers standardized KPI data as quickly as possible.

An additional group to note is the Information Technology (IT) team. This team is adjacent to and works closely with the OxT team but is deployed to the sites and responsible for all IT deployed there. They consist partially of full time SBD employees and partially contractors. They are expected to maintain and support some of the hardware associated with the digital solutions deployed at the sites. As such, they are teamed with the OxT group to ensure long-term sustainability (including cybersecurity & compliance) for these solutions.

2.5 Digital Transformation

The SBD digital transformation strategy has evolved over various iterations. SBD attempted a digital transformation in the past centered around the concepts that drive Industry 4.0 (see Section 3.1). This effort was largely a top-down initiative that focused on forcing conformity at the sites while delivering early-stage production monitoring and connectivity solutions. The primary technology injected into the factories was Syscon Plantstar. It is an off-the-shelf (OTS) manufacturing execution system that monitored manufacturing processes with monitors that showed production progress and centralized stations with input terminals for makers to input information [16]. Unfortunately, this system added significant burden on the manufacturing teams, the initiative ran over budget constraints, and leadership support was cut before the system was completed. As a result, some SBD manufacturing sites were left with an incomplete solution and additional work to revert to original processes.

The new digital transformation initiative is constantly evolving but is centered around providing digital solutions to SBD sites that conform to existing work statements but align to SBD operational standards and collect critical production data and KPIs from the plant floor for analysis locally, regionally, and globally. Some of the solutions provided are built in-house and tailored to the unique needs of the company, while other solutions are OTS from Tulip, a partner company that specializes in digital tools for manufacturing environments [17]. Initially, the teams deployed piece-meal solutions to sites that requested them. In 2024, the strategy shifted to prioritize just two sites and deliver end-to-end connectivity solutions to provide "lighthouses" that demonstrate the value of digitally enhanced manufacturing.

The OxT team, when digitally transforming sites, delivers IT/OT infrastructure upgrades for asset connectivity, production monitoring, quality monitoring, interfaces to review KPIs that conform to process standards, and digitized processes. The first step consists of improving the foundational infrastructure through cyber hardening of existing systems, segmenting the network to isolate operational assets from the business network, and physically connecting the assets to the OT network. Once connected, the OxT team interfaces with the machine PLC to pull key manufacturing metrics in real time to an accessible data repository. Other important data that cannot be obtained from the assets is obtained from advanced sensing (deployed as-needed) or input manually on digital Tulip application interfaces (most commonly through iPads on the shop floor).

The gathered raw data is available to anyone in SBD, but it is primarily utilized by the manufacturing engineers to deep-dive specific processes. The data is automatically processed, and visualizations of key production data are provided in real-time to shop floor displays, conference room displays, tablets, computers, and phones. Near the aisle, there is a display of the Production Overview Dashboard (POD) that monitors performance on an asset-by-asset basis for each line (see Figure 3). It imports the production plan for the day and color-codes the graphics based on the performance to that plan. This data is also available with trends in performance with the Automated Production Monitoring application via the Tulip platform (see Figure 4). Together, these display to the teams on the floor exactly how they're performing letting them know if they are "winning the day".

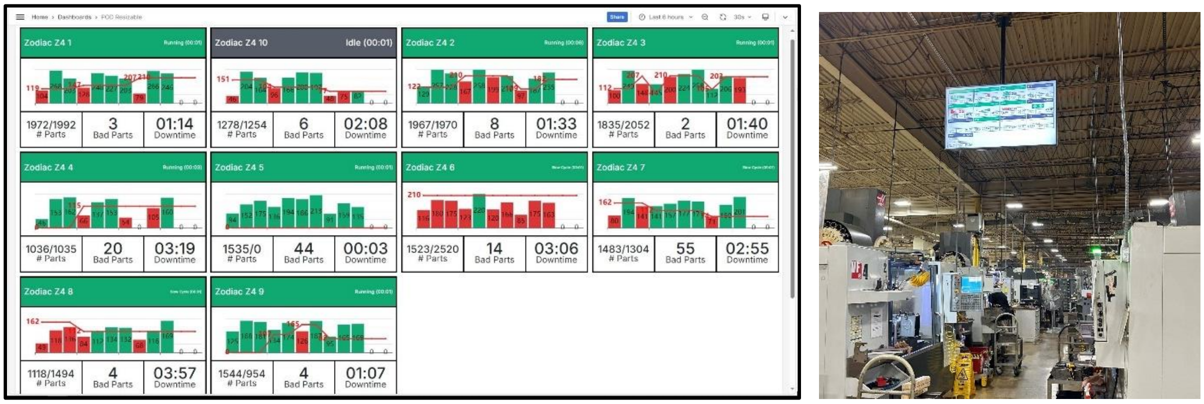

Figure 3: Production Overview Dashboard (POD)

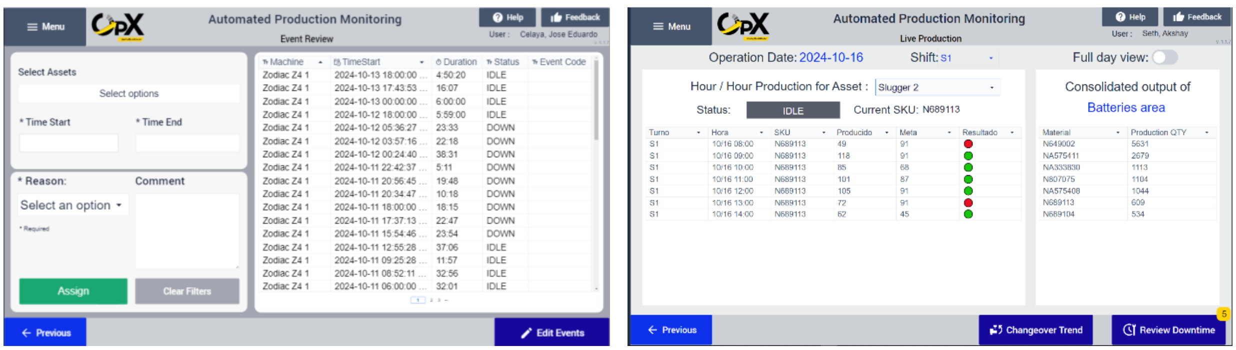

Figure 4: Automated Production Monitoring Application

SBD breaks the complex production environment into various tier levels. The tiers are provided below along with the primary motivators for data at that level. Each value stream has a large screen showing their Tier 3 metrics and there is a large display of the Tier 4 metrics at the entrance to the manufacturing area. The tier board interfaces are touch screen so users can navigate to a highly detailed level when needed to determine driving factors behind the metrics. These are called Tier Boards – examples of the displays and some detailed levels that can be reached are shown in Figure 5 to Figure 8. As standard operating practice, the site leadership has a walk through each morning where they walk to each value stream and review the Tier Board with that supervisor before ending with the site-wide recap at the Tier 4 board.

- Tier 1: asset grouping / subarea of operation
    - Data from Tier 1 reflects performance of specific processes or assets.
- Tier 2: line / area of operation
    - Data from Tier 2 reflects performance under a common operation type.
- Tier 3: value stream / department

    - o Data from Tier 3 provides performance related to certain products
- Tier 4: plant overview
    - o Data from Tier 4 is used for KPIs, site health assessments, and strategic initiatives

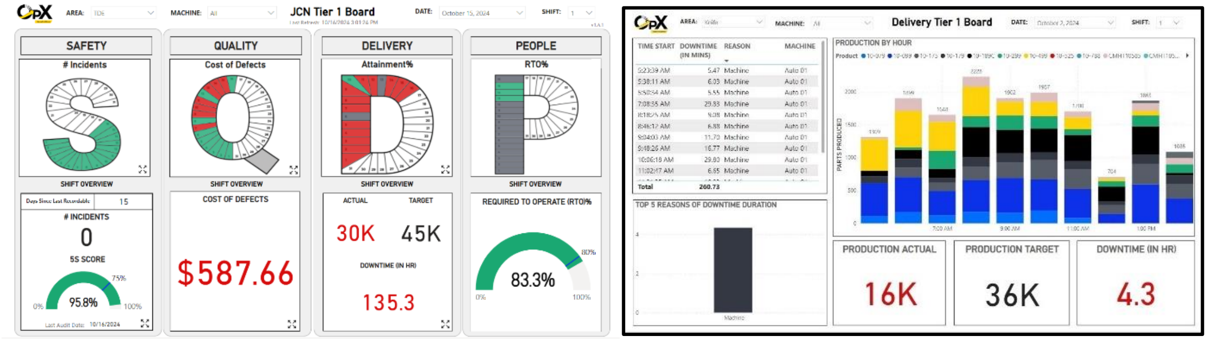

Figure 5: Tier 1 Dashboard

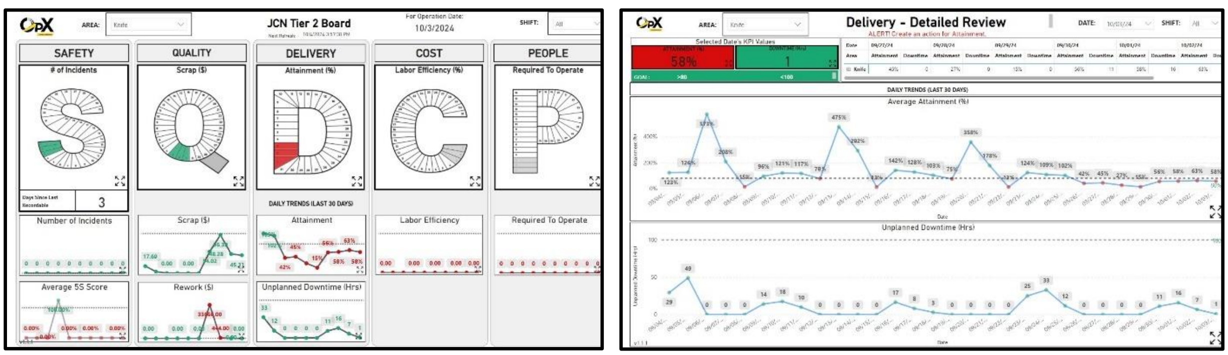

Figure 6: Tier 2 Dashboard

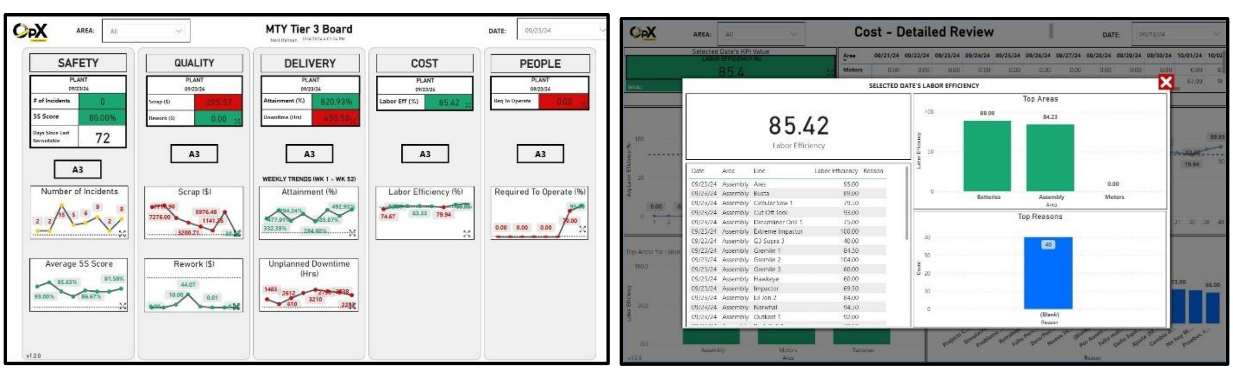

Figure 7: Tier 3 Dashboard

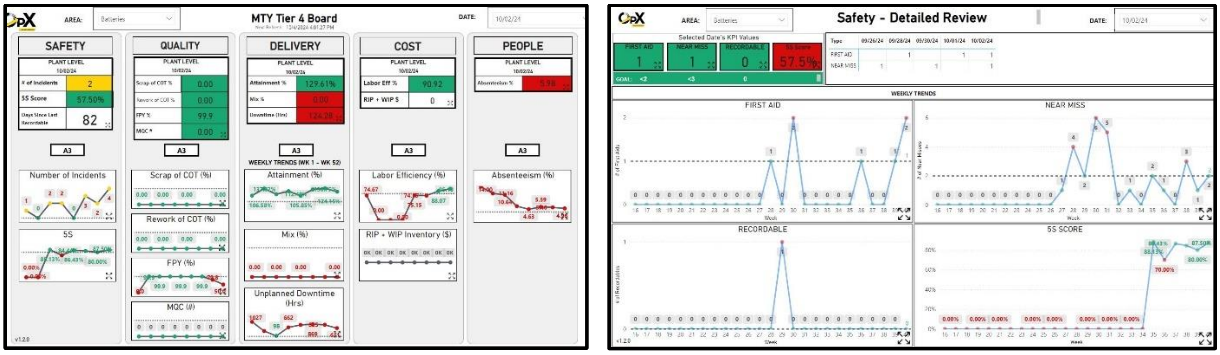

Figure 8: Tier 4 Dashboard

There are multiple other applications built by the team within the Tulip platform that employ this data to support the manufacturing teams. These include a 5S application that improves the efficiency of team members completing a 5S audit by enabling direct picture taking, step-by-step directions to ensure users follow the procedure, and automated notifications to the area supervisor with any findings. Additionally, there are applications to support action tracking during the tier board meetings (accountability board application), inspection applications, and a quality application for inputting non-conformances. The Tulip platform also enables end-users to build their own applications within the OxT environment, which many local manufacturing engineers are prioritizing to expedite common processes.

3 Literature Review

A literature review of academic and industry research on digital transformation implementation, digital leadership, Industry 4.0, and value generation was completed to provide a framework for the project and insights for SBD. There is a large body of work on these subjects, but high-level summaries of the findings are provided.

Many of the terms used in the literature review are considered "buzzwords" and frequently misrepresented. For the purposes of this research, definitions for commonly misunderstood words or concepts are provided in Table 4 below.

Table 4: Concept Definitions

Word	Definition	Source
Comparative Purpose	"…to compare similar practices across organizations in order to benchmark maturity within different industries"	[18]
Descriptive Purpose	"…assessing the as-is situation of the organization or process."	[18]
Digitalization	The use of the technologies and data to improve and transform processes.	[19]
Digital Transformation	Changes in business models, activities, processes, and competencies made through integration of new technology.	[19]
Digital Twin	Digital duplicate of production and logistics processes to enable analysis of the system.	[20]
Digitization	The transformation of the information process from an analog to digital format.	[19]
Hidden Factory	Diverging from prescribed processes with workarounds developed and institutionalized to correct short-term issues.	[21]
Industry 4.0	"…the fourth industrial revolution based on cyber-physical systems, i.e. … a new level of organizing and controlling the entire value chain across product lifecycles"	[20]

Prescriptive Purpose	"…indicating how to approach maturity improvement in order to positively affect business value"	[18]
Smart Factory	"…integrating technology and the physical world into an interconnected network, using streams of data to continuously learn, adapt, and produce"	[22]
Total Addressable Market (TAM)	Maximum possible savings, the quantified opportunity for a project.	[23]

3.1 Industry 4.0

Industry 4.0 is a term introduced around 2011 that pertains to the integration of cyber-physical systems (CPS) into the manufacturing environment. It has received a lot of attention from the industry and is expected to drive a new level of performance across the value chain and product lifecycles [20]. Industry 4.0 research is highly correlated with work around smart factories and the Industrial Internet of Things (IIoT). The goal of Industry 4.0 initiatives is often to achieve create digital twins or self-optimizing factories [24]. This concept is at the heart of the digital transformation efforts and was used to provide key insights and maturity assessment frameworks for the project.

First, it is important to recognize that digital maturity will always have moving goal posts. In other words, as the manufacturing sites grow in capability and as external technology continues to develop, the optimized extent of CPS in the factory will change [19]. Therefore, it is important to have site management and makers take ownership of the process to coordinate, analyze, and improve it. If they are simply operating the systems put in place by other groups, the system developed will stagnate and eventually be outgrown [20].

For Industry 4.0 initiatives, vertical and horizontal data integration should be understood and distinguished for independent growth. Horizonal data integration is site specific, compiling data from individual processes, supermarkets, and operators into value streams that are then combined to represent the site. This is supplemented with asset, material, and resource specific information to generate digital twins of the manufacturing environment. Vertical integration is, instead, taking the data at the process, supermarket, and operator level and compiling it upwards for product specific information at the entire company level. This would capture how the product is produced and flows between different factories [25]. While both types of integration are important, horizontal integration is most pertinent for site leaders and optimization while vertical integration has a larger impact on company-wide strategic initiatives.

Before initiating Industry 4.0 initiatives, the current state needs to be evaluated, and the scope of transformation needs to be defined. There is tremendous research around maturity models for completing this activity. Many of the published frameworks overlap or are designed for specific applications. The two that most aligned with the efforts in this project were the Company Compass (CCMS) 2.0 model [20] and the Maturity Model for Data-Driven Manufacturing (M2DDM) [26]. The CCMS2.0 model suggested a three-step process as follows:

1. Deliver a system for data acquisition and storage
2. Data exploitation for process improvement, optimization, and process support
3. Develop digital twins to simulate different events and predict outcomes

These three steps provide a general path of progress for sites. The CCMS2.0 suggests countering the long delay between initial implementation and digital twin development and implementation by metering expectations and spreading the capital-intensive portions over this three-step process [20]. The M2DDM, on the other hand, highlights the importance of tailoring the digital solution architecture to the company's IT infrastructure and works to objectively assess that success. It suggests 6 stages of development and provides a framework for assessing current position as well as guidance to move up in maturity [26]. Figure 9 shows these stages of development.

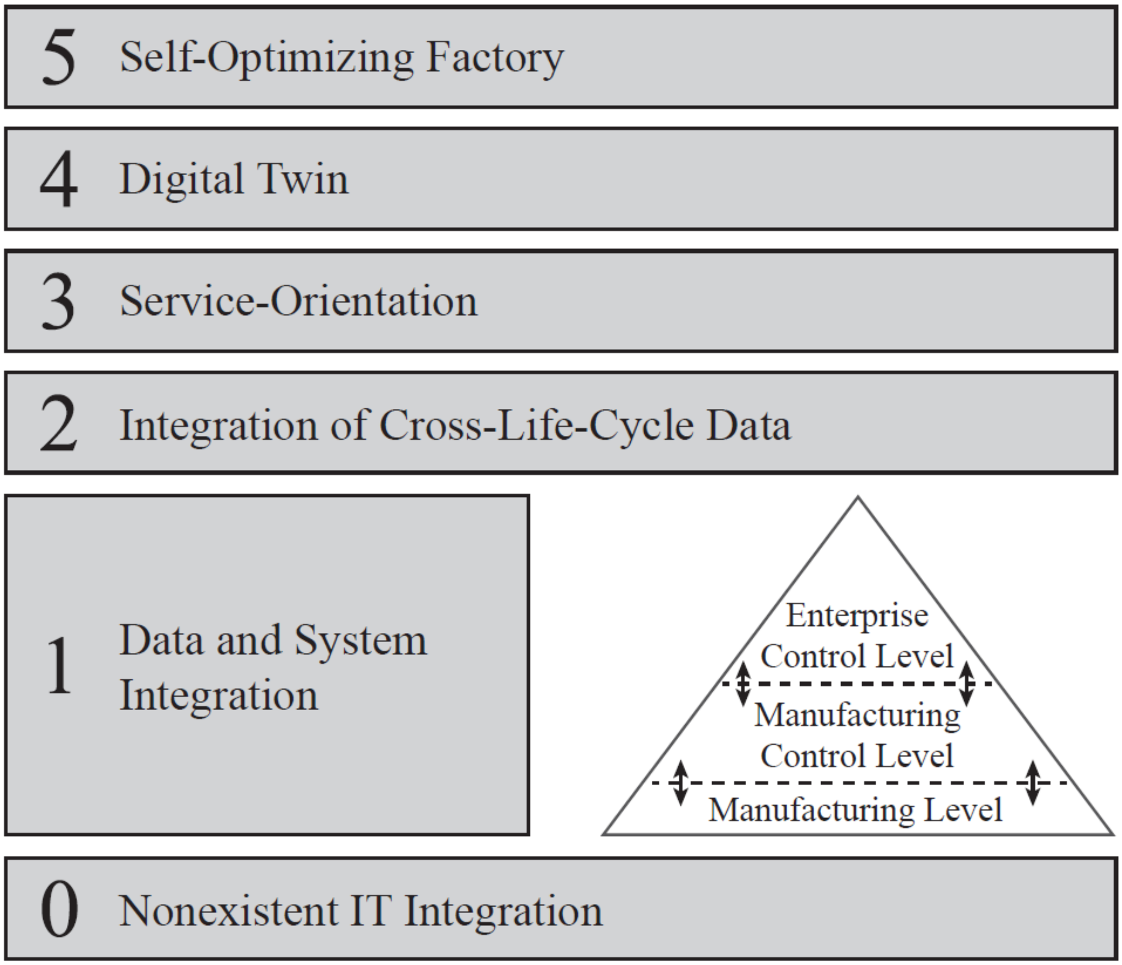

Figure 9: Stages of M2DDM Framework

3.2 Digital Leadership

A common theme throughout the bodies of work is the key role leadership plays in proper execution of digital transformations. The impact of good leaders is significant; research has found that simply role modeling change leads to a 4.1 times higher chance of initiative success, and that's only one aspect of good leadership [27]. There are a variety of approaches to achieve this, including centralized or delegated leadership, adaptation, and modified company structures. While it is outside the scope of this project, the research is presented for consideration.

A method for starting Industry 4.0 efforts is through top-down leadership alignment. This often comes from the implementation of a Chief Digital Officer (CDO) at the company. Successful

CDOs and, more generally, leaders of any digital transformation are categorized into three types of leadership: accelerators, marketers, and harmonizers [28]. Accelerators get the projects going, providing the energy, funding, and initiatives to the employees for development of new solutions. This requires significant focus and a leader who can get into the details with his or her teams. The second type are marketers, those who find allies and align incentives for other organizations with the digital transformation to help build momentum and gain buy-in. For the third category, harmonizers spend time bringing people together to find mutually beneficial solutions and promote utilization across the company [28]. Different types of leaders can produce different results, but high-level leadership is key to initiative success.

Other key pieces of information came from the research on leadership that pertain to project delivery and tool application. It is recommended that the initial assessment process consider employee digital readiness. This should include consideration of the average digital experience, transformational competencies (change control procedures), and workforce learning agility. Where gaps exist, proper training should be deployed to support the teams [29]. Leadership should also work to identify key personnel to become digital champions, who can pioneer new tools and provide in-house support to the holdouts or employees more resistant to change [30]. It is key to empower the people using these digital technologies to innovate and create new solutions or tools with the deployment, as these will drive more value to the organization [31]. Overall, the leadership must help change the culture of the manufacturing environment to have a sustainable solution [32]. That means starting with the leadership teams, making sure they understand the purpose and vision, re-imagining what their areas look like with the digital tools successfully utilized [33]. To gain this support and reward the digital champions, incentive structures should be aligned to this area of growth, especially for front-line employees [34].

3.3 Digital Transformation Implementation

Any change initiative, no matter how robust, can fail due to poor execution during the implementation phase. To maximize chance of success, there should be a robust assessment to confirm viability of implementation of the digital tools in the given environment. The employees required to use the solution must trust it and understand the reasoning behind it. Between 30-84% of digital transformation efforts fail (depends on which estimates are used), often due to attrition of talent, project delays, perceived lack of progress, lack of coordination, misaligned investments, or operations breakdowns due to lack of training [35]. This all can be addressed with proper implementation efforts.

Readiness assessments, as discussed in Section 3.1, play a critical role in implementation success. Aside from the factors already discussed such as viability considerations and workforce digital competency, the initial assessments should identify risks and opportunities during implementation [20]. Having awareness of these enables strong leadership to avoid them and develop plans to mitigate risks and capture the opportunities. Additionally, these pre- and post-implementation assessments should employ structured interviews to limit self-reporting bias [36]. This will result in more consistent and accurate evaluations, increasing chance of implementation success.

The narrative around digital technology is not always friendly. Many front-line employees worry that introducing the new tools will render their hard-earned skills non-significant. They are worried they will lose their jobs if they don't adapt or fight implementation, which generates a significant stress on the individuals [37] [38]. Similarly, middle managers worry it usurps their decision-making power. They often lack trust in what the metrics show and prefer decisions from their hard-earned experience which has served them well to-date [37]. Consequently, teams should spend time conveying the exact purpose of these tools to the teams, that they are meant to empower them, not supplant them. Moving beyond those concerns, the same employees also need to trust the tool [39]. They are in a high-stress job where production is king and switching to digital often leads to a short-term loss in productivity as they learn and integrate the solutions into their work statement [36]. Implementation must focus on minimizing frustration and improving effectiveness the first time it is delivered [39]. The digital tool interface must also be streamlined for easy use and understanding; research on a related subject, switching vending machines to newer and more user-friendly interfaces, found that sales (representative of utilization) increased by 12% from that change alone [36]. Finally, the implementation should balance long-term results with quick wins to gain user buy-in and increase early confidence from the teams [18].

3.4 Digital Solution Value Generation

Many sources from the technical literature identified possible sources of value generation from a digital transformation. These different sources should all be considered when evaluating the strategic and quantitative value of implementing digital solutions. They are categorized into those generating increased productivity, increased data transparency, improved asset performance management (APM), inventory management, and more. Note, many of these noted examples will overlap with each other, so careful delineation is required for quantification of the total value generated.

At top of mind for many digitalization efforts is increased productivity from better "track and trace" programs. The digital tools often enable increased insights into the production environment. This can help surface and fix latent problems, also known as "hidden factories" [40] [41]. It can often be difficult to identify the source of inefficiencies in complex manufacturing processes. With side-by-side comparison of different areas running the same process, comparing step durations to plans, and visibility of rate variability, teams can find these inefficiencies and target them for swarm or lean initiatives. These improvements can then be applied to similar processes throughout the company, enabling global fixes for common problems [40]. Building on that, teams can find and eliminate root causes of material or time waste within each process step [42]. With better track and trace programs, some labor can often be eliminated around report generation and data transmission too [41]. Finally, as systems and operators become more proficient, the data can be built into digital twin architecture. This plant-level system could look at larger scale processes to identify bottlenecks and material or labor shortages and surpluses [23]. These digital twins, with appropriate monitoring and development, can even achieve self-optimizing production to help guide integration of new products or optimize plant-level flows [22] [43].

Another benefit of many digitalized manufacturing lines is increased data transparency. The tools can provide more accurate accounting of key production metrics and often higher quantity data as well. The data acquisition is, after being validated, more consistent than manual processes resulting in overall higher fidelity data [41]. This allows the teams to move from low-frequency to higher-frequency forecasting and review periods [42]. This is also known as accelerating the Internal Clock Speed (ICS) of a company [44]. These reduced review periods enable reduced bullwhip through better communication and lower required inventory per Equation 1 below [45].

Equation 1: Base-Stock Inventory Model Formula [45]

$$I = \frac{r\mu}{2} + z\sigma\sqrt{r + L}$$

Where I = average inventory level, r = review period, μ = mean demand, z = z-score of desired reliability, σ = standard deviation of demand, and L = lead time

This data can be empowered with additional tools that help to identify exactly when quality problems originate and send automated alerts to leadership for problems with key assets or KPIs. This data can form the foundation of automated inventory management systems that optimize inventory levels for each part according to preset formulas and risk levels [22] [43]. Finally, if this data is integrated into digital twin architecture, the supplemental data would enable insights to overall site capacity utilization [41]. To summarize, the improved data access and the track and trace programs can inform decision-making and direct future strategic initiatives [37].

Digitalizing manufacturing processes in environments with many machines can have tremendous impacts on asset performance management (APM). First, through better visibility and higher fidelity data, quality improvement can move to the asset level, showing specific defect rates for each operation [42]. Also, downtime can be tracked by the specific asset and delineated by reason (machine maintenance, material shortage, operator's break, etc.). This allows team members to capture unplanned downtime for each asset, empowering them to make targeted improvement efforts [43]. This information would also lend itself to preventative or condition-based maintenance [22] [43]. The teams could analyze the data and determine asset criticality. By sharing with the maintenance teams or planners which assets were most critical to production flow and which were supplemental (often some have backups ready), teams can modulate their effort levels and reduce unplanned downtime impact on overall site production levels [23]. This criticality assessment can be used for more efficient resource allocation as well, ensuring they are never starved for materials. This most likely overlaps with bottleneck identification tools, but that bottleneck may change if certain assets are not operational [42] [38].

Digital transformations have second-order impacts that influence company performance through cultural changes. While not initially obvious, the site's safety culture is expected to improve; "the most critical issue for organizational safety is the flow of information" [40]. When different nursing environments were evaluated, it was found that those with open and honest communication (good supervisors, generative culture) over 10x more errors were reported [40]. When extrapolated to the manufacturing environment, where the digital tools promote improved and more open communication through increased transparency, teams could expect more near-miss reporting or better information flow from front-line employees. Another cultural impact is through the visibility to people's work. Studies found that displaying progress at an individual level can have major impacts on production and efficiency. Sometimes, this was at the cost of reduced quality (people were rushing not to be behind), but that was highly dependent on team leadership [38].

There are advantages from increasing numbers of manufacturing environments being digitized. For some companies, their sites are remote from headquarters or areas of established employee expertise. Manufacturing sites that have high levels of connectivity can take advantage of remote services – the employees do not need to be on-site to have an impact if all the data is made available to them. For many sites who struggle to attract or retain technically proficient talent, this could have a large impact [43]. "Big Data" is sought in modern business, but it requires significant data volume, velocity, and variety. For large companies with diverse manufacturing bases, that can be achieved and developed into a competitive advantage. Also, as time progresses with the digitized factories collecting tremendous data and newer, higher-technology machines are brought into the manufacturing environment, more data will be available. Data-driven decision-making, alone, has been shown to help companies be 6% more profitable than competitors [42].

4 Methods

Determining the value of an investment is not a new challenge for industry. Normally, the benefits and costs are identified, measured, and compiled to determine total expected value. However, given that these new digital solutions are still being developed and have not been deployed in SBD's complex manufacturing ecosystem before, this becomes much more difficult. The literature review showed that an industry standard approach for evaluations of digital solutions in a manufacturing environment has not yet been established. As such, a generalized approach was initially attempted that primarily focused on learning and information gathering first. Then multiple attempts were made to secure reliable quantitative data that supported assessment of digital tool effectiveness. Unfortunately, due to changing acquisition methods, high level metrics impacted by external factors, and time, people, product, and process dependent results, the quantitative data was insufficient. Instead, through a system dynamics model analyzing interdependencies within the production environment, key factors were identified that strongly correlated to the delivered digital solution. These were assessed qualitatively through numerous interviews with subject matter experts to determine final results through a simple, accessible Excel based Digital Solution Evaluation Tool (DSET) that was built for this project.

4.1 Initial Approach

The project high-level approach started with learning and progressing through iterative ideation and validation steps before finishing with standardization efforts, as depicted in Figure 10 below. The first phase was to learn about the company strategic goals, value streams, and diverse manufacturing environments. This was completed through 11 site visits, hundreds of interviews with key stakeholders, and rigorous reviews of internal tools and resources. The second phase was to ideate on the evaluation procedure through review of independent sources. Almost 100 different independent sources from academia and industry were reviewed and considered with available site-specific financial and production data. The validation process occurred through direct measurement at the Monterrey and Jackson sites where initial digital solutions were being deployed. In addition, the process was reviewed and critiqued by numerous team members who compared the solution against expected results. Finally, the solution was refined and polished for publishing results and drawing conclusions. In addition, ownership was passed to team members for on-going process refinement through working meetings and thorough documentation.

Figure 10: High-Level Project Approach

From a technical standpoint, the project started with understanding the cost of deploying and supporting the digital solutions at Jackson and Monterrey. These costs were well defined through tracked spending over recent years. The value generation was more difficult to identify due to the complexity of the deployed environments. A System Dynamics Model was deployed to understand and isolate trends and impacts from the digital transformation. Finally, the variance between sites, digital tools, processes, and people were identified before compiling and presenting the results for Jackson and Monterrey. These results, consisting of expected Return on Investment (ROI) values, positive externalities, and identified risks and opportunities, were used to influence overall SBD Digital Strategy and determine a path forward for both the company and continued support of this effort.

4.2 Quantitative Data Collection Challenges

Before the OxT team connected the sites, the data sources pertaining to this project were shallow and inconsistent. The Jackson site maintained 27 Access databases that compiled production-oriented data and financial reporting spreadsheets derived from SAP data. The Monterrey site tracked production in separate spreadsheets owned by the value stream managers. As the productivity databases were interrogated, there were often missing data entries and inconsistencies across value streams. Makers, leads, and supervisors were responsible for inputting the information, often first collected from hand-written logs, which led to transfer errors and lost data. Material would sometimes be unaccounted for due to documentation gaps or unreported quality issues. The collection frequency was often defined by SAP backflushing quantities; for some products, the system would only be updated when an entire pallet was filled which could be once every week. The financial data was primarily oriented to site-wide health metrics rather than performance of specific value stream attributes.

In addition to the data collection challenges, the production measures lacked the fidelity required to identify changes to manufacturing performance. The table below shows the KPIs tracked, most often at the site level. These metrics are very sensitive to a variety of sources and, without substantial and reliable time histories, trends reflecting the performance impact of digital tools could not be distinguished. Part shortages would have impacts to attainment that were orders of magnitude larger than expected performance changes. Also, demand and performance annually fluctuate due to seasonal market and workforce changes (holiday season demand, summer vacations). Finally, SBD suffered significantly from the bullwhip effect during the COVID-19 pandemic – the Jackson site had three times as many workers (~1000) during peak demand periods and suffered from surplus inventory as people globally returned to work. This made isolating seasonal changes or performance trends difficult.

Table 5: Tracked KPI List

Safety	# of Incidents	Number of recordables, Number of First Aids, Number of Near Misses
	5S Score	Percentage compliance to 5S standard determined by 5S audit

	CRR Initiative Progress	Percentage against goal for implementing 10 roadmaps
Quality	Scrap $ **OR** QTY	Total dollar value or number of nonconforming components or finished goods that cannot be used and shipped to the customer due to a quality issue
	Rework $ **OR** QTY	Total dollar value associated with or number of re-worked components or finished goods due to a quality issue
	FPY (%)	Percentage of finished goals that are built right and ready to ship first time
	MQC (#)	Any major quality issue that occurs in the plant that results in safety or compliance issue
Delivery	Attainment	Planned production units verses actual production units
	Unplanned Downtime	Total time in hours that equipment is unavailable to run due to unscheduled maintenance
	Mix	Did the plant produce the right qty for the requested SKUs at the time the plant committed to produce them?
Cost	Labor Efficiency	Efficiency of direct labor hours
	RIP + WIP $	Total dollar amount of raw and work in process
People	Absenteeism	The percentage of hourly employees not at work (approved and unapproved)
	Required to Operate (RTO)	Percentage of actual present headcount compared to total required headcount

The last, and potentially most insurmountable, challenge with the quantitative analysis approach was that the digital tools started being implemented in June and were not completed until December. The tools are expected to start returning value over the next few years, but it is understood that initial production impacts may be negative as the workforce learns new tools and processes. Parsing data from the first three months on-site was not sufficient without tools fully implemented and, as applicable data started coming in, the timelines were too short to show any statistically significant changes outside of seasonality and other external factors. During this short window other productivity improving efforts were ongoing for the site including external consultant groups providing new tools and training. This further impeded the analytical approach.

A work-around of time studies was conducted on a small scale for key value streams. These efforts were limited because only short time periods were measured of processes that saw heavy fluctuation. The single day or single process measurements were not statistically significant enough to demonstrate results. Also, these results were found to be inconsistent as behavior changed when Makers realized they were being monitored. A large-scale time study may have been successful at generating a basis for comparison, but with limited resources was deemed infeasible at the time.

For optimal data integrity and validation efforts, the OxT team should complete the factory connectivity portion prior to delivering the tools for applying and leveraging the data. Through this, an adequate baseline could be established to compare to. Unfortunately, this would delay deployment of digital tools and reduce the value delivered to the site by delaying it for one year. Another option would be A-B testing for two parallel lines producing similar products over a set time-period. Finally, the value streams should focus on a single change at a time – bringing in the OxT group at the same time as external consultants to work the same production challenges from different angles strains resources and clouds results for both efforts. This would clearly demonstrate progress but, to see long-term results, this would hamstring the line without digital technology. These may be non-practical for company goals but would improve transparency and confidence in results.

4.3 Qualitative Data Collection

After the analysis of financial and production data fell short of objectives and the time studies failed to generate statistically significant results, qualitative data was obtained from subject matter experts (SMEs) at the sites. Formal and informal interviews were conducted with supervisors, makers, continuous improvement team members, and site leadership to synthesize perspectives and obtain accurate estimates of measurable impacts. Where there was a single source of information, such as asking supervisors the expected time savings for a given change, the SME was asked the question on at least two separate occasions to improve confidence in the answers.

Where possible, secondary forms of validation, either from alternate sources or from rudimentary data analytics, were used.

Given the difficulty in projecting results and inherent biases from the experts providing input, sensitivity studies were performed on their input to understand precision of the results. The findings are reviewed in Section 8. In an effort to continuously improve the review process, the OxT team will be tabulating the digitally sourced data from the sites after deployment (data from the new suite of tools) and hopefully generating more accurate estimates to supplement the SME inputs for the evaluation of future deployment efforts.

4.4 System Dynamics

A system dynamics model was built to decompose the complex interactions between site-wide productivity metrics and the major changes generated through the delivery of digital tools. The objective of the model was not to formulaically identify trends and quantify overall impacts, but instead to characterize and identify relationships. Various versions were built of varying complexities, but the simplest model that adequately characterized the production environment was used. The causal loop diagrams are shown in Appendix B: System Dynamics Model. They were reviewed and iterated on through the inputs from various team members. The model highlighted the extreme complexity and how various site-wide metrics were insufficient to identify impacts from the changes delivered.

The model also demonstrates manifold interdependencies between the changes delivered and factors external to the OxT team. For example, the installation of a Cloud-Based Digital Platform for reviewing productivity data enables automatic alerts which can notify the maintenance team and site leadership immediately when critical assets go down. With earlier notification to the maintenance team, the maintenance issue response time will be reduced, thus reducing the unplanned downtime (and boosting runtime). With earlier notification to the leadership team, production can be rerouted to alternate machines, or overtime can be authorized to help reduce impacts to throughput. This simple change should improve OEE, cost of maintenance, and production. Depending on the magnitude of the issue and criticality of the asset, there may be a negligible or significant impact to site-wide KPIs, such as scrap rates, rework cost, first pass yield, attainment, unplanned downtime, mix, and labor efficiency. However, this is all predicated on proper execution from the maintenance and leadership team. The constantly changing environment, variance in event, required mapping of behavioral response, and risk of improper execution made formulaic representation of these sequences within the model infeasible and helped solidify qualitative analysis as the appropriate method at this time.

4.5 Digital Solution Evaluation Tool (DSET)

After the system dynamics model illuminated the interdependencies between systems, the team decided a simple approach would be best. The analysis had to be repeatable at various sites where the digital solutions were being deployed and streamlined such that updates could continuously be added to keep the analysis accurate to the ever-changing tools and environments. It was also determined that the tool should be as straightforward as possible – there is not sufficient data to merit some complex modeling approaches, and the tool is meant to convince corporate leadership, the OxT team, and the production teams of the results. Black-box components to any of the parties would undermine the purpose. Research has shown that a link between investments and business values is required for sustainable success (26).

To meet these requirements, a tool was built in Excel that performs the calculations in the background with only a handful of inputs required for each new evaluation. Keeping it in Excel maximizes accessibility and keeps the analysis parametric. Various users can use the tool in different ways without significant training. The OxT team can alter the parametric inputs to understand potential impact of new solutions or digitizing new sites. The manufacturing engineers at each site can alter inputs to understand sensitivity, better targeting areas of improvement. Extensive documentation was created, and walk-through meetings were held for the various user groups to ensure a base level of understanding.

The tool is structured with input and calculation tabs. Primary inputs are required from assessors working with SMEs at the site or evaluating data from results. These inputs are categorically isolated to direct labor savings, time-based impacts, and cost inputs. The first time a new site is assessed, the OxT team will also need to update the KPI factors (based on high-level site metrics) and personnel quantities for the different value streams. The calculations tabs show tabulations of cash-flow, the learning curve shapes, and graphical representations of the impacts. Finally, there is a summary tab that shows primary financial reporting metrics.

For continued support and maintenance of the tool, two primary OxT team members were designated. The first has a team responsible for site assessments and evaluating the performance of the delivered solution (among other responsibilities). She and her team will continue to use the tool, applying it to new sites and reassessing previous deployments every 6 months. The second has a team responsible for data analytics around the digital solutions. He and his team will look for ways to integrate those analytics into the tool, slowly replacing the qualitative portions with quantitative-based results. This will take time for the solutions to be implemented, and enough data aggregated to overcome the challenges discussed in Section 4.2, but will dramatically improve tool accuracy when complete.

Note, the DSET was developed for implementation within SBD systems. As such, it conforms to many of their accounting practices even when they differ from industry standards. This includes using return on investment (ROI) as the key solution performance metric instead of adjusted present value (APV), which accounts for additional details and may be more fitting for this scenario [46]. Additionally, reductions in inventory levels are considered a one-time savings of the value of those materials without any reoccurring cost savings. However, the solution does differ from traditional SBD accounting methods in that it considers reoccurring labor and productivity benefits over a 10-year period instead of a 12-month rolling window.

5 Capturing Variance

Each digital tool will have a unique cost and benefit profile depending on multiple factors including time since implementation, how well the implementation phase was executed, and the environment it is deployed in. For example, deploying an accessible productivity database will not be effective until there is enough statistically significant data to draw conclusions, people learn how to utilize it, and the resources are deployed to identify and fix the problems. If that database is not properly implemented, such as having bugs that undermine engagement from the makers and manufacturing engineers, little to no value will be generated. The value generated and cost is also dependent on the digital competency of the workforce, the products being produced, and the type of processes in place. Identifying how these vary enables risk avoidance, maximizes returns, and can help the organization strategically prioritize deployments.

5.1 Time-Dependencies

Any tool or piece of equipment must be learned before it can be properly employed. This causes performance to vary with respect to time since implementation. The curve shape of performance versus time is defined as the learning curve and the shape is dependent on multiple variables such as training processes, individual capabilities, starting proficiency, task complexity, external pressures, and operating environment [47]. The curves shown in Figure 11 were normalized and used to project performance for each of the major changes spurred by the digital solutions.

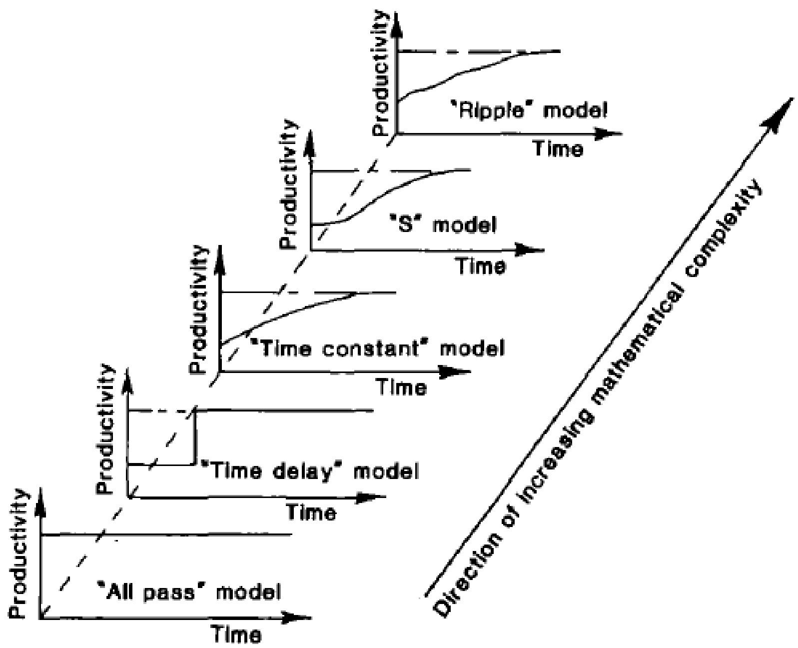

Figure 11: Generalized Learning Curve Shapes [48]

For each change, subject matter expert (SME) inputs were gathered regarding magnitude of performance impacts (y-axis) and the duration until reaching steady-state performance (x-axis). The curve shape was determined based on the complexity of the change. For the changes that generate immediate value (Section 7.1), the "All pass" model was applied. There were limited cases for the "time delay" curve shape, but it would apply to times when the team waits for all systems to be operational before replacing the old system with a new one. The "time constant" curve was used for simple changes that required minimal learning or times when direct documentation was used, such as the OxT team's implementation costs. This is based on experimentation that shows simpler learning efforts follow the exponential curve shape instead of a more complex "S" shape [47]. Finally, the "S" shape was used for complex changes that dramatically change the work statement for employees or learning new skills. The shape parameters were tailored based on expectations from SMEs and discussions of the aforementioned shape parameters, such as maker digital proficiency, application ease-of-use, and quality of training provided. The equations for the "time constant" and "S" models are provided below.

Equation 2: Time Constant Curve Formula [47] [48]

$$P(t) = P_i + P_f(1 - e^{-\mu t})$$

Where $P(t)$ = performance at time t, P_i = performance at time $t = 0$, $P_i + P_f$ = steady state performance, and μ = time constant (measure of speed of improvement)

Equation 3: "S" Curve Formula [47] [48]

$$P(t) = P_i + \frac{\theta_1}{\left[1 + \varepsilon e^{-\theta_2 (t - \theta_3)}\right]^{\frac{1}{\varepsilon}}}$$

Where $P(t)$ = performance at time t, P_i = performance at time $t = 0$, $P_i + \theta_1$ = steady state performance, θ_2 = maximum slope during the growth stage, θ_3 = duration of the infancy phase (determines time of transition points), and ε = defines the transition periods

5.2 Importance of Implementation

The best solutions, when deployed improperly, result in no value generation. It is not enough to have the right tool in the right place at the right time, but it needs to be integrated into the system properly and the people using it need to trust it. During the initial phases of the project, solutions were being delivered to the production environment in an unfinished state. This is common practice for software companies, where you do some initial testing but let users report bugs and fix them by pushing updates. Unfortunately, this fails in high-stress production environments. If the makers want to use a tool and it does not function as intended, they will get frustrated and be behind on the day. The team found that if this happens too frequently, you lose maker by-in and trust in the solutions, causing them to revert to the original methods. The digital solutions are already a stretch for many manufacturing focused employees, as new skills are being required and some lack proficiency. If the team adds to that stress and frustration with a faulty tool, opportunities could be lost as the makers refuse to try new things. This analysis aligns with internal SBD methodologies on risk adjustment rates for incomplete or in-work projects. For all changes that are still being implemented at the site or may be implemented in the future, they are categorized according to Table 6 below and scaled based on Table 7.

Table 6: Risk Status Descriptions [49]

Risk Status	Blue Sky	Pre-Funnel	Funnel	Savings not Started (SNS)	Savings Started (SS)
Description	Ideation	Developing Business Case And Feasibility Analysis	Business Case Complete	Implementation Started	Implementation Complete
Savings Risk Adjustment	0%	50%	70%	100%	100%
Criteria to move into the stage	Project Timing not clearly defined	Estimate of project timing being refined	Project timing established	Project Plan created and started	Project fully implemented
	Savings and Cost are high level estimates	Benefit being refined	Project benefit established **Business Case is Complete AND Attached in ProTrak**	Timing of Savings clearly defined	Realizing savings Track project savings for 12 months
		Project scope being defined	SOW Completed		
	Funding not clearly defined	Funding Potentially available	Funding is available	Funding assigned	
		Budgetary quotes in process	Ready for FAR (if needed) Final Quotes Complete	FAR is approved (if needed)	Close FAR
	Resources not clearly defined	**Resources Requirements Defined**	**Resources Available**	**Resources Committed**	
			Testing Plan developed	Testing In-Process	Testing Passed
Inflation – (Wages /Salaries)	Managed by finance				
Inflation		Inflation Highly Likely Based on Market Conditions	Inflation Formally Requested by Supplier, GSM Negotiating	Inflation Request Approved in Metastorm or Required By Contract	Inflation Approved in Metastorm & Reading Through P&L

Table 7: Recommended Risk Adjustment [49]

Risk Status	Risk Adjustment
Blue Sky (0%)	0%
Pre-Funnel (50%)	50%
Funnel (70%)	70%
Savings not Started (100%)	100%
Savings Started (100%)	100%

5.3 People, Products, Processes

SBD is seeking standardization of processes across the company where possible to streamline integration and improve cohesion. However, due to the diversity of SBD's manufacturing environments (see Section 2), the same process rarely works at all plants. Manufacturing sites want individually tailored solutions unique to their specific needs while the company-wide leadership strives for universal standards. This strategic dilemma is epitomized in the digital tool deployment. The same digital solution, when fielded in different environments, does not yield the same rewards or have the same cost.

The same results and analysis will not be applicable from site-to-site and there are notable differences between results in Jackson and Monterrey. Some themes will persist, but these have not been assessed and validated at this time. To account for this variance, the developed assessment tool for determining total solution portfolio value will be reworked for each site OxT deploys solutions in.

6 Costs of Digital Transformation

To adequately understand the strategic value of the digital transformations, costs must be accounted for and generalized for future applications. The costs are categorized by licensing and partnership fees for the enabling technology, labor for implementation and training the workforce ("effort" costs), and the hardware and equipment required for execution at the site ("non effort" costs). The licensing and partnership fees are applicable to the entire company but, for this accounting purpose, were partitioned to apply to the specific sites based on company-wide utilization. Note, table color-coding is an artifact of the DSET where yellow indicates hard-coded cells, orange indicates referenced cells, and blue indicates calculated cells. This is designed to improve ease-of-use and understanding of the tool.

The cost accounting is shown at a site level for 2024 costs based on actual expenditure for the effort and, consequently, is very accurate. Reoccurring costs are estimated for the next 10 years based on extrapolations from current licensing agreements with an assumed 5% growth rate. OxT team leadership estimated 5% of total labor cost (~0.75 heads) will be required for system support for two years post-implementation and 2% for all years after. For the annual cost of equipment maintenance and upkeep, 10% of total initial cost was assumed based on IT Department experience. These estimated future costs do not account for discount rates or inflation. Depreciation periods were used based on SBD internal accounting methodologies but is not accounted for in these tables outside of equipment repurchasing.

Table 8: Jackson Site Total Costs [USD]

Parameter	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
	0	1	2	3	4	5	6	7	8	9	10
Total Licensing Costs	$220,577	$257,129	$254,906	$133,482	$125,830	$120,095	$115,777	$112,541	$118,216	$124,178	$130,441
Total Non Effort	$937,827	$93,783	$93,783	$93,783	$93,783	$421,867	$93,783	$93,783	$93,783	$93,783	$421,867
Total Effort	$1,556,231	$85,035	$85,035	$41,552	$41,552	$41,552	$41,552	$41,552	$41,552	$41,552	$41,552
Solution Cost	$2,714,634	$435,946	$433,723	$268,816	$261,164	$583,514	$251,111	$247,875	$253,550	$259,512	$593,859

Table 9: Monterrey Site Total Costs [USD]

Parameter	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
	0	1	2	3	4	5	6	7	8	9	10
Total Licensing Costs	$549,259	$638,827	$634,001	$338,944	$320,951	$307,657	$297,841	$290,692	$305,274	$320,589	$336,673
Total Non Effort	$843,065	$84,307	$84,307	$84,307	$84,307	$570,832	$84,307	$84,307	$84,307	$84,307	$570,832
Total Effort	$1,509,913	$78,519	$78,519	$35,036	$35,036	$35,036	$35,036	$35,036	$35,036	$35,036	$35,036
Solution Cost	$2,902,238	$801,652	$796,827	$458,286	$440,293	$913,525	$417,184	$410,035	$424,617	$439,932	$942,541

6.1 Licensing & Partnerships

The delivered solution requires three licenses to properly function. The first and most expensive is from Tulip, a company delivering production enhancing software solutions. It is employed as the Maker-facing application and interface and enables users to build their own applications to continue to enhance production. Given that the licensing contract was based on Tulip instances or workstations, utilization data was used to allocate a portion of the total licensing cost to each site. The second externally sourced tool employed is DeepHow, a tool that employes artificial intelligence (AI) to make and deploy training videos. These videos dramatically reduce training burden on the sites and help streamline implementation. Finally, the deployed solution uses Kepware to build the back-end system architecture. The total costs are provided for each site in the tables below. Note, the licensing cost scales with site scale and, as such, is much more significant for Monterrey (~20% of total cost) than for Jackson (~10% of total cost).

Table 10: Jackson Site Technology Licensing Costs [USD]

Parameter	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
	0	1	2	3	4	5	6	7	8	9	10
Site Tulip Cost	$211,722	$247,800	$245,077	$123,126	$114,917	$108,597	$103,661	$99,773	$104,762	$110,000	$115,500
Site DeepHow Cost	$5,655	$5,938	$6,235	$6,546	$6,874	$7,217	$7,578	$7,957	$8,355	$8,773	$9,211
Kepware Cost	$3,199	$3,391	$3,595	$3,810	$4,039	$4,281	$4,538	$4,810	$5,099	$5,405	$5,729
Total Licensing Costs	**$220,577**	**$257,129**	**$254,906**	**$133,482**	**$125,830**	**$120,095**	**$115,777**	**$112,541**	**$118,216**	**$124,178**	**$130,441**

Table 11: Monterrey Site Technology Licensing Costs [USD]

Parameter	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
	0	1	2	3	4	5	6	7	8	9	10
Site Tulip Cost	$515,550	$603,400	$596,769	$299,814	$279,827	$264,436	$252,416	$242,951	$255,098	$267,853	$281,246
Site DeepHow Cost	$30,510	$32,036	$33,637	$35,319	$37,085	$38,939	$40,886	$42,931	$45,077	$47,331	$49,698
Kepware Cost	$3,199	$3,391	$3,595	$3,810	$4,039	$4,281	$4,538	$4,810	$5,099	$5,405	$5,729
Total Licensing Costs	**$549,259**	**$638,827**	**$634,001**	**$338,944**	**$320,951**	**$307,657**	**$297,841**	**$290,692**	**$305,274**	**$320,589**	**$336,673**

6.2 Labor & Training

Labor is the most significant cost category for both sites. It is primarily driven by the OxT team, but additional costs were incurred by the IT team and the local teams to train the workforce and implement the solution. Because SBD accounting does not distinguish efforts between sites for the shared OxT and IT teams, these costs are assumed to be split evenly for each site. For the Jackson site, the training team estimated approximately 1.5 hours of training per application for every Maker using the new tools. This ended up being over 1,000hrs of labor hours and a measurable cost for the site. For the Monterrey site, though, the Makers didn't need to be trained to use the tools. As an assembly-focused site, the Makers weren't interfacing with the tools on a regular basis so training was limited to a relatively small percentage of the population. The training team in Monterrey saw this small burden as negligible. Due to the overwhelming cost of the OxT team, the labor cost for implementation is approximately $1.5M USD per site.

Table 12: Jackson Site Labor Costs [USD]

Parameter	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
	0	1	2	3	4	5	6	7	8	9	10
OxT Team Travel	$151,039	$7,552	$7,552	$3,021	$3,021	$3,021	$3,021	$3,021	$3,021	$3,021	$3,021
OxT Team Labor	$1,298,400	$64,920	$64,920	$25,968	$25,968	$25,968	$25,968	$25,968	$25,968	$25,968	$25,968
IT Team Effort	$60,474	$6,047	$6,047	$6,047	$6,047	$6,047	$6,047	$6,047	$6,047	$6,047	$6,047
Maker Training	$33,769	$4,750	$4,750	$4,750	$4,750	$4,750	$4,750	$4,750	$4,750	$4,750	$4,750
Supervisor Training	$7,078	$996	$996	$996	$996	$996	$996	$996	$996	$996	$996
CI Implementation	$5,471	$770	$770	$770	$770	$770	$770	$770	$770	$770	$770
Total Effort	**$1,556,231**	**$85,035**	**$85,035**	**$41,552**	**$41,552**	**$41,552**	**$41,552**	**$41,552**	**$41,552**	**$41,552**	**$41,552**

Table 13: Monterrey Site Labor Costs [USD]

Parameter	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
	0	1	2	3	4	5	6	7	8	9	10
OxT Team Travel	$151,039	$7,552	$7,552	$3,021	$3,021	$3,021	$3,021	$3,021	$3,021	$3,021	$3,021
OxT Team Labor	$1,298,400	$64,920	$64,920	$25,968	$25,968	$25,968	$25,968	$25,968	$25,968	$25,968	$25,968
IT Team Effort	$60,474	$6,047	$6,047	$6,047	$6,047	$6,047	$6,047	$6,047	$6,047	$6,047	$6,047
Maker Training	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Supervisor Training	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
CI Implementation	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Effort	**$1,509,913**	**$78,519**	**$78,519**	**$35,036**	**$35,036**	**$35,036**	**$35,036**	**$35,036**	**$35,036**	**$35,036**	**$35,036**

During 2024, the OxT team consisted of about 30 people working to both develop and deploy the solutions for the two focus sites. This consisted of building the tools, training the on-site team members to utilize the tools, and modifying them based on feedback. This was the first time the team provided an end-to-end connectivity solution for a site. The feedback was quite considerable initially, driving significant increases in workload to align the envisioned tool with the reality of high-rate production environments. Additionally, there was significant effort spent developing processes and building the technological infrastructure around the tools. For future sites, it is expected that the team can employ documented best practices and existing applications to dramatically reduce the overall costs. This was already seen towards the end of the first year and, based on discussions with OxT team leadership, should reduce to about 50% 2024 implementation costs by 2026, as shown in Figure 12.

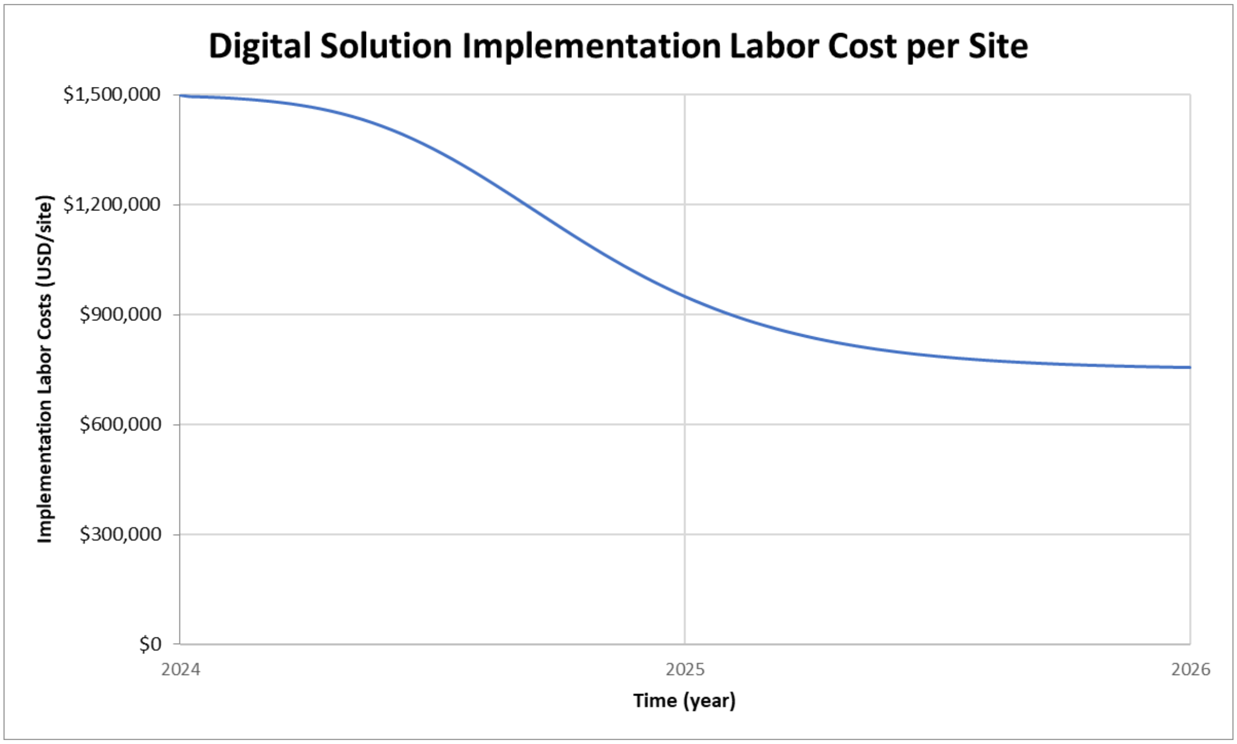

Figure 12: Expected Labor Costs for Implementation at Future Sites

6.3 Hardware & Equipment

The OxT and IT teams delivered and installed a significant amount of hardware and equipment at each site. This consisted of everything from ethernet drops for each machine to pull data from the PLC to iPads for the Makers to interface with the applications. The team laid over 26 miles of cable in Jackson and over 35 miles of cable in Monterrey. As the tables below demonstrate, the costs varied significantly for the sites – the CF team costs (part of OxT team) were higher in Jackson than Monterrey, but the IT team costs were lower in Jackson than Monterrey. Given the site differences (see Section 2.2), it is difficult to draw trends to help project costs of future implementation projects – this should instead be a part of the initial assessment procedure.

Table 14: Jackson Site Hardware and Equipment Costs [USD]

Parameter	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
	0	1	2	3	4	5	6	7	8	9	10
Connected Factory	$573,288	$57,329	$57,329	$57,329	$57,329	$57,329	$57,329	$57,329	$57,329	$57,329	$57,329
IT Team Non Effort	$364,538	$36,454	$36,454	$36,454	$36,454	$364,538	$36,454	$36,454	$36,454	$36,454	$364,538
Total Non Effort	**$937,827**	**$93,783**	**$93,783**	**$93,783**	**$93,783**	**$421,867**	**$93,783**	**$93,783**	**$93,783**	**$93,783**	**$421,867**

Table 15: Monterrey Site Hardware and Equipment Costs [USD]

Parameter	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
	0	1	2	3	4	5	6	7	8	9	10
Connected Factory	$302,482	$30,248	$30,248	$30,248	$30,248	$30,248	$30,248	$30,248	$30,248	$30,248	$30,248
IT Team Non Effort	$540,584	$54,058	$54,058	$54,058	$54,058	$540,584	$54,058	$54,058	$54,058	$54,058	$540,584
Total Non Effort	**$843,065**	**$84,307**	**$84,307**	**$84,307**	**$84,307**	**$570,832**	**$84,307**	**$84,307**	**$84,307**	**$84,307**	**$570,832**

7 Value Generation

The digital solutions delivered in SBD create value in multiple complex and interdependent ways, as discussed in Section 4.4. To isolate and evaluate these, the impacts were categorized into three groupings. The first accounts for the impacts that directly generate immediate value for the plant. These consist primarily of implementations that eliminate superfluous tasks or tools that amplify capabilities. These should be used to win over the workforce and gather momentum behind the efforts. The second accounts for time-based improvements: items that are expected to generate value as data is accumulated or as the team learns how to utilize the tools. These will be some of the primary drivers of productivity improvements but are highly variable – capturing this variance is discussed in Section 5. The third category accounts for improvements that are considered too variable to quantify. These are still intentional and designed improvements but must be interpreted based on strategic importance to the business.

7.1 Immediate Value Generation

To gather advocates from the shop floor and site leadership, immediate wins are needed from the solution. During execution, two major types of immediate savings were found as a direct result of the OxT team's work. The first is elimination of manual data entry, giving time back to the production teams. The second was improvements to the training process, increasing productivity and enhancing workforce flexibility.

7.1.1 Elimination of Manual Data Entry

Initially at the Jackson and Monterrey sites, significant time was spent obtaining, compiling, and processing data from the shop floor. This often consisted of hour-by-hour production logs that the makers maintained, pulling data from the machine interfaces or counting parts. These were then collected and compiled by supervisors, who reviewed them independently and passed along important information to manufacturing leadership. This process was both slow and time consuming, especially for the supervisors. Additionally, it was error prone as hand-written paper logs can be mis-interpreted or lost in the transition.

The connectivity solutions delivered by the OxT team pulled this data directly from the asset PLCs. Where supplemental information was required, such as assembly lines or older machines, an additional suite of tools was used to gather it digitally. This consisted of hand-held scanners, additional sensors installed on the machines, or Tulip-based interfaces on iPads with simplified queries for the Makers. The background programming compiled the data and produced user-friendly plots, counts, and other pertinent results for the supervisors and manufacturing leadership. Outside of the improvements to data quality, quantity, accessibility, and traceability, this resulted in time savings for the people directly creating value for the company. The Makers saved time by eliminating the need for hand-written logs and the supervisors no longer had to run down and decipher each of these logs, compiling and flowing the information to higher levels of leadership. This won allies early from the end users, which was an integral part of solution adoption. The estimated time savings, gathered by the supervisors of each value stream, are provided in the tables below. The time savings are translated to an annual financial impact through average labor rates.

Table 16: Jackson Site Labor Savings from the Elimination of Manual Data Entry

		Knives	TDE Shop	TDE Pack	Compressors	PWD	Castings	Heat Treat	Steel	Shafts
Parameter	**Unit**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Site Employee Count										
Individual Contributor	people	24	29	19	57	8	15	6	19	33
Team Leads	people	3	5	2	10	0	3	0	5	2
Supervisors	people	1	1	1	2	1	1	1	1	1
Savings from Manual Data Entry, Collection, and Processing Time										
Individual Contributor	hr/person/shift	0	0.58	0.50	0	0	0.17	0	0.33	0.17
Team Leads	hr/person/shift	0	0	0	0	0	0	0	0	0
Supervisors	hr/person/shift	0	2	2	0	0	0.4	0	2	2
Total Savings	$/yr	$0	$116,226	$63,303	$0	$0	$18,290	$0	$58,479	$51,284

		Gears	Quality	Materials	Engineering	CI	Maintenance	Cleaning	Buyer/Planner	Misc.	Total
Parameter	**Unit**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**N/A**
Site Employee Count											
Individual Contributor	people	19	15	24	12	1	31	4	7	0	323
Team Leads	people	1	0	2	0	1	4	0	0	0	38
Supervisors	people	1	0	0	0	0	1	0	1	3	16
Savings from Manual Data Entry, Collection, and Processing Time											
Individual Contributor	hr/person/shift	0.17	0	0	0.33	0.8	0	0	0	0	---
Team Leads	hr/person/shift	0	0	0	0	0.8	0	0	0	0	---
Supervisors	hr/person/shift	2	0	0	0	0.8	0	0	0	1.2	---
Total Savings	$/yr	$37,409	$0	$0	$52,462	$23,261	$0	$0	$0	$36,125	$456,839

Table 17: Monterrey Site Labor Savings from the Elimination of Manual Data Entry

Parameter	Unit	1 (Assembly)	2 (Batteries)	3 (Motors)	N/A (Total)
Site Employee Count					
Individual Contributor	people	1174	283	286	1743
Team Leads	people	138	33	34	205
Supervisors	people	58	14	14	86
Average Labor Rates					
Individual Contributor	$/hr	$7.81	$7.81	$7.81	$7.81
Team Leads	$/hr	$9.33	$9.33	$9.33	$9.33
Supervisors	$/hr	$12.02	$12.02	$12.02	$12.02
Savings from Manual Data Entry, Collection, and Processing Time					
Individual Contributor	hr/person/shift	0.08	0.08	0.08	---
Team Leads	hr/person/shift	0	0	0	---
Supervisors	hr/person/shift	0	0	0	---
Total Savings	$/yr	$185,699	$45,000	$45,000	$275,699

The differences between the two sites are stark; despite Monterrey's large workforce, there is minimal time savings for the site compared to Jackson. This is due to the site organization and production environment, something that also explains the differences between value streams in Jackson. In assembly focused environments, there are few machines to pull the required data from – the makers simply enter the data on a Tulip application instead of on a hand-written log. Some savings is achieved from the gathering of that data, but it was found to be minimal in an organized manufacturing environment. Asset heavy value streams, such as Taps, Dies, and Extractors (TDE) Shop, where the ratio of assets to makers is higher, can save more time for the workforce because more data is available. If a single maker is operating a number of machines, it is time consuming to track production on each of them and, with the new tools, that is eliminated. Other areas that are counting focused, such as TDE Pack, where makers are packaging products for shipments, the scanner application dramatically reduces logging efforts. Together, these savings become quite considerable for more industrial sites.

7.1.2 Digitally Enabled Training

Software and iPads were delivered to the Monterrey site to digitally enhance the training efforts. With the large quantity of makers at the site, there is a designated assembly line for training that can be configured for different production. It is used to teach new hires and those transferring between departments the skills required to assemble the products. Originally, the teams there used paper work instructions in a booklet for individuals to work through and reference as they work. This was replaced by iPads that played DeepHow videos. These videos are generated by the trainers and AI support, demonstrating of each step in the build process.

Initially, the team assumed this would be a small impact for the site, but results showed differently. Over a one-month period, the training line gathered production data for the digitally enhanced training and compared it directly to historical records of traditional methods. This consisted of data from six different configurations, two shifts, four weeks, and various levels of target proficiency. The plot shown in Figure 13 below shows the results for the new methods compared to the baseline normalized for target production rates. The error bars show 95% confidence intervals. At time when traditional methods strive for 25% full daily production rate, the lines with iPads and videos were achieving 55% of the rate. The gap was maintained to the 50% target point but started narrowing as the group achieved full proficiency. When the target was 95% of production, though, the digitally enabled group performed worse than the baseline.

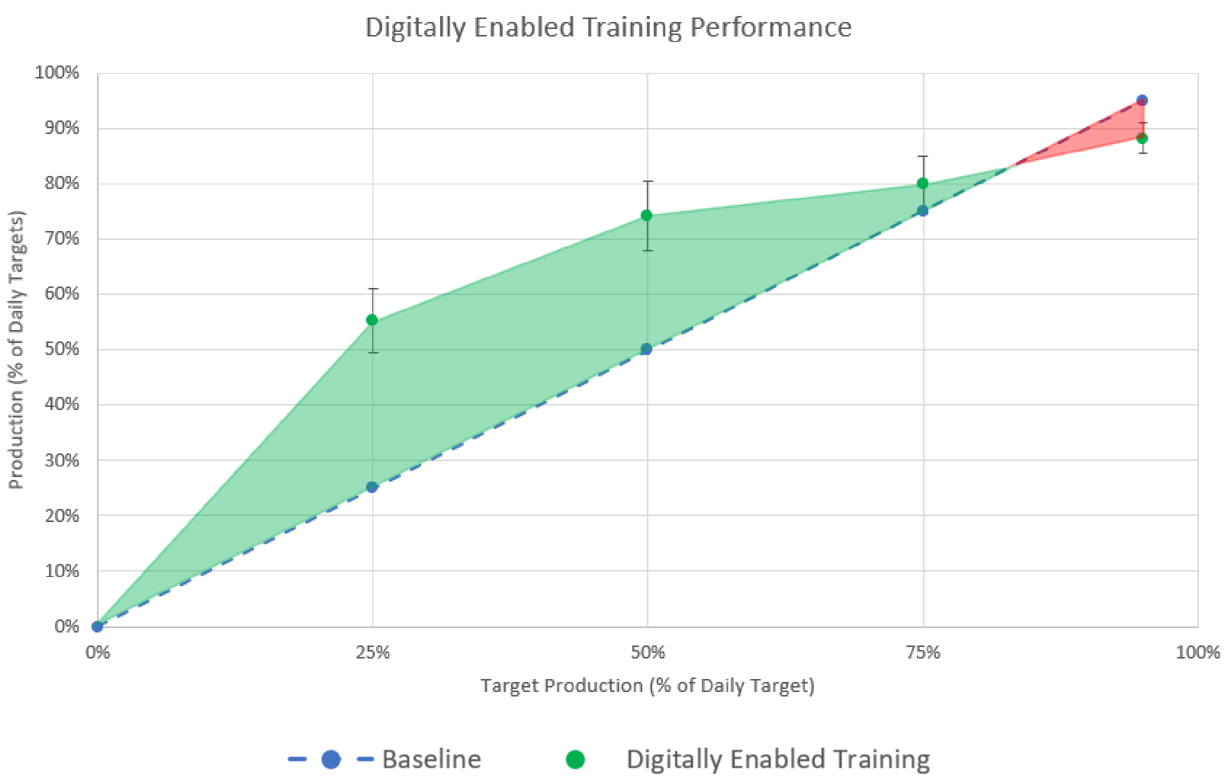

Figure 13: Digitally Enabled Training Performance

There are two primary benefits revealed by this data. First, the trainees are skilling up faster than traditionally. This enables a more agile workforce and promotes workforce resiliency through cross-training opportunities. Secondly, because real products are being made during this training period, there is a measurable quantity of additional revenue generated (assuming demand is present). This can be measured by the gap between curves, shown as the shaded areas, with green indicating additional productivity and red indicating reduced productivity. That gap was measured as 0.140 and annual profitability from this implementation can be found from the formula below. For the Monterrey site, that value was found to be $1.8M.

Equation 4: Digitally Enabled Training Profitability

$$Annual\ Profit = 0.140 * Rate * Training\ Duration * N_{Trainings} * Profit\ per\ Unit$$

The reduced productivity gap as full production rates were achieved is expected given that no additional tools were provided – the trainees eventually all learn the same skills, whether from videos or paper instructions, and achieve the performance goals. However, the dip below target at the 95% point is concerning and merits further research by SBD. This could indicate that some critical piece of training is missed and, if the trainee final skill level after training is reduced, it would impact site-wide production rates. At the same time, this could also just be an indication of cultural impacts where the employees feel they've learned the skill already and stop pushing or the trainers' attention drifts as early goals were achieved with such success.

7.2 Delayed Value Generation

Through the system dynamics model (see Section 4.4) and discussions with the production teams at the sites, the implemented solutions were delineated into five primary changes. While measuring impacts of every individual application or impetus should be considered, for this scenario mapping each of them would drive increased workload and risk of double-counting impacts. For each change, the team quantified the total expected impact to the business through seven major KPIs and the expected time for full implementation. The impacts were scaled according to the applicable, normalized learning curve shapes (see Section 5.1) and translated to dollar value through site-based KPI metrics. Finally, some of these changes were in different phases of implementation. A risk value was applied to scale expected return from each change based on maturity in accordance with standard SBD methodologies (see Section 5.2).

7.2.1 Automated Data Collection and Cloud-Based Visualization

The automated data collection serves to increase the quantity of data available and reduce the erroneous entry rate due to timing issues, missing entries, or wrong entries. All machine PLC data is essentially free to capture after the system is in place; industrial engineers can dive into extensive data around each critical asset to look at bit replacement rates, specific processes, and other operational factors. Additionally, there is more data captured to contextualize uncommon events; each time a machine goes down without an asset related issue flagged by the PLC (material shortage, unscheduled operator break, etc.), the operator inputs the issue into the system. This enables closer monitoring of unplanned downtime and easier identification of problem areas. Finally, production rates were often tracked in hour-by-hour logs from the Makers. These individuals would document part counts from the asset interface at set intervals to help show trends. However, the makers have other responsibilities and are not recording the information exactly on the hour. Instead, it is often ±15 minutes from the top of the hour, which can distort the trends. Also, these logs can go missing or the last entry of the day is often forgotten, which can generate outliers and discontinuities that undermine data validity. The new system circumvents that, resulting in cleaner and more granular data available which empowers the production team to be more specific and targeted in their productivity improvement efforts.

This, in turn, helps improve production insights because there is more, and more accurate, data available. Also, the platform helps viewing results and expediting information transfer. The solution delivered by OxT builds in data visualization and manipulation through an accessible, user-friendly webpage interface. Anyone with access to the SBD network can delve into this data, already processed into common trend and summary plots, and start generating insights about the production environment. This system short-circuits the previous methods of gathering data from the data logs, inputting it manually into Access-based productivity databases, and processing results by the handful of people with access and knowledge of the system.

Table 18 below shows a summary of the delayed productivity impacts from this change. The change was successfully implemented, the system was operational in Year 0 (first year on site), and the team was starting to see measurable impacts (risk status: savings started), but the on-site team believed it would take around three years to fully realize the benefits from it (time for full adoption). During this time, due to a lack of familiarity, the team believed it would follow a standard "S" shaped learning curve. As a result, the total expected improvements for each KPI are delayed by that function over the next three years, starting in 2025 (year 1) and being fully executed by the end of 2027 (year 3) as displayed in Figure 14.

Table 18: Jackson Site Delayed Productivity Impacts – Data System

Title	Automated Data Collection & Cloud-Based Platform → Better Production Insights						
Year Implemented	0			Risk Status	Savings Started (100%)		
Time for Full Adoption	3			Learning Curve Shape	1 - Standard		
Type	Indirect: non-OxT action			10yr Savings	$2,814,818.85		
Expected Improvements	Scrap	Rework	Attainment	Unplanned Downtime	Mix	Labor Efficiency	RIP + WIP
	10.0%	10.0%	0.0%	7.5%	0.0%	2.0%	0.0%

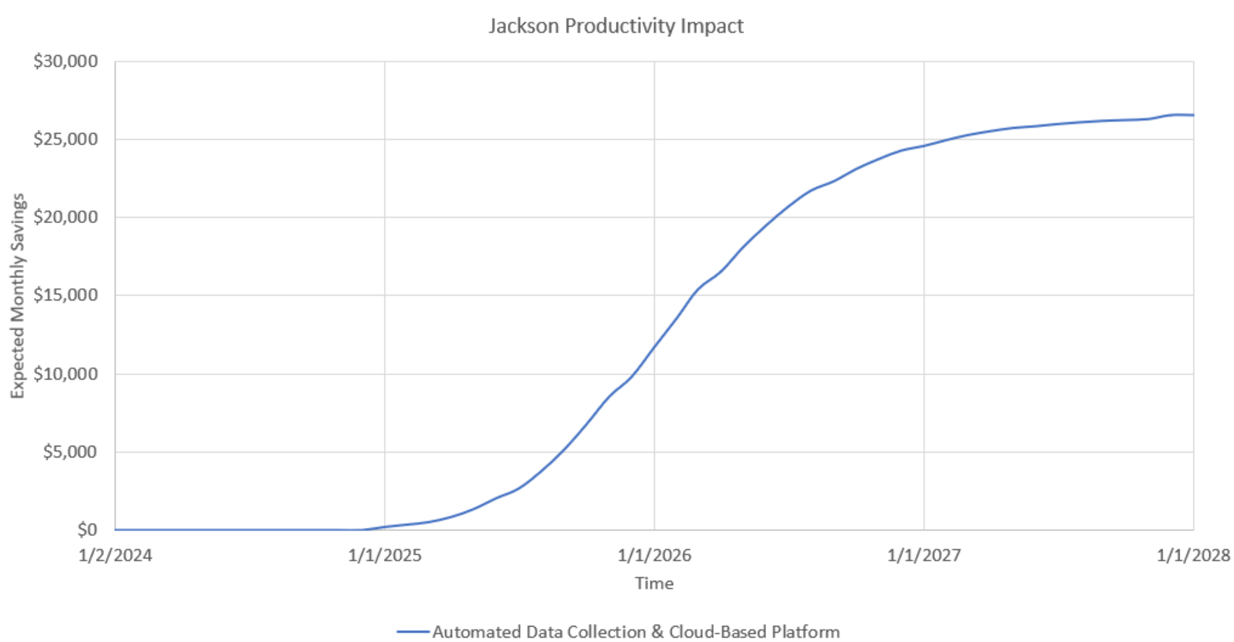

Figure 14: Jackson Productivity Impact – Data System

7.2.2 Improved Inter-Site Data Accessibility

As mentioned in the previous section, the production data can be reviewed and visualized by anybody with access to the internal SBD network. This now enables sites to compare and contextualize their performance relative to other sites within SBD. For example, Jackson can review production rates of other sites that assemble utility knives. If they find a significant gap, either Jackson can invite the other site's team to visit, or they can travel to that plant to observe why they are able to achieve higher rates. This sharing of best practices within the company can help SBD leverage its size and standardize production methods.

The transparency also serves a purpose on the supply chain side. Many plants are producing internal products, shipping production to internal SBD plants who do final assembly. If the team is falling behind required production rates, the teams could identify this immediately and start troubleshooting instead of waiting for the next backflush point to SBD (often right before shipments). This should reduce bullwhip, which has been a major challenge for SBD in the past (see Section 2).

The improved accessibility also enables increased access to talent for the production teams, which are often located in more remote areas. People who are better suited for data analytics do not need to be on-site for the duration of the project but instead can be reviewing the data and building conclusions remotely. For sites that, due to their location, can struggle to find certain skillsets, this is very impactful. Also, these resources can be shared across sites, enabling central productivity analytics groups to be much more effective.

Table 19 shows that this impact is not expected for approximately 10 years. Savings are expected to start after Year 1 because OxT is bringing three more sites online in 2025. Then these impacts will slowly be realized as more and more sites are brought online and they share their relative expertise. The expected results are displayed graphically in Figure 15.

Table 19: Jackson Site Delayed Productivity Impacts – Inter-site Data Accessibility

Title	Improved Inter-Site Data Accessibility						
Year Implemented	1			**Risk Status**	Savings not Started (100%)		
Time for Full Adoption	9			**Learning Curve Shape**	2 - Linear		
Type	Indirect: non-OxT action			**10yr Savings**	$288,486.81		
Expected Improvements	Scrap	Rework	Attainment	Unplanned Downtime	Mix	Labor Efficiency	RIP + WIP
	0.0%	0.0%	0.0%	0.0%	5.0%	0.5%	0.0%

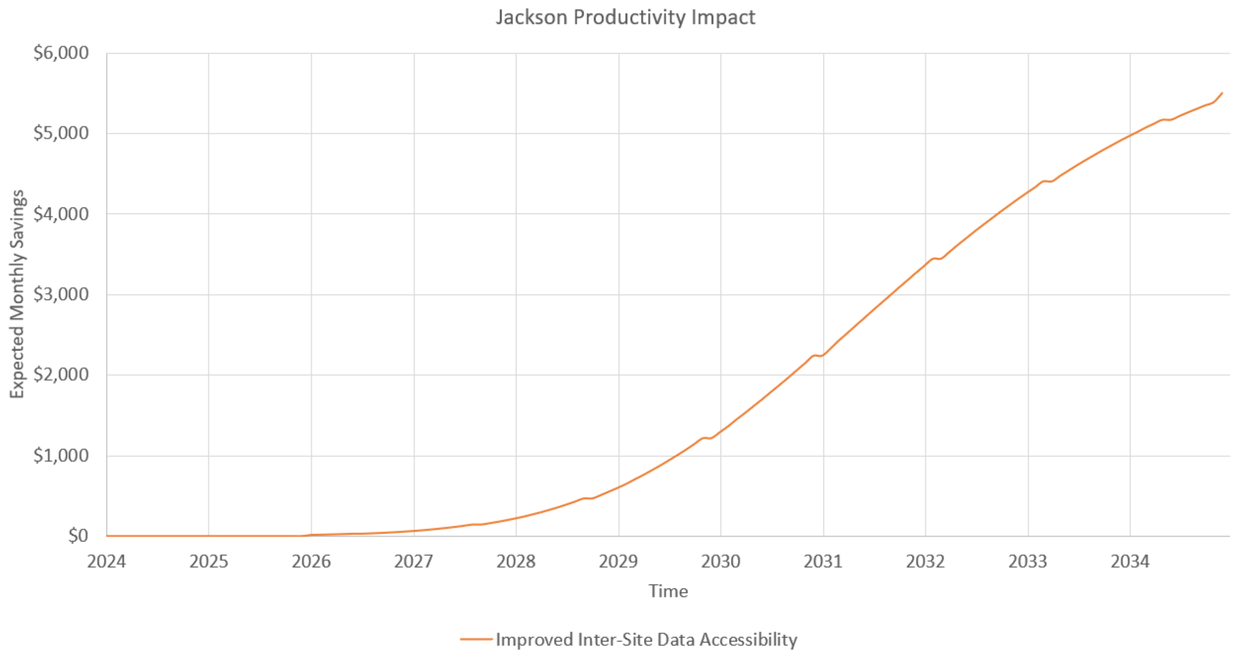

Figure 15: Jackson Productivity Impact – Inter-Site Data Accessibility

7.2.3 Increased Data Prominence and Accountability

Screens were installed over each of the production areas to show real-time status and daily production statistics. These graphics showed, asset by asset, when things were behind or down by turning red and highlighting it for production supervisors and other leadership members walking by. At central points on the production floor, there were larger screens that showed value stream level metrics and even plant-wide metrics. These central screens were touch-enabled and allowed those passing by to delve deeper when there were issues. Conference room screen backgrounds and sleep settings were adjusted to show the plant-wide production health metrics. Examples of these displays are provided in Section 2.5.

This resulted in heightened oversight and awareness of whether the teams were "winning the day". In the cafeteria on breaks, Makers would mention to each other when they noticed unusual events or teams significantly behind. This was found to drive a cultural shift towards more results-oriented mindsets and many makers naturally pushed harder to get their zones out of the red. This is not isolated to just SBD or the production environment but is common across industries and is supported by literature (Section 2.5). Unfortunately, that push can sometimes be at the cost of quality, depending on team leadership.

Adding to the cultural shift is more clarity around the data. When it is displayed prominently throughout the plant and in conference rooms, people get intimately familiar with the data and the format in which it is presented. This can streamline meetings and troubleshooting as the discussions do not focus on the data itself but, rather, the results. It can be seen as the "one source of truth", saving team members from the time to understand new data and graphics.

Table 20 and Figure 16 display the results from this change. The value is primarily driven from the expected attainment growth and labor efficiency. The curve shape is expected to be steep shortly after the teams acclimatize to the screens. The scrap and rework see a detriment due to the increased results focus, but the team was made aware of the potential impact and will be closely monitoring to ensure quality does not significantly suffer.

Table 20: Jackson Site Delayed Productivity Impacts – Data Prominence

Title	Increased Data Prominence and Accountability						
Year Implemented	0			**Risk Status**	Savings Started (100%)		
Time for Full Adoption	1			**Learning Curve Shape**	3 - Delayed Steep		
Type	Direct: OxT action			**10yr Savings**	$2,947,350.74		
Expected Improvements	Scrap	Rework	Attainment	Unplanned Downtime	Mix	Labor Efficiency	RIP + WIP
	-2.0%	-2.0%	0.5%	0.0%	0.0%	2.0%	0.0%

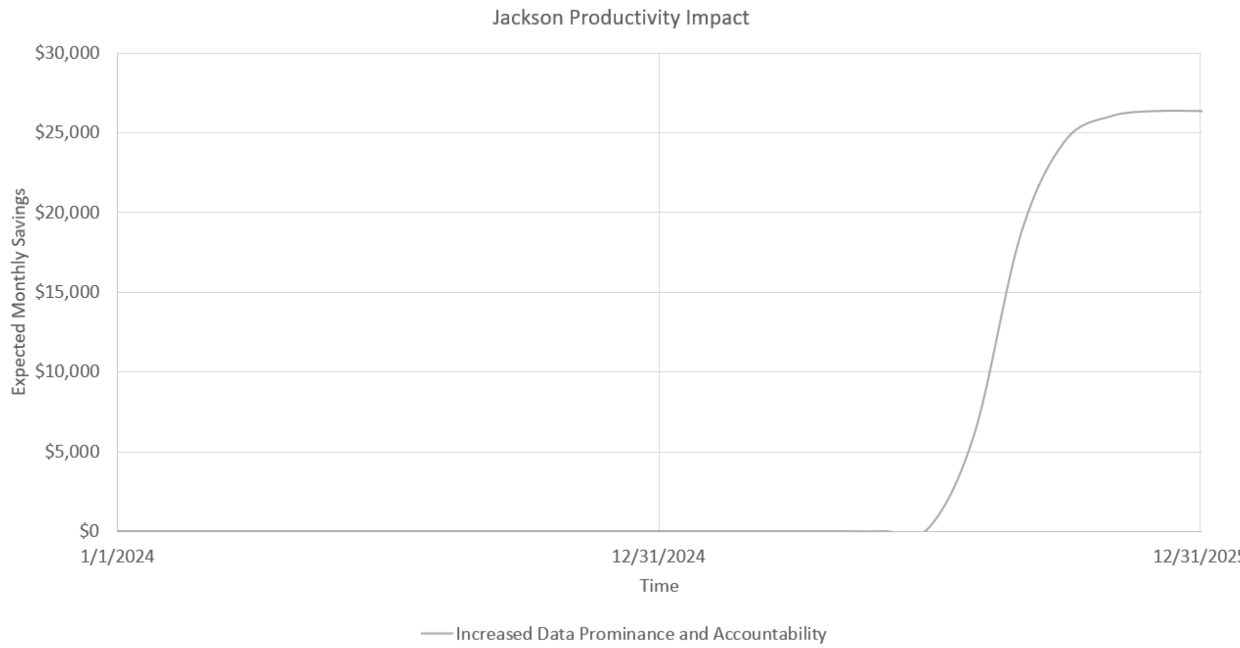

Figure 16: Jackson Productivity Impact – Increased Data Prominence

7.2.4 Automatic Alerts and Streamlined Processes

An in-work feature of the digital tool suite OxT delivers to the manufacturing teams is the ability to enable automatic alerts and integrate with other existing digital tools. The team members will be able to set preferences and have messages sent to their email or Teams (internal messaging system) when events occur in the plant. For example, supervisors could choose to receive an email whenever an asset goes down in their area. Site leadership could be pinged when critical assets are down for more than 30 minutes or production drops below goals for three consecutive hours. This allows for faster response time from the site as a whole, resulting in more agile teams.

In addition to those email notifications, the new system can send information to the existing systems. The maintenance teams use a platform called "E-Maint" for generating work orders or triaging repair needs. With the digital applications and increased information obtained from the assets, the OxT team is developing a method for completing work orders directly and pushing information to those systems. This will streamline processes and give more time back to the makers and the maintenance teams. The results are displayed in Table 21 and Figure 17 below. Given that the solution is fully planned and in the process of being executed, but not complete yet, it is scaled to account for the "Funnel" risk status.

Table 21: Jackson Site Delayed Productivity Impacts – Automatic Alerts

Title	Automatic Alerts & Digital Work Orders						
Year Implemented	1			**Risk Status**	Funnel (70%)		
Time for Full Adoption	1			**Learning Curve Shape**	1 - Standard		
Type	Indirect: non-OxT action			**10yr Savings**	$399,295.14		
Expected Improvements	Scrap	Rework	Attainment	Unplanned Downtime	Mix	Labor Efficiency	RIP + WIP
	0.0%	0.0%	0.0%	5.0%	0.0%	0.5%	0.0%

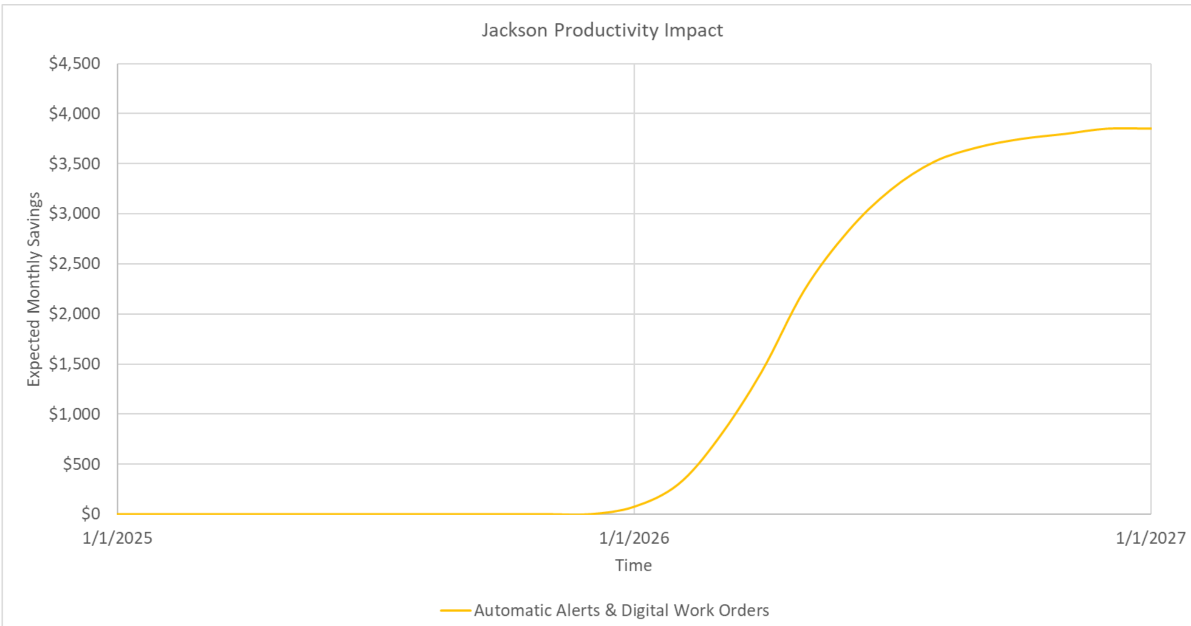

Figure 17: Jackson Productivity Impact – Automatic Alerts and Streamlined Processes

7.2.5 Improved Inventory Management

The final tracked change is an application in development that will help to track and manage inventory at the site. This is still in development but expected to fill a tremendous need for some SBD sites. The current systems in place track production part counts as the parts move through each process in the value stream. These part counts, with SAP data on material requirements, will inform material consumption at an incremental level throughout the site. If a tool is built that helps to track when material stocks are shifted from the warehouse to the supermarkets near each value stream, then teams can always track exact material quantities in each location. Current systems track material utilization each time SAP is backflushed, which can be as slow as once every few weeks. Also, there are many "waterspiders" (material handler team members who count quantities in the supermarket and warehouse) that constantly move about the plant tracking this information to guide other material handlers. A new application with access to all this information could send notifications to each of the material handlers identifying material needs before they become a problem for the production teams.

This application is still being formulated, so it is designated as "Pre-Funnel" and the results are scaled to account for the risk. The results show in Table 22 and Figure 18 highlight the potential impact of this application, something that helped drive the change itself after the DSET identified it. Note, that while the improvements are mapped according to the generalized learning curve shape, the changes to inventory (RIP + WIP) are one-time savings as inventory is reduced. As such, the expected monthly savings will take the shape of the derivative of the "S" shape with some compound effects as the quality metrics (scrap, rework, labor efficiency) follow traditional behavior. Note, while some firms account for the carrying cost of inventory, SBD treats inventory savings as one-time events which drives the methodology here.

Table 22: Jackson Site Delayed Productivity Impacts – Inventory Management

Title	Inventory Management Application						
Year Implemented	1			**Risk Status**	Pre-Funnel (50%)		
Time for Full Adoption	4			**Learning Curve Shape**	3 - Delayed Steep		
Type	Direct: OxT action			**10yr Savings**	$2,477,211.64		
Expected Improvements	Scrap	Rework	Attainment	Unplanned Downtime	Mix	Labor Efficiency	RIP + WIP
	3.0%	3.0%	0.0%	0.0%	0.0%	2.0%	10.0%

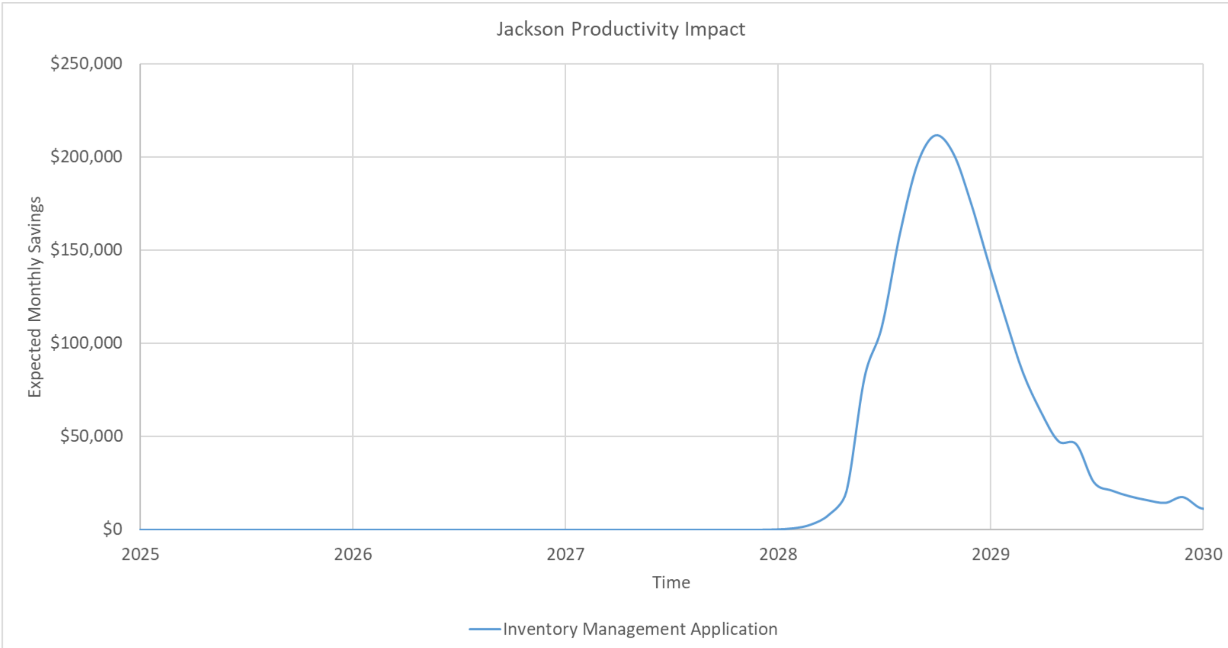

Figure 18: Jackson Productivity Impact – Inventory Management Application

7.3 Positive Externalities

Attempts were made to quantify all impacts from the digital solutions in Jackson and Monterrey. Some expected benefits, though, had significant variability. If captured in the quantitative tabulations, it may cloud the results from other areas or lose the trust of some key stakeholders. Instead, these aspects were left unquantified and simply noted as positive externalities, left to leadership to interpret based on their strategic understanding of SBD.

7.3.1 Culture

The first positive externality captured was the cultural improvements at the sites. Through refocusing and investing heavily in the manufacturing and maker capabilities at the site, SBD leadership is sending a clear message about the importance of performance. This can invigorate people at the site to start bettering their areas and having more pride in their performance. Visually, it was clear that when new equipment was installed many makers went above usual scope to keep the area cleaner and better maintained. For the leadership and supervisors, there is easily accessible data at their fingertips. This promotes data-driven decision making, which can improve overall site performance through compilation of making the right decisions over time.

7.3.2 Safety

Another important feature of this manufacturing environment with more transparency is the impact to safety. From studies on other high-stress operational environments, cultures with open and honest communication saw up to 10 times more errors reported [40]. If the implementation of these digital solutions leads to more near miss reporting (assuming no negative safety impact), teams will be able to better identify unsafe areas and correct them prior to an injury. Also, as discussed in Section 2.5, a Tulip application was built to improve the 5S process leading to better results tracking and more frequent inspections. This should boost overall site cleanliness and organization, which has a positive correlation with workplace safety [40]. Together, these changes should demonstrate a measurable improvement to safety but, in the short time of implementation so far, there aren't enough safety events to validate this. Additionally, the team decided that it was imprudent to put a dollar value to the importance of safety issues because it could undermine the perceived value to the makers.

7.3.3 Data Standardization

The different sites at SBD have been established or acquired at different times and have different legacy processes (see Section 2). These different processes apply to data capture and utilization. A major strategic effort for SBD is to ensure all sites are not only capturing and reporting the same KPIs, but that they are using the same methods for capturing the information. The acquisition method, which in production environments is often imperfect, can result in different reported results. For example, sites using hand-written logs to determine scrap rates are often under-representing the actual values relative to digitally acquired scrap rates that trace all material flow. That makes it difficult to compare site-to-site performance and make corporate level strategic decisions. The resulting value generation is unique for each specific case; it is dependent on the severity of strategic decisions and discrepancies in the data. Quantifying this is outside of the scope of this project.

7.3.4 Track and Trace

Section 7.2 detailed the value of having better transparency into the production environment, but there are supplemental benefits that are more nebulous. With data at their fingertips, the team is expected to slowly transition from low to high frequency projections and data review. In other words, data that was previously reviewed at a weekly, monthly, or even quarterly basis is now compiled continuously and can be reviewed much more often. This enables the leadership to identify discrepancies and problems earlier, hopefully enabling faster response time and limiting severity of problems. The impact is difficult to quantify since the value of agile response to problems is inherently dependent on the specific problem being addressed. With additional data and time, such as documented issue avoidances, the value could be evaluated in future iterations. It is important to note that this faster response time can also lead to hyperreactivity, which can enhance localized bullwhip effects.

Another unclear aspect of this increased transparency is the impact to asset management decisions. Having clear measurements of OEE and other data to enhance asset criticality assessments enables teams to make more informed decisions around asset repairs, replacements, and redundancies. This, however, requires the team to become intimately familiar with the data and proficient in its application, which takes time (has not occurred yet). Similar to the problem avoidance discussed, savings from asset management decisions are highly dependent on the specific situation and, therefore, difficult to assess without data. After demonstrated success with data utilization for this purpose, the teams should reassess this category, generalizing results to quantify the expected savings.

7.3.5 Cybersecurity & Governance

Cybersecurity has become increasingly important to companies, especially as more aspects of the business are digitally enabled. For SBD, improved cybersecurity has been a major strategic goal in recent years. As more technology is injected into the production environment, it will continue to be important for the company. The highest levels of leadership allocated significant funds to upgrade this capability. While the OxT team is bringing more connectivity to the plants, it is teamed with the IT team to upgrade network security as this is happening. Many sites had very old network solutions which were vulnerable to digital attacks. Consequently, this project helps SBD achieve the set strategic goals. As with the other positive externalities, this is difficult to quantify this without significant data on the number of attacks, financial severity, and resilience of new systems compared to the old ones. This was considered outside the scope of the project.

8 Results

While the analysis of the costs and the value generation have been discussed in Section 6 and Section 7, respectively, the site-specific results must be compiled. The autonomy of SBD sites and current internal political structures suggest that the decisions for expanding the digitization initiatives must be supported by site leadership. As such, these customers must understand the full picture and compare the levied costs against the future gains. It is important to note that these compiled results are very sensitive to the assumptions and inputs made, getting less accurate over longer time periods. As such, sensitivity studies were run to determine higher and lower-end projections, specifically scaling the delayed value generation sources discussed in Section 7.2. The net present value (NPV) calculations are based on a standard corporate discount rate of 12%.

8.1 Jackson

The investment for end-to-end connectivity solutions and digitizing the manufacturing lines in Jackson, Tennessee required a total capital investment of 2.7 million dollars. The expected payback period is 3.5 years with a 5-year ROI of 18%. The financial result summary is displayed in Table 23 below. The full cash flow summary, showing sources and year-by-year projections, is provided in Appendix C: Cash Flow Summaries as Figure 25. Note, this financial accounting excludes the positive externalities discussed in Section 7.3.

Table 23: Jackson Financial Results Summary

	Lower-Bound	Best Projection	Upper-Bound	Unit
Scale Factor (delayed value generation)	50%	100%	150%	---
Total Capital Investment	$2.71			M USD
Avg. Non-Recurring Expense	$0.36			M USD
Net Payback	4.0	3.5	3.2	years
DCRR Payback	6.4	4.2	3.6	years
5-yr NPV	-$0.35	$0.44	$1.22	M USD
10-yr NPV	$0.57	$2.04	$3.51	M USD
5-yr ROI	7%	18%	27%	---
10-yr ROI	17%	28%	37%	---

8.2 Monterrey

The investment for end-to-end connectivity solutions and digitizing the manufacturing lines in Monterrey, Mexico required a total capital investment of 2.9 million dollars. The expected payback period is 3.4 years with a 5-year ROI of 26%. The financial result summary is displayed in Table 24 below. The full cash flow summary, showing sources and year-by-year projections, is provided in Appendix C: Cash Flow Summaries as Figure 26. Note, this financial accounting excludes the positive externalities discussed in Section 7.3.

Table 24: Monterrey Financial Results Summary

	Lower-Bound	Best Projection	Upper-Bound	Unit
Scale Factor (delayed value generation)	50%	100%	150%	---
Total Capital Investment		$2.90		M USD
Avg. Non-Recurring Expense		$0.60		M USD
Net Payback	3.8	3.4	3.1	years
DCRR Payback	4.9	3.7	3.3	years
5-yr NPV	$0.04	$1.44	$2.83	M USD
10-yr NPV	$0.79	$3.31	$5.84	M USD
5-yr ROI	12%	26%	38%	---
10-yr ROI	18%	34%	45%	---

8.3 Future Sites

The results for both sites are promising but rely heavily on the delayed value generation sources, as revealed by the sensitivity to the scale factor. This heightens the importance of implementation, continued support, and teaming between OxT and the implementation site personnel. The impact at Monterrey resulted in a significantly higher ROI due primarily to the capital investment not scaling with site size and revenues. Monterrey generates approximately 2.5x more revenue than the Jackson site but, due to more modern infrastructure and less assets to connect, the site implementation costs did not scale linearly with revenue. These factors should be considered before deciding which sites to digitize in the future.

For SBD productivity investments, the teams require a net payback period of less than three years. As such, these investments do not meet the financial investment criteria without the positive externalities. However, the investments could be classified differently due to the strategic and infrastructure-based objectives achieved (specifically cybersecurity and data standardization), so the financial investment criteria are adjusted to the business needs. These investment types are longer-term and primarily evaluated by requirements for continued operation and long-term ROI. Given that the ROIs are above the 12% standard corporate discount rate for both sites and the major strategic initiatives around cybersecurity requirements, the digitization of future sites meets SBD investment evaluation criteria.

9 Conclusion

Through this project, a tool was developed and successfully deployed at SBD to assess the value of the digital transformation that took place at their plants in Jackson, TN and Monterrey, MX. The tool is streamlined to increase frequency of performance reviews and transparent enough to obtain the buy-in from all three customer groups. The tool captures variability in different ways. Time-dependent results are captured through the integration of learning curves, implementation challenges are captured through risk factors, and people-product-process variability is captured through refined input parameters. Additional time gathering data on solution performance and post-implementation results will guide further development and refinement of this tool, which has been passed to internal teams at SBD for continued use.

The results suggest a 5-year ROI of 18% and 26% for the Jackson and Monterrey sites, respectively. This is primarily driven by the labor savings from the elimination of manual data entry and productivity improvements from an automated data collection and cloud-based visualization system coupled with increased data prominence and accountability. The most significant cost driver for these digital solutions was the labor and overhead for the implementation team. A number of unquantified positive externalities are captured, such as impacts to company culture and improved cybersecurity. Some risks, opportunities, lessons learned, and best practices are highlighted below.

9.1 Risks

The primary risk to delivering value to the sites is a lack of buy-in. If the Makers do not follow required processes and use the applications properly, the data will be of little value. Makers, supervisors, and team leaders who are on-site and expected to use the data may not be digitally fluent – this is a new skill being introduced into their work statement. Given the high-stress environment these people operate in, there is a high chance of losing user buy-in if the solutions do not function properly the first time or impede workflow. The team implementing digital solutions should ensure any deployment includes adequate training of key personnel on-site, helping them become digital champions who will stay engaged. These personnel must understand the impacts and motivations behind the efforts; they will convey the message to the other makers at the site. Improved relationships with the OxT team, hands-on demonstrations, and being judicious with tool deployment will help too.

A secondary risk of note is if the users do not trust the data being obtained. If the site leadership, CI teams, and engineering teams do not trust or utilize the data, minimal improvements will be made. The data coming in must be validated and these team members must understand the process to obtain the data, rather than seeing it as a "black box". With changing acquisition methods and more fidelity in the data, some KPIs may go down and ugly truths come up. Increased reporting is likely to result in more near misses, reduced 5S scoring, and identification of hidden factories. If the data is not trusted, the teams will resent the system and discount the results rather than seek solutions.

Teams should be careful of overwhelming amounts of information – too much data can sometimes have the same result as no data. It should be prioritized and filtered to maximize impact for the teams, especially early in the deployment. For example, after deployment of the 5S Application, supervisors were getting emails for every finding from every audit completed in their designated area. For one supervisor, this ended up being over a hundred emails in the first month. He was inundated with information, became numb to the requests, and continued to operate as he had before the emails.

9.2 Opportunities

There are major opportunities within the digital space that are not currently captured. As the digital maturity of SBD sites and the OxT team grow, consider support around asset and inventory management. With end-to-end connectivity, material movement and consumption can be tracked in detail throughout the site. Additionally, with high fidelity production rates, downtime, and other metrics, simplified digital twins could be generated to optimize product flow, size inventory buffers, and complete asset replacement trade studies. The OxT team should consider integrating an off-the-shelf (OTS) production optimizing software solution (such as Linelab) with the in-house built digital data acquisition such that the analytical workload on site personnel is limited. The common solution could be applied to many sites, substituting local data and procedural information from SAP with local manufacturing engineering support. This would pay significant dividends but requires a high level of maturity and should be considered after demonstrated success with the digital tools delivered initially.

Opportunities around low-level inventory management support, using scanners and a Tulip application were identified early in the project and is currently in development (see Section 7.2.5). Similarly, another opportunity identified early in the project was around streamlining maintenance reporting procedures and providing automated alerts to key personnel. This is already a feature in some Tulip applications so the work to develop the same for the digital tools in Jackson and Monterrey is minimal. Solutions are in development as discussed in Section 7.2.4.

The Monterrey team independently realized the tremendous value to providing more technology to the training process. With simple iPads and AI generated videos, the teams notably improved the early production rates by trainees. This can and should be extended to other areas, especially those that require more training or sites with high turnover. The OxT team should also delve deeper into this area and consider other ways to empower training teams.

The last opportunity to note is around the implementation and team organization for continued support of the digital solutions. It takes significant amounts of time for the OxT team to reach the level of familiarity and trust required to successfully develop and deploy digital solutions at each site. They need to build relationships, learn the new processes, adapt to the site culture, and modify the solutions for the given application. This is difficult to do while on short-term travel and within a single year (current digitization strategy). After completing deployment, there will be need for continued troubleshooting and support as the teams learn and utilize them. Instead of having the team swarm a site with a revolving door of multiple members on short-term travel, OxT leadership should consider long-term designated on-site support of a few team members who can translate needs and communication back to the remote OxT team.

9.3 Lessons Learned

Throughout the project, many lessons were learned by the team. They were learned through analysis of the results, the literature reviews, and informal interviews. These help to shape the path forward and optimize future growth at SBD. The major lessons have been categorized and documented here.

9.3.1 Impact Sources

The best returns came from unexpected locations. Initially, the teams prioritized reduced rework and scrap to achieve savings through reduced cost of poor quality (COPQ). For both Jackson and Monterrey, though, the annual COPQ alone was not significant enough to merit the investments. Even if the teams eliminated all rework and scrap costs without significant prevention and appraisal costs, the capital investment required is too high to meet the financial criteria and merit the investment. However, as Juran's Model depicts in Figure 19, as the quality initiatives get more and more extensive, the total product cost will actually start increasing [50]. This does not align with SBD strategic goals for the digital transformation.

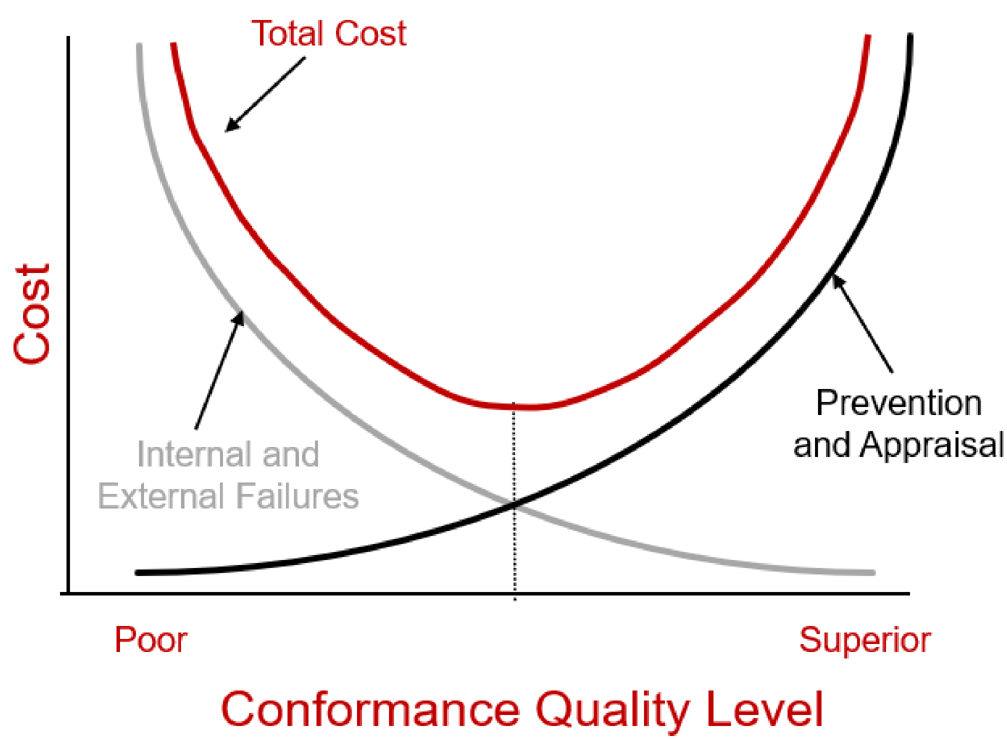

Figure 19: Juran's Model – Quality vs. Cost [50]

After analyzing the areas of cost savings, the largest impact was from labor efficiency improvements. While it was understood that the technology enabled workforce improvements, the SBD teams did not realize the extent of the impact. After finding this, the OxT team shifted mindsets to prioritize workforce enhancing applications and spending more time listening to the production team members, making their jobs easier through digital tools.

Analysis of the results and running various sensitivity studies in the DSET revealed additional areas of opportunity. While the magnitude of COPQ was relatively minor when compared with the capital cost, the inventory and attainment factors were not. If the inventory could be improved with better monitoring or reducing review periods, the total quantity of in-house inventory could be reduced. Targeting inventory reductions (without increasing risk of shortages) enables quick wins of significant cost savings for the site that measurably improve the ROI and payback periods. Additionally, if attainment can be improved through reduced downtime on critical assets or higher production rates, the impact can be significant and is expected to be reoccurring. For context, the impacts of various improvements are shown in Table 25 below, normalized by the COPQ.

Table 25: Relative Impacts of Various KPIs (normalized by COPQ)

Relative Impact Scale Factors [1% change in parameter / 1% COPQ reduction]		
Parameter	**Jackson**	**Monterrey**
Attainment	23	38
Labor Efficiency	24	53
Inventory*	59	360

*Note: Inventory improvements are a one-time savings and not directly comparable to COPQ improvements, which are reocurring

The final lesson learned centered around maximizing impact comes from an assessment of the costs. The OxT team labor and travel costs were half the total capital cost required for the first year (53% for Jackson, 50% for Monterrey), which surprised the team. This is, in part, because it is a new solution and the team was developing tools and processes while implementing them. This emphasized the importance of working down these costs through effective documentation to streamline processes, employing existing solutions at future sites, and maintaining team capability.

9.3.2 Implementation Lessons

The OxT team has an imperfect understanding of the production site because they are not located on-site and are subject to schedule pressures that limit acclimation time. On the other hand, the production teams have a limited understanding of future digital tool capabilities, because production is prioritized over digital fluency. This generates a disconnect that makes it difficult to prioritize implementation and future development projects. A symptom of this was developers pushing applications or updates to full rate production environments without extensive testing. They were trying to move fast and knew the best way to get feedback was to test it in real time, but did not realize the impact this would have on the production teams. The makers who were already daunted by the technology injection into their work statement, got frustrated with imperfect tools that delayed production and made it harder to hit attainment goals over the short-term.

Through identifying and acknowledging this gap, the teams learned to prioritize effective, clear communication. The OxT team learned how important it is to have developers integrated and frequently traveling to the site. They learned that the tools must first be demonstrated throughout development to make sure they align with the production team's expectations. They started to thoroughly test them in a controlled environment or deploy them in a limited scope initially, validating the tool before full scale integration. The improved communication paired with the DSET helped to identify the numerous risks and opportunities identified in Section 9.1.

During the year-long implementation, the team worked to connect every asset in the plant and have full visibility of the entire production environment. There is tremendous value in seeing the full picture of the entire factory, but also significant cost. The team should consider reducing full connectivity initially and prioritize the critical assets and value streams. This helps achieve the "quick wins" to get production team buy-in and helps to have demonstrated results early. Machines that are under-utilized, targeted for replacement, or providing minimal data should not be connected until it is shown to be needed by the site. Also, some machines that are older or from certain manufacturers are very difficult to communicate with or provide limited data. These should instead be considered on a case-by-case basis to assess the value and the cost of getting them online.

9.4 Best Practices

Moving forward, multiple new best practices are being implemented by the team. First of all, the team is being more diligent about selecting the sites to digitize. Upon realizing some of the challenges and seeing the areas with most opportunity, the OxT team developed an assessment procedure to evaluate potential and strategic value from improved manufacturing capabilities. The initial assessment should take note of the site financial metrics to identify areas of opportunity or risk. Secondly, the team is implementing the lessons learned around implementation, focusing on areas with larger relative impacts like inventory, attainment, and labor efficiency while being more strategic about the order of asset connection.

Throughout the project, the team recognized the need for a baseline. There were no systematic measurements taken of key productivity metrics. This is primarily what forced the team to utilize qualitative data instead of quantitative data for some key aspects of the analysis. Moving forward, the team should assess site capabilities, complete some time studies of critical value streams, and take reliable KPI measurements using the new connectivity solutions before delivering solutions. This would enable more accurate accounting of solution performance, helping the team to continue to optimize the digital solutions offered at SBD.

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Appendix B: System Dynamics Model

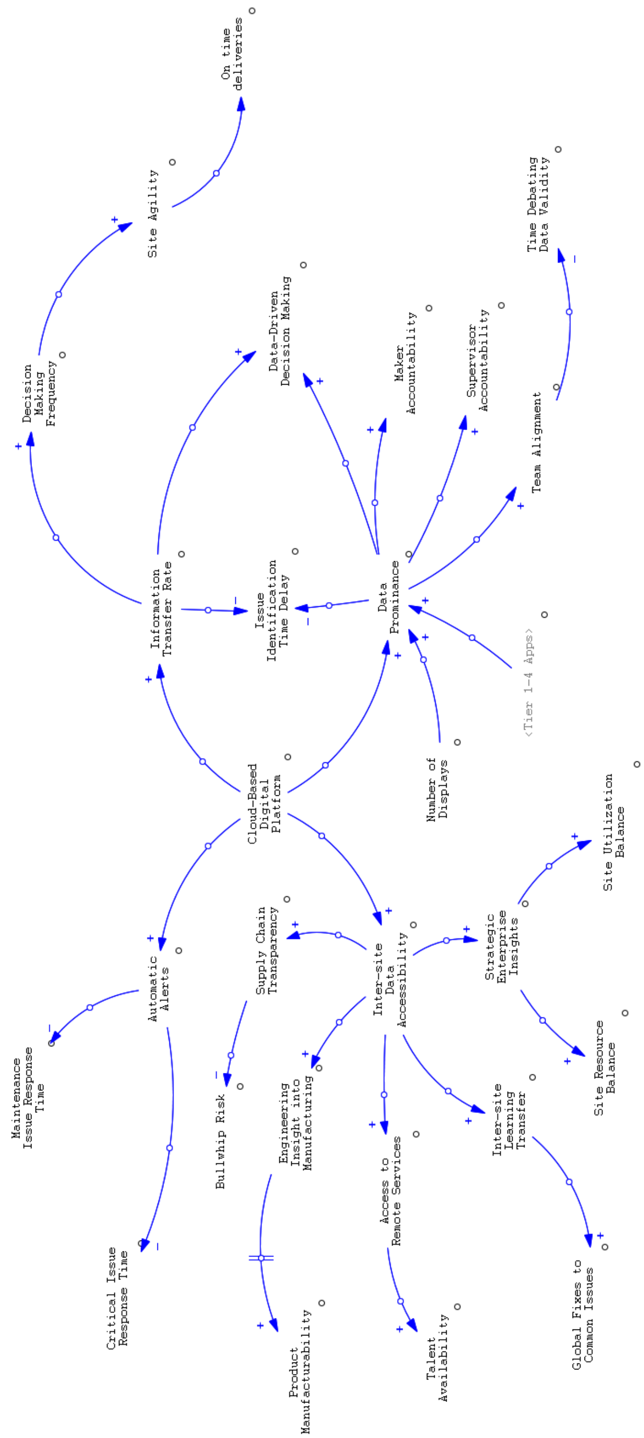

Figure 20: System Dynamics Model – Cloud-Based Digital Platform

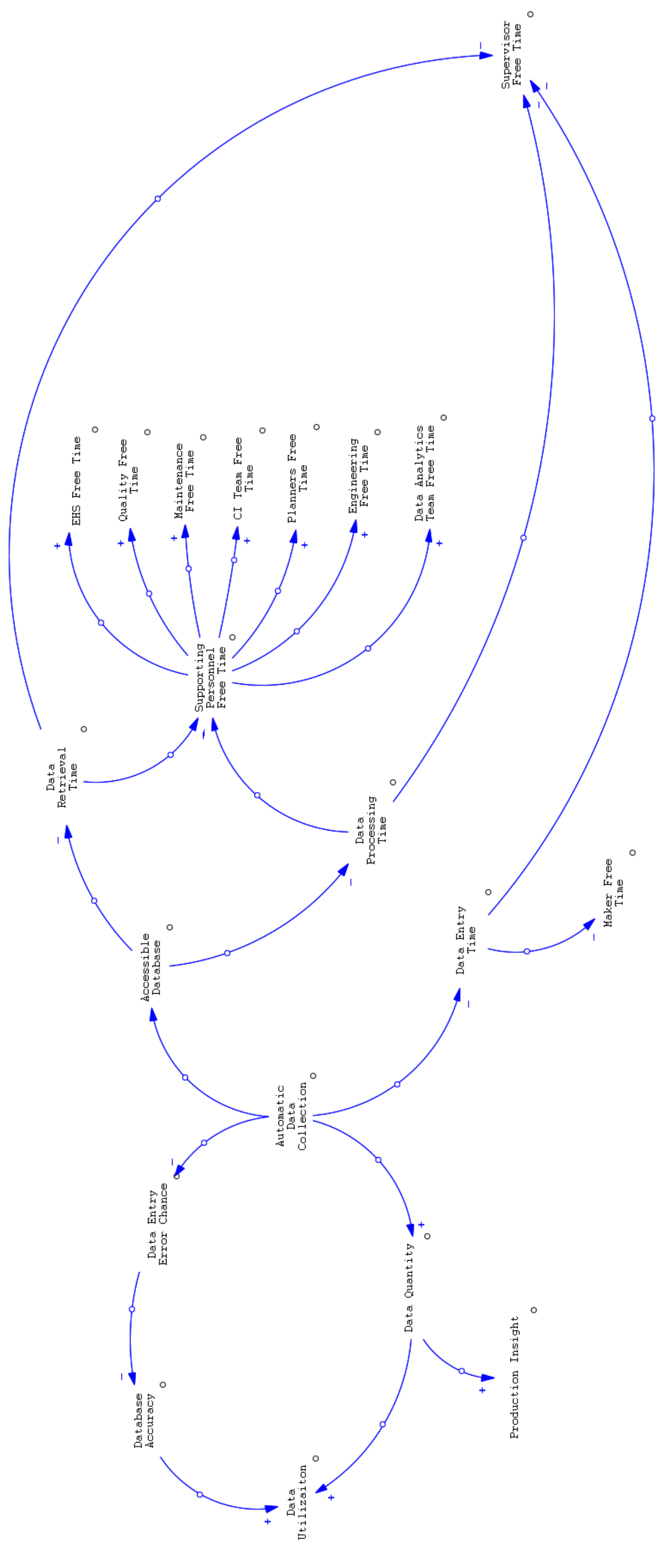

Figure 21: System Dynamics Model – Automatic Data Collection

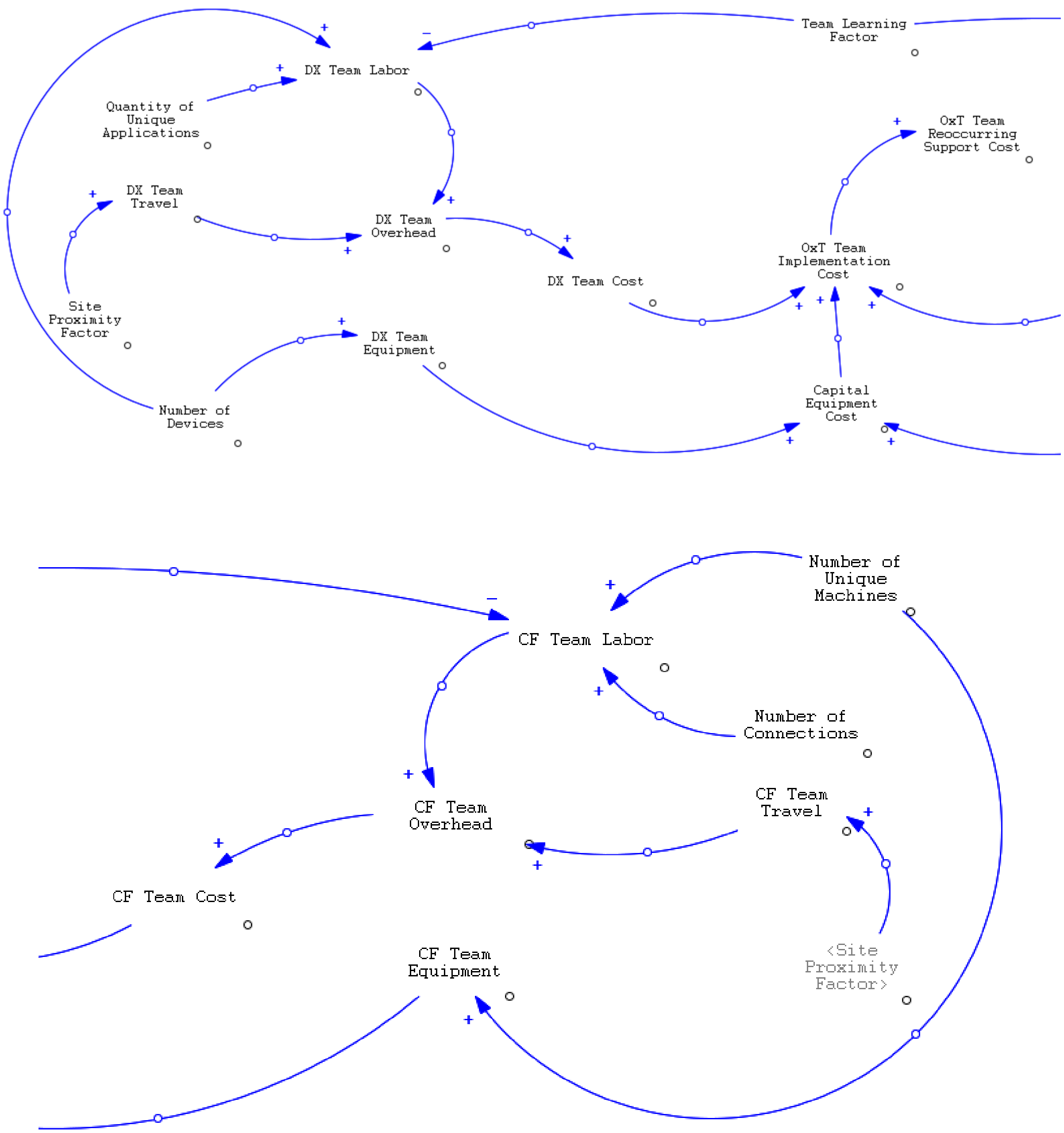

Figure 22: System Dynamics Model – Cost Mapping

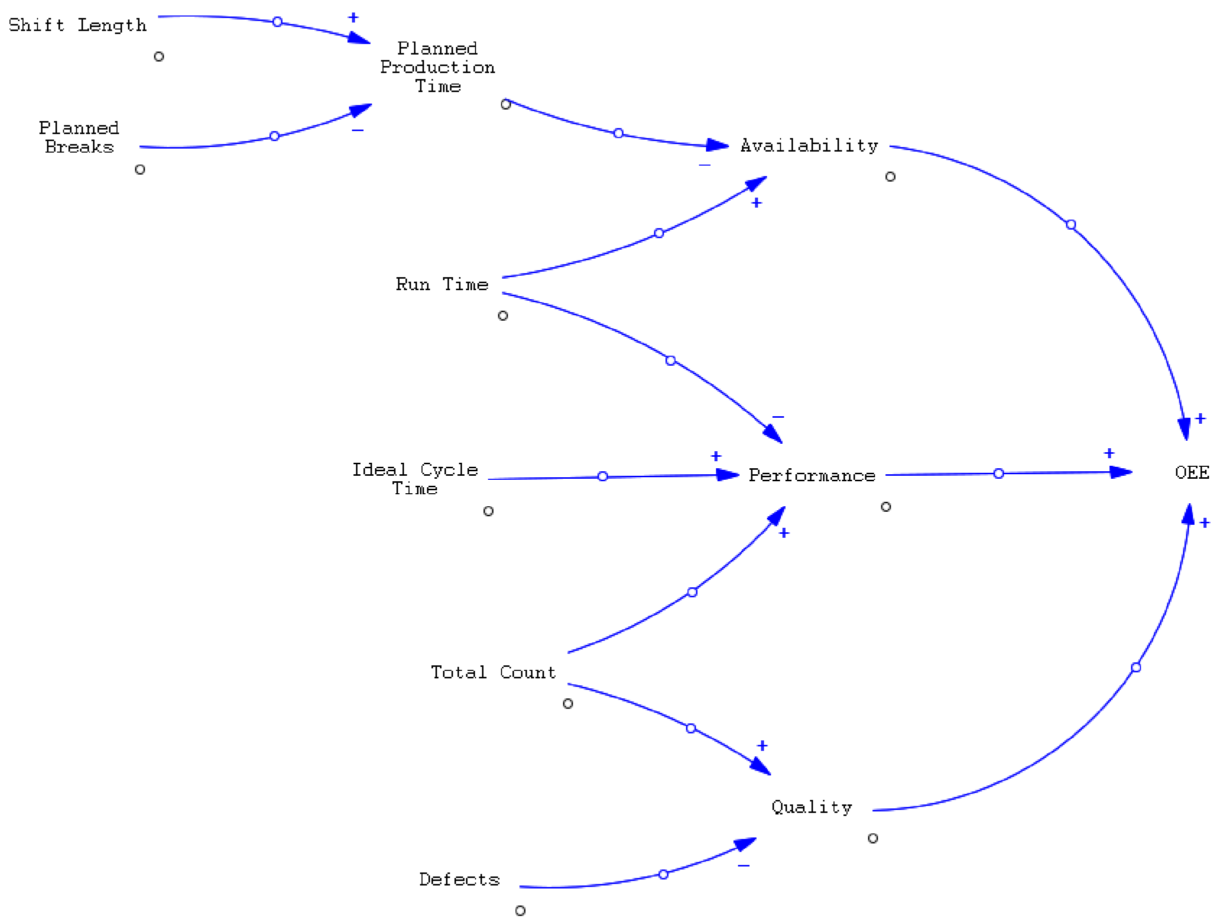

Figure 23: System Dynamics Model – Overall Equipment Effectiveness

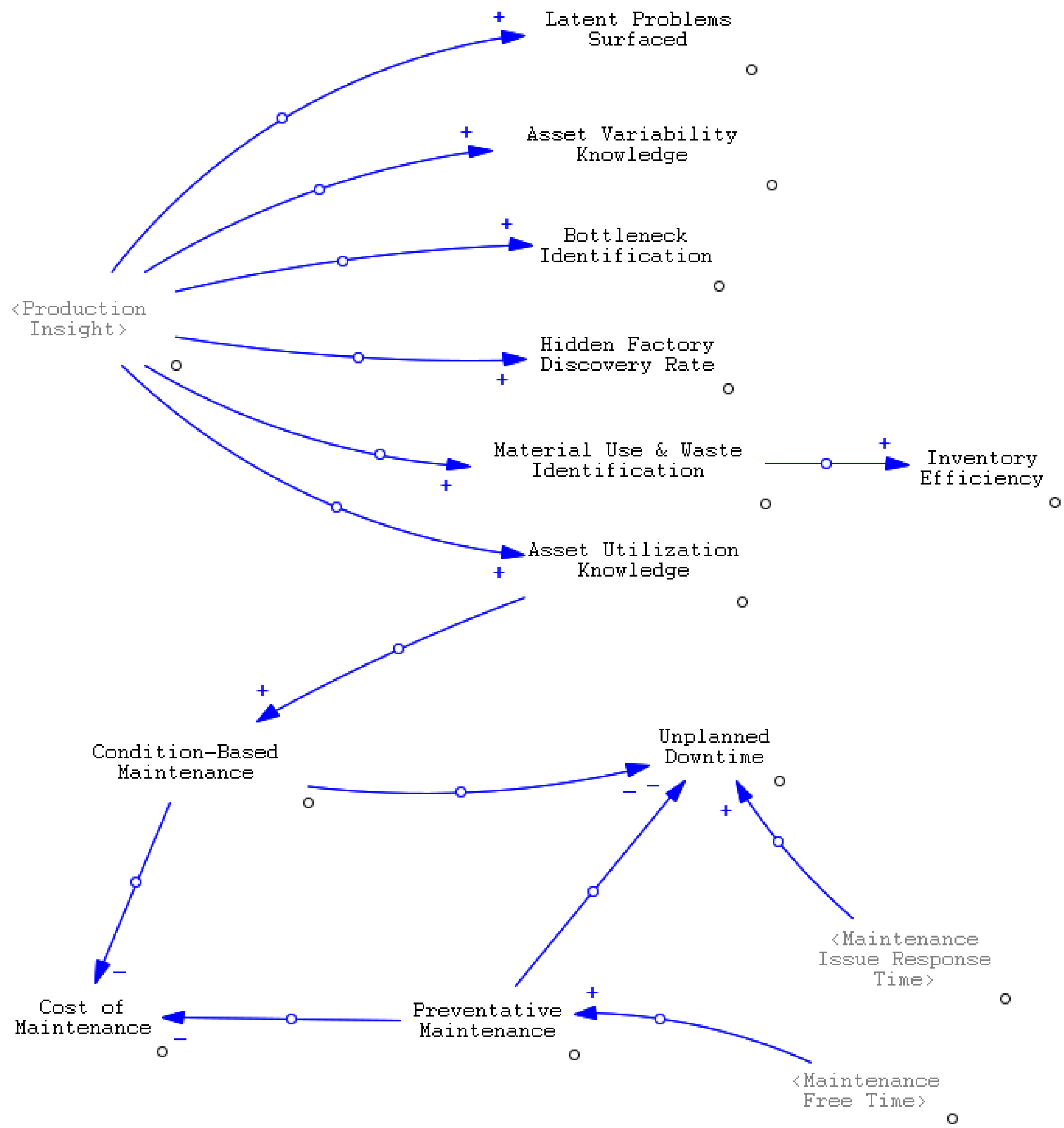

Figure 24: System Dynamics Model – Tier 2 Impacts

Appendix C: Cash Flow Summaries

Parameter	Unit	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	Total
		0	1	2	3	4	5	6	7	8	9	10	
Total Investment / Expense													
Total Licensing Costs	[$]	$220,577	$257,129	$254,906	$133,482	$125,830	$120,095	$115,777	$112,541	$118,216	$124,178	$130,441	$1,713,171
Total Non Effort	[$]	$937,827	$93,783	$93,783	$93,783	$93,783	$421,867	$93,783	$93,783	$93,783	$93,783	$421,867	$2,531,822
Total Effort	[$]	$1,556,231	$85,035	$85,035	$41,552	$41,552	$41,552	$41,552	$41,552	$41,552	$41,552	$41,552	$2,058,712
Total Cost	[$]	$2,714,634	$435,946	$433,723	$268,816	$261,164	$583,514	$251,111	$247,875	$253,550	$259,512	$593,859	$6,303,705
Savings - Grouped By Implemented Change													
Labor Reduction	[$]	$0	$456,839	$456,839	$456,839	$456,839	$456,839	$456,839	$456,839	$456,839	$456,839	$456,839	$4,568,394
Automated Data Collection & Cloud-Based Platform	[$]	$0	$63,054	$346,315	$464,294	$478,366	$478,366	$478,366	$478,366	$478,366	$478,366	$478,366	$4,222,228
Improved Inter-Site Data Accessibility	[$]	$0	$0	$568	$2,215	$6,799	$16,492	$31,542	$49,589	$67,580	$82,505	$93,829	$351,119
Increased Data Prominance and Accountability	[$]	$0	$152,707	$474,258	$474,258	$474,258	$474,258	$474,258	$474,258	$474,258	$474,258	$474,258	$4,421,026
Automatic Alerts & Digital Work Orders	[$]	$0	$0	$44,149	$69,349	$69,349	$69,349	$69,349	$69,349	$69,349	$69,349	$69,349	$598,943
Inventory Management Application	[$]	$0	$0	$0	$180	$1,751,929	$911,442	$210,453	$210,453	$210,453	$210,453	$210,453	$3,715,817
Digitally Enabled Training	[$]	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Direct Savings	[$]	$0	$609,547	$931,097	$931,277	$2,683,026	$1,842,539	$1,141,550	$1,141,550	$1,141,550	$1,141,550	$1,141,550	$12,705,238
Total Indirect Savings	[$]	$0	$63,054	$391,032	$535,858	$554,514	$564,207	$579,258	$597,305	$615,295	$630,221	$641,545	$5,172,290
Total Savings	**[$]**	**$0**	**$672,601**	**$1,322,129**	**$1,467,135**	**$3,237,541**	**$2,406,746**	**$1,720,808**	**$1,738,855**	**$1,756,846**	**$1,771,771**	**$1,783,095**	**$17,877,527**
Savings - Grouped Catagorically													
Labor Impact	[$]	$0	$636,673	$1,184,727	$1,309,310	$1,368,713	$1,522,526	$1,548,433	$1,566,481	$1,584,471	$1,599,397	$1,610,721	$13,931,454
Production Impact	[$]	$0	$30,394	$94,394	$94,394	$94,394	$94,394	$94,394	$94,394	$94,394	$94,394	$94,394	$879,935
Quality Impact	[$]	$0	$5,534	$43,009	$63,254	$68,350	$77,306	$77,981	$77,981	$77,981	$77,981	$77,981	$647,358
Inventory Impact	[$]	$0	$0	$0	$119	$1,137,389	$475,013	$0	$0	$0	$0	$0	$1,612,520
Total Savings	**[$]**	**$0**	**$672,601**	**$1,322,129**	**$1,467,076**	**$2,668,846**	**$2,169,239**	**$1,720,808**	**$1,738,855**	**$1,756,846**	**$1,771,771**	**$1,783,095**	**$17,071,267**
P&L Impact													
Project Expense (Non-Recurring)	[$]	-$1,776,807	-$342,164	-$339,941	-$175,034	-$167,381	-$161,647	-$157,328	-$154,092	-$159,767	-$165,729	-$171,992	-$3,771,883
Depreciation on New Equipment	[$]	-$65,118	-$130,237	-$130,237	-$130,237	-$130,237	-$130,237	-$130,237	-$130,237	-$130,237	-$130,237	-$65,118	-$1,302,365
Net Expense	[$]	-$1,841,925	-$472,400	-$470,177	-$305,270	-$297,618	-$291,883	-$287,565	-$284,329	-$290,004	-$295,966	-$237,110	-$5,074,248
Taxes	[$]	$432,852	$111,014	$110,492	$71,739	$69,940	$68,593	$67,578	$66,817	$68,151	$69,552	$55,721	$1,192,448
Net Income Impact	**[$]**	**-$1,409,073**	**-$361,386**	**-$359,686**	**-$233,532**	**-$227,678**	**-$223,291**	**-$219,987**	**-$217,512**	**-$221,853**	**-$226,414**	**-$181,389**	**-$3,881,800**
Cashflow Impact													
Expense Items adjusted to cash basis	[$]	-$1,343,955	-$231,150	-$229,449	-$103,295	-$97,441	-$93,054	-$89,751	-$87,275	-$91,617	-$96,177	-$116,271	-$2,579,435
Capital Expenditures	[$]	-$937,827	-$93,783	-$93,783	-$93,783	-$93,783	-$421,867	-$93,783	-$93,783	-$93,783	-$93,783	-$421,867	-$2,531,822
Inventory Impact	[$]	$0	$0	$0	$119	$1,137,389	$475,013	$0	$0	$0	$0	$0	$1,612,520
Working Capital Impact	[$]	$0	$30,394	$94,394	$94,394	$94,394	$94,394	$94,394	$94,394	$94,394	$94,394	$94,394	$879,935
Total Cashflow Outflows	**[$]**	**-$2,281,781**	**-$294,538**	**-$228,838**	**-$102,566**	**$1,040,558**	**$54,485**	**-$89,140**	**-$86,664**	**-$91,006**	**-$95,566**	**-$443,745**	**-$2,618,801**
Total Benefits													
Material Savings	[$]	$0	$5,534	$43,009	$63,254	$68,350	$77,306	$77,981	$77,981	$77,981	$77,981	$77,981	$647,358
Labor Related Savings	[$]	$0	$636,673	$1,184,727	$1,309,310	$1,368,713	$1,522,526	$1,548,433	$1,566,481	$1,584,471	$1,599,397	$1,610,721	$13,931,454
Net EBIT Impact	**[$]**	**$0**	**$642,207**	**$1,227,736**	**$1,372,564**	**$1,437,064**	**$1,599,833**	**$1,626,414**	**$1,644,462**	**$1,662,452**	**$1,677,378**	**$1,688,702**	$14,578,811
Taxes	[$]	$0	-$150,919	-$288,518	-$322,552	-$337,710	-$375,961	-$382,207	-$386,449	-$390,676	-$394,184	-$396,845	-$3,426,021
Net Income Impact	**[$]**	**$0**	**$491,288**	**$939,218**	**$1,050,011**	**$1,099,354**	**$1,223,872**	**$1,244,207**	**$1,258,013**	**$1,271,776**	**$1,283,194**	**$1,291,857**	$11,152,791
Total Benefits													
Net EBIT	**[$]**	**-$1,841,925**	**$169,807**	**$757,559**	**$1,067,294**	**$1,139,446**	**$1,307,949**	**$1,338,850**	**$1,360,133**	**$1,372,448**	**$1,381,412**	**$1,451,592**	**$9,504,563**
Net Income	**[$]**	**-$1,409,073**	**$129,902**	**$579,532**	**$816,480**	**$871,676**	**$1,000,581**	**$1,024,220**	**$1,040,502**	**$1,049,923**	**$1,056,780**	**$1,110,467**	**$7,270,991**
Cashflow	**[$]**	**-$2,281,781**	**$196,750**	**$710,380**	**$947,445**	**$2,139,912**	**$1,278,357**	**$1,155,067**	**$1,171,349**	**$1,180,770**	**$1,187,627**	**$848,112**	**$8,533,989**
Cumulative Cashflow	**[$]**	**-$2,281,781**	**-$2,085,031**	**-$1,374,652**	**-$427,206**	**$1,712,706**	**$2,991,063**	**$4,146,131**	**$5,317,480**	**$6,498,250**	**$7,685,877**	**$8,533,989**	**$30,716,826**
Payback Sum	[-]	0	1.0	1.0	1.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	---
DCCF Annual	**[$]**	**-$2,281,781**	**$175,670**	**$566,310**	**$674,373**	**$1,359,953**	**$725,374**	**$585,193**	**$529,859**	**$476,893**	**$428,270**	**$273,069**	**$3,513,184**
Cumulative DCCF	**[$]**	**-$2,281,781**	**-$2,106,112**	**-$1,539,801**	**-$865,428**	**$494,525**	**$1,219,899**	**$1,805,092**	**$2,334,951**	**$2,811,844**	**$3,240,114**	**$3,513,184**	**$8,626,485**
DCCF Payback Sum	[-]	0	1.0	1.0	1.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	---

Figure 25: Cash Flow Summary - Jackson

Parameter	Unit	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	Total
		0	1	2	3	4	5	6	7	8	9	10	
Total Investment / Expense													
Total Licensing Costs	[$]	$549,259	$638,827	$634,001	$338,944	$320,951	$307,657	$297,841	$290,692	$305,274	$320,589	$336,673	$4,340,707
Total Non Effort	[$]	$843,065	$84,307	$84,307	$84,307	$84,307	$570,832	$84,307	$84,307	$84,307	$84,307	$570,832	$2,659,181
Total Effort	[$]	$1,509,913	$78,519	$78,519	$35,036	$35,036	$35,036	$35,036	$35,036	$35,036	$35,036	$35,036	$1,947,241
Total Cost	[$]	$2,902,238	$801,652	$796,827	$458,286	$440,293	$913,525	$417,184	$410,035	$424,617	$439,932	$942,541	$8,947,129
Savings - Grouped By Implemented Change													
Labor Reduction	[$]	$0	$275,699	$275,699	$275,699	$275,699	$275,699	$275,699	$275,699	$275,699	$275,699	$275,699	$2,756,994
Automated Data Collection & Cloud-Based Platform	[$]	$0	$75,426	$414,264	$555,392	$572,226	$572,226	$572,226	$572,226	$572,226	$572,226	$572,226	$5,050,661
Improved Inter-Site Data Accessibility	[$]	$0	$0	$5,246	$12,355	$24,621	$42,145	$62,522	$82,700	$100,695	$114,887	$125,590	$570,761
Increased Data Prominance and Accountability	[$]	$0	$161,920	$502,869	$502,869	$502,869	$502,869	$502,869	$502,869	$502,869	$502,869	$502,869	$4,687,742
Automatic Alerts & Digital Work Orders	[$]	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Inventory Management Application	[$]	$0	$0	$0	$262	$2,518,415	$1,060,242	$9,908	$9,908	$9,908	$9,908	$9,908	$3,628,460
Digitally Enabled Training	[$]	$0	$0	$135,363	$259,261	$259,261	$259,261	$259,261	$259,261	$259,261	$259,261	$259,261	$2,209,454
Total Direct Savings	[$]	$0	$437,619	$778,568	$778,831	$3,296,984	$1,838,810	$788,477	$788,477	$788,477	$788,477	$788,477	$11,073,195
Total Indirect Savings	[$]	$0	$75,426	$554,873	$827,008	$856,107	$873,632	$894,009	$914,187	$932,182	$946,374	$957,077	$7,830,875
Total Savings	**[$]**	**$0**	**$513,045**	**$1,333,441**	**$1,605,839**	**$4,153,091**	**$2,712,442**	**$1,682,486**	**$1,702,664**	**$1,720,659**	**$1,734,850**	**$1,745,553**	**$18,904,070**
Savings - Grouped Catagorically													
Labor Impact	[$]	$0	$512,896	$1,317,392	$1,577,310	$1,604,952	$1,622,477	$1,642,853	$1,663,032	$1,681,026	$1,695,218	$1,705,921	$15,023,076
Production Impact	[$]	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Quality Impact	[$]	$0	$149	$16,049	$28,267	$31,883	$39,089	$39,632	$39,632	$39,632	$39,632	$39,632	$313,598
Inventory Impact	[$]	$0	$0	$0	$262	$2,516,257	$1,050,876	$0	$0	$0	$0	$0	$3,567,396
Total Savings	**[$]**	**$0**	**$513,045**	**$1,333,441**	**$1,605,839**	**$4,153,091**	**$2,712,442**	**$1,682,486**	**$1,702,664**	**$1,720,659**	**$1,734,850**	**$1,745,553**	**$18,904,070**
P&L Impact													
Project Expense (Non-Recurring)	[$]	-$2,059,172	-$717,346	-$712,520	-$373,980	-$355,987	-$342,693	-$332,877	-$325,728	-$340,311	-$355,625	-$371,709	-$6,287,948
Depreciation on New Equipment	[$]	-$69,182	-$138,365	-$138,365	-$138,365	-$138,365	-$138,365	-$138,365	-$138,365	-$138,365	-$138,365	-$69,182	-$1,383,649
Net Expense	[$]	-$2,128,355	-$855,711	-$850,885	-$512,345	-$494,352	-$481,058	-$471,242	-$464,093	-$478,676	-$493,990	-$440,891	-$7,671,597
Taxes	[$]	$500,163	$201,092	$199,958	$120,401	$116,173	$113,049	$110,742	$109,062	$112,489	$116,088	$103,609	$1,802,825
Net Income Impact	**[$]**	**-$1,628,191**	**-$654,619**	**-$650,927**	**-$391,944**	**-$378,179**	**-$368,009**	**-$360,500**	**-$355,031**	**-$366,187**	**-$377,903**	**-$337,282**	**-$5,868,772**
Cashflow Impact													
Expense Items adjusted to cash basis	[$]	-$1,559,009	-$516,254	-$512,562	-$253,579	-$239,814	-$229,644	-$222,135	-$216,666	-$227,822	-$239,538	-$268,099	-$4,485,123
Capital Expenditures	[$]	-$843,065	-$84,307	-$84,307	-$84,307	-$84,307	-$570,832	-$84,307	-$84,307	-$84,307	-$84,307	-$570,832	-$2,659,181
Inventory Impact	[$]	$0	$0	$0	$262	$2,516,257	$1,050,876	$0	$0	$0	$0	$0	$3,567,396
Working Capital Impact	[$]	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Cashflow Outflows	**[$]**	**-$2,402,074**	**-$600,560**	**-$596,869**	**-$337,623**	**$2,192,136**	**$250,400**	**-$306,442**	**-$300,973**	**-$312,128**	**-$323,844**	**-$838,931**	**-$3,576,908**
Total Benefits													
Material Savings	[$]	$0	$149	$16,049	$28,267	$31,883	$39,089	$39,632	$39,632	$39,632	$39,632	$39,632	$313,598
Labor Related Savings	[$]	$0	$512,896	$1,317,392	$1,577,310	$1,604,952	$1,622,477	$1,642,853	$1,663,032	$1,681,026	$1,695,218	$1,705,921	$15,023,076
Net EBIT Impact	**[$]**	**$0**	**$513,045**	**$1,333,441**	**$1,605,577**	**$1,636,834**	**$1,661,566**	**$1,682,486**	**$1,702,664**	**$1,720,659**	**$1,734,850**	**$1,745,553**	$15,336,675
Taxes	[$]	$0	-$120,566	-$313,359	-$377,311	-$384,656	-$390,468	-$395,384	-$400,126	-$404,355	-$407,690	-$410,205	-$3,604,119
Net Income Impact	**[$]**	**$0**	**$392,480**	**$1,020,082**	**$1,228,266**	**$1,252,178**	**$1,271,098**	**$1,287,101**	**$1,302,538**	**$1,316,304**	**$1,327,161**	**$1,335,348**	**$11,732,556**
Total Benefits													
Net EBIT	**[$]**	**-$2,128,355**	**-$342,666**	**$482,556**	**$1,093,232**	**$1,142,483**	**$1,180,508**	**$1,211,244**	**$1,238,571**	**$1,241,983**	**$1,240,860**	**$1,304,662**	**$7,665,077**
Net Income	**[$]**	**-$1,628,191**	**-$262,139**	**$369,155**	**$836,322**	**$873,999**	**$903,089**	**$926,601**	**$947,507**	**$950,117**	**$949,258**	**$998,066**	**$5,863,784**
Cashflow	**[$]**	**-$2,402,074**	**-$208,081**	**$423,214**	**$890,643**	**$3,444,314**	**$1,521,498**	**$980,660**	**$1,001,565**	**$1,004,175**	**$1,003,316**	**$496,417**	**$8,155,648**
Cumulative Cashflow	**[$]**	**-$2,402,074**	**-$2,610,155**	**-$2,186,942**	**-$1,296,299**	**$2,148,016**	**$3,669,514**	**$4,650,174**	**$5,651,739**	**$6,655,914**	**$7,659,231**	**$8,155,648**	**$30,094,765**
Payback Sum	[-]	0	1.0	1.0	1.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	---
DCCF Annual	**[$]**	**-$2,402,074**	**-$185,786**	**$337,383**	**$633,942**	**$2,188,924**	**$863,339**	**$496,833**	**$453,057**	**$405,570**	**$361,806**	**$159,833**	**$3,312,826**
Cumulative DCCF	**[$]**	**-$2,402,074**	**-$2,587,861**	**-$2,250,478**	**-$1,616,535**	**$572,389**	**$1,435,728**	**$1,932,560**	**$2,385,617**	**$2,791,187**	**$3,152,993**	**$3,312,826**	**$6,726,352**
DCCF Payback Sum	[-]	0	1.0	1.0	1.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	---

Figure 26: Cash Flow Summary - Monterrey