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Manufacturing x Digital

MxD FINAL REPORT PROJECT 20-04-01

Digital Transformation Toolkit for SMMs: Accelerating Adoption of Digital Manufacturing	
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I. EXECUTIVE SUMMARY

Rochester Institute of Technology (RIT) collaborated with Cuesta Partners (Cuesta) to complete MxD project 20-04-01 in support of small and medium sized manufacturers (SMMs). The project capitalized on the prior work completed under MxD 17-01-01 to address the needs of SMMs in their efforts to assess digital maturity/readiness and develop comprehensive plans for deploying the highest-value Industry 4.0 (I4.0) and digital manufacturing technology solutions to manufacturing challenges.

The project focused on enabling SMMs to build their knowledge and skill with Industry 4.0 solutions in the following four technology areas:

1. Automation (shopfloor, enterprise, and facility)
2. Industrial Internet of Things (IIoT) and Connectivity (shopfloor, enterprise, and facility)
3. Manufacturing Execution Systems (MES) and Enterprise Resource Planning (ERP) systems
4. Data Analytics (and Business Intelligence systems)

Over the multi-year project, work was completed to understand the current state of digital readiness within SMMs and identify roadblocks to deploying I4.0 solutions via a landscape survey, to develop an online tool (web application) to help SMMs assess their digital maturity and provide a prioritized list of relevant I4.0 technologies to consider, and finally, to provide a digital manufacturing starter kit (e-book) resource that showcases four high-value I4.0 technology solutions and provides details on how to get started along with expected costs and benefits. Key findings:

- The results from the landscape survey identified I4.0 technology areas where SMMs saw significant opportunity for improvement to manufacturing and business practices. This informed the development of both the web application in terms of technology recommendations for given technology dimension such as Shop-floor Automation, and the I4.0 Starter Kit.
- A digital maturity scoring rationale and associated questionnaire were developed and implemented within the web application to allow for SMM self-assessment. This provides a digital maturity ranking for 16 process, technology, and organizational dimensions based on the Smart Industry Readiness Index (SIRI) framework. For the 12 technology-focused SIRI dimensions, detailed recommendations, including estimated costs (where available), and benefits are provided.
- Feedback was gathered on the web application from three volunteer SMMs during Beta-testing, and this was incorporated into several updates and improvements to the web application. The feedback sessions with SMMs also brought to light a potential high-value use-case for the web application: whereby an SMM partners with a trusted technology partner, e.g., a NIST MEP center, to complete the online assessment as part of I4.0 planning and implementation efforts.

The original project scope was modified in spring 2023 to address project timing and transition activity challenges uncovered during project execution. Per the amended agreement, the team delivered the following:

- Landscape Survey - The team presented and delivered a summary of findings from the 2021 SMM digital readiness landscape survey to MxD members; 28 SMMs completed the survey.
- “How To Get Started” resource - “Your Digital Manufacturing Journey” Web App (Web App) – Cuesta and RIT developed and delivered a web application for assessing digital maturity across the 16 SIRI dimensions via the Appian platform. For the 12 SIRI dimensions that are technology focused, the Web App includes I4.0 technology solution recommendations that



provide detailed descriptions of the technology and their expected benefits and costs. The 12 SIRC technology-focused dimensions are:

1. Vertical Integration (Operations Management)
 2. Horizontal Integration (Supply Chain Management)
 3. Integrated Product Lifecycle Management
 4. - 6. Enterprise Connectivity, Intelligence and Automation
 7. - 9. Shopfloor Connectivity, Intelligence and Automation
 - 10.-12. Facility Connectivity, Intelligence and Automation
- “How To Get Started” resource - “Your Digital Manufacturing Journey” Web App instructions – Cuesta delivered instructions on how to maintain the content within the Web App within the Appian platform (see appendices)
 - “Digital Manufacturing Starter Kit” – Industry 4.0 Starter Kit e-book – Leveraging Cuesta and RIT extensive project experience supporting SMM I4.0 technology implementations, RIT created and delivered an Industry 4.0 Starter Kit (see appendices). The starter kit focused on these four technology areas and includes four high-value I4.0 technology solution case studies:
 1. Manufacturing Operations Software
 - a. Discussion of Enterprise Resource Planning (ERP) and related business software systems
 - b. Case 1 – Getting Started: Electronic Work Instructions (EWI)
 - c. Case 2 – Getting Started: Manufacturing Execution Systems (MES)
 2. Machine Monitoring and the Industrial Internet of Things (IIoT)
 - a. Discussion of machine monitoring systems and IIoT technologies
 - b. Case 3 – Getting Started: Shopfloor Visibility (Machine Monitoring and IIoT)
 3. Data Analytics and Business Intelligence
 - a. Discussion of data analytics, business intelligence and machine learning technologies
 - b. Case 4 – Getting Started: Business Intelligence Systems
 4. Automation
 - a. Overview of high-value opportunities across the fixed, programmable, and flexible automation types. Includes discussion of both hardware, e.g., robots, and software automation.



II. PROJECT DELIVERABLES

The following list includes all deliverables created through this project. These deliverables will be referenced throughout this report and will be accessible on the MxD membership portal in accordance with the rights defined by the Membership Agreement. Specific deliverable types include, but are not limited to, the following items.

- Software – Web app
- App instructions
- Workforce development material/case studies

Table 1: MxD 20-04 Project Deliverables

#	DELIVERABLE	DESCRIPTION	FORMAT OF DELIVERY
1	Understanding the Landscape – Key Findings (RIT; Cuesta)	Consolidation of key findings and presentation of the SMM digital manufacturing readiness landscape survey in executive summary format at MxD forum	PDF
2	Project Immersion Workshop (RIT)	Presentation of pilot and transition plan to MxD, project partners, and interested Members	PowerPoint
3	Your Digital Manufacturing Journey – Web Application (RIT; Cuesta)	Online tool to conduct a digital maturity assessment. Upon completion of assessment, the Web App delivers a prioritized list of relevant I4.0 technologies to increase digital maturity with a discussion of expected ROI ranges for deploying the technology	Web App - Appian platform software code
4	Post Project Transition Plan (RIT; Cuesta)	Transition plan focused on long-term recommendations to promote use and sustain the technology.	PowerPoint
5	MxD Member Technical Review (RIT; Cuesta)	Review of project in-process status after milestone 1 – completion of SMM digital manufacturing readiness landscape survey, and to demo the Web App	PowerPoint
6	End of Project Presentation (RIT; Cuesta)	Overview of project results and transition plan including aggregated summary of SMM readiness (based on tool users) and KPI	PowerPoint
7	Draft Final Report (RIT; Cuesta)	Comprehensive summary of all work performed, and significant accomplishments achieved	Word document
8	Final Report (RIT; Cuesta)	Comprehensive and cumulative summary of all technical advancements and significant accomplishments achieved – written using this template	PDF



The following reflect the revised agreed upon deliverables per the March 2023 modification			
#	DELIVERABLE	DESCRIPTION	FORMAT OF DELIVERY
9	Develop and release version 1.0 of web application	Cuesta to enable creation of user ids and logins for testing	Web App
10	Identify 4 to 6 companies that might be willing to meet on a recurring basis to provide feedback on the application	RIT to identify at least 2 companies in Finger Lakes / Central New York region that will participate in project meetings to share feedback: 3 SMMs participated Cuesta to identify at least 2 companies that will participate in MxD project meetings to share feedback	Emailed Zoom meeting notices
11	Collect, aggregate and implement end-user feedback of v1.0 web application	Summarize feedback provided by companies identified in step above and make any clarifications that might be needed in: - Logic used for digital maturity assessment (this may include investigating root causes of disagreement with the application results, adjusting the logic to ensure the application works for different business models, etc.) (RIT) - Language pertaining to questions and answers (RIT) - User experience of application (this could include capability of reassigning a question to other users / adjusting display on the screen for improving clarity, etc.) (Cuesta) - User interface of application (Cuesta)	Word documents for internal project team usage
12	Development and Release of version 2.0 of web application	RIT to adjust as needed based on feedback on version 1. Cuesta to implement the Technological solutions database and generate output from the web app in the format previously provided by RIT	Web App
13	ROI Estimator and Customized DM investment strategy development	RIT: - Develop logic for qualitative ROI estimation. - If possible, summarize the practices followed by 4 to 6 companies identified to work with RIT. - Provide a mock-up of output format (results and recommendations) to Cuesta and provide content about ROI estimation and implementation complexity. Cuesta – Provide inputs as and when needed about ROI estimation and implementation complexity; develop formats and logic to accept RIT content in the Web App	Web App
14	Development and release Version 3.0 of web application	RIT to provide support to Cuesta as and when needed. Cuesta to implement the qualitative ROI estimator and generate output (results and recommendations) in the format provided by RIT.	Web App
15	Select high value case studies for DM Starter Kit	RIT and Cuesta each to create at least 2 high value case studies based on technologies identified by MxD in their RFP.	PDF
16	Draft base version of pilot case study for DM Starter Kit	RIT to continue the initial layout and document design work from early 2022 and complete the base version of the digital manufacturing starter kit. Cuesta and RIT to provide the case study content.	PDF

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III. PROJECT REVIEW

Introduction

There is a fundamental lack of understanding of digital manufacturing (DM) and Industry 4.0 (I4.0) by small and mid-sized manufacturers (SMMs) which represent 98% of the manufacturers in the U.S. A large majority of these companies do not know how to get started with digital manufacturing, develop a digital transformation strategy, or implement appropriate technologies that will have cost-effective business benefits.

The project set out to address these issues via the following goals:

1. Survey the Industry 4.0 knowledge base and identify the digital manufacturing readiness “landscape.” Summarize the needs and opportunities for manufacturers across the SMM size spectrum. The effort builds upon the initial landscape analysis that was done under MxD 17-01-01.
2. Develop a “Digital Manufacturing Journey” Web App for the SMM to assess their current digital maturity levels, provide a prioritized list of focus areas (Smart Industry Readiness Index (SIRI) dimensions) and relevant technologies that the company should consider for adoption, and provide guidance on high-value technologies with an estimate of the return on investment (ROI) for their successful adoption.
3. Create a Digital Manufacturing Starter Kit including four key technology use cases that are based on needs and opportunities identified in the landscape survey.
4. Develop a transition strategy to facilitate broad dissemination of the Web App and starter kit.

Problem Statement & Use Cases

From the MxD RFP MxD-20-04, “According to the U.S. Census Bureau, 98% of the approximately 250,000 manufacturing organizations in the United States have less than 500 employees. Of that 98%, approximately 75% of the companies have less than 20 employees.¹ Thus, when it comes to maximizing the competitiveness and resiliency of the U.S. manufacturing base, it is critical that smaller organizations are not left behind. Unfortunately, when it comes to Industry 4.0 and the promises of digital manufacturing, most of the buzz is directed towards larger manufacturers that have the capital to make large investments in technology. Currently, we are seeing a sustained effort by larger manufacturers to embrace digital manufacturing, but this is not the case among their supply base. According to BMO US, only 5% of mid-sized manufacturing organizations have implemented digital manufacturing technologies.² The technology gap between Original Equipment Manufacturers (OEMs) and SMMs will continue to widen unless there is a concentrated effort to provide the resources and technologies that are needed to help small and mid-sized organizations get started and maximize their returns on short and long-term digital manufacturing investments.

There is no question that implementing digital technology can lead to substantial returns for a company’s bottom line if applied correctly. The internet is full of success stories from larger manufacturers that capture how technologies like the Industrial Internet of Things (IIoT),

¹ US CENSUS BUREAU'S 2017 SUSB ANNUAL DATA TABLES BY ESTABLISHMENT INDUSTRY. (2020, APRIL 3).

² INDUSTRY 4.0: REDEFINING HOW MID-MARKET MANUFACTURERS DERIVE AND DELIVER VALUE. (2019, MARCH). RETRIEVED APRIL 7, 2020, FROM [HTTPS://WWW.BDO.COM/INSIGHTS/INDUSTRIES/INDUSTRY-4-0/INDUSTRY-4-0-REDEFINING-HOW-MID-MARKET-MANUFACTUR](https://www.bdo.com/insights/industries/industry-4-0/industry-4-0-redefining-how-mid-market-manufactur)

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automation, and model-based engineering tools are reducing costs, maximizing productivity, and allowing manufacturers to build better quality parts. Even with the wide availability of these success stories, there is a gap in transferring this knowledge in a format that enables small and mid-sized manufacturers to employ new technologies to increase their competitiveness. According to research by a former MxD-funded project team led by Auburn University, the greatest barriers to adoption are a lack of understanding and misperceptions.³ The existing resources in the public domain may help broaden the awareness of digital manufacturing and its potential, but they do not provide the end-to-end visibility of the implementation process needed to de-risk investment and instill confidence that digital manufacturing can positively impact the bottom line. Thus, for most companies, there is still a considerable amount of effort needed to understand the myriad technologies involved in digital manufacturing and prioritize the areas to invest resources in. The question many SMMs are asking is “Where should I get started and what steps should I take to maximize my ROI in digital manufacturing technology?”⁴

The project set out to address three primary use cases:

1. “As the owner of a small machine shop, I need a resource to understand what technologies I need to implement to stay competitive and how to invest in them to maximize my ROI in the short and long term.
2. As a production manager at a small manufacturer, I want to launch a low-cost, I4.0 project and understand how to pitch it, plan it, execute it, and then scale it.
3. As a consulting engineer at a MEP Center, I want a resource that I can use to create further services to help my clients get started in digital manufacturing.”⁴

Related Work (background)

The MxD project, numbered 17-01-01 and spearheaded by Auburn University, effectively laid the groundwork for this initiative by delineating the pressing necessity for its existence. Through a survey encompassing 12-14 Small and Medium Manufacturers (SMMs), the project underscored a significant deficit in Digital Manufacturing (DM) literacy and readiness among the surveyed companies. Astonishingly, less than 20% of the SMMs participating in the study displayed any active efforts towards cultivating digital capabilities.^{5,6}

A 2015 IMPULS study funded by the VDMA, a large German and European trade association of equipment and machinery manufacturers, provides a good, detailed view of the state of Industry 4.0 readiness for SMMs, albeit a bit dated and only addressing German companies. The look and feel of the IMPULS survey was used as a style model for this project, for both the landscape survey and for collecting digital readiness and maturity assessment data in the Web App.

Objectives

The project scope included four main objectives:

³ HARRIS, G., YARBROUGH, A., ABERNATHY, D., & PETERS, C. (2019). MANUFACTURING READINESS FOR DIGITAL MANUFACTURING. MANUFACTURING LETTERS, 22, 16–18. DOI: 10.1016/J.MFGLET.2019.10.002

⁴ MxD Request for Proposal Technical Summary & Program Overview - MxD-20-04: Getting Started and Maximizing Your ROI From Digital Manufacturing As A Small Manufacturer, Revision 1.0, Release Date: April 9, 2020.

⁵ HARRIS, G., “DIGITALLY ENABLING THE SUPPLY CHAIN,” FINAL PROJECT PRESENTATION FOR MxD 17-01-01, DEC 9, 2019.

⁶ INDUSTRY 4.0 READINESS ONLINE SELF-CHECK FOR BUSINESSES, WWW.INDUSTRIE40-READINESS.DE, LAST ACCESSED 29 JUNE 2020.

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1. Conduct a comprehensive assessment of the Industry 4.0 landscape, identifying the specific requirements and potential advantages for SMM's. Insights gathered from this evaluation serve as the foundation for web application and Starter Kit.
2. Develop and deploy a Digital Manufacturing Journey web application.
3. Develop and disseminate a Digital Manufacturing Starter Kit, complete with practical use cases.
4. Develop a Transition strategy to broadly disseminate the web application and starter kit.

Scope

Conduct a comprehensive Landscape Survey

The first task was to develop a deep understanding of the SMM market needs and opportunities. The team conducted a digital readiness landscape survey of SMM discrete manufacturing companies, including both contract manufacturers and product manufacturers. The survey built upon the initial landscape analysis that was done under MxD 17-01-01 to gather data around five areas:

1. Common pain points
2. Industry size and other company data
3. Use cases
4. Perspectives on digital manufacturing adoption
5. Assessment of level of interest in I4.0 by SMM

Develop and deploy a Digital Manufacturing Journey Web Application

The next task was to develop a web application that included:

1. A baseline capability assessment of the company's digital maturity across the 16 SIRI⁷ dimensions,
2. A computational rationale and methodology to rank a company's digital maturity across the 16 SIRI dimensions and identify needs of the company,
3. A prioritized list of focus areas (SIRI dimensions) and relevant technologies that the company should consider for adoption,
4. And guidance on high-value technologies with an estimate of the return on investment (ROI) for their successful adoption.

The baseline capability assessment was developed based on the SIRI assessment framework. The web application was developed using a lean startup methodology to focus on the value proposition from the data generated by the landscape survey.

The Digital Manufacturing Journey web application is built using the Appian software platform.

⁷THE SMART INDUSTRY READINESS INDEX (SIRI, [HTTPS://SIRI.INCIT.ORG/](https://sirincit.org/), LAST ACCESSED 29 AUGUST 2023.

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Create and disseminate a Digital Manufacturing Starter Kit

This task was to develop an easy to digest summary of high value I4.0 projects. The Starter Kit was to address four technology use-cases based on needs and opportunities identified in the landscape survey. The selected use-cases were to consider the financial and human resource limitations of SMMs, particularly those on the smaller end of the range. The Starter Kit was to discuss digital manufacturing technology prescriptions that include the infrastructure and human resource needs, budgetary estimates, other technology guidance, and expected results for successful implementation.

Develop a Transition Strategy

Finally, the team was to develop a transition strategy collaboratively with MxD to broadly disseminate the Starter Kit and develop multiple pathways for adoption of the web app by SMMs and their trusted technology partners (MEPs, etc.).

Planned Benefits

Benefits upon project completion

One planned benefit of the project was to provide a deep understanding of the I4.0 and digital manufacturing needs and opportunities for SMMs in discrete manufacturing industries via the landscape survey. The landscape survey highlights common pain points for SMMs, the current state of digital manufacturing adoption, and an assessment of the level of interest in particular I4.0 technology solutions.

Additionally, the project was planned to benefit companies via two “How to Get Started” resources that enable SMMs to easily self-assess their digital readiness and to advance their planning and implementation of I4.0 and digital manufacturing technologies and processes. Some of the benefits planned from these two resources include:

1. The Web App provides each company/site a baseline digital maturity capability assessment, a ranking of a company’s digital maturity to identify needs and opportunities for the business, a prioritized list of focus areas (SIRI dimensions) that the company should consider pursuing, and technology recommendations to advance their digital maturity in support of their business goals.
2. The Web App at project completion represents an initial implementation of the SIRI digital maturity assessment framework, developed with input from a small number of SMMs.
3. The Web App at project completion provides an assessment of digital maturity across each of the 16 SIRI dimensions, and includes recommendations for the 12 technology-related dimensions, including:
 - a. Vertical Integration (Operations Management)
 - b. Horizontal Integration (Supply Chain Management)
 - c. Integrated Product Lifecycle Management
 - d. Enterprise Connectivity, Intelligence and Automation
 - e. Shop-floor Connectivity, Intelligence and Automation

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f. Facility Connectivity, Intelligence and Automation

4. The Industry 4.0 Starter Kit provides an easy to digest summary of high value projects that address four technology use cases based on needs and opportunities identified in the landscape survey. The Industry 4.0 Starter Kit describes the infrastructure and human resource requirements, budgetary estimates, planning and implementation guidance, and likely results.

Future looking (2-5 years) benefits

In the longer term, with active promotion and refinement of the Web App and starter kit tools, there is high potential to impact a larger number of SMMs through increased knowledge of recommended I4.0 technologies. As the Web App is more broadly understood and utilized, feedback from a larger number of users could lead to enhancements that provide higher value with more focused assessments and recommendations.

IV. TECHNICAL APPROACH

The Golisano Institute for Sustainability (GIS) at Rochester Institute of Technology (RIT), with its staff of over 100 full-time technicians, engineers, research faculty and sponsored students, brought significant experience with the digital manufacturing technologies referenced in the Web App and Starter Kit to the project. RIT also led development of the assessment process and associated questions to provide an implementation of the SIRI framework.

Cuesta Partners, a technology advisory firm that supports private equity firms and manufacturing companies through their technology journey, brought strong operating knowledge of Industry 4.0 systems and technologies, along with deep technical skill (software, data, cyber, and infrastructure) to the Web App development process. Cuesta led the Web App development effort for the project and contributed two technology case studies to the Industry 4.0 Starter Kit.

Overview

This section provides insight into the technical methodology utilized throughout the development and execution phases of three deliverables:

1. Landscape Survey
2. Digital Manufacturing Starter Kit (Starter Kit)
3. Digital Manufacturing Journey Web App (Web App)

The project began with development of the landscape survey. This task commenced with an in-depth review of prior efforts within the 2015 IMPULS foundation study funded by the VDMA⁸. Following this review, the team formulated the specific project tasks in alignment with well-established industry best practices for survey development and implementation.

The team created the Digital Manufacturing Starter Kit to address specific knowledge gaps identified in the landscape survey. The Starter Kit discusses four different general technology areas, with an overview of four high value technology implementation project use-cases across these four areas.

⁸ <https://www.vdma.org/en/association>, LAST ACCESSED 29 AUGUST 2023

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The project use-cases were selected as examples of relatively high return on investment projects that could be undertaken by SMM getting started in digital manufacturing. The four technology use cases selected for the Starter Kit describe financial and human resource constraints and considerations often faced by SMMs. It also provides guidance on infrastructure requirements, typical cost considerations, and anticipated benefits.

The “Your Digital Manufacturing Journey” Web App was designed on top of the Appian cloud platform to allow for quicker standup of infrastructure, database, and security. Appian is also considered low-code development and can manage multiple form factors with little additional coding. As part of the development process, the team utilized the learnings from the landscape survey as well as team experience with development and deployment of Industry 4.0 technologies for SMMs.

Review of work performed

Landscape Survey

The team developed an online survey using SurveyMonkey, crafting questions to address key areas that shaped the development of the Digital Manufacturing Journey Web App and Starter Kit. These questions encompassed a variety of aspects, ranging from fundamental data like NAICS codes, revenue, and the type of manufacturing the business engages in, to more focused inquiries regarding the Industry 4.0 technologies and implementation. For instance, participants were asked to rank the I4.0 technologies they believed would yield the greatest benefits, gauge their level of expertise with specific technologies, and identify obstacles in the adoption of I4.0 technologies. The answers provided insights into the company's digital manufacturing and I4.0 resources and knowledge. In total, the survey comprised 51 questions, including two optional questions. The team provided the results of the survey in a PowerPoint presentation during a regular MxD technical call.

Digital Manufacturing Journey App

The “Your Digital Manufacturing Journey” web application was developed on the Appian cloud environment utilizing agile methodology to review progress each sprint as the team continued to develop and deliver content. Several potential end user companies provided feedback on the software usability at various points during the development process. The Web App is a fully contained application that contains database, security, web page development, etc. The Web App is meant to intake information from the user, analyze results utilizing the SIRI framework, and make recommendations to the SMM on what technologies would have the most impact to their operations.

Digital Manufacturing Starter Kit

The team developed the “Industry 4.0 Starter Kit” e-book to help inexperienced SMMs get started with digital manufacturing technologies; it includes four high-value technology areas that align with the original MxD RFP goals:

1. Manufacturing Operations Software
2. Machine Monitoring and the Industrial Internet of Things (IIoT)
3. Data Analytics and Business Intelligence
4. Automation



The Starter Kit includes four in-depth case studies that explain the technology, costs and benefits, requirements and functionality, tips for getting started, and a comparison of select commercially available products.

The Starter Kit leveraged recent case studies from RIT projects with SMMs developing and deploying machine monitoring/IIoT (shopfloor visibility) solutions and implementing Electronic Work Instruction (EWI) systems. It also leveraged Cuesta's recent experience in implementing Manufacturing Execution Systems (MES) and Business Intelligence solutions in two additional use-case studies. Each use-case study aggregates experience from multiple different projects in each technology area.

Project Task Discussion

Landscape Survey

RIT developed the survey questions, built the survey, collected the responses, analyzed, and summarized the findings and presented them to MxD. RIT partnered with Cuesta Partners, an MEP from NY State, and a Rochester, NY based trade organization to identify potential SMMs that may be interested in I4.0 topics and to market the survey to encourage participation.

FuzeHub, the statewide MEP (Manufacturing Extension Partnership) servicing all of New York State, has a wealth of experience in outreach and support for SMMs, including in the Industry 4.0 technology area. They aided in reviewing the survey also.

The Rochester Technology & Manufacturing Association (RTMA), a manufacturers association serving a network of 159 companies in the Rochester, NY area provides advocacy and growth-oriented services to its members. Notably, the majority of RTMA's members are small-scale manufacturers, including many small machine shops. RTMA provided input on the needs of SMM and recruited companies to participate in the landscape survey.

The following 10 sub-tasks were completed by the team:

1. Review the online IMPULS survey tool for its look and feel to model the landscape survey.

The 2015 IMPULS Foundation study provides a comprehensive view of Industry 4.0 readiness among SMMs, although it is somewhat dated and focuses primarily on German and European firms. One key outcome of the 2015 study is the IMPULS I4.0 readiness self-check web tool⁹, available online. The self-check questionnaire takes about 30 minutes to complete and serves as a preliminary assessment of a company's readiness. The team utilized the IMPULS self-check web tool as a style model for the landscape survey.

However, since the project required a deeper exploration of high-value use cases for SMMs deployment of I4.0 technologies, the team developed a more detailed questionnaire as described below.

2. Identify partners to help distribute the survey to SMMs.

The project tapped into the extensive membership base of small manufacturing shop members of the RTMA to gather unique perspectives from this user segment. Additionally, the Manufacturers Association of Central NY (MACNY), and FuzeHub, the New York Statewide Manufacturing

⁹ <https://www.industrie40-readiness.de/?lang=en>, LAST ACCESSED 29 AUGUST 2023

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Extension Partnership (MEP), provided their extensive contact lists of small/medium-sized companies operating in the manufacturing sector.

3. *Develop questions that address the level of understanding of digital manufacturing by SMMs.*

The effort was divided into three distinct tasks to develop three sets of questions. The first set of questions addressed the level of understanding of digital manufacturing among SMMs. The questions aimed to provide clarity as to how SMMs regarded digital manufacturing strategies and the anticipated cost-benefit of I4.0 technology implementations. The second set of questions sought to determine the alignment of SMMs priorities with the goals of the Web App. The final set of questions sought to identify topics of interest for the Starter Kit. In total, 51 questions were included in the landscape survey.

4. *Review SurveyMonkey and verify it is a good host for the survey.*

The team reviewed SurveyMonkey to assess its suitability as a host for the landscape survey. After developing and evaluating a mockup of the survey on the platform, the team selected SurveyMonkey to host the survey. The team had prior positive experiences with this platform and found it to be a reliable choice with no need to investigate alternative platforms.

5. *Determine the optimal timing to distribute the survey.*

To determine the optimal time for survey distribution, industry best practices and team members' experience was considered. The survey was sent via email at 9:07 am to three distributions on separate days of the week spread over three months.

6. *Develop an incentive for respondents to participate and complete the survey.*

All respondents were offered a summary report if they completed the survey.



7. Summarize the participants' answers into a report with data visualizations.

The survey responses were summarized into a spreadsheet and the data sets for each of the three distributions were analyzed. Data visualizations were created and insights from the survey responses were compiled into a report.

8. Present the results.

The results were organized to accommodate two distinct presentations to MxD. The first presentation encompassed a comprehensive review of all findings derived from the 51 questions, while the second was a shorter high-level summary of major findings.

9. Use the insights gained from the data analysis to support the development of the web app and starter kit.

The insights and conclusions from the survey played a pivotal role in identifying digital technologies of interest for inclusion in the Web App as recommendations, based on the companies' digital maturity assessment, to improve high priority Key Performance Indicators (KPI). The survey also identified high-value digital technology use cases for the starter kit that aligned with SMMs interests and strategic plans.

Digital Manufacturing Web Application

RIT developed the questions and scoring logic/algorithms for the web application based upon the SIRI framework and a series of assessments conducted with SMMs. A joint effort between MxD, RIT, and Cuesta created concepts for the web page designs and Web App workflows. Cuesta developed the web application from these concepts. Several companies agreed to evaluate the Web App at the later stages of development and provided valuable feedback to the development team used to update and improve the Web App.

The team completed the following 10 sub-tasks:

Web App - Content Development

1. Develop the assessment questions and technology prescription framework based, in part, on the SIRI format assessment. For each SIRI dimension and band, develop questions that are answerable by a predetermined menu.

Outside of this MxD project, RIT conducted several onsite Industry 4.0 digital maturity assessments at clients' manufacturing facilities. The assessments included both an observation of processes and discussions with key personnel. These discussions were framed with prepared questions based on the SIRI dimension and band, or level, within the dimension. This experience was used to convert the in-person questions into a set of carefully crafted progressive multiple-choice questions usable within a web application in a self-assessment by companies. For each dimension, RIT developed a set of questions such that the maturity for that dimension could be assessed, and that questions would only be asked at the appropriate level of the company's maturity.



2. Develop logic/algorithms for each SIRI dimension to compute a band score based upon the answers from each questionnaire.

RIT made several iterations of the questions described under Sub-task 1 and of the algorithms to assess the appropriate maturity band for each dimension. The algorithms were evaluated with multiple companies to validate the results. The transition plan envisions further validation testing after the end of this MxD project during the process of deployment and maturation of the tool.

3. Develop a simple profit and loss (P&L) questionnaire

An important component of the SIRI process is connecting the digital maturity priority assessment to business drivers. This prioritization utilizes the high-level financial data collected on the financial information page. Some companies that provided feedback on the use of the tool were uncomfortable with providing dollar-based financial data, so RIT and Cuesta redesigned the tool to collect this data based on percent of total sales.

The user input fields include 10 expense categories: raw material and consumables, utilities, labor, maintenance and repair, rent and operating lease, depreciation, research and development, marketing and sales, aftermarket service or warranty, selling general and administrative expenses. To assist the user in quickly completing the form, detailed explanations for each expense category were developed. These explanations are adjacent to categories on the financial information web page.

Financial Information Page

Please enter expenses by category and Earnings Before Interest and Taxes (EBIT). As you input expenses, the survey updates the bottom field, EBIT. Note that Expense Categories may be blank. The app utilizes the percentages to calculate the Profit & Loss (P&L) Weightage and give some dimensions more importance in the results.

Profit and Loss Inputs		Profit and Loss Definitions	
Expense Category	Expense Input (In %)		
Raw Materials and Consumables	0	Raw Materials and Consumables	Inventory of all component parts currently in stock that have not yet been used in work-in-process or finished goods production. They include both direct materials, which are incorporated into the final product, and indirect materials that are consumed during the production process but not incorporated into the final product
Utilities	0		
Labor	15	Utilities	Cost of electricity, heat (gas/fuel), sewer, and water used by a factory or plant to ensure the smooth running of both the direct manufacturing process and its surrounding environmental conditions.
Maintenance and Repair	0		
Rent and Operating Lease	0		
Depreciation	0		

4. Develop a key performance indicator (KPI) questionnaire with ranked KPIs.

Digital maturity priorities within SIRI are also based on company KPI rankings. The online assessment asks users to rank 10 KPIs into five priority groupings. In the key performance indicators page, users rank order the KPIs across five levels of importance (most to least) and must place two KPIs in each level of importance. The KPIs cover 10 functional areas of the typical manufacture, including: asset and equipment efficiency, inventory efficiency, utilities efficiency, workforce efficiency, process quality, product quality, safety and security, planning and scheduling effectiveness, production flexibility, and time to market.



Key Performance Indicators Page

These 10 KPI's pertain to operating efficiency, quality assurance, speed and flexibility metrics at your company/facility/business unit. The app utilizes KPI ranking calculate the KPI Weightage and give some dimensions more importance in the results.

Please select **EXACTLY TWO KPI's** for each column - 5 through 1.

Selecting 5 indicates that the KPI is the most important, and selecting 1 indicates that the KPI is the least important.

	Most Important			Least Important		
Asset and Equipment Efficiency ?	5 ☐	4 ☒	3 ☐	2 ☐	1 ☐	
Inventory Efficiency ?	5 ☐	4 ☐	3 ☐	2 ☒	1 ☐	

5. Develop a scorecard that will provide a snapshot of the assessment results.

The strategy used was to minimize descriptions to, in most cases, a single word. This allowed for the grouping of the 16 dimensions within the Blocks and Pillars format used by SIRI. The three SIRI Blocks are Process, Technology, and Organization. The eight SIRI Pillars include Operations, Supply Chain, Product Lifecycle, Automation, Connectivity, Intelligence, Talent Readiness, and Structure & Management.

The layout chosen was a spreadsheet with the Blocks, Pillars, and Dimensions listed vertically and the Band Maturity score and definition listed horizontally. This provides all the assessment scores in an easy to digest single view. With each score highlighted, it is easy to spot trends in digital maturity across the operation and identify priorities for improvement.

Home

Digital Manufacturing Journey

RESULTS SCORECARD PAGE

RECOMMENDATIONS PAGE

BAND CALCULATIONS PAGE

Results Scorecard Page

Block	Pillar	Dimension	Undefined	Defined	Digital	Integrated	Automated	Intelligent
Process	Operations	Vertical Integration	0	1	2	3	4	5
	Supply Chain	Horizontal Integration	0	1	2	3	4	5
	Product Lifecycle	Integrated Product Life Cycle	0	1	2	3	4	5
Technology	Automation	Band definitions	None	Basic	Advanced	Full	Flexible	Converged
		Shop-Floor Automation	0	1	2	3	4	5
		Enterprise Automation	0	1	2	3	4	5
		Facility Automation	0	1	2	3	4	5
	Connectivity	Band definitions	None	Connected	Interoperable	Secure	Real-Time	Scalable
		Shop-Floor Connectivity	0	1	2	3	4	5
		Enterprise Connectivity	0	1	2	3	4	5
		Facility Connectivity	0	1	2	3	4	5
	Intelligence	Band definitions	None	Computerized	Visible	Diagnostic	Predictive	Adaptive
		Shop-Floor Intelligence	0	1	2	3	4	5
		Enterprise Intelligence	0	1	2	3	4	5
		Facility Intelligence	0	1	2	3	4	5
Organization	Talent Readiness	Band definitions	Informal	Structured	Continuous	Integrated	Adaptive	Pwd-Looking
		Workforce Learning and Dev.	0	1	2	3	4	5
		Band definitions	Unfamiliar	Understanding	Informed	Dependent	Independent	Adaptive
		Leadership Competency	0	1	2	3	4	5
	Structure and Mgmt	Band definitions	Informal	Communicating	Cooperating	Coordinating	Collaborating	Integrated
		Inter/Intra Collaboration	0	1	2	3	4	5
		Band definitions	None	Formalized	Developed	Implemented	Scaled	Adaptive
		Strategy and Governance	0	1	2	3	4	5

A filled cell denotes the band score recieved for each dimension you completed when going through the survey.

FINISH SURVEY



6. Develop list of digital maturity priorities for recommendations page.

The recommendations page was designed to serve as a comprehensive guide for users seeking to elevate their digital maturity. At its most basic level, the recommendations page takes the lowest scores from the digital maturity assessment, and then ranks them using the company's financial information and KPIs provided in the beginning of the assessment. To arrive at the top three priorities, the Web App incorporates an evaluation of the company's current performance compared to industry peers.

In addition to this prioritization, the recommendations page features a curated list of technology solutions to consider. This list was based on insights gained from the landscape survey and the experience of the RIT project team. The example below shows a recommendation for the top priority area of improvement (Shop Floor Automation). The example shows that the company's current Shop Floor Automation maturity is at band level 2 (Advanced) and automated material delivery systems [e.g., automated mobile robots (AMRs) and automated guided vehicles (AGVs)] is one of several recommended technologies to consider for implementation.

Home

RESULTS SCORECARD PAGE **RECOMMENDATIONS PAGE** BAND CALCULATIONS PAGE

▼ Recommendations Page

Review a prioritized list of suggested technologies that can increase your company's digital maturity level.

PRIORITY #1

Dimension	Band Score	Band Name
Shop-Floor Automation	2	Advanced

Definition
Repetitive production processes are automated, with minimal human intervention. Repetitive support processes are not automated

Description
Production processes are predominantly executed by equipment, machinery and computer-based systems. Human intervention is required to initiate and conclude each process

Automated material-delivery systems [e.g., automated mobile robots (AMRs) and automated guided vehicles (AGVs)]

General Description:
There are two basic types of autonomous vehicles: automated guided vehicles (AGVs) and autonomous mobile robots (AMRs). Both types are material-handling systems or load carriers that travel autonomously throughout a distribution or manufacturing facility without an onboard or remote operator. AGVs use route guides such as magnets, magnetic tape, and beacons to follow a predictable pathway. AMRs are built with wireless sensors (e.g., lasers and onboard computing) to guide the vehicle and can redefine routes when an obstacle is observed, while AGVs will stop and wait until it is removed. There are approximately 200 vendors in this market supplying vehicles, software systems, and sensors.

Benefit Description:
Automated material-handling systems can have a variety of potential benefits. They can reduce material-handling labor costs, improve on-time availability of parts, lower the incidence of safety issues and material damage, and increase dispatch and shipping accuracy.

Cost Description:
Costs vary depending on the application. Basic AGVs range from \$60 to \$200K, depending on truck-type, lift-capacity, reach, and aisle-width requirements. AMRs are more expensive than AGVs because of their added capabilities. Other significant cost drivers are the navigation sensors and installation requirements, and software control and safety systems. Integration with an ERP (enterprise resource planning) system, MES (manufacturing execution systems), or material-management system can increase the overall cost of ownership.

7. Describe the reasons for achieving each band for each dimension and how to advance to the next higher band.

The initiative leveraged the well-established definitions derived from the SIRI format. The team at RIT utilized these definitions for every dimension and band, then enhanced them by describing the current state and the gaps to achieving the next band.

Furthermore, the team developed a textual description of strategies for progression to the subsequent band. This entailed a comprehensive exploration of not only the "what" but also the

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"why" behind the assessment results, fostering a solid understanding of the current state and the actionable steps required to advance to a higher band in the SIRI format.

8. *Develop the technology list adding a general description, expected benefits description, cost description, and relevant products that we have experience with.*

Having identified the relevant technologies, the subsequent crucial phase was to furnish the user with comprehensive information. This entailed crafting a well-structured explanation highlighting the advantages of adopting this technology and providing a clear understanding of the costs associated with its acquisition, integration, configuration, and utilization to propel their digital manufacturing efforts. These meticulously developed descriptions came about through extensive research and drew upon the invaluable real-world experiences of RIT engineers who have successfully implemented and harnessed this technology.

Beginning with the General Description, this overview provides users with a baseline understanding of the technology with emphasis on how to utilize it as a method to improve digital maturity. A review of expected top-level benefits and their qualitative contribution to ROI follows this discussion. The final discussion is a qualitative cost review. This list includes a review of acquisition and ongoing costs compared to the expected reduction in labor and increase in quality, productivity, and accessibility of the data output.

9. *Identify the technology needed to improve digital maturity and move to a higher band for each dimension.*

RIT created a consolidated list of candidate technologies by integrating insights from both the landscape survey, which pinpointed digital manufacturing technologies recognized by SMMs as investment priorities providing competitive advantages, with experience from the RIT and Cuesta teams to assist a diverse range of SMMs. RIT developed a general description for each candidate technology, along with ROI content (as described below), and scrutinized the terminology to make sure that it was accessible to engineers that might not be familiar with underlying technologies and associated jargon.

RIT assigned individual technology investment options from the long list of candidate technologies to the band advancement (e.g., band 1 to band 2) for a specific SIRI dimension. This mapping was done for the 12 process and technology bands, but not for the four organizational bands as those are generally not technology related. The web app may list individual technologies as candidates for more than one dimension and for more than one band. The web app presents users with technology recommendations for the priority SIRI dimensions (i.e. those that scored as most important for that company). The recommendations do not consider all the data collected during the survey. For example, a company might have indicated that they are using an ERP system; however, if their readiness indicated that their Enterprise Automation maturity was at the level "Defined" and not "Digital" based on the totality of their responses, ERP would show up as a technology recommendation. The full set of company Q/A data provides an opportunity to make the recommendations more company specific; however, that requires development of a more complex logic system, which was not within the project scope.

10. Develop a return on investment (ROI) estimation for the technologies.

The team originally spent effort to develop and evaluate approaches to a quantitative ROI analysis framework. However, this quickly became too complex when considering the many facility, process, and company specific variables for a particular company. The team, therefore, developed a qualitative approach to describe the ROI opportunity based on a general description of the potential Benefits and Costs associated with implementation of a particular technology with respect to the dimension.

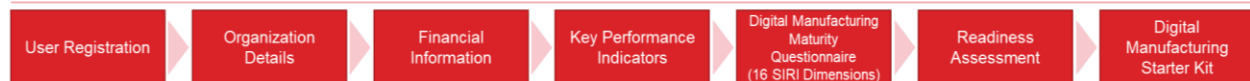
11. Assemble all the information above to support web app development.

The team carefully organized the underpinning algorithms and section/page mockup designs in Microsoft Excel spreadsheets, ensuring easy reference and access for web application developers. For the written descriptions and explanations, the team utilized Microsoft Word documents and Microsoft collaboration tools, facilitating a structured presentation of the information and a detailed look into the specific aspects of the assessment.

Web App - Software Development

The “Your Digital Manufacturing Journey” web application is built as a cloud-based system that utilizes the Appian platform. There are three major software environments that were delivered to MxD at the conclusion of this project (Development, QA, and Production). The Web App was built out in phases using the logic, algorithms, content, and mockups described above. The app development phases followed the user and app workflow as seen below:

App Workflow



The first environment, Development, is intended to be an area where the developers can design and build new functionality, extensions to existing functionality, or fix defects that are discovered. The second environment, Quality Assurance (QA), is meant to be an area for testing of the application by the appropriate testers from MxD and SMMs. The third environment, Production, is where all the clients will be utilizing the tool.

In addition to the phased development approach, the Web App was deployed to QA for testing across several major releases, with extensive end-user testing of each release to enable bug fixes and define future feature sets for implementation.

As part of the project technology transition plan, the Web App is designed to enable integration with the new MxD member portal sign-on process. This integration will entail additional software development work once the new MxD member portal is implemented.

Digital Manufacturing Starter Kit

The Industry 4.0 starter kit (Starter Kit) was developed using four key digital manufacturing/Industry 4.0 technology case studies drawn from technology assistance client projects successfully completed by both Cuesta Partners and RIT. The case study topics were selected from the initial



MxD request for proposal (RFP) list of “high value” technologies. Each case study draws upon the experience of the project team with several different companies and generalizes the case to relate to multiple SMMs in different industries or with different business drivers. These case studies are organized within one of four categories and each category has its own high-level description:

1. Manufacturing Operations Software,
2. Machine Monitoring and the Internet of Things,
3. Data Analytics and Business Intelligence, and
4. Automation

Individual case studies were developed around a particular technology thought to bring high value to SMMs and discuss at length the business opportunity/use-case, the benefits of deploying the technology, requirements to implement, tips for getting started, and where available, a summary of the expected costs for several market-leading technologies.



V. RESULTS

The first deliverable, the SMM digital manufacturing readiness landscape survey, was presented to MxD on August 19, 2021, and the summary of findings final report document is available on the MxD Project 20-04 web page.

For the other two deliverables, there has not been enough time since the project was completed to thoroughly assess the impact and outcomes of the Digital Manufacturing Starter Kit and the Web App. It is anticipated that a more in-depth assessment will be possible once more time has passed as the project team continues outreach efforts to both recruit test users of the Web App and broadly disseminate the Starter Kit.

Table 2: MxD 20-04 Technology Deliverables

#	DELIVERABLE NAME	DESCRIPTION	FORMAT OF DELIVERY
1	SMM Digital Manufacturing Readiness Survey - Final report	Presentation of the SMM digital manufacturing readiness landscape survey findings in executive summary format at MxD forum on August 19, 2021	PDF
2	Digital Manufacturing Starter Kit	In-depth case studies of four key technology resources to support SMM digital transformation efforts	PDF
3	Digital Manufacturing Web App	Provides SMM with a baseline digital maturity assessment, prioritized list of the technology areas that will enable an increase in digital maturity, and provides a discussion of estimated ROI for deploying the technology	Source code for Website

SMM Digital Manufacturing Readiness Results

The SMM digital manufacturing readiness landscape survey had 28 respondents from 13 NAICS sectors across the United States and yielded invaluable insights that provided clear guidance for the Web App development. Survey data highlighted the technologies essential for the successful implementation of I4.0 projects, with an initial set of 16 priority technologies identified for SMMs. The team expanded this list to over 30 technologies in the Web App based on its experience supporting SMMs as they progress in their digital transformation journeys.

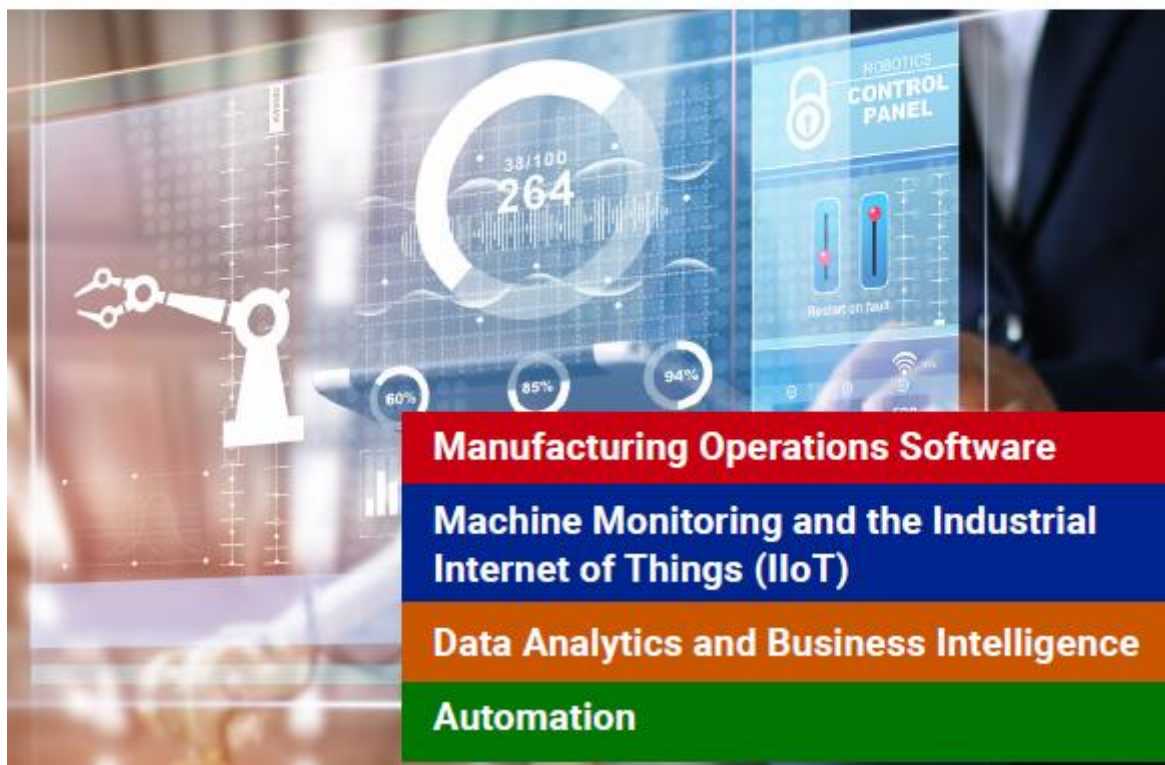
Digital Manufacturing Starter Kit Results

The Industry 4.0 Starter Kit has four technology case studies covering electronic work instructions (EWIs), manufacturing execution systems (MES), shopfloor visibility technologies and business intelligence (BI) systems. The case studies are discussed within the context of four high level digital technology topics: manufacturing operations software, machine monitoring and the industrial internet of thing (IIoT), data analytics and business intelligence, and automation.

The Starter Kit is provided as a PDF document and is planned to be made available to users that complete the Web App surveys in the recommendations section, and to be widely disseminated to SMMs through outreach efforts to be undertaken after project completion.

INDUSTRY 4.0 STARTER KIT

How to get started with digital manufacturing technologies



Web App Results

System Overview

The Digital Manufacturing Journey web application (Web App) is a cloud-based application that manages the collections of all user input for the digital maturity web assessment.

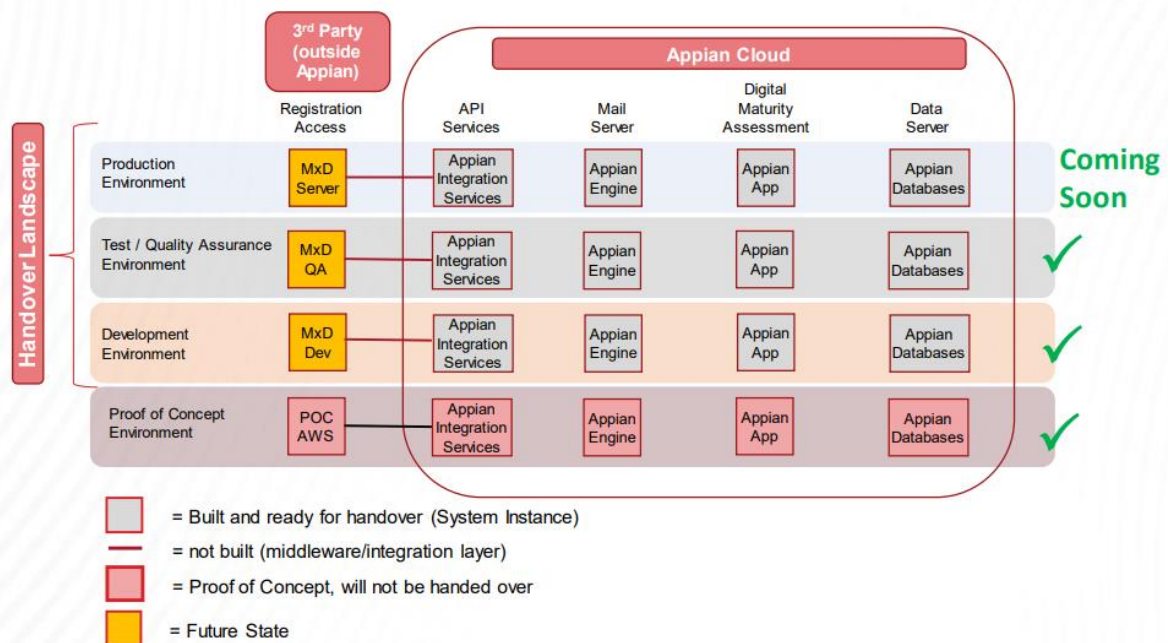
System Requirements

The Web App is currently accessed through the Appian portal and requires a modern web- or mobile-supported browser like Chrome, Edge, Firefox, or Safari to access the current functionality of the assessment tool. Appian keeps its application and environment compatible with the currently supported versions from these web browser vendors. For a complete list of current Appian compatibility requirements, you can view them [here](#).

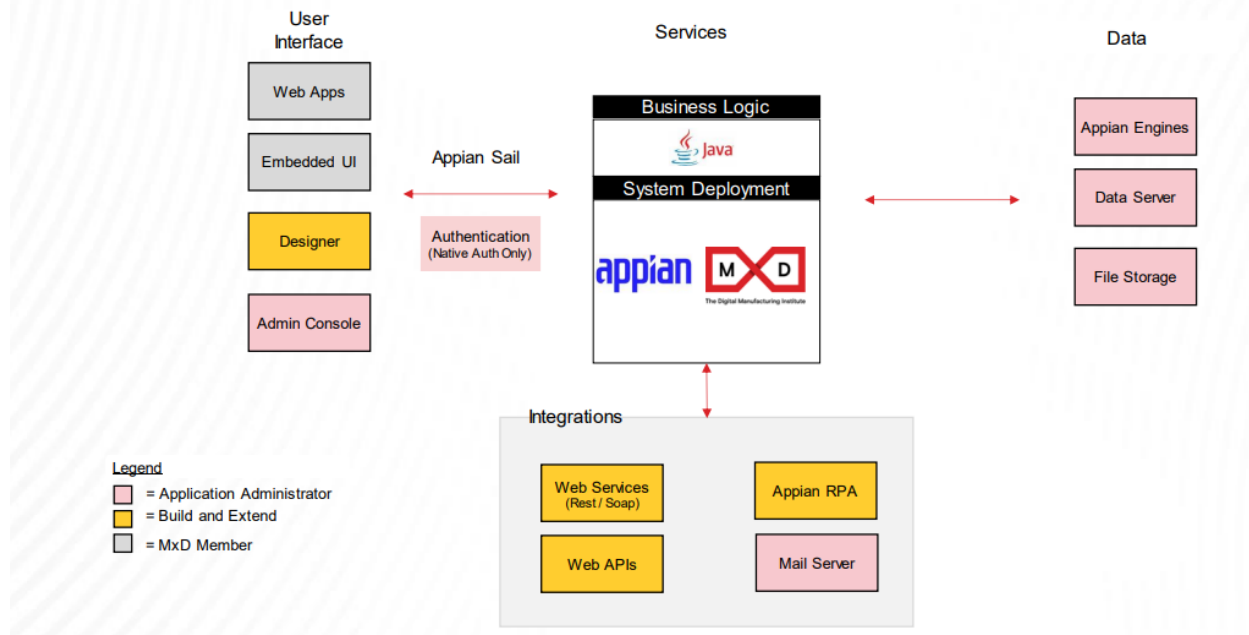
System Architecture

There are three major software environments that were delivered to MxD at the conclusion of this project (Development, QA, Production). The first environment, Development, is intended to be an area where the developers can design and build new functionality, extensions to existing functionality, or fix defects that are discovered. The second environment, quality assurance (QA), is meant to be an area for testing of the application by the appropriate testers from MxD and the SMM community. The third environment, Production, is where all clients will utilize the tool. An overview of the software architecture and environments is below:

Web app – Overview of the software architecture



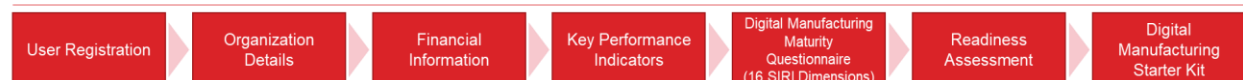
Digital Manufacturing Journey - Environment



Features & Attributes

The web application is broken into a few sections that capture the user data and input before producing recommendations and next steps in the journey.

App Workflow



1. **User Registration** – This process is intended to be done outside of the application with users created through an API call on a 'brochure' MxD page or with MxD credentials, e.g., MxD members single-sign-on (SSO) login credentials. Currently, this process needs to be done in the background of the Appian platform - the new user needs to directly request access from someone at MxD via email, and then they are provided with the sign-on username, email, and initial password.
2. **Organization Details** – This page of the Web App assessment tool is designed to gather critical metadata of the client that could be used for future connections and analysis of the companies taking the survey. This page has a minimal build out factor currently and it is recommended that MxD should explore what further data they would like to capture from users of the assessment.



Start of the assessment

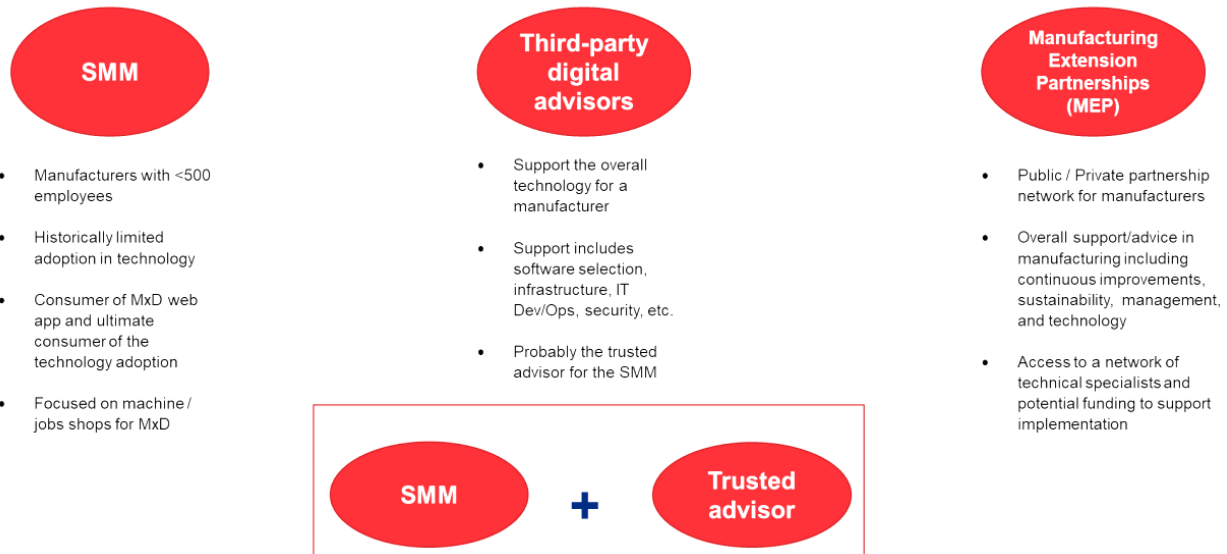
3. Financial Information – Captures pertinent financial metrics to help the Web App tool prioritize what expense categories may be impacted the highest when deploying Industry 4.0 technologies. Financial metrics along with the KPIs would weight certain metrics higher on the SIRI framework.
4. Key Performance Indicators (KPI) – KPIs are force ranked by the user of the application to help focus in on what is most important to the user. There are 10 key metrics focused around three major areas: Efficiency, Speed and Flexibility, and Quality and Assurance. These metrics are ranked to provide weighting in the final assessment results.
5. Questionnaire – The questionnaire is broken into 16 dimensions that cover the entire organization and its readiness for Industry 4.0. These 16 dimensions are grouped into three building blocks (process, technology, and organization) and the DM journey web tool asks a series of questions around these dimensions to get a final maturity band score (0-5) for each of the dimensions.
6. Readiness Assessment – The readiness assessment provides the user with a scorecard and prioritized dimensions that should be address by the organization. These prioritized dimensions are based on a combination of financial metrics, KPIs, and band scores of the 16 dimensions. For each prioritized dimension, a set of candidate technologies for the SMM to consider are provided along with qualitative cost and benefit information.

Target Users & Modes of Operation

The web application can be utilized by anyone within the SMM that has enough knowledge about the operations to answer each questionnaire. The web application was designed to allow for a particular user to answer one or more dimensions to allow users to focus on the sections they understand. Questions are ordered and progressive, so when the logic establishes the minimum band ranking for a dimension, later questions (associated with higher bands) are not asked. The assessment is also designed to allow SMMs to work with a trusted technology advisor that can help answer the questions, understand the results and recommendations, and select and assist in the implementation any of the Industry 4.0 technologies described in the recommendations. Finally, the Web App is seen as a tool to be used by manufacturing extension partnerships (MEPs) and their clients to assess digital maturity and aid with planning and prioritizing technology deployments.

Targeted Users for the Web App

Potential users – 3 different personas (user types) and who we think would benefit the most



Software Development/Design Documentation

See appendices - Administration Guide for handover documentation links. The files are located on the MxD project 20-04 web page.

VI. DISCUSSION AND ANALYSIS

Due to various scheduling constraints, there has not been sufficient time since the project was completed to thoroughly assess the impact and outcomes of the deliverables. As a result, we currently lack the necessary data and insights to comprehensively gauge how the project has influenced the objectives and goals. We anticipate that a more in-depth evaluation will be possible once more time has passed, allowing MxD to better understand the long-term impacts, implications, and limits of our project's deliverables on the overall strategy. The known industry impacts and status of key performance indicators at project end are discussed below.

Industry Impact

The project focused on discrete product and contract manufacturers with the primary technology focus on machine monitoring, industry internet of things (IIOT), data analytics and business intelligence (BI), process automation, manufacturing, and enterprise software systems such as enterprise resource planning (ERP) and manufacturing execution systems (MES).

The project was driven by a set of stakeholder user stories focused on the following potential users, as described in the MxD RFP:



- As the owner of a small machine shop, I need a resource to understand what technologies I need to implement to stay competitive and how to invest in them to maximize my ROI in the short and long term.
- As a production manager at a small manufacturer, I want to launch a low-cost, Industry 4.0 project and understand how to pitch it, plan it, execute it, and then scale it.
- As a consulting engineer at a manufacturing extension partnership (MEP) Center, I want a resource that I can use to create further services to help my clients get started in digital manufacturing

The team believes the way to maximize the impact of using the Web App is to complete the assessment with a trusted technology advisor that understands both manufacturing and Industry 4.0. Feedback from end-user testers indicated that a trusted advisor could assist not only in completing the assessment questionnaires, but also help with the selection, implementation, and ongoing support of any recommended and relevant technologies. These advisors may be found internally within the company, hired as a third-party partner, or found via a MEP network center.

Key Performance Indicators & Metrics

Table 3: KPI's and Metrics

METRIC	BASELINE	GOAL	RESULTS	VALIDATION METHOD
User time to enter company details for baseline assessment	N/A	4 hrs.	4 to 6 hours	Beta testing with three companies
User time to enter company financial and needs / opportunity assessment	N/A	2 hrs.	Less than 1 hour	Beta testing with three companies
% of companies stating understanding of their digital maturity / readiness is good	<20%	>80%	Unable to assess – not enough time since delivery of the Web App at project completion.	Planned validation via web site visitor survey
% companies stating that a significant barrier is understanding of business opportunity and ROI	70%	<20%	Unable to assess – not enough time since delivery of the Web App at project completion.	Planned validation via web site visitor survey
% of companies likely to consider an implementation of IIOT, analytics, MES, automation	<20%	>50%	Unable to assess – not enough time since delivery of the Web App at project completion.	Planned validation via web site visitor survey
% of users rating ease of use/understanding of starter resources is good or excellent	N/A	>90%	Unable to assess – not enough time since delivery of the Web App at project completion.	Planned validation via web site visitor survey
% of users that state that starter kit case studies provide a good idea on the details of how to get started	N/A	>80%	Unable to assess – not enough time since delivery of the Industry 4.0 starter kit at project completion.	Planned validation via web site visitor survey
% users abandoning starter kit before completing engagement	N/A	<20%	Unable to assess – not enough time since delivery of the Industry 4.0 starter kit at project completion.	Planned validation via web site analytics

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Accessing the Technology

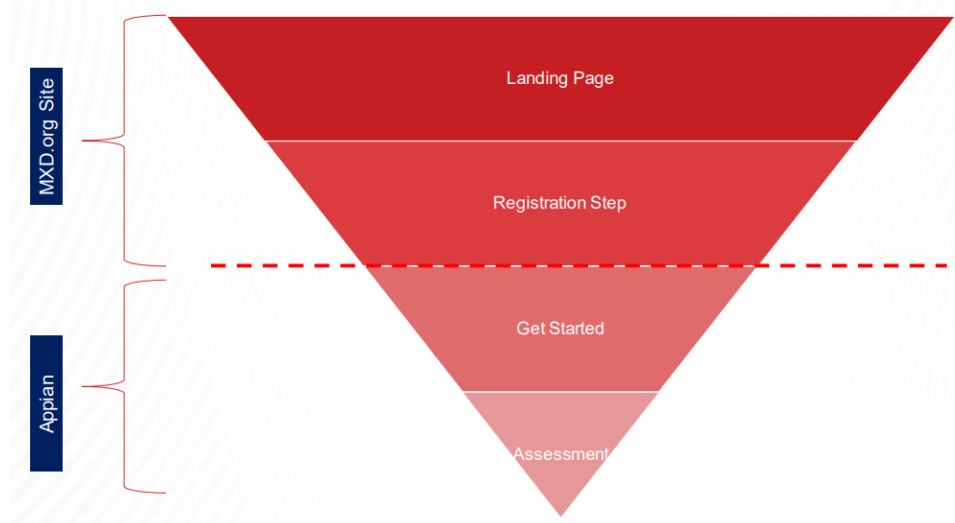
As of the release of this report, the Web App will only be accessible to MxD member companies via a direct setup within the Appian MxD environments. Any commercially available web browser can access the Web App.

The Web App was designed with an application programming interface (API) that can be called from an outside application. One intended use is to setup the user automatically, with the idea that the user would be authenticated through MxD's new member portal, and the applicable metadata would be pushed into Appian. When MxD deploys a new member portal system, additional software development work will be required to integrate the member portal with Appian to onboard new users and push out sign-on information to users. Instructions are included in the Administration Guide to facilitate this work.

Currently, the Digital Maturity Assessment Web App is not accessible or known via a search engine. To help better market the web assessment tool and describe the Web App itself, the top portion of the onboarding process funnel graphic below will need to be built after project completion. It is envisioned that this additional software development work will build landing and registration pages within the www.MxDusa.org landscape.

Maintenance of the Web App will require expertise with the Appian platform. Regular periodic updates of the content in the recommendations section, for example, as relevant technologies evolve, and the scoring algorithms will require subject-matter expertise in both the SIRI assessment framework and Industry 4.0 technology deployments. Regular updates of the content are recommended to keep the Web App current with technology developments and Industry 4.0 trends.

Web App - Onboarding process



Workforce Development

Workforce development was not a focus of this project. However, the Industry 4.0 Starter Kit can be used as a resource for SMM workers to learn about core technologies that make up the Industry 4.0 landscape.



Lessons Learned

What went well?

The assessment tool Web App has 16 robust questionnaires, prioritizes areas of the business that are likely to most improve overall digital maturity, and describes I4.0 technologies most relevant to SMMs.

The Appian (low code) tool was relatively easy to stand up and performed well in the overall development and deployment of the tool.

The SMM digital manufacturing readiness landscape survey provided insights into the manufacturing and business issues SMMs were dealing with and identified gaps where Industry 4.0 technologies may be able to help.

What went poorly? And associated learnings?

The scheduled project start was delayed, which impacted team members and delayed the overall project timing and results.

Appian has some limitations to the overall developer and user experiences; however, these limitations did not impede delivery of the final product.

It was very difficult to sign-up SMMs to run through end-user pilot testing and feedback sessions with the project team. One barrier was the initial design requirement of the Web App to require completion of all 16 questionnaires before providing results and recommendations. Based on end-user sessions with SMMs, the team received valuable feedback that using a subset of the 16 dimensions would be most applicable to their businesses. As a result of this feedback, the team redesigned the Web App to allow for completion of as few as one or up to 16 questionnaires. For example, end-user feedback highlighted a few key areas of interest such as automation and connectivity.

The project scope did not address sustainment of the tool after transition, which will likely impact commercialization/adoption of the tool for the MxD and broader SMM community

What do you want to do differently?

Develop with MxD mechanisms and protocols that address the ongoing sustainment of web apps and digital tools after project completion and incorporate those into future projects and project calls.

VII. CONCLUSIONS AND FUTURE WORK

It is worth noting that there has not been ample time since the completion of the project to conduct a thorough assessment of the impact and outcomes of the Digital Manufacturing Starter Kit and the Web App deliverables. Consequently, the situation is one where the necessary data and insights related to usability and value to SMM are currently lacking, making it challenging to comprehensively gauge how the project has influenced the objectives and goals. The project team



looks forward to a more in-depth evaluation as time progresses, allowing MxD to gain a better understanding of the long-term impacts, and areas for improvement.

Given the absence of detailed analysis, conclusions drawn at this point would be rooted in assumptions and are therefore not included.

Next Steps & Challenges

RIT is planning to broadly disseminate the Starter Kit resources to NYS companies and RIT partners via a focused marketing campaign. Once the Web App is deployed by MxD, another outreach effort is planned by RIT to get the Web App in front of as many SMM partners in NY State as feasible.

The team will continue to do additional testing and hardening of the Web App. Due to the limited number of SMMs who participated in testing during the initial testing phase to find and resolve defects, the team is looking for additional test users to provide feedback. After additional testing sessions, the team should be ready to push the assessment tool into production. MxD should also consider approaches to long-term support and maintenance of the application and user community.

Transition Plan

The table below provides a catalog of all the project deliverables and their respective transition routes. Deliverables can transition through deployment at an industry member's site, as an educational reference, or through a commercialization effort. Each of these transition routes are detailed below.

Table X: Deliverable Deployment Summary

#	DELIVERABLE FILE NAME	TECHNOLOGY INTEGRATION	EDUCATION	COMMERCIALIZE
1	SMM Digital manufacturing Readiness Survey - Final report		X	
2	Industry 4.0 Starter Kit		X	
3	Digital Manufacturing Web App	X	X	

Transitions activities

The SMM digital manufacturing readiness landscape survey findings were compiled into a file entitled "SMM Digital manufacturing Readiness Survey - Final report" and reviewed with MxD members and staff during an MxD technical call on August 19, 2021. A copy of the full report is posted to the MxD project 20-04 web page.

The digital manufacturing starter kit resource was compiled into file entitled "Industry 4.0 Starter Kit." A copy of the e-document is posted to the MxD project 20-04 website as well as the RIT website at: <https://www.rit.edu/advancedmanufacturing/industry-40>. RIT plans an outreach campaign to share the learnings within the Starter Kit. The campaign will target SMMs and will utilize government and industry partners to broadly disseminate the findings and engage the SMM community in what is hoped to be the beginning of an ongoing dialogue on Industry 4.0 deployment and digital transformation strategies.

Relative to transition of the Digital Manufacturing Web App, the team suggests that after the Web App is available on MxD servers, MxD engage with the MEP network to facilitate transition and engagement to the SMM community.

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VIII. APPENDICES

Appendix A: Definitions

AGV	automated guided vehicles
AMR	automated mobile robots
API	application programming interface
BI	business intelligence
COVID	Corona Virus Disease
DM	digital manufacturing
ERP	enterprise resource planning
EWI	electronic work instructions
GIS	Golisano Institute for Sustainability
IIOT	Industrial Internet of Things
IMPULS Foundation	The IMPULS Foundation of the German Engineering Federation (VDMA) explores fundamental issues of strategic importance to the German engineering industry.
KPI	Key Performance Indicator
MACNY	Manufacturers Association of Central NY
MEP	Manufacturing Extension Partnership
MES	manufacturing execution system
NAICS	North American Industry Classification System
NIST	National Institute of Science and Technology
OEM	Original equipment Manufacturer
QA	Quality Assurance
RFP	Request for Proposals
RIT	Rochester Institute of Technology
ROI	Return on Investment
RTMA	Rochester Technology & Manufacturing Association
SIRI	Smart Industry Readiness Index
SMM	small and medium sized manufacturers
VDMA	The German Engineering Federation



Appendix B: Demos

The June 15, 2023 MxD technical call, July 20, 2023 MxD technical call, and October 19, 2023, final presentation slides include demos of the Web App over time and all three are posted to the MxD Project 20-04 web page. The eight short videos presented during the June 15 and July 20, 2023 technical calls are also provided.



Appendix C: Validation & Testing

The following testing and validation plan was utilized for the Web App:

#	Development phase	Testing and validation steps	Resources utilized
1	Concept design and digital mockup of the assessment tool look and feel, workflow development for the Web App	Mockup design reviews	RIT, Cuesta, MxD
2	Develop content for the Web App = the 16 questionnaires to assess the SIRI dimensions	Onsite assessments with several SMM companies	RIT
3	Initial Web App development, version 1 – limited to the company information screen, profit and loss summary screen, KPI prioritization screen, and questionnaire portions of the workflow – NO results, scorecard, or recommendations	Team design reviews, internal testing of each page to validate the workflow	RIT, Cuesta, MxD
4	Concept design and digital mockup of the results, scorecard, and recommendations sections of the Web App	Team design reviews, internal testing of each page to validate the workflow	RIT, Cuesta, MxD
5	Develop content for the Web App = the recommendations that can increase digital maturity, including discussion of what each relevant technology is, how it works, and an ROI estimation.	RIT content development, review, and editing process utilizing a technical writer	RIT
6	Continued Web App development, version 2 – rollout of the initial content and look/feel of the results, scorecard, and recommendations section	Team design reviews, internal testing of each page to validate the workflow, SMM company end-user testing	RIT, SMM testing partner companies
7	Continued Web App development, version 3 – final content integration for the results, scorecard, and recommendations section, rollout of the report section	Team design reviews, internal testing of each page to validate the workflow, SMM company end-user testing	RIT, SMM testing partner companies



Appendix D: User Resources

Installation Manual

There is no Installation Manual needed for the Web App – the end user does not need to install any software to run the Web App. The three software environments and all the web pages were built within an MxD instance/license of the Appian cloud-based platform, so no installation is required.

User Guide

See the file entitled “8 December Administration Guide_v2” on the MxD Project 20-04 SharePoint web page folder.