Assessing the Current State of Industry 4.0 for Industry and Academics: Survey Development Challenges and Lessons Learned

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Abstract

Though originally introduced more than a decade ago, Industry 4.0 (I4.0) has progressively gained popularity [1]. More recently, through the COVID-19 pandemic, I4.0 has gained further traction and popularity to address worker shortages and supply chain issues [2]. The continued progression and popularity of I4.0 has resulted in an increase in questions on how to make I4.0 work in manufacturing industries of all kinds. There are many resources and consulting groups willing to support manufacturers in I4.0 development, but there is a limited understanding of how and where the greatest opportunities lie and potential areas of impact. A survey was developed to assess the current state of I4.0 to identify high priority areas of I4.0 implementation. The survey had a low response rate and provided limited information on where the greatest impacts could be made. This work assesses the process of developing and distributing an I4.0 assessment survey aimed at improving response rate and the utility of the results, while still characterizing the complexity and technical depth of the topic. Long and complex surveys have a low likelihood of participants responding to or completing the survey. Though this survey was developed following a reduced model of I4.0, the completion rate of the survey was limited and findings provided limited utility. Implications for future I4.0 survey development and options for reducing complexity while still maintaining the detail necessary to assess the state of I4.0 implementation and needs are primary results of this work.

Introduction

The fourth industrial revolution, Industry 4.0 (I4.0) encompasses the usage of data, automation, and interconnectivity driven by the desire for instant system status and feedback. The connectivity and instantaneous nature of Industry 4.0 allows manufacturers to assess, understand, and control their systems in real time. Though simply stated, the implementation and management of highly interconnected systems is a complex task with various levels of understanding that are challenging to define. When investigating what I4.0 is, it becomes apparent that there is no clear answer and thus authors attempt to categorize parts of I4.0 to better describe, research, and understand it in a piecewise method. For example, the Center for Industrial Research and Service (CIRAS) at Iowa State University has categorized industry 4.0 into nine categories, Cybersecurity, Augmented and Virtual Reality, Big Data, Robotics/Automation, Additive Manufacturing/3D printing. Simulation, System Integration, Cloud Computing, and Internet of Things [3]. Already the topic of discussing I4.0 has grown considerably complex by defining the different tools and components of I4.0, especially for those who are new to the manufacturing industry.

Developing an understanding of what I4.0 tools and components can do and their potential impact in a manufacturing environment can be a daunting task. Other authors have addressed this by describing I4.0 in through a theoretical framework. For example [4], broke the components down into front-end technologies and base technologies. Front end technologies are categorized as Smart Supply Chain, Smart Working, Smart Manufacturing and Smart Product. These front-end technologies are supported by base technologies, Internet of Things, Cloud, Big Data, and Analytics. The base technologies are supportive of the front-end technologies to generate products . Now, rather than a large grouping of categories, there is a theoretical framework to better understand the functions of I4.0 technologies and tools. Additionally, this framework describes the stages of I4.0 adoption in 3 stages based on the technologies and methods being utilized.

The State of Iowa is a relatively large manufacturing state in the Midwest, making Iowa a key interest in manufacturing developments. Iowa State University Center for Industrial Research and Service (CIRAS) monitors, reports on, and supports manufacturing in the state of Iowa. A significant task that CIRAS takes on is to publish an Iowa manufacturing needs assessment report. This needs assessment report implements data to identify the state of manufacturing in Iowa across various categories. One of the categories in the Iowa manufacturing need assessment report provides a status report on I4.0 based on the CIRAS I4.0 readiness assessment survey [3].

CIRAS surveys the primary nine I4.0 categories and reports on them. The survey results provide an overview on the status of Iowa manufacturers in the implementation of the nine categories of I4.0. The survey results from Iowa manufacturers needs assessment report further show four different levels of implementation of each I4.0 category, implemented and sustained, the implementation is in progress, planning complete and starting implementation, and implementation planning started [3]. This part of the survey provides valuable information on I4.0 status in Iowa as well as where it is expected to be in the near future.

The purpose of developing a survey was to supplement the information CIRAS was already gathering on the nine primary categories of I4.0 with more detailed information following the framework proposed by Frank et al., [4]. This work aimed to explore more of the details within each of the categories in I4.0 to better understand the status under each category. A detailed understanding of the difficulties and successes of Iowa manufacturers in relation to I4.0 assists in providing a more comprehensive picture to better understand options and abilities moving into the future.

Survey Development

With a theoretical framework that describes I4.0 tools and technologies as well as their purpose and function, a survey was developed to obtain a measure on the status of I4.0 in Iowa. The survey followed a theoretical framework, defined by [4], to ask manufacturers about the technologies that they utilized as well as how those technologies were being used. Additionally, participants were asked about training needs revolving around different I4.0 technologies to better understand the areas for the greatest impact.

To ask participants directly about their needs, participants were asked about technologies that support I4.0 and their needs in relation to training on those technologies. For each of the technologies, participants selected the level of training their organization needs. To further understand what the primary needs are of organizations, participants were provided with open ended questions. The open-ended questions asked participants to describe their three primary challenges in relation to industry 4.0 and what incentives would get them to advance in the I4.0 categories. Finally, to identify if there was any connection between different manufacturing sectors and sizes, and their I4.0 status and needs, participants were asked to provide demographic information about their organization.

While developing the questions for the survey, the complexity of the survey continued to increase with each new section added. By following the framework of front end and base technologies, the goal was to get a measure of where Iowa manufacturers were with each section. To accomplish this, there needed to be a measure for each front-end technology and each base technology. The primary difficulty occurred when developing questions to get a measure for each of the front-end and base technologies. The difficulty is that the survey began to grow exponentially with each new topic. For example, in the case of front-end technologies, smart manufacturing can be measured to get an understanding of what stage a company is at in its implementation. To measure the stage, questions about vertical integration, energy management, traceability, automation, virtualization and flexibilization needed to be defined and created. To get a true measure of each of those categories, questions about the technologies and tools utilized in each category needed to be asked. For example, just with vertical integration questions about ERP, MES, SCADA and sensing needed to be asked to provide a measure.

While it appeared to be simple methodology to follow on the surface, the further the survey was developed the more it grew and increased in complexity. The solution to address this challenge was to group questions in the survey by the types of technologies and processes that required a measurement. This led to tables questions such as: approximately how many of your machines can share, receive, and store data? These types of questions allowed for interpretation of technologies being used rather than asking about specific tools and equipment, reducing the number of required questions. Further, by asking scenario or capability-based questions it prevented the inclusion of additional information for the participants to read and process, rather participants just described the capability of their equipment. Though scenario or task-based questions were utilized, there were questions required to ask directly about the usage of specific tools and technologies.

To increase participation and receive a diverse sample of responses, multiple channels of survey distribution were used. SME chapter leaders in Iowa were contacted and asked to distribute the survey to their members. Contacts known through partnership with the Iowa State University Department of Agricultural and Biosystems Engineering were sent the survey. Finally, the survey request was sent through multiple newsletters from CIRAS and the Iowa Association of Business and Industry.

Though the survey followed a theoretical framework and had reduced questions through grouping methods, the survey still required about one to two hours to complete. A testament to survey burnout is the number of people who started and fully completed the survey. The survey reached nearly 220 people directly and likely over 1,000 people when accounting for distribution through professional organizations and newsletters. Though the survey was distributed through multiple channels only 23 participants took the survey and of those only 16 completed the survey. The participants who completed the survey were beginning to provide short and unclear responses about halfway through the survey. Though there were 16 who completed the survey, the responses provided at the end of the survey compared to the responses at the beginning indicated that the participants had lost interest or were rushing to complete the task.

Conclusions and Future Work

The survey developed in this work does measure a detailed state of Industry 4.0 in a more practical and simplified way. However, the vastness of the I4.0 field still required a large and complex survey to gather information on the level of detail needed for a comprehensive understanding of the state of I4.0 in Iowa. To measure in detail all things related to I4.0 requires a large time investment and based on the results from this survey, that time investment is too large to compete in a single survey. Additionally, the overall response rate was relatively low indicating that people are not interested in I4.0, their company does not do any I4.0 related things, or the size of the survey was a deterrent.

Future work will be focused on two different methodologies. First, a narrowing approach will be followed where high level I4.0 probing questions are asked to identify high need areas and then a follow up survey will be detailed specific to only those high need areas. The second method will follow a component methodology where surveys will be distributed in the same level of detail but split into sections that only require a short period of time to complete.

References

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Biography

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