OVERVIEW OF SMART MANUFACTURING IN WEST VIRGINIA

WINTER 2018

West Virginia University.
COLLEGE OF BUSINESS AND ECONOMICS
Bureau of Business & Economic Research

West Virginia University.
BENJAMIN M. STATLER COLLEGE OF
ENGINEERING AND MINERAL RESOURCES

Overview of Smart Manufacturing in West Virginia

is published by:
Bureau of Business & Economic Research
And Industrial and Management Systems Engineering
West Virginia University College of Business and Economics
West Virginia University Benjamin M. Statler College of Engineering and Mineral Resources

(304) 293-9439
thwuest@mail.wvu.edu
statler.wvu.edu

(304) 293-7831
bebureau@mail.wvu.edu
bber.wvu.edu

WRITTEN BY

Dr. Thorsten Wuest, Assistant Professor
WVU Industrial and Management Systems Engineering

Patrick Schmid, MS Graduate Student
WVU IMSE & Karlsruhe Institute of Technology

Brian Lego, Research Assistant Professor
WVU Bureau of Business and Economic Research

Dr. Eric Bowen, Research Assistant Professor
WVU Bureau of Business and Economic Research

Funding for this research was provided by TransTechEnergy. The opinions herein are those of the authors and do not necessarily reflect those of the West Virginia Higher Education Policy Commission or the West Virginia University Board of Governors.

The authors thank Gerald Biser, Director and his team of the WV Manufacturing Extension Program; Dr. Caulton 'Carl' Irwin, Director TransTech Energy; Anne Barth, Executive Director TechConnect West Virginia; the West Virginia Manufacturers Association; Dr. Zane Shuck; Dr. Bhaskaran Gopalakrishnan, Director Industrial Assessment Center; WV Department of Commerce; Jens Kiel, CEO Made in Germany; the Smart Manufacturing Leadership Coalition (SMLC) and the Karlsruhe Institute of Technology (KIT), specifically Dr. Gisela Lanza and Christoph Liebrecht.

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Executive Summary

The manufacturing sector is currently reinventing itself by embracing the opportunities offered by the industrial internet, automation, and machine learning, just to name a few. This development is commonly referred to as the Fourth Industrial Revolution or Smart Manufacturing. While Smart Manufacturing can be observed around the globe, there are distinct differences in how it is adopted and embraced between countries, industries, and companies of different sizes. Small- and medium-sized manufacturers are generally understood as the backbone of the manufacturing sector. However, these manufacturers face specific challenges when it comes to the transition toward Smart Manufacturing.

This report presents the results of a recent 2017 survey conducted by Dr. Thorsten Wuest and Patrick Schmid of West Virginia University on Smart Manufacturing adoption in West Virginia. The survey analyzed West Virginia's manufacturing landscape and preparedness, as well as existing challenges when it comes to Smart Manufacturing and associated technologies, with a special emphasis on small- and medium-sized manufacturers. Based on the results of the survey, we present six recommendations for how the small- and medium-sized manufacturers in West Virginia can be supported in their Smart Manufacturing journey and ultimately profit from this new reality.

Before presenting the survey results and recommendations, we present a comprehensive overview of the manufacturing sector in West Virginia. This overview provides details on a variety of manufacturing-related topics, including current workforce statistics, trends in employment, manufacturing-related degrees, and average income. We also present the West Virginia Economic Outlook for the manufacturing sector developed by the WVU Bureau of Business and Economic Research. This provides in-depth background information that enhances and supplements the results of the Smart Manufacturing study.

1 Introduction

The manufacturing industry is currently undergoing a major transition, commonly referred to as the fourth industrial revolution. The three previous industrial revolutions focused on mechanization, electrification/mass production, and automation/IT. All have substantially changed the way we produce goods, have increased productivity and, in the end, have created wealth for economies. The fourth industrial revolution, enabled by the integration of Cyber-Physical (Production) Systems (CP(P)S) as well as the application of the (Industrial) Internet of Things throughout the enterprise (Schröder 2016; Thoben et al. 2017; Mittal et al., 2018), is believed to have a similarly significant or even greater impact on the economy as its predecessors. In the United States, this manufacturing revolution is often referred to as Smart Manufacturing.

While larger companies and multi-national corporations have dedicated resources readily available for adopting new technologies and frameworks like Smart Manufacturing, small and medium-sized enterprises (SMEs) often face substantial barriers to this adoption. This stands true for many small manufacturers in West Virginia as well, especially given the traditional ties to the coal industry of many companies. The decline of the mining industry also affected the many connected suppliers within the value chain and left limited resources to invest. Nevertheless, it has to be understood that SMEs play a critical role in the manufacturing industry of the US economy. They are often called the backbone of the country's industrial capabilities (Uygun & Reynolds 2017) and as such, supporting them in their endeavor will help to build and retain a solid manufacturing foundation for the state of WV and the nation.

In this study we provide an overview of Smart Manufacturing in the context of West Virginia's manufacturing economy.[1] We begin with a brief overview of the state's manufacturing sector and our forecast of the sector's future growth. We then analyze the current state of small and medium-sized manufacturers in West Virginia with a focus on their take on Smart Manufacturing. We conclude with a set of recommendations to support the adoption of Smart Manufacturing and Industry 4.0 in West Virginia.

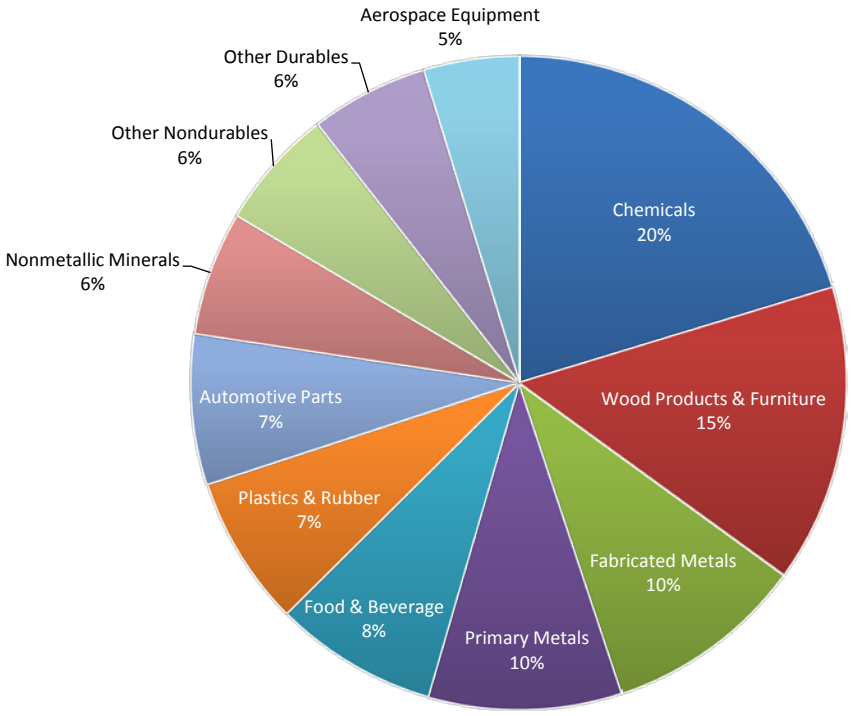
[1] This report is adapted from Deskins et al (2017), and Schmid (2017). Please refer to these publications for further details on this research.

2 Manufacturing Overview

The manufacturing sector has seen its share of the total economic footprint shrink over the past few decades, both within West Virginia and the nation as a whole, but manufacturing activity continues to play an important role in shaping the state's economic fortunes. Overall, the manufacturing sector accounts for 7 percent of all jobs and roughly 10 percent of total economic output in the state, but several regions within West Virginia retain a sizable dependence on manufacturing activity as a handful of industries retain their historical relevance.

CHEMICALS The chemicals industry accounts for one-fifth of the manufacturing sector's jobs and nearly 40 percent of its total output. Most of the state's chemical manufacturers lie along the Kanawha and Ohio River valleys and produce a range of organic and inorganic compounds used in industrial applications, but also manufacture composite materials such as resins and synthetic fibers. In addition to these companies, Monongalia County contains large manufacturing and research operations for generic drug producer Mylan Pharmaceuticals. Aside from jobs and output, the chemicals industry heavily factors into the state's global economic reach, representing the state's largest-exporting industry, based on market value, during calendar year 2016 at total of more than $1.5 billion.

Figure 1: Share of Total Manufacturing Employment (2016)



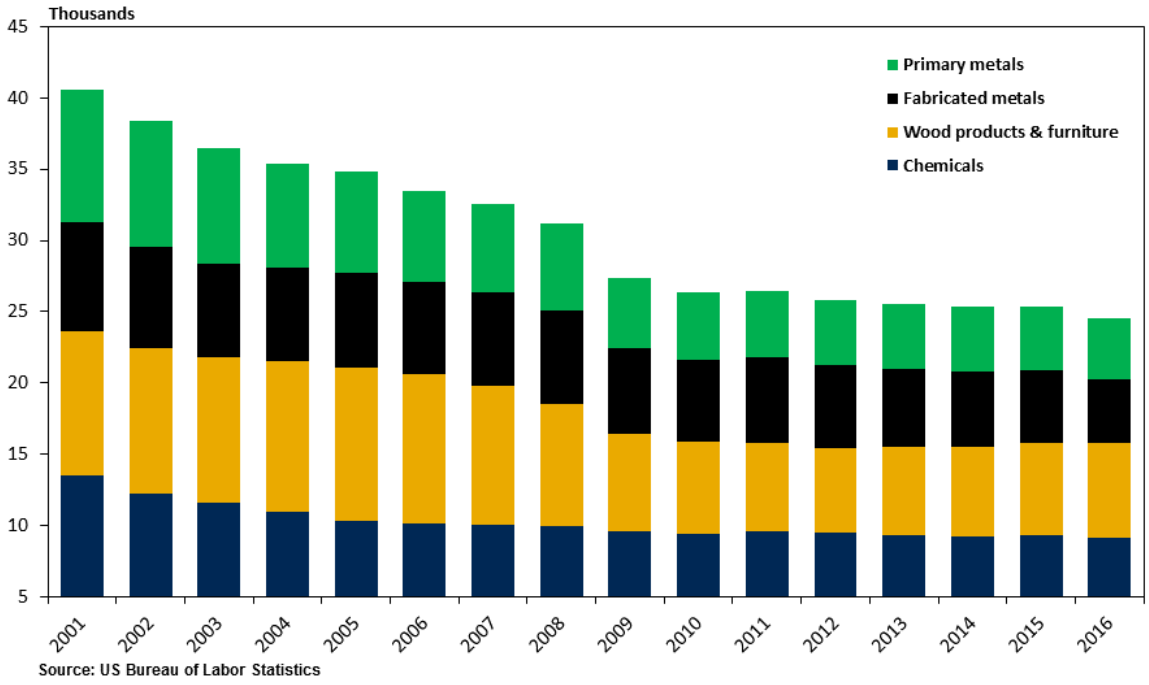
Source: US Bureau of Labor Statistics

OTHER MANUFACTURED PRODUCTS Other than the chemicals industry, other key segments of the state's manufacturing sector include wood products, fabricated metals, transportation equipment (auto parts as well as defense and non-defense aerospace) and primary metals, i.e. steel and aluminum. Combined, these industries accounted for more than three-fourths of the sector's output and two-thirds of all manufacturing jobs found in the state during 2016.

2.1 Subsectors

Most of the state's manufacturers are highly sensitive to the broader US business cycle or tightly linked to domestic or global changes in underlying conditions for specific industries (such as coal, housing, etc.). As a result, the state's manufacturing base has experienced a significant amount of volatility over the past decade and many parts of the sector have moved in sizably different directions. West Virginia's wood products and furniture industry was easily the hardest hit segment during the Great Recession, with employment and output at the state's sawmills, furniture, flooring, and other building materials manufacturers falling by roughly 50 percent after the US housing market bust. Conditions have improved measurably thanks to a national recovery in single- and multifamily housing starts, lifting overall output 60 percent from its cyclical low point in mid-2009. The industry is also far more productive than it was prior to the recession, generating approximately 15 percent more inflation-adjusted output on a per-worker basis in 2016 compared to 2007. While this has helped to lift wage rates roughly 5 percent since 2012 after adjusting for inflation, it also reveals job gains for the industry have been less robust at cumulative increase of 8 percent since 2012.

Figure 2: West Virginia Manufacturing Employment by Industry



The downturn was less severe for the state's chemicals manufacturers as aggregate industry output declined less than 15 percent and employment levels fell by 7 percent. With that said, chemicals industry payrolls in West Virginia, and for the US in general, have mostly been on a downward trend for decades due to a combination of increased technological innovation and greater competition from lower-cost producers overseas. Rapid growth in shale gas production across the Marcellus and Utica Shale plays has served to arrest a degree of the chemicals industry's secular declines of the past couple of decades by pushing production costs lower. Nonetheless, chemicals industry employment in West Virginia declined 2.6 percent during 2016.

At the national level, the fabricated metals subsector tends to track overall manufacturing activity. Within West Virginia, however, a significant percentage of the subsector serves in a supporting role to the state's coal operators. Several companies manufacture turned products, and screws/nuts and bolts that are specifically designed for underground mining operations or serve as machine shops for mining equipment. Not surprisingly, the subsector has declined in terms of its share of overall manufacturing output as southern West Virginia coal production has diminished over the years, but conditions have been particularly weak for fabricated metals manufacturers since 2012. Indeed, output and employment for the subsector have contracted by 13 and 29 percent, respectively, on a cumulative basis since 2012.

TRANSPORTATION EQUIPMENT The state's transportation equipment subsector, which is made up of auto parts equipment manufacturing as well as civilian and defense aerospace manufacturers, shed nearly 1,000 workers over an extended time frame that spanned from prior to the recession's onset through the earliest stages of the US economic recovery. Conditions appear to have stabilized to some extent for the state's aerospace industry, but federal budget issues continue to cloud the picture for the defense portion and new civilian aircraft orders have been sluggish for the past couple of years. By contrast, auto parts manufacturing has approximately doubled in size since its cyclical low point in mid-2010. Expansions at Toyota, NGK Spark Plugs and European auto parts manufacturing and supply chain companies (Sogefi and Gestamp) have accounted for most of the new activity in recent years.

2.2 Education to Workforce Pipeline[2]

An important consideration for manufacturing firms wishing to locate or expand in West Virginia is whether they will find a skilled workforce that meets their needs. In the 2013-2014 academic year, West Virginia's public colleges and universities graduated some 16 thousand students, of which approximately 8,800 were working in West Virginia the following year, a work participation rate of 54 percent.

In Table 1, we report the number of students who graduated with manufacturing-related fields of study in the 2013-2014 academic year. In all, about 3,800 students graduated with degrees relevant to manufacturing, with about one-third coming in skilled trades. Almost 800 of those graduates received Associate's degrees, which are often more directed at skills-based training.

Table 1: Number of 2013-2014 graduates with manufacturing-related degrees, 2015

	Total	Associate's	Bachelor's	Master's
Business, management, marketing	1,965	357	1,267	316
Communications technologies/technicians	22	8	13	
Computer and information sciences	241	111	92	28
Construction trades	24	22		
Engineering	661	5	518	109
Engineering technologies and engineering-related fields	297	121	133	11
Mathematics and statistics	80		40	37
Mechanic and repair technologies/technicians	33	26		
Physical sciences	230		177	27
Precision production	19	19		
Science technologies/technicians	287	111		
Transportation and materials moving	10		10	
Total	**3,869**	**780**	**2,250**	**528**

[2] This section adapted from Bowen, et al (2017).

In Table 2, we report the work participation rates for students who graduated with manufacturing-related fields of study. These rates indicate the percentage of students who graduated with these fields that were working in West Virginia one year later. Overall, students who graduated with Associate's degrees were far more likely to be working in the state the following year. Several of the skilled trades—including engineering technologies; mechanic and repair technologies; and science technologies—were well above the overall average for Associate's degree holders. Students who graduated with bachelor's degrees were less likely to remain in the state for work. With the exception of communications technologies, work participation rates for all manufacturing-related degree holders were lower than the overall average for bachelor's degree holders.

Table 2: Work participation rate for 2013-2014 graduates with manufacturing-related degrees, 2015

	Associate's	Bachelor's	Master's
Business, management, marketing	70.3	43.1	44.0
Communications technologies/technicians	n/d	92.3	
Computer and information sciences	67.6	43.5	39.3
Construction trades	45.5		
Engineering	n/d	28.8	10.1
Engineering technologies and engineering-related fields	76.9	48.1	27.3
Mathematics and statistics		42.5	21.6
Mechanic and repair technologies/technicians	88.5		
Physical sciences		43.5	29.6
Precision production	68.4		
Science technologies/technicians	73.0		
Transportation and materials moving		0.0	
Average for all fields of study*	**71.4**	**49.7**	**52.2**

n/d: For privacy reasons we do not disclose work participation and income data for categories with fewer than 10 graduates.
*** Includes non-manufacturing fields of study.**

In Table 3, we report average income for recent graduates with manufacturing-related degrees. Salaries are based only those workers who were employed in West Virginia. Salaries for recent graduates varied considerably based on the type of degree and the degree earned. However, in general graduates with manufacturing-related degrees were more likely to earn higher income than the overall average for their degree type.

Table 3: Average income of 2013-2014 graduates with manufacturing-related degrees, 2015

	Associate's	Bachelor's	Master's
Business, management, marketing	21,118	28,285	64,631
Communications technologies/technicians	n/d	n/d	
Computer and information sciences	23,133	36,525	n/d
Construction trades	n/d		
Engineering	n/d	49,973	n/d
Engineering technologies and engineering-related fields	36,953	44,687	n/d
Mathematics and statistics		40,350	n/d
Mechanic and repair technologies/technicians	34,584		
Physical sciences		27,905	n/d
Precision production	30,682		
Science technologies/technicians	30,408		
Transportation and materials moving			
Average for all fields of study*	**27,937**	**27,837**	**45,102**

n/d: For privacy reasons we do not disclose work participation and income data for categories with fewer than 10 graduates.
*** Includes non-manufacturing fields of study.**

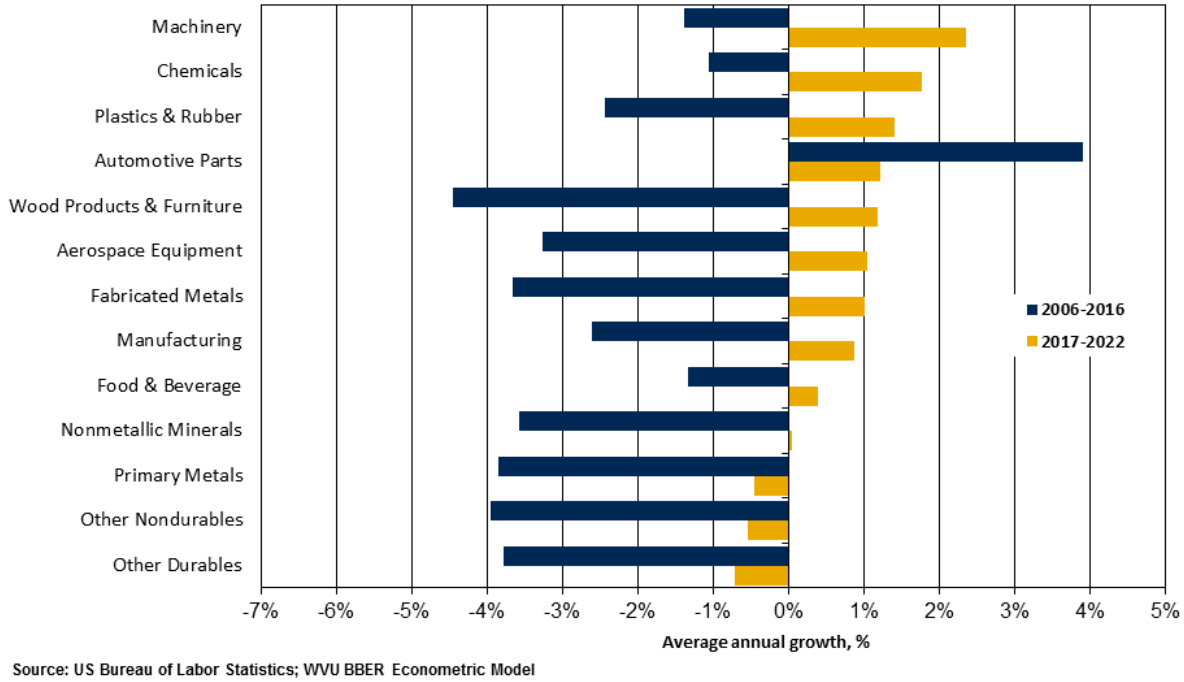
3 Manufacturing Outlook

When compared to the past 10 years, the forecast calls for West Virginia's manufacturing sector as a whole to face appreciably better conditions for the next five years. Overall, manufacturing employment is expected to rise at a pace of nearly 0.9 percent per year. The machinery subsector will post the fastest rate of growth going forward, due in large part to a rebound in domestic orders from energy companies and stronger export activity thanks to depreciating dollar and increased demand.

The chemicals subsector will make the largest positive contribution to manufacturing sector growth over the next five years. Continued growth in natural gas exploration and development will provide stimulus, particularly as downstream development efforts come closer to reality with the Shell ethane cracker facility in Pennsylvania, and possibly the PTT Global plant in Ohio, both of which will be within a relatively short distance of the West Virginia border. In addition, Mylan's presence will remain a source of stability for the sector, although some downside risk is possible due to continued concerns over drug pricing. The largest contributor to the subsector's growth going forward will be the opening of two new facilities in the Eastern Panhandle, chiefly the $500 million P&G facility that is slated to commence operations later this year and expand production around 2019 and 2021 as more product lines are added. Insulation manufacturer ROXUL is projected to begin production at a new facility in Jefferson County by early-2020. These two projects are expected to yield a gross increase of nearly 900 jobs by the latter portion of the outlook period and could eventually result in larger gains as each facility's regional supply chains develop over time.

Wood products and furniture is expected to enjoy a solid rate of growth, though most of the subsector's anticipated gains will likely be concentrated in the early portion of the outlook period. The US housing market recovery remains firmly in place as underlying demand remains healthy and supplies remain tight relative to historical standards due to the protracted low levels of construction that were recorded during the housing market bust. At the same time, however, prospects for higher long-term interest rates, reported labor shortages by builders and long-term regulatory uncertainty for banks and finance companies will likely dampen construction activity to some extent. The state's plastics industry should also see solid growth due in part to the US housing market's continued improvements, while the spillover effects created by downstream natural gas industries in the Mid-Atlantic Region bode well for plastics manufacturing activity over the longer term.

Figure 3: West Virginia Manufacturing Industry Employment Growth Forecast



Source: US Bureau of Labor Statistics; WVU BBER Econometric Model

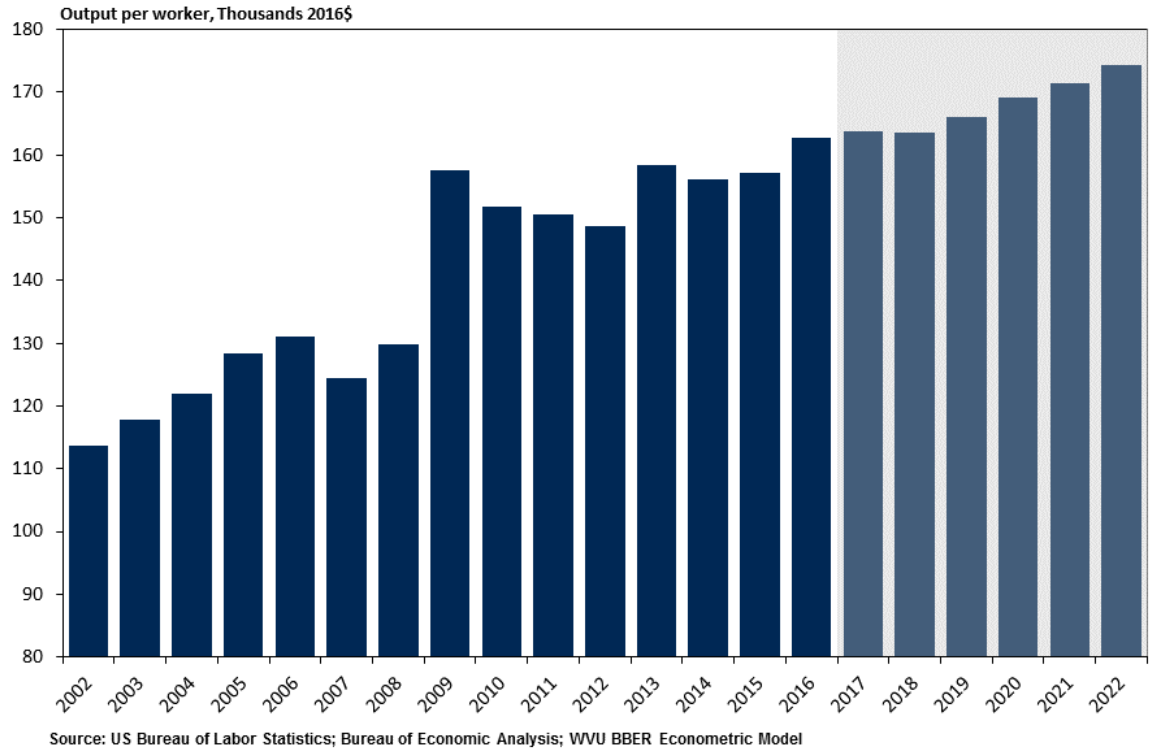
The auto parts supply segment of the state's manufacturing sector will see appreciably slower growth over the next five years as automakers deal with a lower level of consumer auto purchases linked to "spent-up" demand and higher interest rates on auto loans. The state's aerospace industry will see moderate gains in employment and output, though most of this is expected to accrue to the civilian aircraft portion located in Harrison County as the federal defense and nondefense segments face uncertainty from gridlock arising from budget debates in Washington, DC.

The fabricated metals industry is expected to see an average annual gain of 1 percent in employment over the next five years. Given its interconnectedness with the coal industry in some parts of the state, however, these increases will occur early in the forecast horizon and the level of payrolls will slowly decline over the latter half of the outlook period. Overall payrolls in the nonmetallic minerals manufacturing subsector will likely be stable going forward, though the underlying segments will see different outcomes over most of the next five years. Cement production is expected to benefit from greater levels of infrastructure spending in the state, but this will be offset by the continuing long-term secular decline in West Virginia's traditional glass manufacturing. Primary metals manufacturing employment will decline slightly over the next five years, with most of the losses reflecting long-term trends in the industry's productivity and continued displacement of the US steel industry to overseas competition.

PRODUCTIVITY Real output for the manufacturing sector as a whole is expected to rise at an average annual rate of 2.2 percent during the outlook period. This more than doubles the rate of job growth expected for the sector over the next five years, which points to additional gains in productivity during the forecast horizon. A couple of industry segments should enjoy measurably stronger increases in average worker productivity going forward, especially primary metals. For example, industry

employment will likely drift lower over the next five years, but the remaining productive steel capacity in the state will benefit from growth in natural gas exploration, production and distribution and higher infrastructure spending. Furthermore, Constellium's capacity additions in Ravenswood for producing aluminum plating for Airbus will offset the output the state has lost in previous plant closings. Overall, the real value of steel and aluminum output per worker from West Virginia is expected to rise 2.3 percent between 2017 and 2022.

Figure 4: West Virginia Manufacturing Sector Productivity



Source: US Bureau of Labor Statistics; Bureau of Economic Analysis; WVU BBER Econometric Model

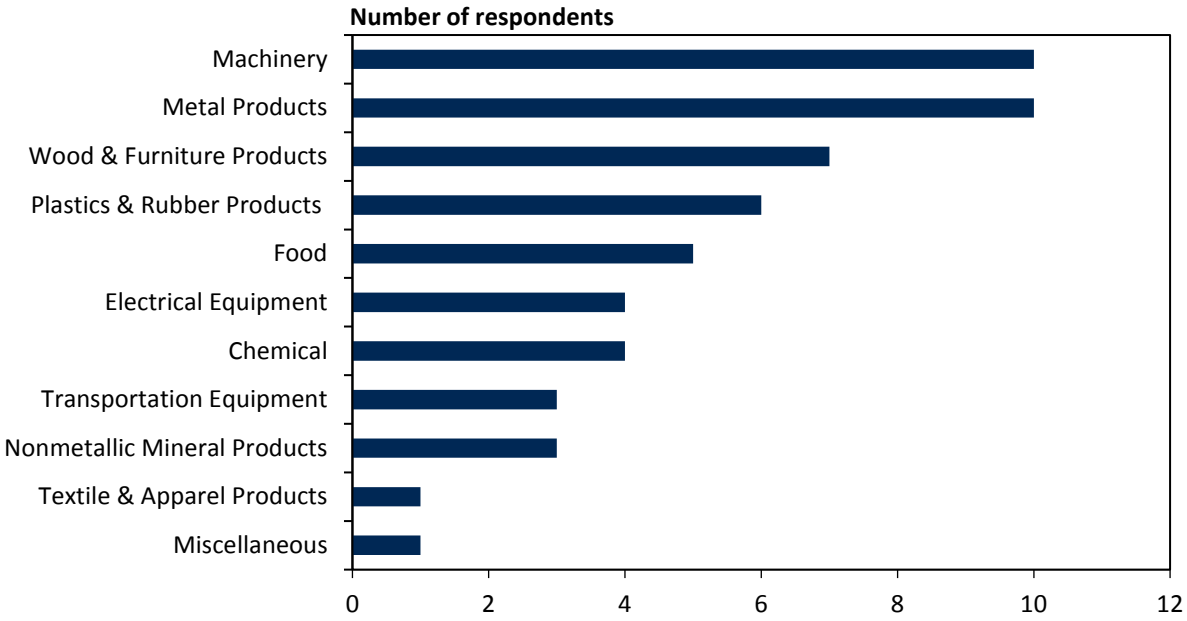
4 Smart Manufacturing Awareness

To assess the potential for Smart Manufacturing in West Virginia, WVU's Dr. Thorsten Wuest and Patrick Schmid surveyed manufacturers in the state about their plans for integrating sensor technology into their manufacturing processes. The study was set up based on a mixed-method research approach and was deployed in two phases (Bryman 2012; Bryman 2004). The first phase followed a quantitative research strategy to gain a comprehensive overview of the adoption of Smart Manufacturing, whereas the second phase utilized a qualitative approach to complement the findings in greater depth and detail. Moreover, the initial phase was utilized to identify suitable participants for the second phase of the study.

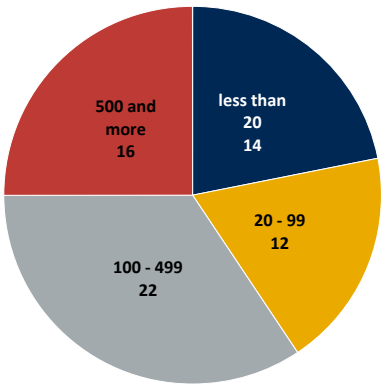
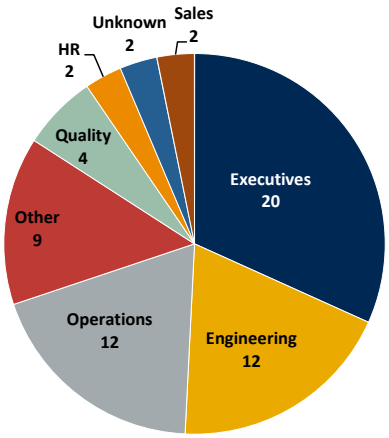
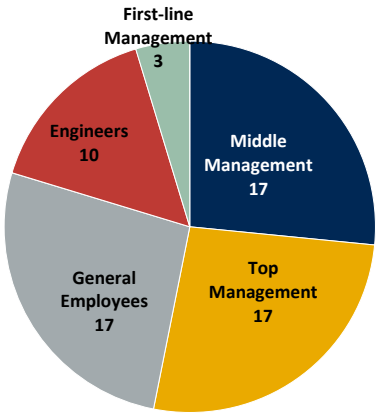
In the **first phase**, a survey was conducted through an online questionnaire. The questionnaire was designed and published using the online tool Qualtrics and distributed via newsletters of the Manufacturing Extension Partnership West Virginia, TransTech Energy, TechConnect West Virginia, West Virginia Manufacturers Association, and the social media channels of WVU as well as the WV Department of Commerce. The resultant survey data was analyzed and visualized in Microsoft Excel.

Overall, the initial online survey led to 64 respondents. Of those 64 respondents, 54 were associated with the manufacturing sector and therefore included in the analysis. The composition of respondents' specific industry background is illustrated below.

Figure 5: Composition of participating industries, departments & backgrounds



Source: Authors' Calculations

Company Size	Respondent's Department	Respondent's Job Category
		

In the **second phase**, qualitative interviews were conducted to gather more detailed information and more in-depth knowledge and insights on the research subject. For the purpose of this study, *semi-structured interviews* were chosen, since they allow to probe and provided the opportunity to raise additional aspects by the interviewees (Bryman 2004). A so-called *interview guide* was developed to propose questions and structure the interview.

In total, 14 in-depth interviews were conducted, recorded, transcribed, and analyzed using a meaning condensation approach (Kvale 1996). The interviewees consist of nine company representatives (location depicted on left side of figure below) and five experts from academia, associations, or state agencies (location depicted on right side of figure below). Insights from the different interviews were aggregated, compared and key findings were ultimately extracted. As a result, the key findings are reported below, structured according to the focal subjects of the study: current Smart Manufacturing landscape; awareness and perceived relevancy; adoption; barriers and challenges; workforce preparation; and available support infrastructure.

Figure 6: Location of interviewed company representatives (left) and experts (right)

4.1 Key findings

4.1.1 Landscape: Manufacturing companies face economic and cost-related challenges

> ***'West Virginia's industry historically has relied on coal as a primary source of business. West Virginia industry needs to understand that now, coal is not the only answer, and they should be looking at other types of industry.' (Gerald Biser, WV Manufacturing Extension Partnership)***

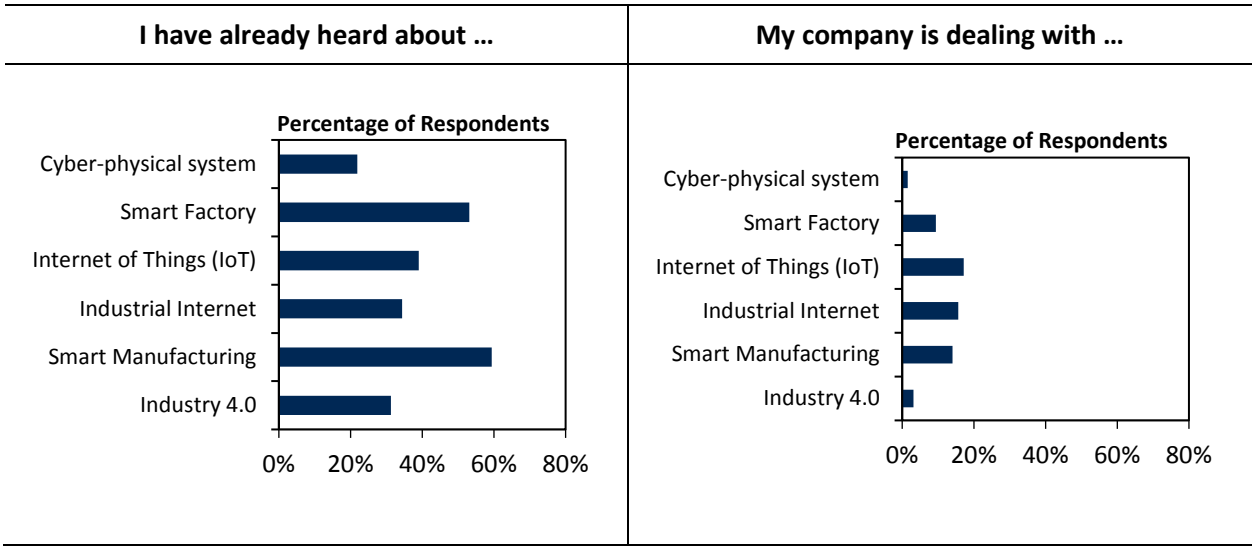
West Virginia has had strong and competitive manufacturing in a variety of sectors according to several interviewees. However, many companies and even whole sectors have disappeared over the last few decades. Furthermore, West Virginia's manufacturing landscape has been very dependent on the coal industry for many years. The majority of manufacturers serviced the coal business in one way or another. The gradual decline of the coal industry led to a void in the state's industrial sector, which especially impacted smaller manufacturing companies that are focused on service operations. Therefore, the main challenges of the manufacturing sector in WV today are 1) the lack of economic opportunities, 2) access to capital, and 3) cost-related challenges. These challenges to some extent tie manufacturer's hands regarding needed investment in new technologies and frameworks like Smart Manufacturing. Our results confirm that these challenges are even more serious for small companies, since they cannot rely on as many resources and diversified business compared with larger companies in order to absorb a downturn.

4.1.2 Awareness: Little awareness and knowledge of Smart Manufacturing

Overall, there is little awareness of Smart Manufacturing and related topics among manufacturing SMEs in WV (Figure 7). While almost 60 percent of the respondents have previously heard the term 'Smart Manufacturing' (see figure below), the awareness of other related terms is even lower. This might be due to the fact that Smart Manufacturing is the most common term to describe this transition and received increasing media attention in recent months within the United States. It is strongly promoted by the *Smart Manufacturing Leadership Coalition* (SMLC, 2017), whereas the term Industry 4.0 has its roots in Germany/Europe and is thus more common there.

Another finding of the survey was that there seems to be some uncertainty regarding the meaning of Smart Manufacturing itself. This might have led to few companies having fully embraced the idea. This corresponds with the assessment of most interviewees, that there is very little knowledge on Smart Manufacturing and related technologies as well as potential applications within local companies. Interviewees also mentioned that there is again a gap between smaller and medium/large companies when it comes to awareness, with even less awareness associated with small companies compared to medium-sized or large companies.

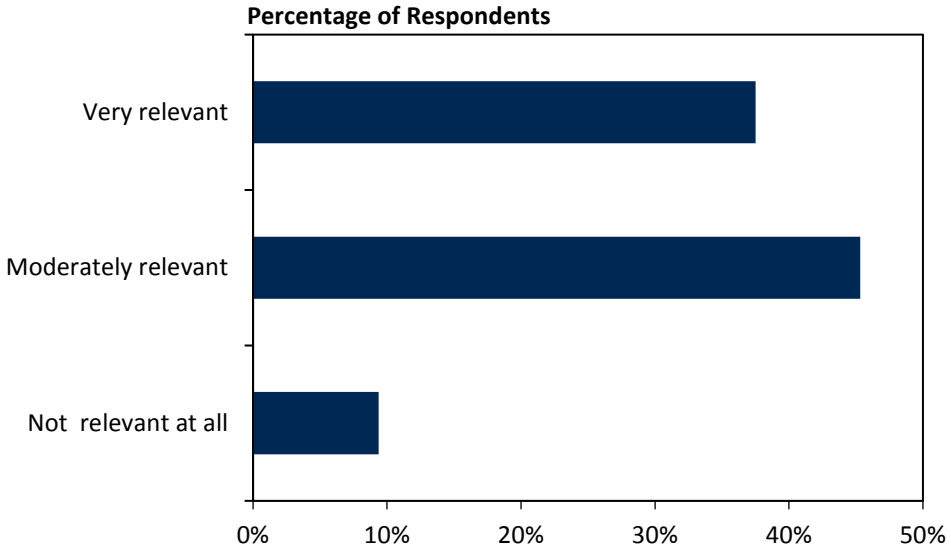
Figure 7: Smart Manufacturing awareness of participants



4.1.3 Relevancy: Majority of companies convinced that Smart Manufacturing is relevant

A majority of the surveyed companies is convinced that Smart Manufacturing is relevant to their business as depicted in Figure 8. Smart Manufacturing is considered relevant to more than 80 percent of the surveyed companies. While more than a third (37.5 percent) judge it as very relevant to their company, almost half (45.3 percent) believe that Smart Manufacturing is moderately relevant for their business success. Additionally, companies and experts agree on the influence and benefits of Smart Manufacturing to improve efficiency and competitiveness of manufacturing companies.

Figure 8: Relevancy of Smart Manufacturing for surveyed companies



4.1.4 Management / adoption: Few companies are actively embracing Smart Manufacturing

'We can't stay stagnant and expect to survive.' (Jimmy Keaton, East River Metals)

It is striking that even though 60 percent of respondents have heard of Smart Manufacturing and more than 80 percent consider it relevant for their business, just a limited number of companies are actively engaged in Smart Manufacturing related activities today. While 60 percent of the companies/representatives have heard of Smart Manufacturing, only 14 percent are in some form or another working on adopting it in their operation. Nevertheless, the study showed that several companies are actively trying to get started with their Smart Manufacturing journey, yet lack a targeted, strategic approach and do not collaborate with or employ available resources.

Overall, most small and medium-sized manufacturing companies are approaching the Smart Manufacturing revolution in a rather passive manner so far. The interviews showed that the companies that are interested in the topic are predominantly in the early phases of the transition. These early phases are mainly the informational and educational part of the transition. During this early phase, many of the companies are struggling to free up required resources. In essence, most surveyed companies do not have dedicated resources, including budgets and/or qualified people to face the transition at this point. Small companies especially seem to struggle to provide the needed resources to work on Smart Manufacturing applications on the shop floor. As a result, only selected applications, that are limited in their scope, are in place in West Virginia's companies. This is not necessarily surprising or different from the development in other areas of the United States. However, it indicates the need for supportive actions to provide the needed resources to interested and motivated companies to help them identify and achieve their individual Smart Manufacturing objectives.

4.1.5 Barriers: Several barriers hinder companies from embracing Smart Manufacturing

The study identified several barriers that are perceived as hindering when it comes to the adoption of Smart Manufacturing. The main barriers that were identified are: 1) above all the mind-set, 2) financial barriers, 3) knowledge, and 4) a perception that Smart Manufacturing will not add value within their operation. The latter is largely based on the fact that manufacturers find it difficult to imagine specific (scaled down) solutions that provide added value to their processes and operations.

According to the interviewees, the first obstacle companies have to overcome is the willingness to consider Smart Manufacturing. Adopting new technologies is important in order to stay competitive and ensure long-term success of a business, especially in manufacturing. Unfortunately, daily business often tends to get in the way of strategic initiatives like adopting and embracing the Smart Manufacturing paradigm. Therefore, one main obstacle is to create a mind-set of change within the company.

For companies that are already eager to start their Smart Manufacturing journey, the main barrier is cost. Most of the companies do not have the resources to overcome the initial cost associated with adopting and ramping up new technologies. Aside from financial resources, providing additional required resources is a challenge for most companies. This includes but is not limited to human resources, i.e., identifying, training and retaining qualified people that have (or are willing to acquire) knowledge of Smart Manufacturing as well as time resources, i.e., spending time on Smart Manufacturing projects besides the daily business.

Another major barrier reported by many companies is the lack of expertise on how to approach Smart Manufacturing. Also, manufacturers said they could not imagine how Smart Manufacturing applications would provide added value in a small-scale manufacturing environment—more specifically their own shop-floor/factory. This can partly be attributed to the fact that there are, so far, no well-known and broadly communicated "success stories," reporting on how small manufacturing companies successfully took advantage of Smart Manufacturing solutions. This is unfortunate; as during this study, several innovative solutions developed by WV manufacturing SMEs were identified that addressed critical pain points and directly delivered a value add to the core business.

> ***'Capability creates Opportunity' (Craig Hartzell, Azimuth)***

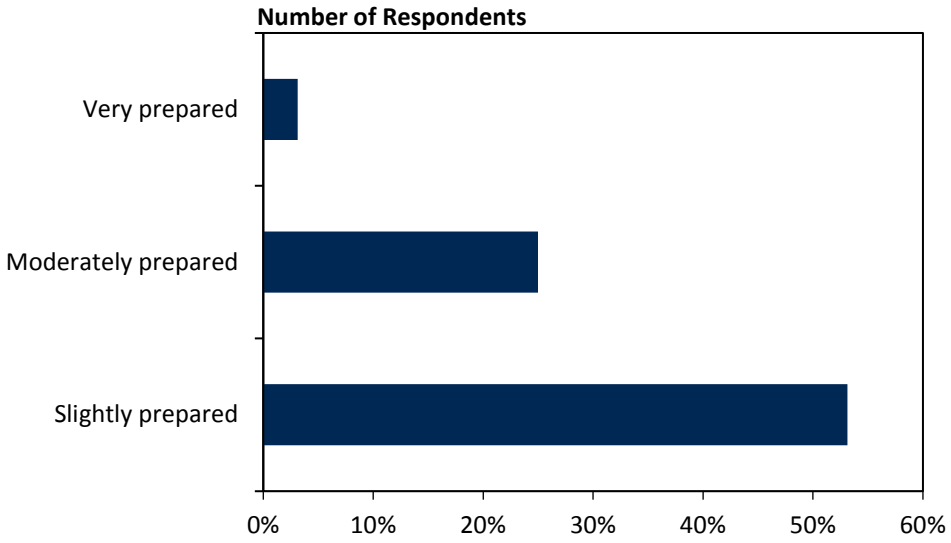
As a result, many companies fail to identify and act on opportunities that might help to develop their business further based on Smart Manufacturing applications. This can be boiled down to two main causes: the lack of perceived and expected value and, the economic situation tying their hands with respect to needed investments.

4.1.6 Preparedness: Workforce marginally prepared for Smart Manufacturing realities

> ***'Basically, smart technologies make work easier and not more complicated' (Gat Caperton, Gat Creek)***

In the survey, more than half (53 percent, see Figure 9) of the respondents reported that they see their companies and employees as slightly prepared for the new Smart Manufacturing requirements, a sharp contrast to 3 percent responding with "very prepared." Another quarter of respondents see themselves as moderately prepared for the upcoming transition in manufacturing. Making matters worse, West Virginia's population is decreasing, partly because there are not many desirable job opportunities for highly educated people with an interest in manufacturing and technology in the state. As a consequence, many people have left the state, in particular young, educated people who graduated from college with a STEM degree, particularly those with bachelor's degrees or higher. Graduates with Associate's degrees in manufacturing related areas like engineering technologies or precision production tend to stay in WV in relatively high numbers. In the past, manufacturing had a reputation of "dirty, dangerous and strenuous." However, with the transition towards Industry 4.0, manufacturing jobs and careers are becoming high-tech and with it the overall manufacturing environment. Shop floors in leading manufacturing companies around the world are now clean, connected and rather safe and thus a valid and highly rewarding option for a qualified workforce. In consequence, it is critical to retain and attract educated workforce at all levels—including four-year STEM degree holders—for a successful transition towards Smart Manufacturing. Companies and experts agree that new skill sets are required when it comes to Smart Manufacturing, including knowledge of new technologies, overall understanding of systems, software skills, and management of complex systems. Considering these required skills sets, almost all interviewees agree that the majority of the current workforce is not sufficiently prepared for incorporating Smart Manufacturing into their existing business models.

Figure 9: Preparedness of the workforce for the transition to Smart Manufacturing



4.1.7 Support: Support needs to be oriented towards guiding small companies

'The big challenge is change.' (Gat Caperton, Gat Creek)

To support the imminent transition, assistance and support for manufacturers is essential. Interestingly enough, none of the companies and experts were aware of any resources currently available to support the Smart Manufacturing adoption of SMEs in West Virginia. However, most companies reported previous positive experience with training opportunities for manufacturing in the state, e.g., through the WV Manufacturing Extension Partnership (WVMEP) or the Robert C. Byrd Institute.

Smart Manufacturing support needs to address the specific needs of SMEs, initially focusing on education regarding the possibilities this entails, and subsequently guiding companies through their first steps of the transformation. In the study, companies declared their interest in further information, trainings, and workshops as initial support. Most importantly, training need to show the benefits of Smart Manufacturing and success stories to show how it can be applied in SMEs.

Small companies participating in the survey specifically asked for further resources to guide them through the early stages of their Smart Manufacturing journey. These resources include motivation, training, road mapping, support on the actual implementation, and assurance that solutions yield the profits they are supposed to, rather than fascination for technical applications in and of themselves. Associations and academia need to reach out and encourage companies to take the first step towards Smart Manufacturing.

4.2 Key Recommendations / what we need to do:

'I truthfully believe that almost every challenge hides great opportunities to grow.' (Joe Eddy, Eagle Manufacturing)

Our comprehensive study on Smart Manufacturing adoption in West Virginia, with a specific focus on small and medium-sized enterprises in the manufacturing industry, brought forth several interesting insights. The results can inform strategic decisions and tactics on how to better support and strengthen the manufacturing industry in West Virginia and prepare our companies for the challenges ahead.

Our study showed that several significant challenges and barriers towards Smart Manufacturing adoption exist that need to be addressed. At the same time, we found that Smart Manufacturing presents a great opportunity for West Virginias manufacturing industry to modernize, work together, enter new markets, and diversify to some extent from the coal driven business. Furthermore, many of the surveyed companies, associations and industry experts are open to learning more about Smart Manufacturing and how this will impact their business. A few selected companies already implemented successful projects to solve immanent problems on the shop floor using IoT.

Another opportunity emerging from the Smart Manufacturing transition might soften the challenge of having not enough skilled workers and young talent leaving the state at the same time. With the modernization and introduction of new technologies throughout the enterprise, the manufacturing work environment will become more digital and thus more attractive to highly qualified millennials who are looking for challenging and impactful careers in the state. West Virginian graduates tend to have a strong connection with the state and given the right opportunity choose to stay and contribute to a brighter future for the mountain state.

We put together the following ***recommendations*** to create a supportive environment for Smart Manufacturing in West Virginia based on our study:

- Provide educational resources on Smart Manufacturing and Industry 4.0 in order to spread the word in an accessible way for industrial partners.
- Jointly develop curriculum for 1) professionals to equip them with required knowledge to innovate and operate within a Smart Manufacturing environment, and 2) include Smart Manufacturing in existing engineering curricula across institutions ('high school to masters/Ph.D.'), departments and majors.
- Communicate successes broadly and encourage peer-to-peer exchange across industries of best practices and lessons learned.
- Build strong and sustainable partnerships between companies, academia and industry associations. For example, leverage local technology start-ups to team-up with established manufacturers and academia.
- Start with small "lighthouse" projects targeting specific pain points to learn and achieve quick wins.
- Leverage state and federal funding to complement the limited recourses available to WV manufacturing SMEs.

Appendix A: Interview Partners

Name	*Title*	*Organization*
Craig Hartzell	President & CEO	Azimuth, Inc.
Seth Weisberg		Service Wire Company, Inc.
Bob Alexander	Manager of Corporate Process Engineering	Simonton Windows, Inc.
Gerald Biser	Director	Manufacturing Extension Partnership,
Gat Caperton	CEO	Gat Creek
Joshua L. Jarrell	Deputy Secretary	West Virginia Department of Commerce
Anne Barth	Executive Director	TechConnect West Virginia
Kevin DiGregorio	Executive Director	Chemical Alliance Zone
James Reszler	President	Dyna-Mix
Brian Lamb	Quality Manager	Fairmont Tools
Sean Edkins	Director Technical and Operations	Homer Laughlin China Company
Joe Eddy	President/CEO	Eagle Manufacturing Company
Bhaskaran Gopalakrishnan	Director	Industrial Assessment Center
Jimmy Keaton	Operations Manager	East River Metals

References

Bowen, Eric, John Deskins, John Meszaros, and Justin Parker, "From Higher Education to Work in West Virginia, 2015." (Morgantown, WV: West Virginia University Bureau of Business and Economic Research, 2017).

Bryman, A., 2004. *Social Research Methods* 2nd ed., Oxford; New York: Oxford University Press.

Bryman, A., 2012. *Social Research Methods* 4th ed., New York: Oxford University Press.

Deskins, John, Eric Bowen, Christiadi, Brian Lego, Melissa McKenzie, Justin Parker, Ananya Sarker, and Fani Agelaraki, *West Virginia Economic Outlook: 2018-2022* (Morgantown, WV: West Virginia University Bureau of Business and Economic Research, 2017).

Kvale, S., 1996. *Methods of Analysis.* In Interviews: An Introduction to Qualitative Research Interviewing. pp. 187–191.

Schmid, Patrick, "Smart Manufacturing in small and medium-sized enterprises in West Virginia: Current state and first steps of Smart Manufacturing adoption" (Master's Thesis, Karlsruhe Institute of Technology, Germany in collaboration with West Virginia University, 2017).

Schröder, C., 2016. *The Challenges of Industry 4.0 for Small and Medium-sized Enterprises*. Available at: http://library.fes.de/pdf-files/wiso/12683.pdf [Accessed May 17, 2017].

SMLC, 2017. *Smart Manufacturing Leadership Coalition.* Available at: https://smartmanufacturingcoalition.org [Accessed December 10, 2017].

Thoben, K., Wiesner, S. & Wuest, T., 2017. "Industrie 4.0" and Smart Manufacturing – A Review of Research Issues and Application Examples. *International Journal of Automation Technology, 11*(1), pp.4–16.

Uygun, Y. & Reynolds, E.B., 2017. *Advanced Manufacturing Innovation Ecosystems: The Case of Massachusetts.* In S. Jeschke et al., eds. Industrial Internet of Things: Cybermanufacturing Systems. Cham: Springer International Publishing, pp. 691–715. Available at: http://dx.doi.org/10.1007/978-3-319-42559-7_29.

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