West Virginia University
Benjamin M. Statler College of Engineering and Mineral Resources
Department of Industrial and Management Systems Engineering

Smart Manufacturing and Industry 4.0 - Opportunities and Challenges for SMEs

1st Industry 4.0 School & Industry Night

February 18, 2018

Kelonwa, Canada

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2005

2013

Schmid & Wuest, 2017

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Agenda

1. Smart Manufacturing
2. Smart Manufacturing Technologies
3. SmartMfg Survey of SMEs in West Virginia
4. Recommendations

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“Manufacturing creates wealth”

Prof. Ronald G. Askin, Arizona State University (USA)

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“Obama plans executive actions to strengthen U.S. manufacturing”

(http://www.reuters.com/article/2014/10/27/us-usa-obama-industrialoutput-idUSKBN0IG0UR20141027)

“Obama pushes for high-tech manufacturing”

(Pace, J., June, 24th 2011, NBC News)

“Obama confirms funding for manufacturing innovation hubs”

(Skiba, K., Chicago Tribune, Feb, 25th 2014)

“We’re building Ironman – Manufacturing Innovation”

(Obama, Feb, 2014)

https://s-media-cache-ak0.pinimg.com/736x/38/92/57/389257d[illegible]42e9a9bc34df0a5d0[illegible].jpg

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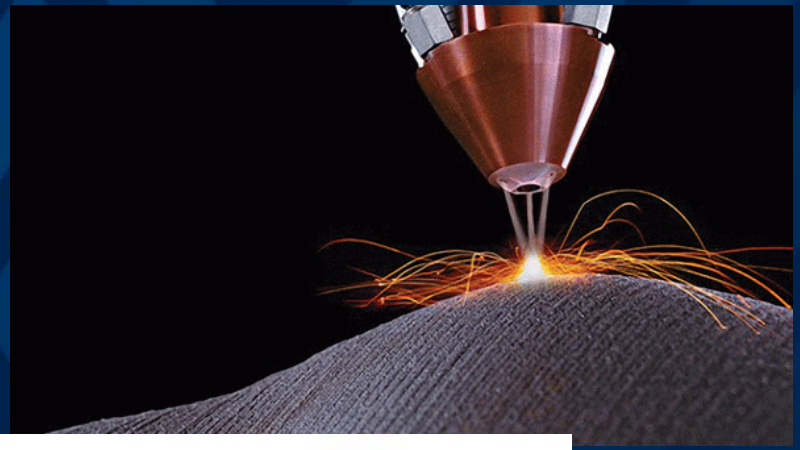
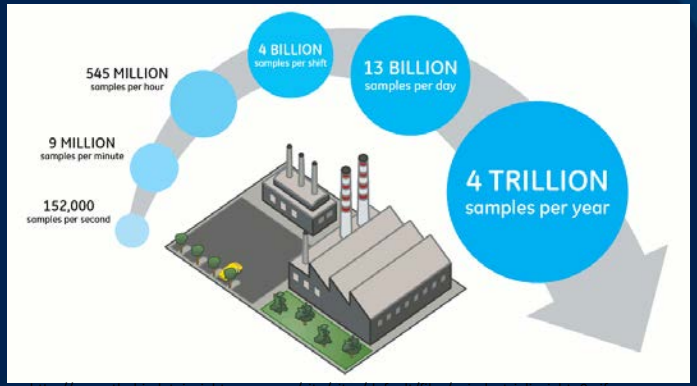
Manufacturing today

- New technologies
- New global rules
- New opportunities
- New challenges…





http://www.thebigdatainsightgroup.com/site/sites/default/files/geindustrialinsight_0.gif

http://3.bp.blogspot.com/-YGLBPWZFOxY/VC10ThjQAoI/AAAAAAAAAbI/VZT7ELIwCiE/s1600/ttip.png

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You may have heard of

Smart Manufacturing

Intelligent Manufacturing

Industrial Internet

IMS

Industrie 4.0

Cyper-Physical (Production) Systems

Industry 4.0

Factory of the Future

Smart Factory

Manufacturing Intelligence

Cloud Manufacturing

… and many more!

All these terms describe a similar development!

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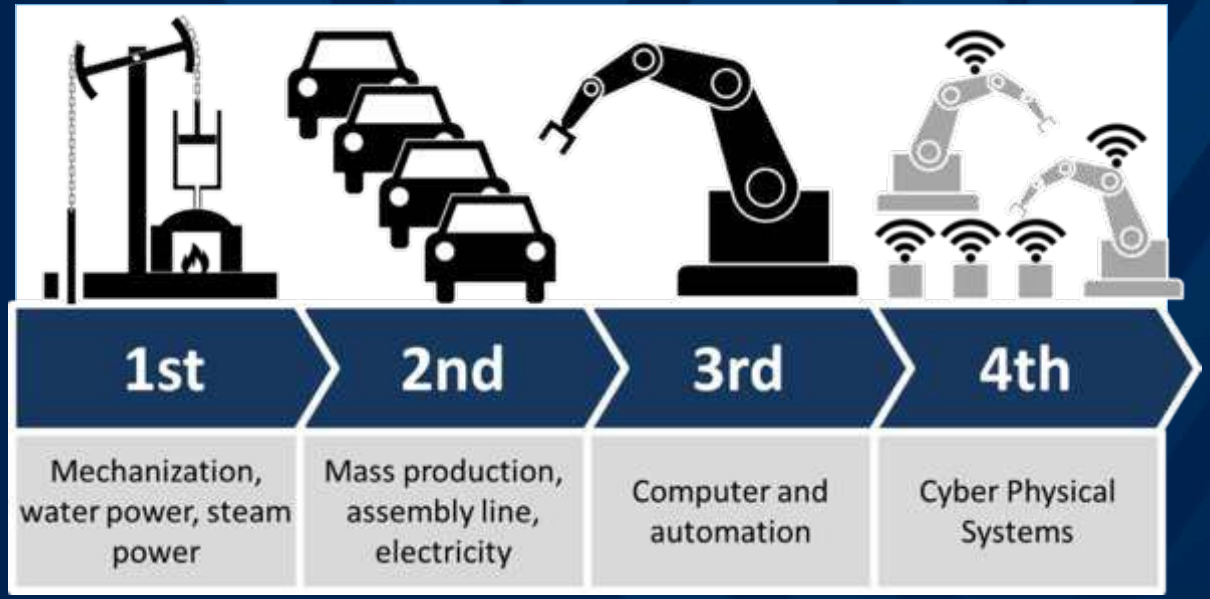
Heading towards the 4th industrial revolution



Value from… People Process Technology Information

Source: https://www.i-scoop.eu/industry-4-0/

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Automation

Physical vs. Cognitive

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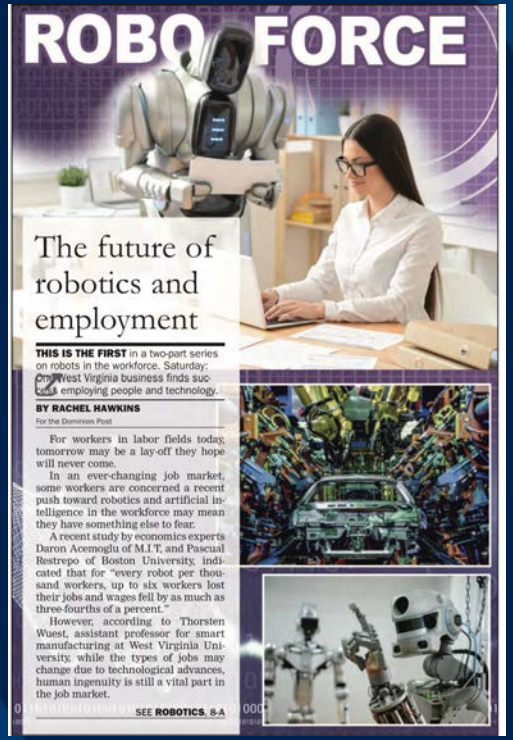
Industry 4.0 and employment



ROBO FORCE

The future of robotics and employment

THIS IS THE FIRST in a two-part series on robots in the workforce. Saturday: One West Virginia business finds success employing people and technology.

BY RACHEL HAWKINS

For the Dominion Post

For workers in labor fields today, tomorrow may be a lay-off they hope will never come.

In an ever-changing job market, some workers are concerned a recent push toward robotics and artificial intelligence in the workforce may mean they have something else to fear.

A recent study by economics experts Daron Acemoglu of M.I.T. and Pascual Restrepo of Boston University, indicated that for "every robot per thousand workers, up to six workers lost their jobs and wages fell by as much as three-fourths of a percent."

However, according to Thorsten Wuest, assistant professor for smart manufacturing at West Virginia University, while the types of jobs may change due to technological advances, human ingenuity is still a vital part in the job market.

SEE ROBOTICS, 8-A

Dominion Post Dec. 29, 2017

tree and its branches.

"If you still hold to the tra-

■ Chop or grind smaller branches for wood chips to use in

ty Extension Agent H. R. Scott s several agencies advertise for t

Machine learning

Photo courtesy of Eagle Manufacturing

Eagle Manufacturing in Wellsburg has found success with using robots in the plant.

Bridging the entry gap with robots

THIS IS THE SECOND in a two-part series on robots in the workforce.

BY RACHEL HAWKINS

Dominion Post

For those who dream of better products to improve lives, the process between idea and fabrication is often long, arduous and expensive, but with the help of machine learning and business connectivity, everyone may soon be able to invent.

Thorsten Wuest, assistant professor of smart manufacturing at West Virginia University, said he believes a new era of manufacturing and design is on the way in time, thanks to a new way of connecting businesses to individuals who need the services and technology they provide.

"One thing that we are working on and really excited about, that will not be in the near future I'm afraid, is the democratizing of manufacturing and design," he said.

Wuest said this process will involve machine learning and technology helping ordinary people with creative innovation to achieve their production goals. He likened this process to the way the internet changed business for many people.

"When you look what we have with the internet and what kind of innovation that spurred," he said, "it was basically an IT system which all of a sudden everyone had access to. So, now on an html browser, everyone can program a blog or

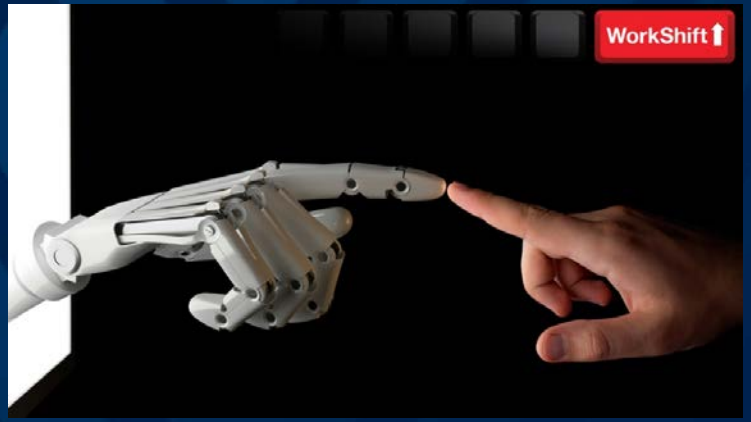
SEE ROBOTICS, 8-A

Photo courtesy of Eagle Manufacturing

Alan "A.J." Klein works with robotics at Eagle Manufacturing.

City needs more time to amend pa

Dominion Post Dec. 30, 2017



http://www.cbc.ca/radio/quirks/september-9-2017-1.4280509/will-you-have-to-become-a-cyborg-for-your-job-1.4280516

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It is a global development

High-Tech Strategy

Projects for the future

- Industry 4.0 initiative
- Smart Services Program
- Smart Data Program for SME

Industry Revitalization Plan

Restructuring of industry

World's leading IT society

Connected factory

Manufacturing Renaissance

- Industrial Internet Consortium
- Smart Manufacturing Leadership Coalition (SMLC)
- Manufacturing USA

China Manufacturing 2025

IT integration in industrial processes

High-end automatization & robotics

Source: Siemens Ltd. Seoul 2014

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Advanced & Smart Manufacturing

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Advanced vs. Smart Manufacturing

Two different ways of differentiation

Advanced Manufacturing
New technologies, products, materials and processes

Smart Manufacturing
Use of data throughout the product life cycle

Source: Shipp et al. 2012

Advanced Manufacturing
Focus on physical manufacturing-technology

Smart Manufacturing
Focus on data and analytics

Source: Mittal, Khan & Wuest 2017

Schmid & Wuest, 2017

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Smart Manufacturing

"Smart Manufacturing is a data intensive application of information technology at the shop floor level and above to enable intelligent, efficient and responsive operations."

Wallace & Riddick, 2013

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Smart Manufacturing

*Smart manufacturing marries **information, technology and human ingenuity** to bring about a rapid revolution in the development and application of manufacturing intelligence to **every aspect of business.***

*It will fundamentally **change how** products are invented, manufactured, shipped and sold.*

*It will **improve** worker safety and protect the environment by making zero-emissions, zero-incident manufacturing possible.*

*It will help **keep jobs in this country [USA]** by keeping manufacturers competitive in the global marketplace despite the substantially higher cost of doing business in the United States.*

Chand & Davis, 2010

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Schmid & Wuest, 2017

Smart Manufacturing Opportunities

The Industrial IoT creates various improvement opportunities

+49 %
product quality

+80 %
efficiency

-30 %
production time

+25 %
productivity increase

+40 %
customer satisfaction

-25 %
safety incidents

+25 %
energy efficiency improvement

+1 %
GDP

Source: https://www.slideshare.net/solaircorporate/

Schmid & Wuest, 2017

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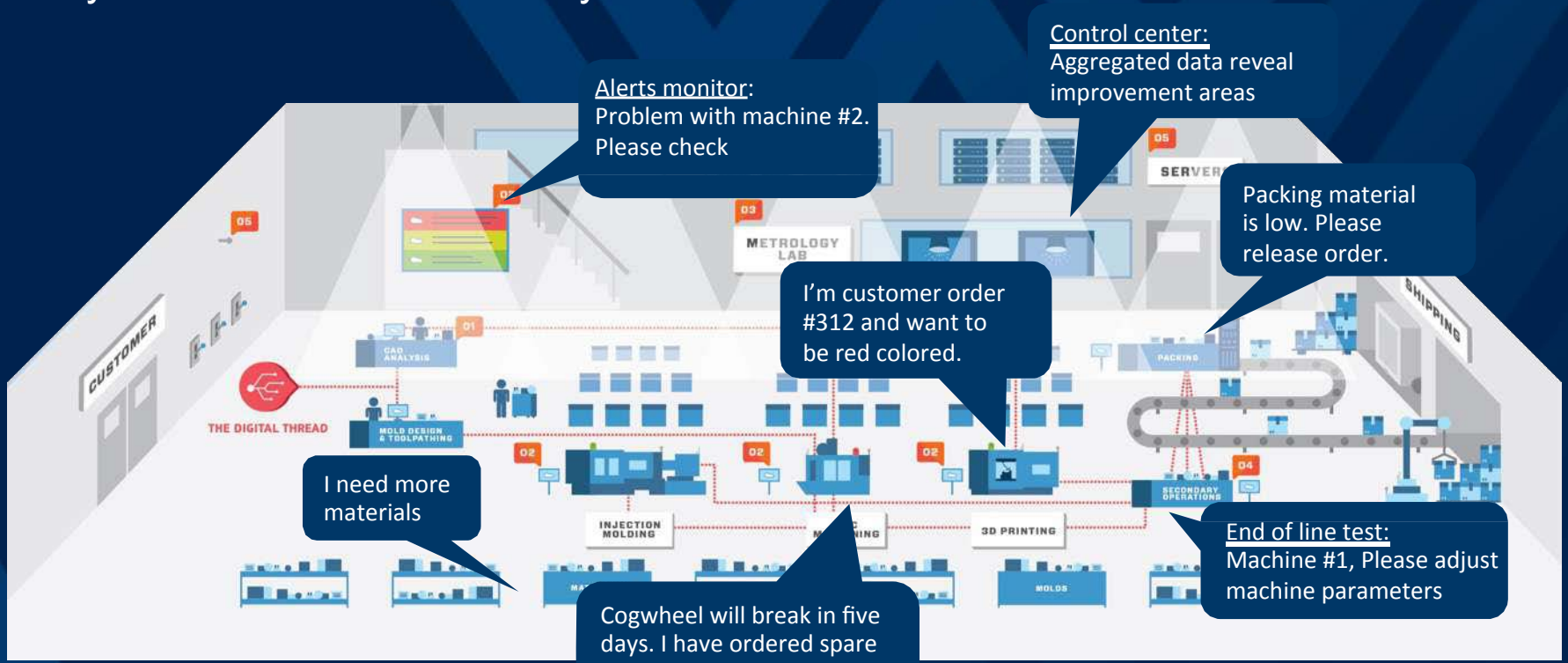
Smart Manufacturing Vision

Fully Connected Smart Factory



Source: http://smartamerica.org/teams/smart-manufacturing/

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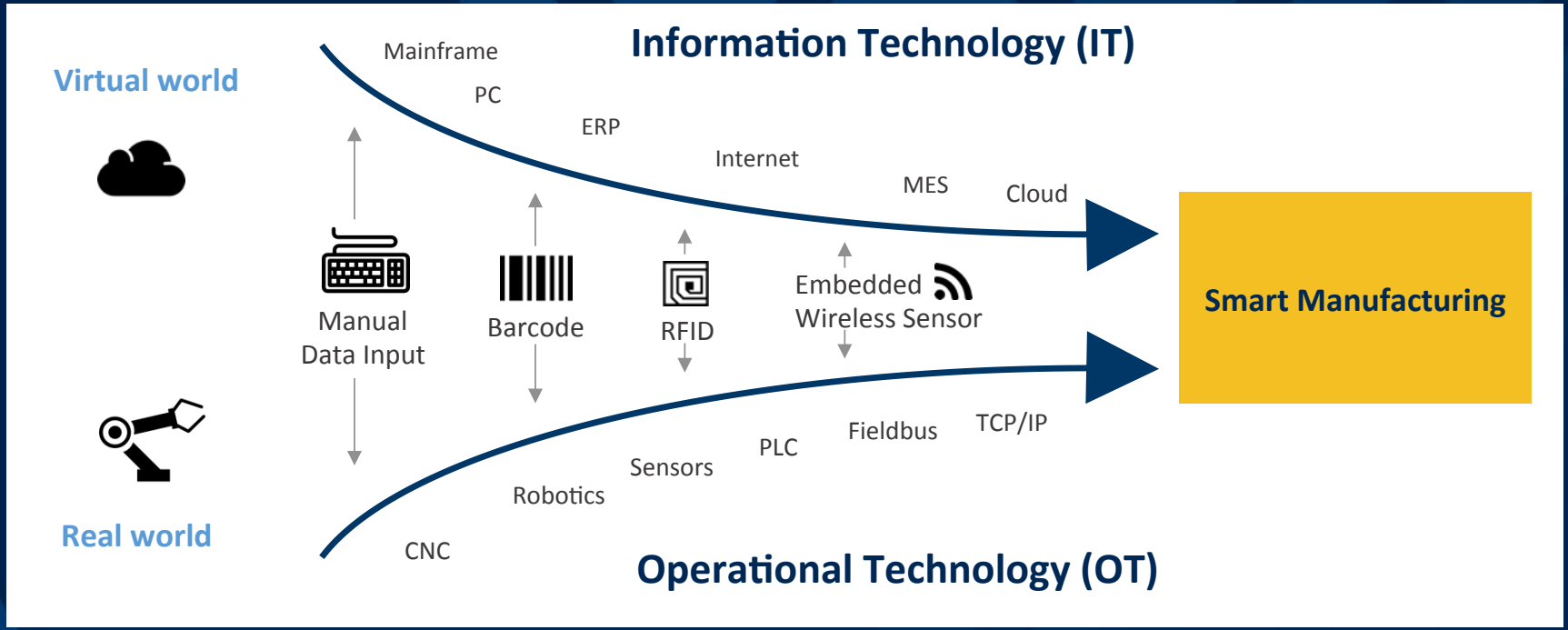
IT/OT Integration enabling Smart Manufacturing

Convergence of the virtual and real world



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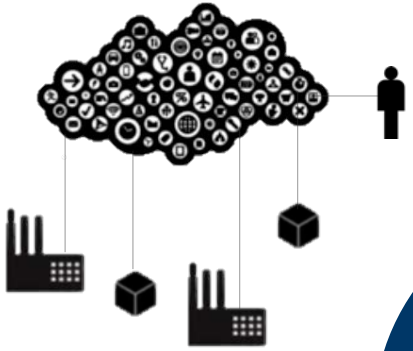
Smart Manufacturing and (I)IoT

(I)IoT as an enabler of Smart Manufacturing



Smart Plants

Smart Products

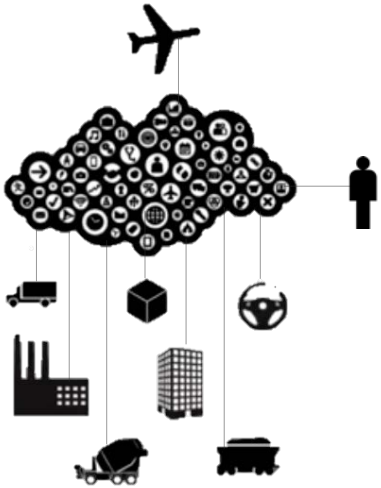
Smart Processes

Internet of Things

- All industries
- All things and devices

Smart Manufacturing

- Manufacturing industries
- Systems, things, devices, on the shop floor
- Products throughout their life cycle



Smart Cities

Connected Cars

Smart Grids

Smart …

Source: https://www.youtube.com/watch?v=1Q5Iyw8vll8

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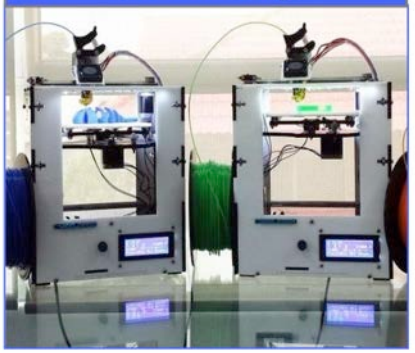
SMART MANUFACTURING MARRIES TECHNOLOGY, DATA AND HUMAN INGENUITY

WestVirginiaUniversity.

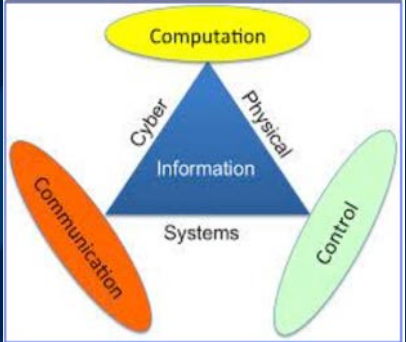
Schmid & Wuest, 2017

Smart Sensor

3D Printing



CPS



Energy Saving

IoT

Cloud

Big Data

Hologram

Source: Jinwoo Park, 2015

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Smart Manufacturing Technologies

- ***Technology*** is always a ***key enabling factor***
- But what are ***Smart Manufacturing*** associated technologies?
- We created a comprehensive overview as a ***basis for discussion*** and a first step towards a Smart Manufacturing Ontology
- ***Open Access Paper:*** Mittal, S., Kahn, M. Romero, D. & Wuest, T. (2017). **Smart Manufacturing: Characteristics, Technologies and Enabling Factors**. *Part B: Journal of Engineering Manufacture*, Online first, 1-20. DOI 10.1177/0954405417736547

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#	Technology	Definition	Reference(s)
1	Augmented Reality and Virtual Reality	Creating an artificial (virtual) environment of the real world using various innovative technologies like mobile devices, wearables, etc.	• Kolberg & Zühlke (2015) • Tzong-Ming & Tu (2009) • Rüßmann et al. (2015) • Wu et al. (2013)
2	Additive Manufacturing	Additive manufacturing creates complex parts from the ground up, mostly adding one layer at a time, based on a 3D CAD model.	• Huang et al. (2013)
3	Internet of Things (IoT)	IoT (also referred to as the Internet of Everything or Industrial Internet of Things) describes the connection and communication of physical 'things' over internet.	• Wu et al. (2013)
4	(Big) Data Analytics	Data sets (or data lakes) are now characterized by their high volume, velocity and variety nature (3Vs) plus veracity and value (5Vs). Specific technologies with new analytical methods and tools are required to transform big volumes of data effectively and efficiently into information and knowledge.	• De Mauro et al. (2015) • Addo-Tenkorang & Helo (2016)
5	Autonomous and Collaborative Robots	Robots that are capable of autonomous decisions and are able to assist or work alongside humans in operations (i.e. CoBots).	• Beer et al. (2014) • Maurice et al. (2014)
6	Cyber-Physical Systems	CPS are systems of collaborating computational entities that are in intensive connection with their surrounding physical world and their on-going processes, providing and using, at the same time, data-accessing and data-processing services available on the internet.	• Monostori et al. (2014) • Zhong & Nof (2015)

Mittal et al., 2017

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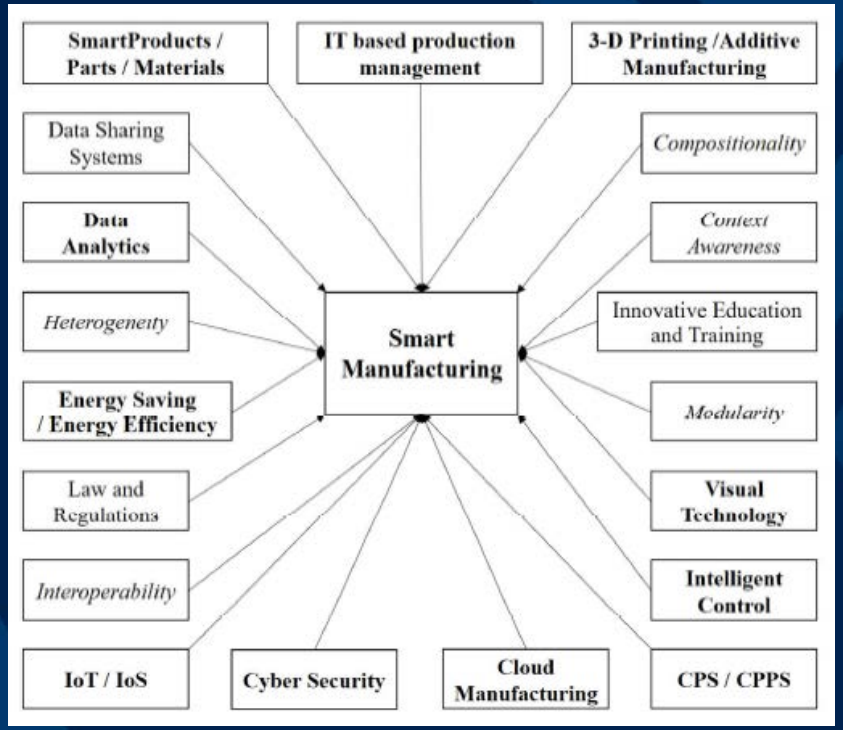
Smart Manufacturing

Technology Clusters



Mittal et al., 2017

38 technologies (27 char. / 7 enabl. factors)

We decided to ***cluster***, resulting in:

1. 3- D Printing / Additive Manufacturing
2. Cloud Manufacturing
3. CPS (Cyber Physical Systems) / CPPS (Cyber Physical Production Systems)
4. Cyber Security
5. Data Analytics
6. Energy Saving / Energy Efficiency
7. Intelligent Control
8. IoT / IoS / IIoT
9. IT based Production System
10. Smart Product / Part / Material
11. Visual Technology

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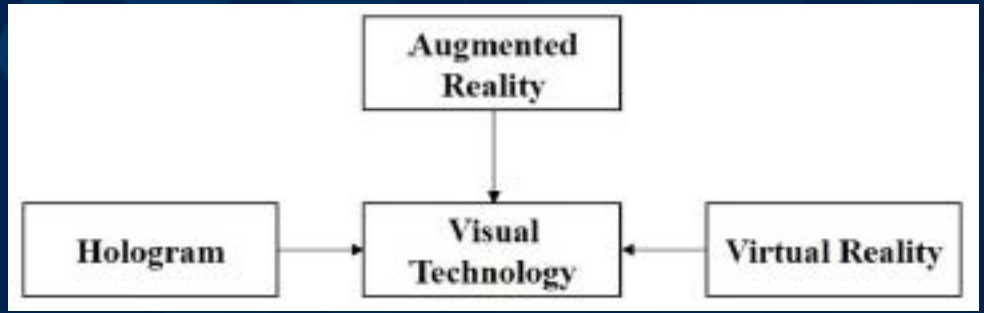
Example: Visual Technologies

- Example Cluster: ***Visual Technology***
- Comprised of three technologies:
  - *Hologram / Digital Twin*
  - *Augmented Reality*
  - *Virtual Reality*

Source: https://compass-ssl.surface.com/assets/d4/8d/d48dbc28-aec3-4417-b319-bed3aac91c81.jpg?n=Overview_Hero_1920_img_new.jpg



Mittal et al., 2017

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… But what does all that mean for manufacturing companies?

- ***Continuous innovation***
  - *Question current processes & practices!*
- ***Adaption*** of new technologies, tools and frameworks
  - *Data & Information driven!*
- Skilled ***workforce***
  - *Lifelong learning!*

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Smart Manufacturing in
Small- and Medium-sized Enterprises (SMEs)

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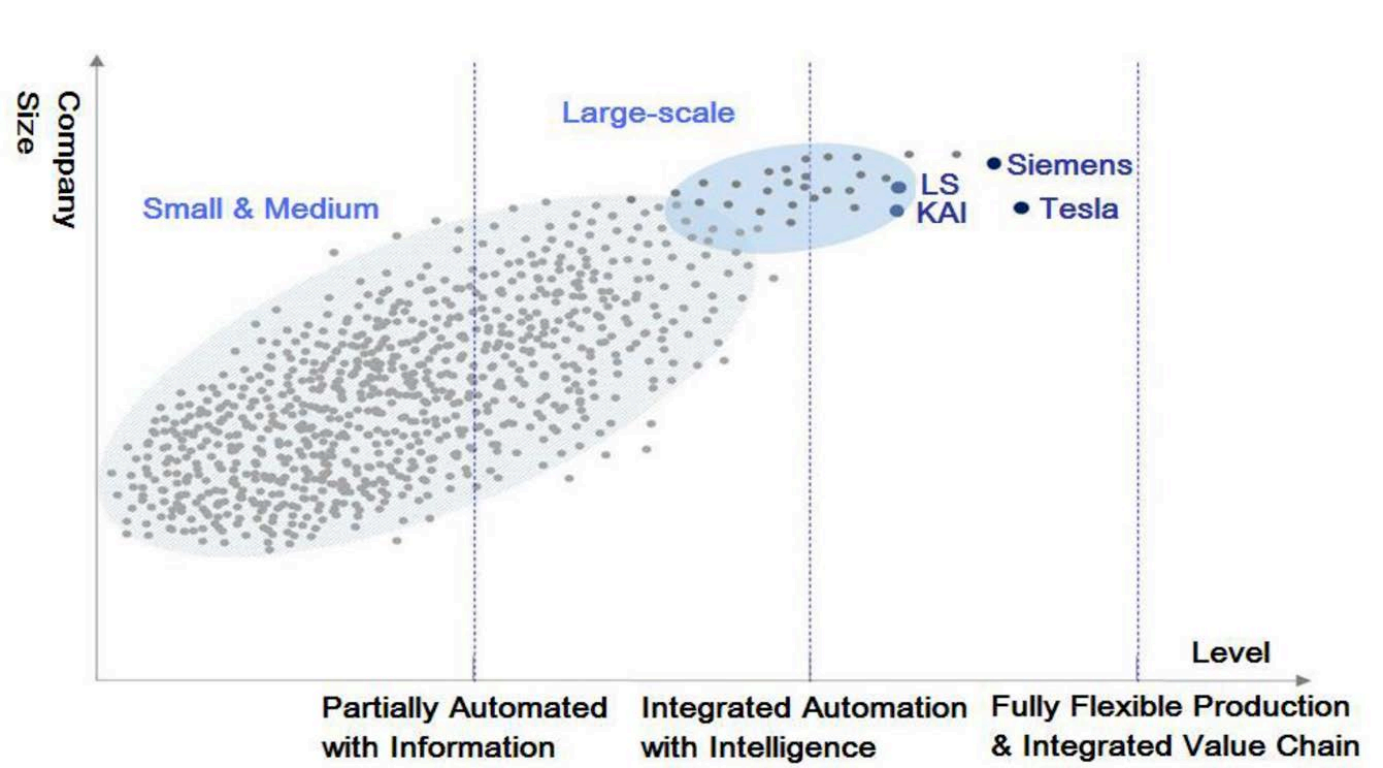
Status of Industry



Source: Jinwoo Park, 2015

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Siemens Digital factory

- Siemens' plant in Amberg, Germany
- ***Products communicate*** with manufacturing machines
- IT systems control and optimize all processes
- Production quality is at ***99.99885 %***

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SMEs vs MNEs – Different requirements

#	Features	SMEs	MNEs
1	Use of Advance Manufacturing Technologies	Low	Very High
2	Financial Resources	Limited	Comparatively more
3	Organization Culture/ Leadership	Conservative	Flexible
4	Company Strategy	Dictated by Gut Feeling of the Leader (Owner)	Market Research and Accurate Analyses
5	Decision Making	Restricted to Leader/ Few Knowledge Carriers	Board of Advisory
6	Human Resources	Engaged in Multiple Domains	Have Own Area of Specialization
7	Human Resource Development	Exposure	Training, Mentors, Workshops
8	Alliances with Universities/ Research Institutions	Not so Strong	Strong
9	Important Activities	Outsourced	Internal to the Organization
10	Nature of Product	Highly Specialized	Little Specialized
11	Collaborative Network	High Dependence	Not so much Dependent
12	Customer/Supplier Relations (Partner Dependence)	Very Strong	Not so Strong
13	Standards	Not so Strictly	Strictly Obeyed
14	Organizational Structure	Less Complex and Informal	Complex and Formal
15	Software	Provides Tailored Solutions to Problems	Standardized Solutions
16	Use of Resources/ Research & Development	Low	High
17	Knowledge and Experience	Focused in a Specific Area	Spread Around Different Areas

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Upgrade existing systems

- Bosch upgraded ***Lathe from 1887*** to be Smart Manufacturing ready
- ***New capabilities***:
  - process monitoring for constant quality assurance
  - another is condition monitoring in order to prevent unplanned downtimes
- Extreme example but ***showcases the potential***

http://ww

http://www.bosch-presse.de/pressportal/en/69632.html

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Project Scope

Background

- Internet of Things is **changing** the industrial landscape
- Manufacturing is undergoing a major **transition**
- **Large** corporations are dealing with this topic intensively

⇒ **But how to apply Smart Manufacturing in small companies?**

⇒ **How can small manufacturers take advantage of it?**

Objectives

- Examine the **current state** of manufacturing with a **survey**
- Understand the manufacturing landscape and its specific **challenges** and **concerns** by conducting **interviews** and plant visits
- Support **small** manufacturers in adopting Smart Manufacturing technologies by setting up a training **workshop**

Work Packages

1. Online survey
2. Interviews & plant visits
3. Analysis of results & report
4. Training workshop

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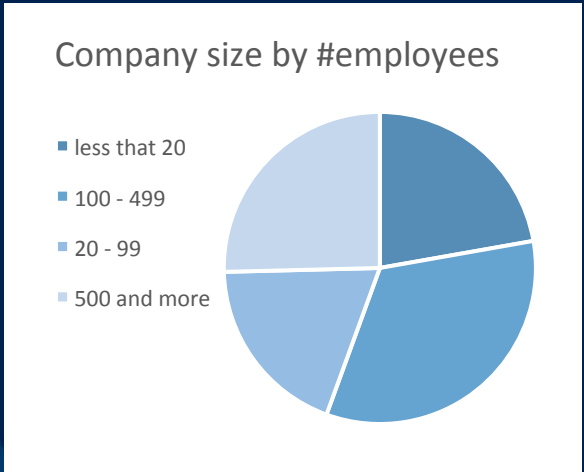
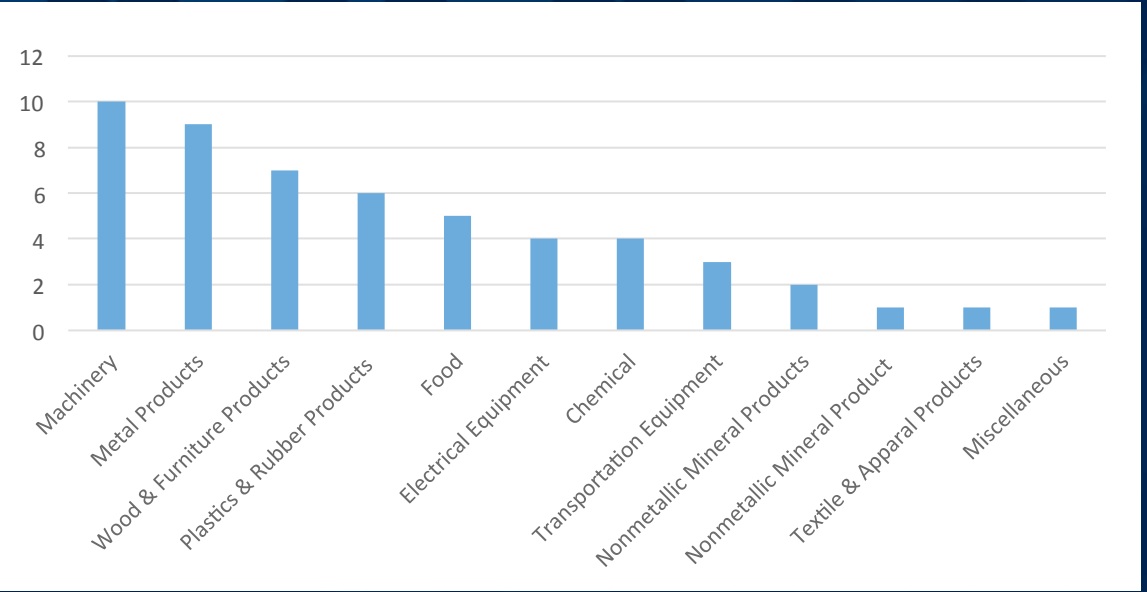
Survey Method

Who participated in the survey?

53 Total # of respondents from manufacturing





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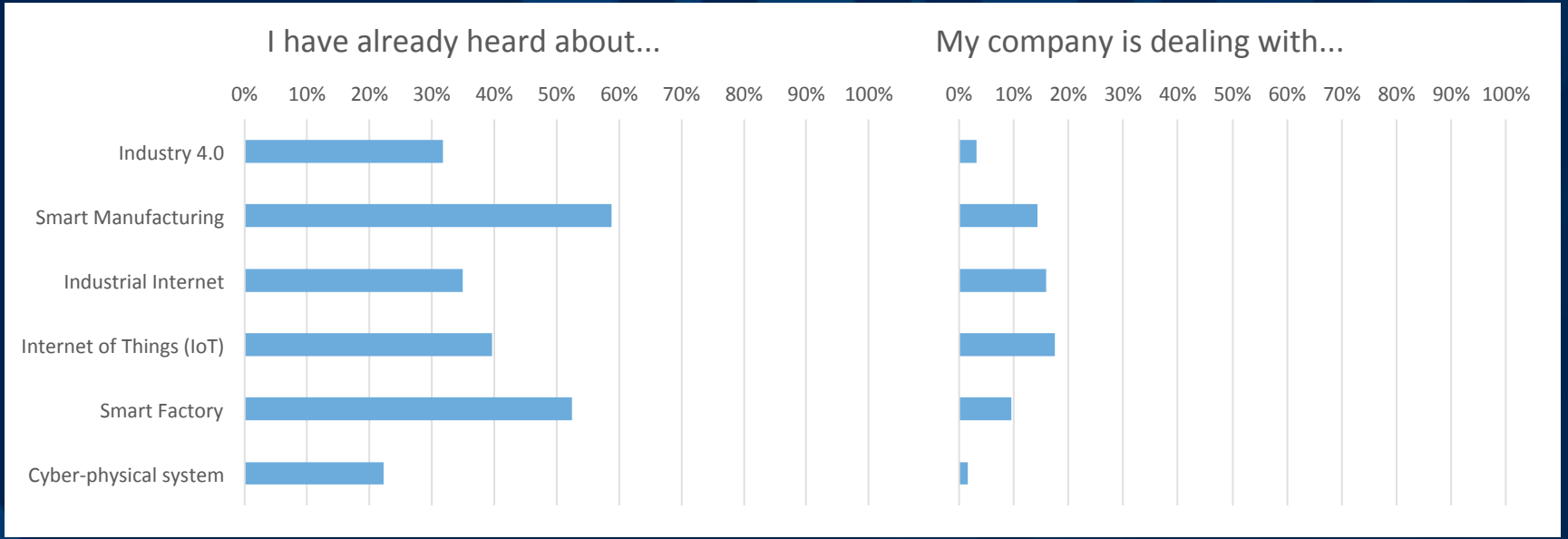
Survey Results

How aware are companies of the transition towards Smart Manufacturing?



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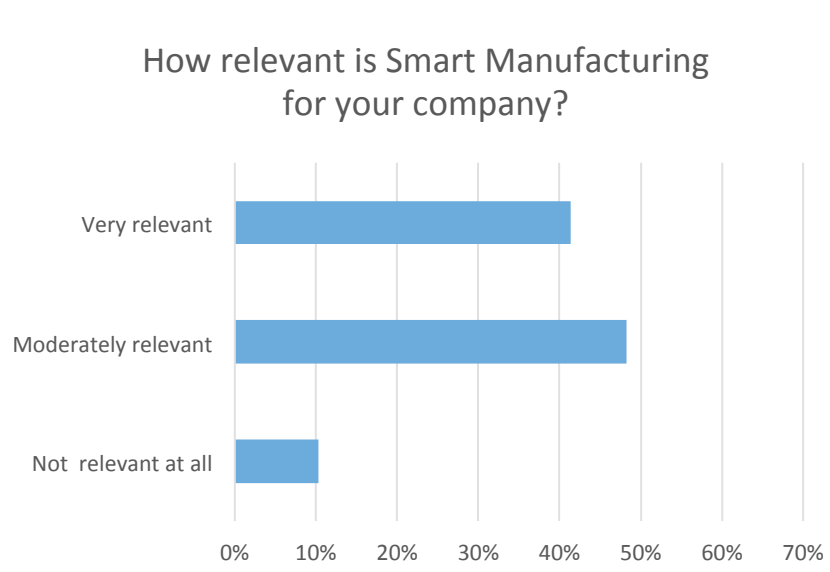
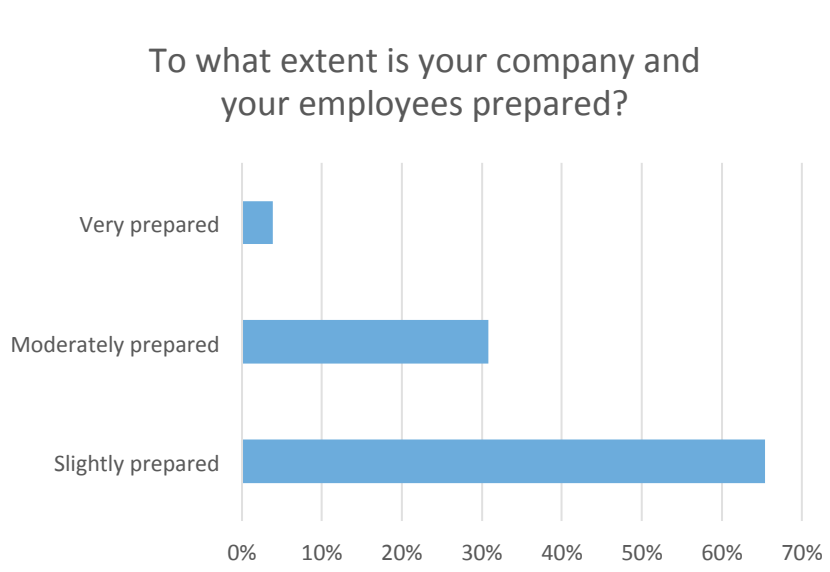
Survey Results

How prepared are companies for Smart Manufacturing?





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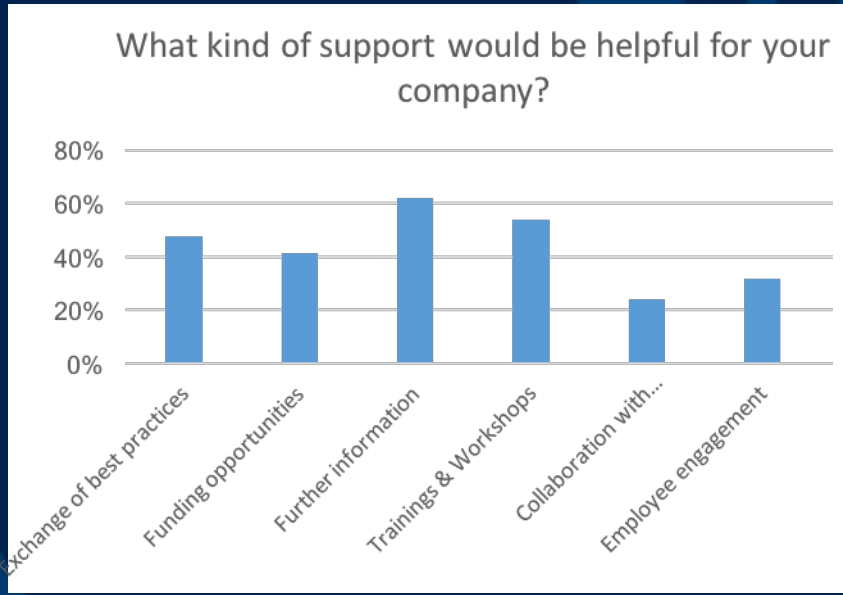
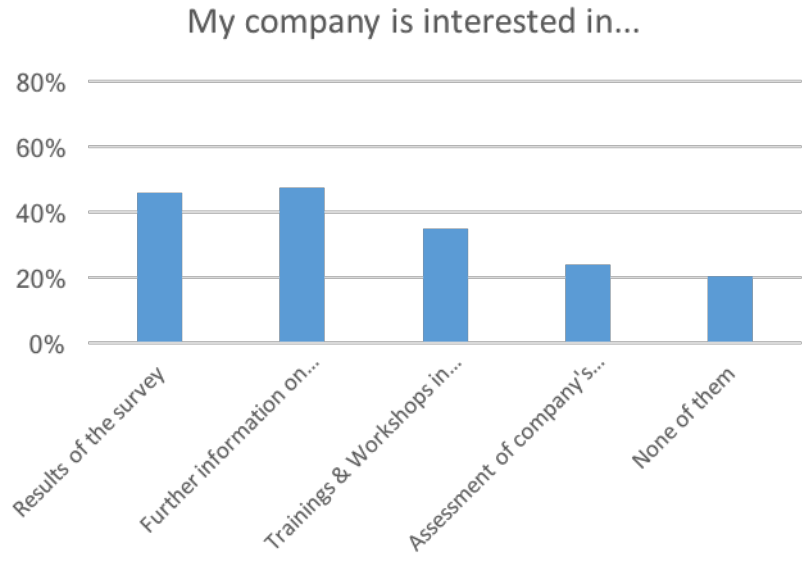
Survey Results

What are the needs of manufacturers when it comes to Smart Manufacturing?





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Interview Method

Who participated in the interview sessions?

Manufacturers

9

Interviewees in manufacturing companies

Manufacturing Experts

5

Experts in academia, associations & state agencies

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Schmid & Wuest, 2017

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Selected insights from interviews

Lack of economic opportunities

- Decline of coal industry
- Decline in local markets
- Oversupply in global markets
- Global competition

Infrastructure challenges

- Telecommunication infrastructure
- Lack of investments in facilities/tech.
- Infrastructure of support systems

Increasing cost

- Increasing utility rates
- Rapidly rising healthcare cost
- Lack of capital to 'keep up' w/ tech.

Manufacturing reputation problem

- Mindset of 'second-class' jobs & low wages
- Misconception of dirty and dangerous work

Perception of Smart Manufacturing value

- Lack of awareness of existing tech. & potential impact
- Hard to imagine value-add for discrete manufacturing
- Difficult to imagine in a small scale
- Lack of show cases & success stories / role models

"It's a different deal in small companies in many ways"

- Small companies could move faster
- Less resources reg. humans resources, money & time

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Key challenges of Smart Manufacturing adoption for SMEs

Lack of opportunity

Resources & cost

Knowledge & awareness

Skilled workforce

Missing ‘success stories’

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‘Capability creates Opportunity’

Craig Hartzell, Azimuth Inc., 2017

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Schmid & Wuest, 2017

Opportunities for collaboration & entrepreneurs

Brave new world

'Low' initial investment

Dedicated 'Apps' (Platform solution)

Scalable solutions (interoperable & extensible)

Fast deployment

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Recommendations (1/2)

for Smart Manufacturing in SMEs

- Provide **educational resources** on Smart Manufacturing and Industry 4.0 (‘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.

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Recommendations (2/2)

for Smart Manufacturing in SMEs

- 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 manufacturing SMEs.

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Schmid & Wuest, 2017

My take on this issue:

- Solutions must be ***tailored to SMEs***' (real!) needs & requirements!
- Create ***real value*** (short AND long term)!
- Fit the strategy / vision!

To do so **SMEs need** to:

- ***Assess*** their current processes critically
- ***Identify*** their core competencies
- ***Build*** on those and
- Develop a roadmap with specific milestones / objectives
- (keep ***80/20 rule*** in mind!)

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Thank You!

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