Artificial Intelligence for Production Management and Control towards Mass Personalization in Industry 4.0

Professor Dimitris MOURTZIS

Laboratory for Manufacturing Systems and Automation (LMS)
Department of Mechanical Engineering and Aeronautics
University of Patras, Greece

Email: mourtzis@lms.mech.upatras.gr

Outline

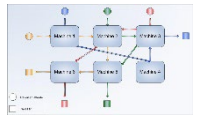
- Evolution of Manufacturing Paradigms
- Industry 4.0 and Smart Manufacturing
- Mass Personalization
- The Rise of AI in Manufacturing
- How can AI support the Production Management and Control towards Mass Personalization in Industry 4.0
- AI Basics and Factories of the Future
- Automation Applications at the Industrial Internet of Things (IIoT) Edge
- Discussion
- Looking Ahead: Exploring the Metaverse and the Digital Future
- Conclusion
- Key References

Introduction

Industrial Revolutions

Craft Production

Job Shops



First Factories

Dedicated Manufacturing Systems (DMS)
Agile / Lean Manufacturing
Mass Production

Flexible Mfg. Systems (FMS)
Reconfigurable Mfg. Systems (RMS)
Computer Integrated Manufacturing (CIM)
Mass Customization (MC)

Smart Manufacturing Systems (SMS)
Cloud Manufacturing
Cyber-Physical Manufacturing
Circular Economy Mfg.

Adaptive Cognitive Mfg. Systems

1st Industrial Revolution
18th Century

Steam-based Machines

2nd Industrial Revolution
19th-20th Century

Electrical Energy-based Mass Production

3rd Industrial Revolution
Late 20th Century

Computer and Internet-based Knowledge

Artificial Intelligence Information Technology

AI Software

Intelligence

Big Data
IoT
Cloud

4th Industrial Revolution
Early 21st Century

Internet of Things (IoT)
Cyber Physical Systems (CPS)
Digital Platforms
Product Service Systems (PSS)
Networks

5th Industrial Revolution

Personalization
Mass Customization
Co-operation between man, and machine
Cyber Physical Cognitive Systems
Sustainable Systems
Human Centric Systems
Resilient Systems

Complexity

1850 — 1910 — 1980 — **Time** — 2010 — 2025

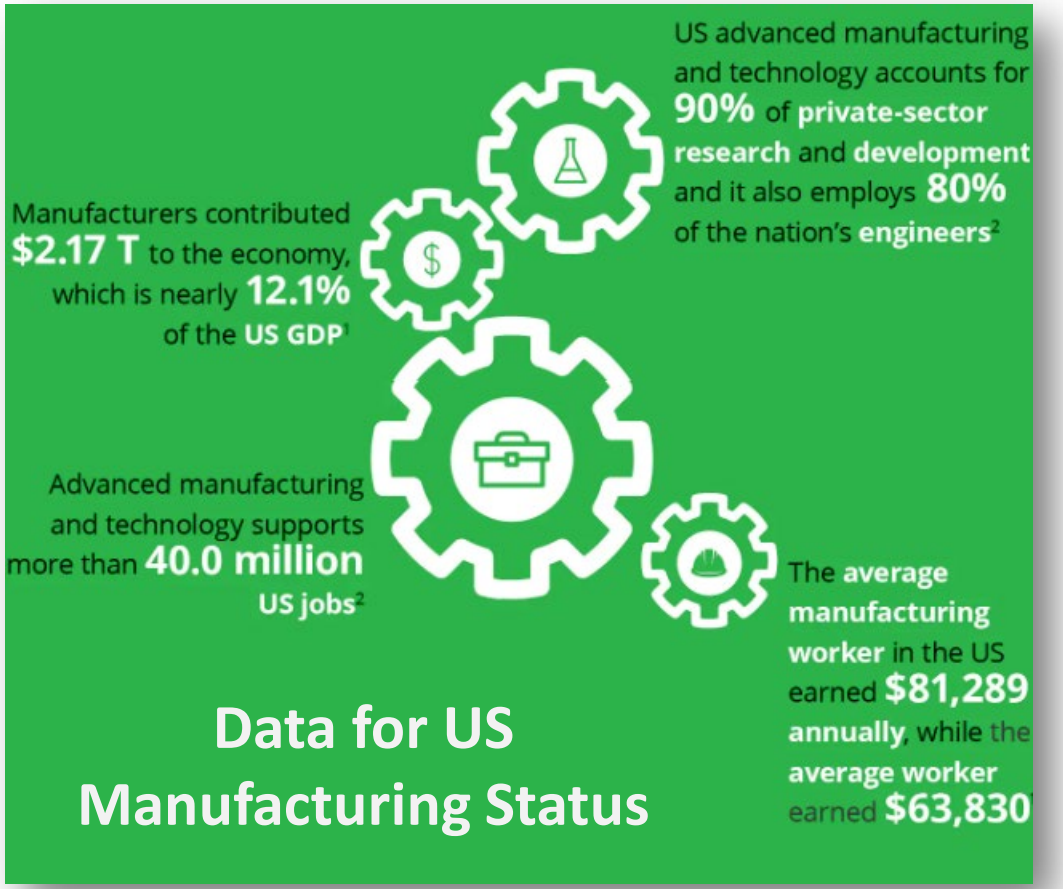
SW: Software
IoT: Internet of Things

AI will lead the fourth industrial revolution of human beings' intelligence

[Adapted from "WorldBank; Kearns P., 2019; Li et al., 2020; Mourtzis D., 2020; ElMaraghy et al., 2022]

Why Manufacturing Matters

- ✓ The manufacturing industry is propelled by advanced technologies and constant innovation
- ✓ It plays a key role in enhancing economic prosperity through increased productivity, raising GDP output, and creating higher-income jobs



Top 12 drivers of global Manufacturing Competitiveness

Top Manufacturing Competitive Nations (by 2020):

USA China

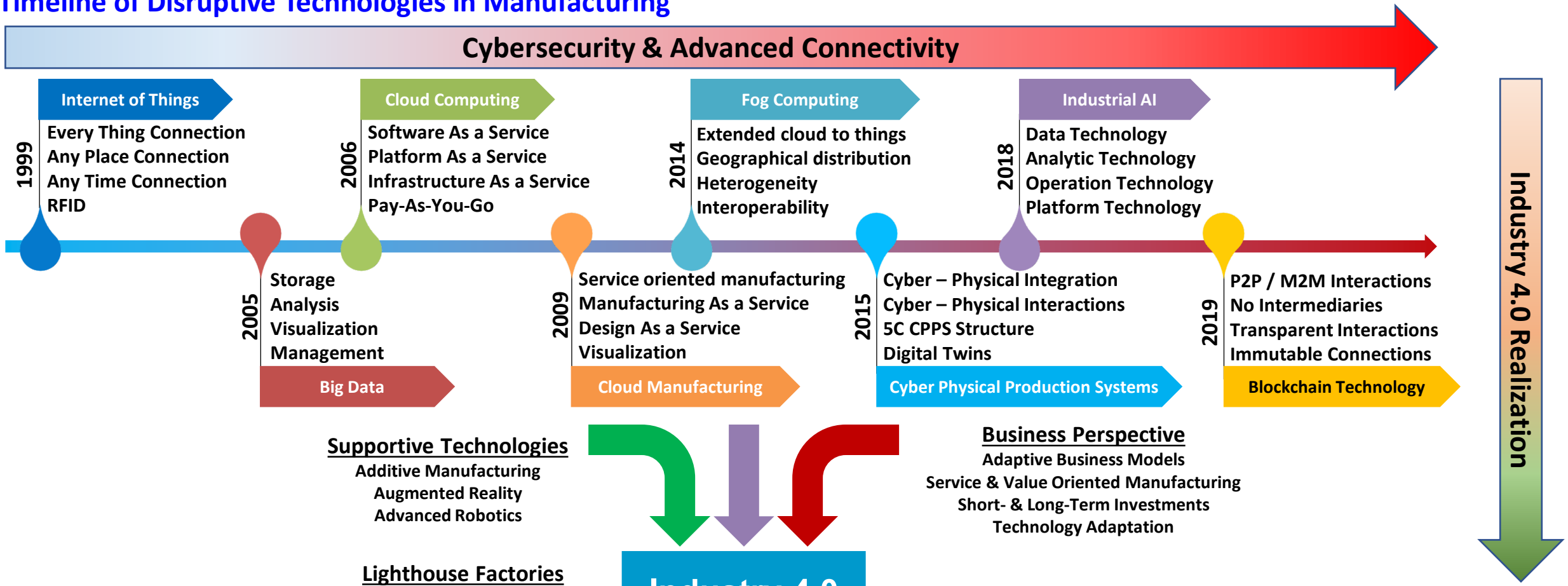
Germany Japan India

[Source: Deloitte, 2021]

Introduction

Industry 4.0 – AI as a catalyst to Intelligent Manufacturing

Timeline of Disruptive Technologies in Manufacturing



Supportive Technologies
Additive Manufacturing
Augmented Reality
Advanced Robotics

Lighthouse Factories
Bosch Automotive
BMW
Tata Steel
Procter & Gamble, etc.

Industry 4.0

Business Perspective
Adaptive Business Models
Service & Value Oriented Manufacturing
Short- & Long-Term Investments
Technology Adaptation

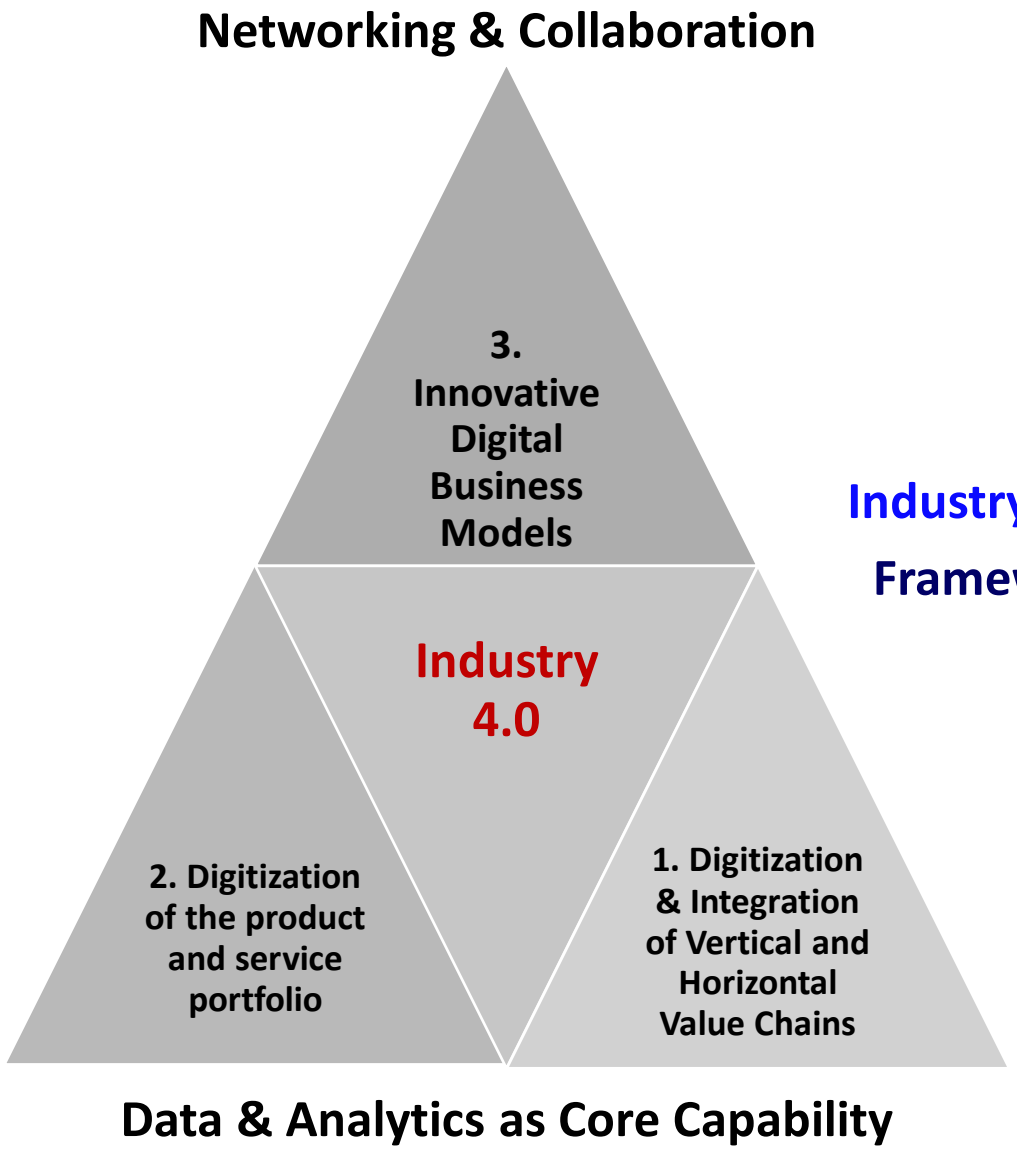
P2P: Peer to Peer
M2M: Machine to Machine
RFID: Radio Frequency Identification

[Source: Jay Lee et al., 2019]

Industry 4.0 and Smart Manufacturing

Industry 4.0 – The Framework

- ✓ Networking of value chains
- ✓ Digitization of products & processes
- ✓ Digitalization of platforms & processes
- ✓ New Business Models



Industry 4.0 – Framework

[Source: Industry 4.0 – Opportunities and challenges of the Industrial Internet, PwC, 2020]

Industry 4.0 – The Origin

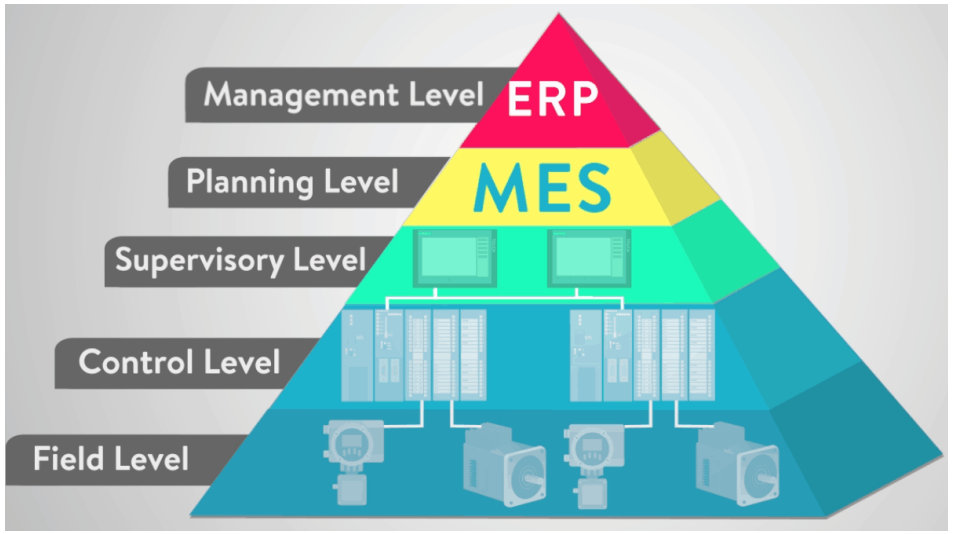
✓ Is Industry 4.0 a brand-new business model? ⇨ NO!

~1980s: Computer Integrated Manufacturing (CIM)

Islands of Automation

ERP: Enterprise Resource Planning

MES: Manufacturing Execution Systems



Full Integration

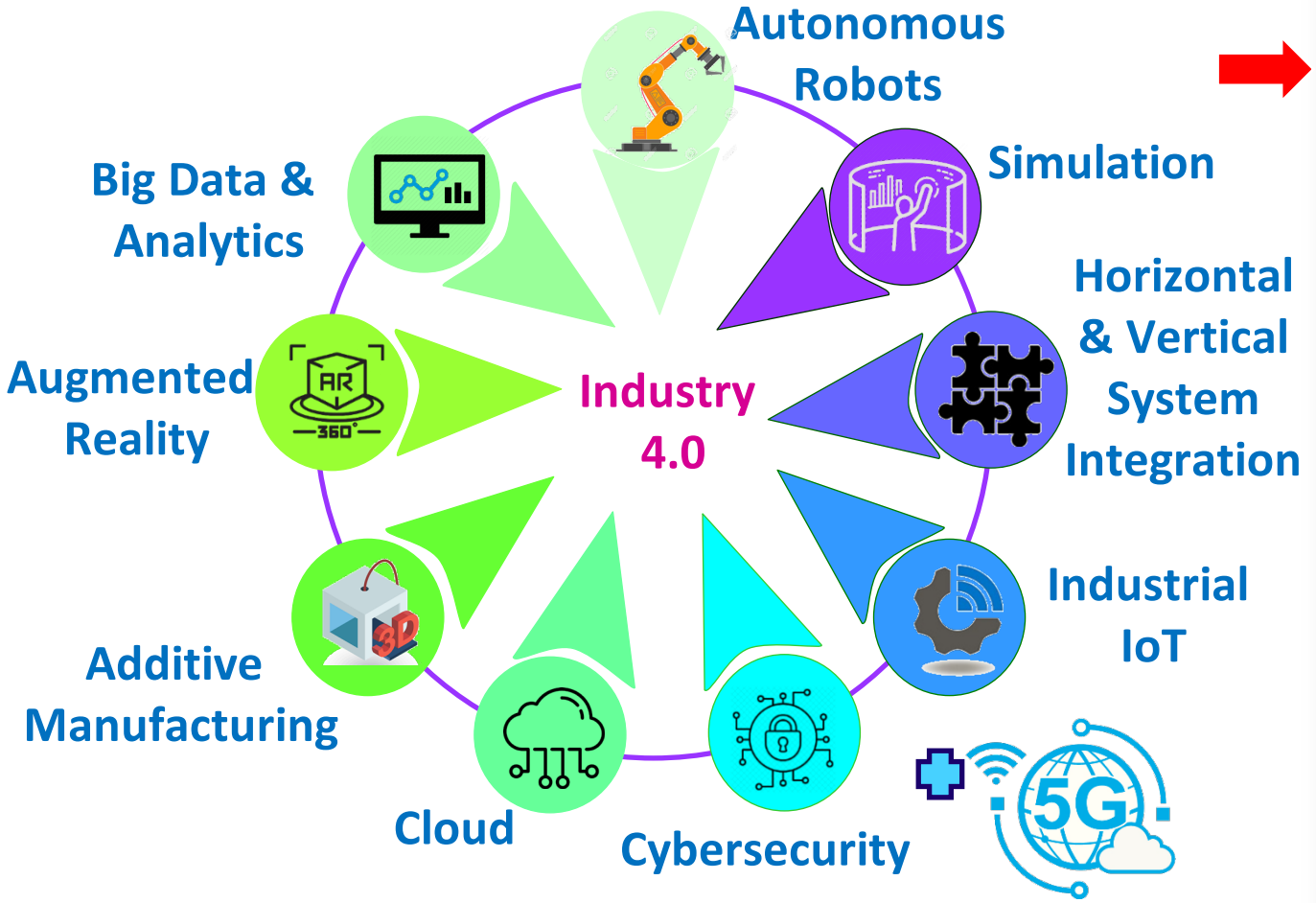
Digital Transformation

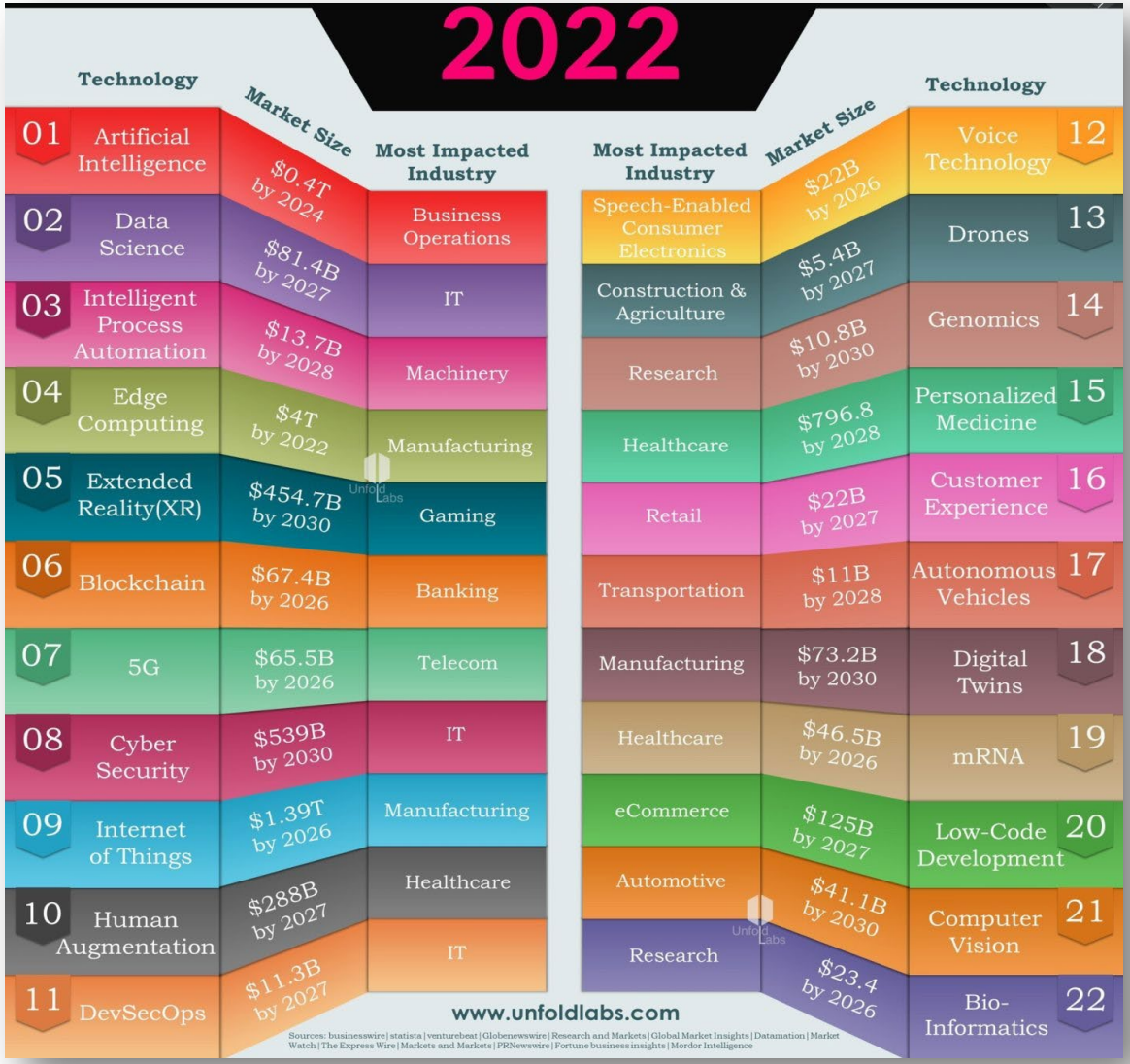
Interoperability

[Source: Matthews, R. (1997), "Islands of automation", Assembly Automation, Vol. 17 No. 4, pp. 291-294. https://doi.org/10.1108/01445159710191552; https://medium.com/world-of-iot/92-what-is-the-five-layer-automation-pyramid-d0ccc1b903c3

Industry 4.0 and Smart Manufacturing

Technological Pillars Towards Digital Transformation





[Adapted from BCG: Embracing Industry 4.0 and Rediscovering Growth, https://www.bcg.com/capabilities/operations/embracing-industry-4.0-rediscovering-growth.aspx]

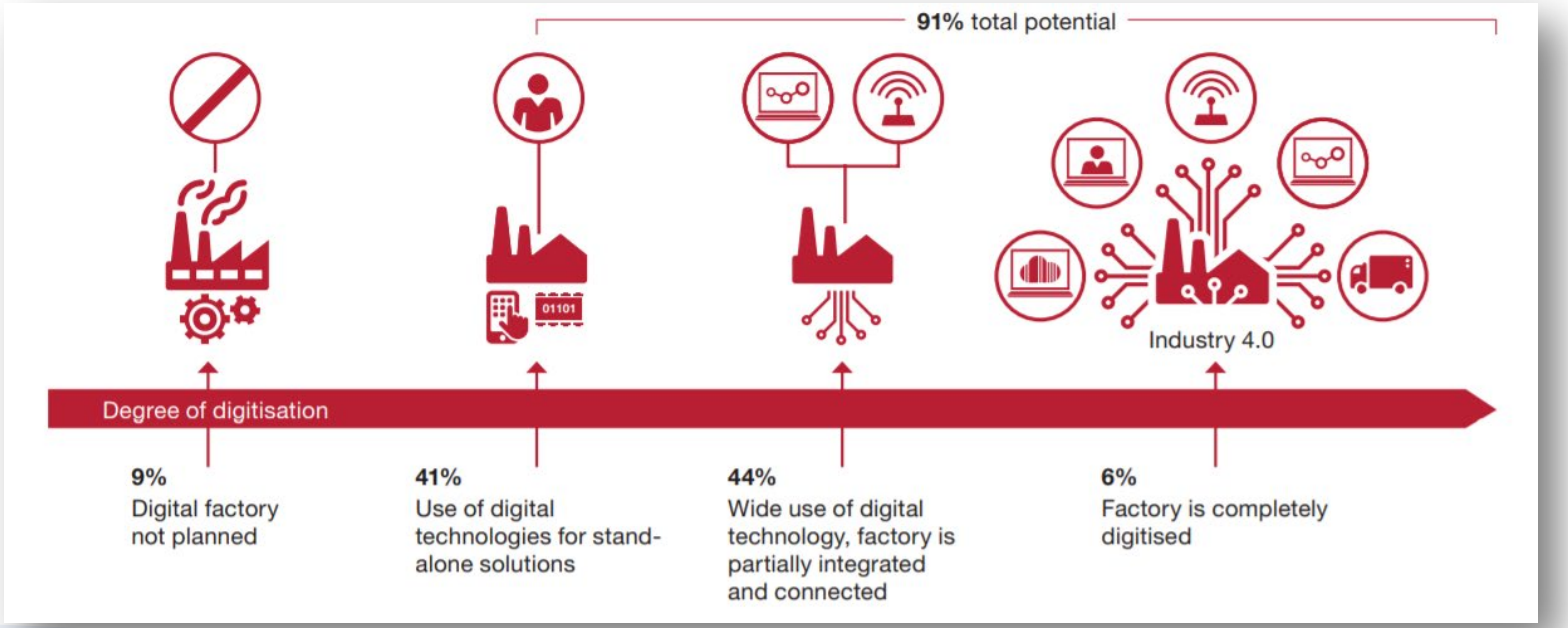
Industry 4.0 – Digitalization of Manufacturing is NOT a Future Trend

Manufacturing has a real impact on the global economy: It accounts for 70 percent (70%) of global trade

Digitalization of Manufacturing has created new job positions for 34 million people

Industry 4.0 is NO longer a 'future trend' [PwC, 2016]

Digital factories at the top of the Agenda



Industry 4.0 and Smart Manufacturing

Problem Statement

- ✓ Increase in the involvement/engagement of end-users in the product lifecycle
- ✓ **Requirement:** Flexible manufacturing operations to produce **cost-effective individualized products** in dynamic batch sizes at scale taking into consideration the unique preferences of each customer

Challenge

Quick Response to changing demands and disruptions for increased resilience to:

- The factory Operation
- Supply chains & Production Networks
- Unique Customer needs

How is this achieved?

- ✓ Production Management & Control
- ✓ Self-optimizing manufacturing systems & operations to achieve:
  - flexible, autonomous, and error-tolerant production
- ✓ The main technological drivers of MPe are the Big Data Sets and Artificial Intelligence (AI)

Mass Personalization

Personalization vs. Mass Personalization

Personalization

"degree to which receivers perceive a message reflects their distinctiveness as individuals differentiated by their interests, history, and relationship network"

[Source: O'Sallivan and Carr, 2018]

≠

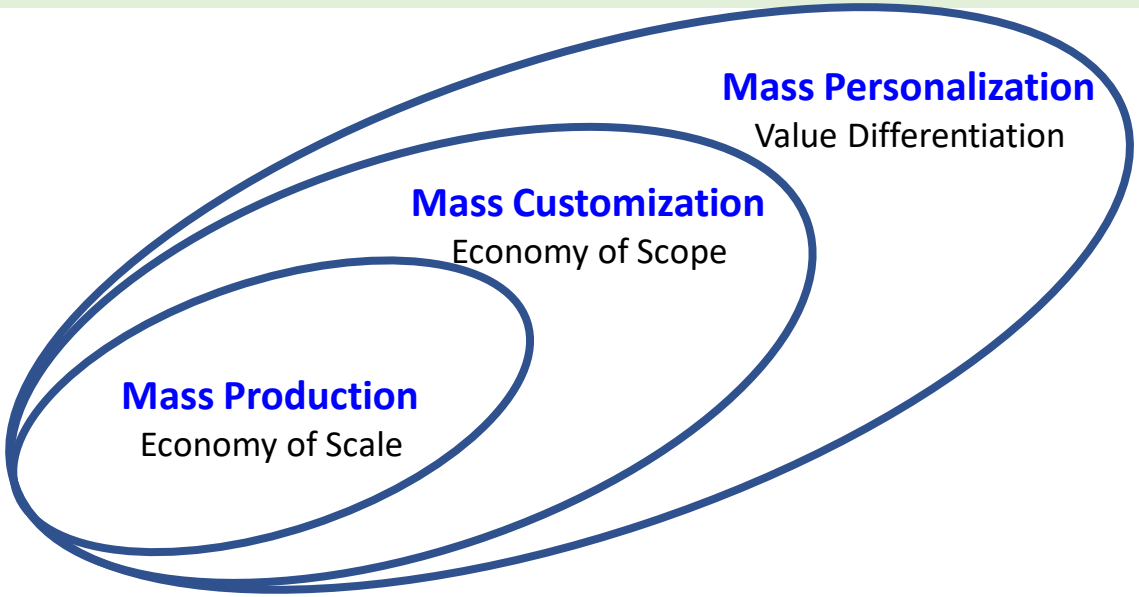
Mass (user-initiated) customization

"individuals deliberately tailor content by choosing options and/or creating new content and become sources of communicative interactions (i.e. self-as-source)"

[Source: Mourtzis and Doukas, 2014; Elmaraghy et al., 2021]

Mass Personalization

"the act of creating highly-personalized digital experiences for specific audiences based on a set of criteria.
Usually, this will be using a segmentation model, which helps businesses split their customer base for effective targeting"



Goals of Manufacturing Paradigms [Source: Hu J., 2013]

Mass Personalization

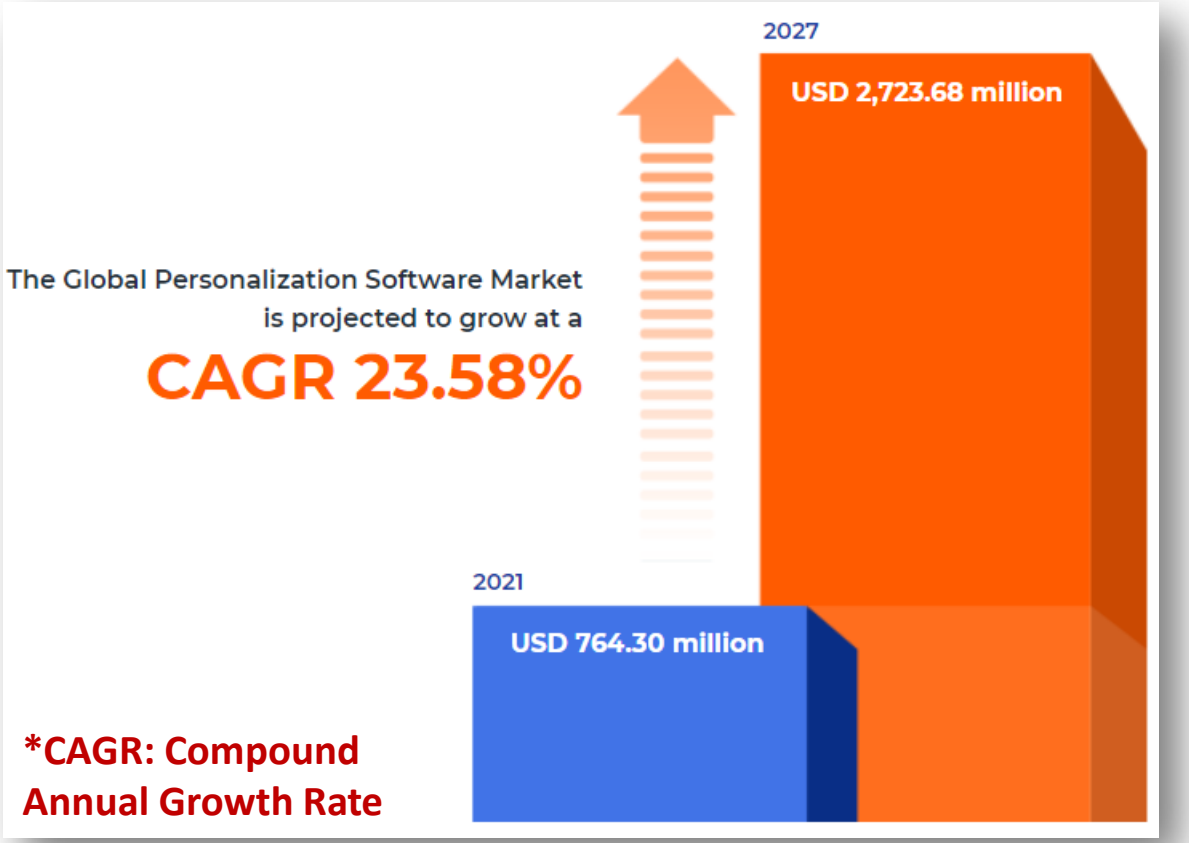
Why Personalization Matters – Market Share

- The global personalization software market is expected to grow from $620 million in 2020 to $2.2 billion by the end of 2026

- The recommendation engine market size is projected to reach $12.03 billion by 2025, up from $ 1.14 billion in 2018, with a CAGR of 32.39% during 2020-2025

[Source: Exciting Personalization Trends to Watch for in 2022]

Personalization Software Market Share



The global personalization software market was estimated to be $764.30 million in 2021 and is expected to reach $943.25 million in 2022, at a CAGR of 23.58 percent to reach $2.72 billion by 2027

[Source: 360i Research Report, 2022]

Mass Personalization

Reasons for Mass Personalization

DATA is the Key!

Why does Mass Personalization Matter

- ✓ **Customer:** being integral part of **Online Personalized Experience**
- ✓ **Elevated Consumer Expectations:**
  - **Relevant, Contextual & Convenient Experiences to Unprecedented Heights**

91% of consumers are more likely to shop with brands who recognize, remember, and provide them with relevant offers and recommendations

[Source: Accenture survey, 2018]

Personalization means using **Audience** and **Data Analytics** to meet the **individual needs of a consumer**

1. Use your data to outline the details of who each of your customers is,
2. What their intention is at any particular moment, and
3. Where, when, and how they've engaged with your brand previously

[Source: Personalization: The Basics, SITESCORE, 2022]

Key Marketing Personalization Statistics

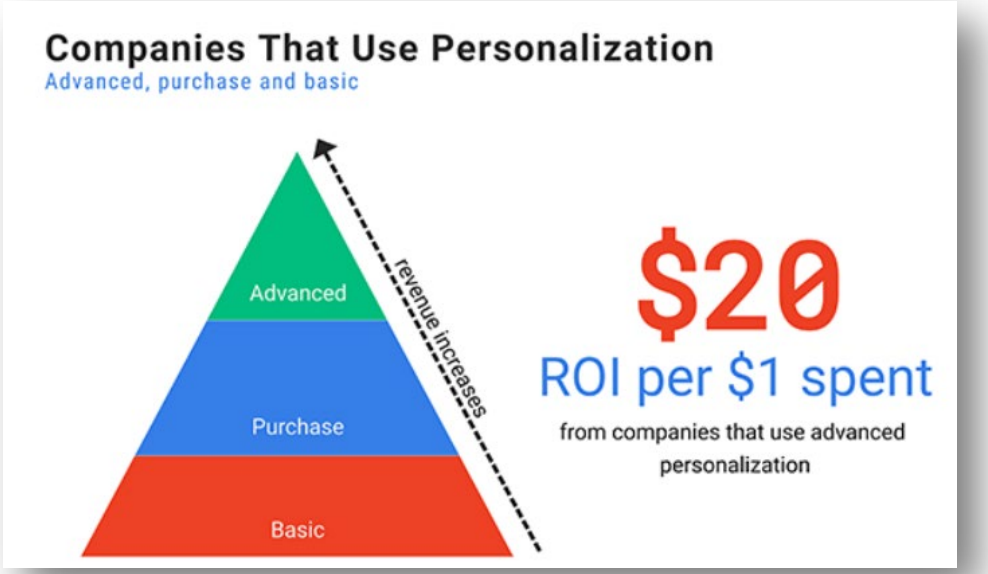
- 80% of consumers are more likely to buy from a company that provides a tailored experience
- 66% of consumers expect brands to understand their individual needs
- 70% of consumers say that how well a company understands their individual needs impacts their loyalty
- 71% of customers are frustrated by impersonal shopping experiences
- 42% of customers are frustrated by impersonalized content
- 72% of customers will only engage with personalized messaging
- 63% of consumers won't buy from brands that have poor personalization
- 60% of marketers say their digital content is extensively or very extensive personalized
- 88% of marketers say their biggest goal with personalization is to improve the customer experience
- 70% of consumers are more likely to buy from company's that understand how they use their products/services

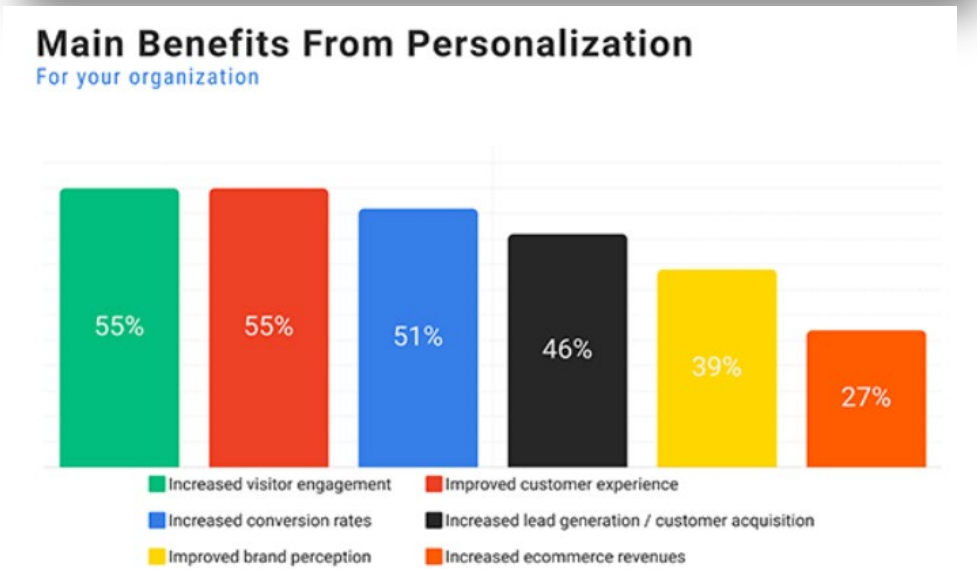
[Source: 56 Top Personalization Statistics: Facts And Trends For 2022, Link]

Mass Personalization

Key Marketing Personalization Statistics

- Companies that use advanced personalization see returns of $20 per $1 spent
- Personalization reduces customer acquisition costs by as much as 50%
- According to 55% of marketers, the #1 benefit of personalization is better visitor engagement and customer experiences
- Including personalized subject lines in your emails improves open rates by 26%
- Personalized emails drive 6x more transactions
- 52% of consumers will look elsewhere if an email isn't personalized
- 74% of consumers are frustrated by website content that is not personalized





[Source: 56 Top Personalization Statistics: Facts And Trends For 2022, Link]

Mass Personalization

Reasons for Mass Personalization

How to Make Personalization a Reality?

Scale

Start small. Then scale across your brand's channels at your own pace and deploy personalization **where it will drive impact**

Speed

No need for months of development

Insights

From holistic reporting to actionable recommendations, intelligent insights enable constant improvement

Personalized Experience
Digital Platforms

Optimize every interaction

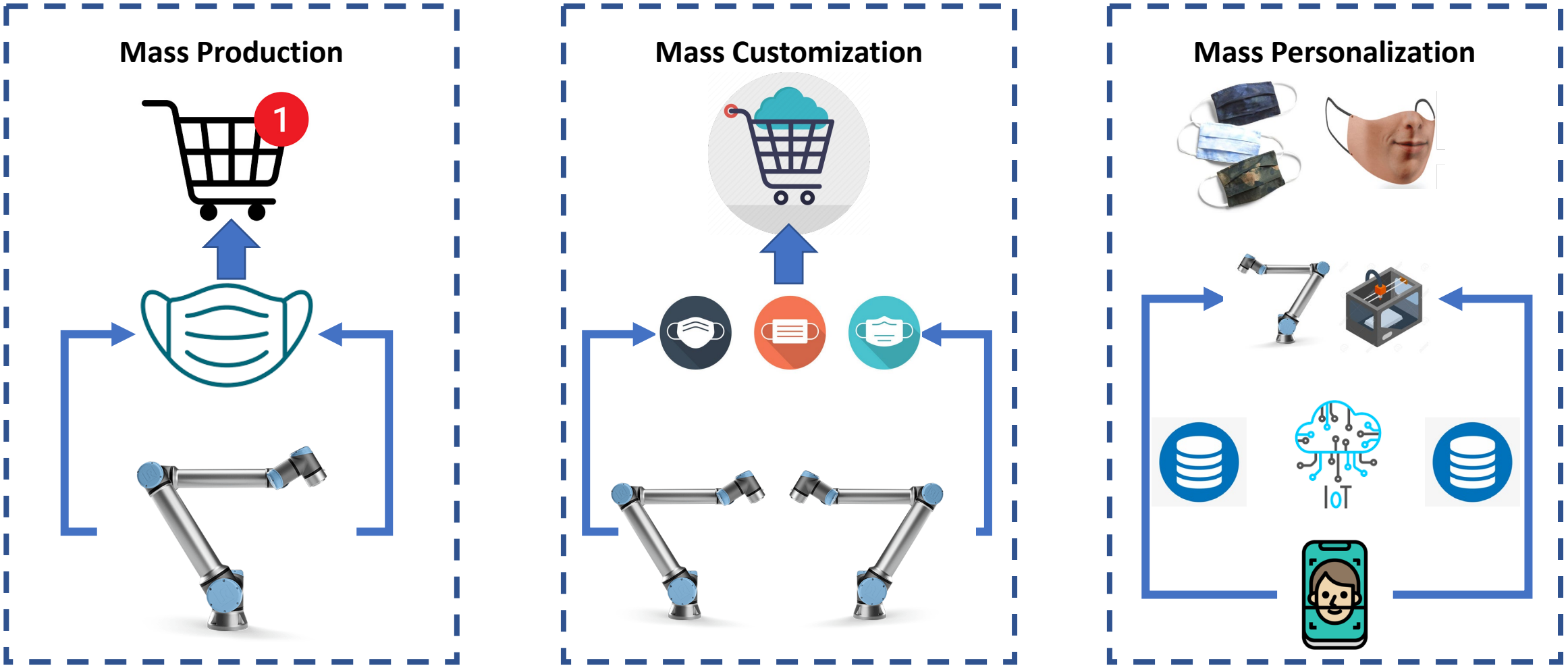
Deliver the right content, at the right time, on the right channel

- **Know your customers**
- **Make a good first impression**
- **Drive KPIs and ROI**

***KPIs: Key Performance Indicators**
ROI: Return of Investment

Mass Personalization

Mass Personalization Overview



Mass Production, Mass Customization, and Mass Personalization Manufacturing (MPe) Paradigms

[Source: Adapted from Aheleroff, 2019]

Mass Personalization

Mass Customization, the Next Big Trend in eCommerce

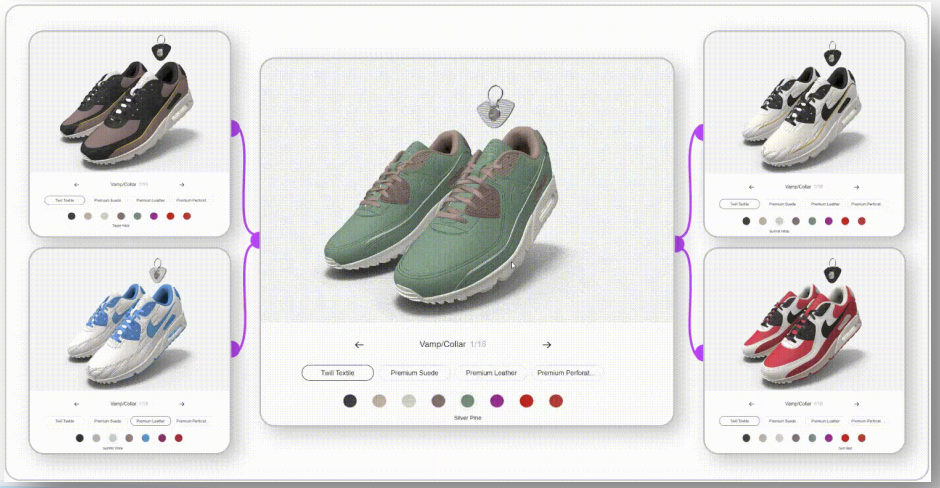
- **Situation:** global acceleration in the adoption of digital trends, such as eCommerce, due to COVID pandemic
- 84% of Americans expect their digital brands to have a seamless experience between physical and online

[Source: The Digital Consumer, Appnovation Research Report, 2021]

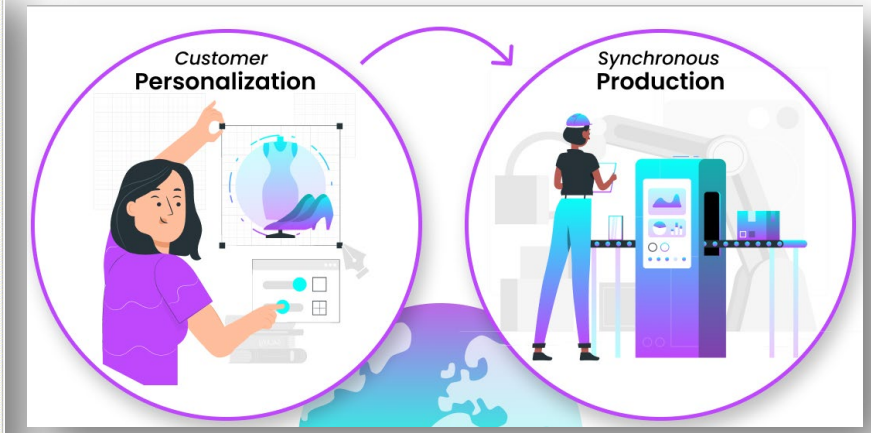
What are the next trends and practices that will put early adopters ahead of the competition?

Mass Customization?

- **Personalization based on user choice**



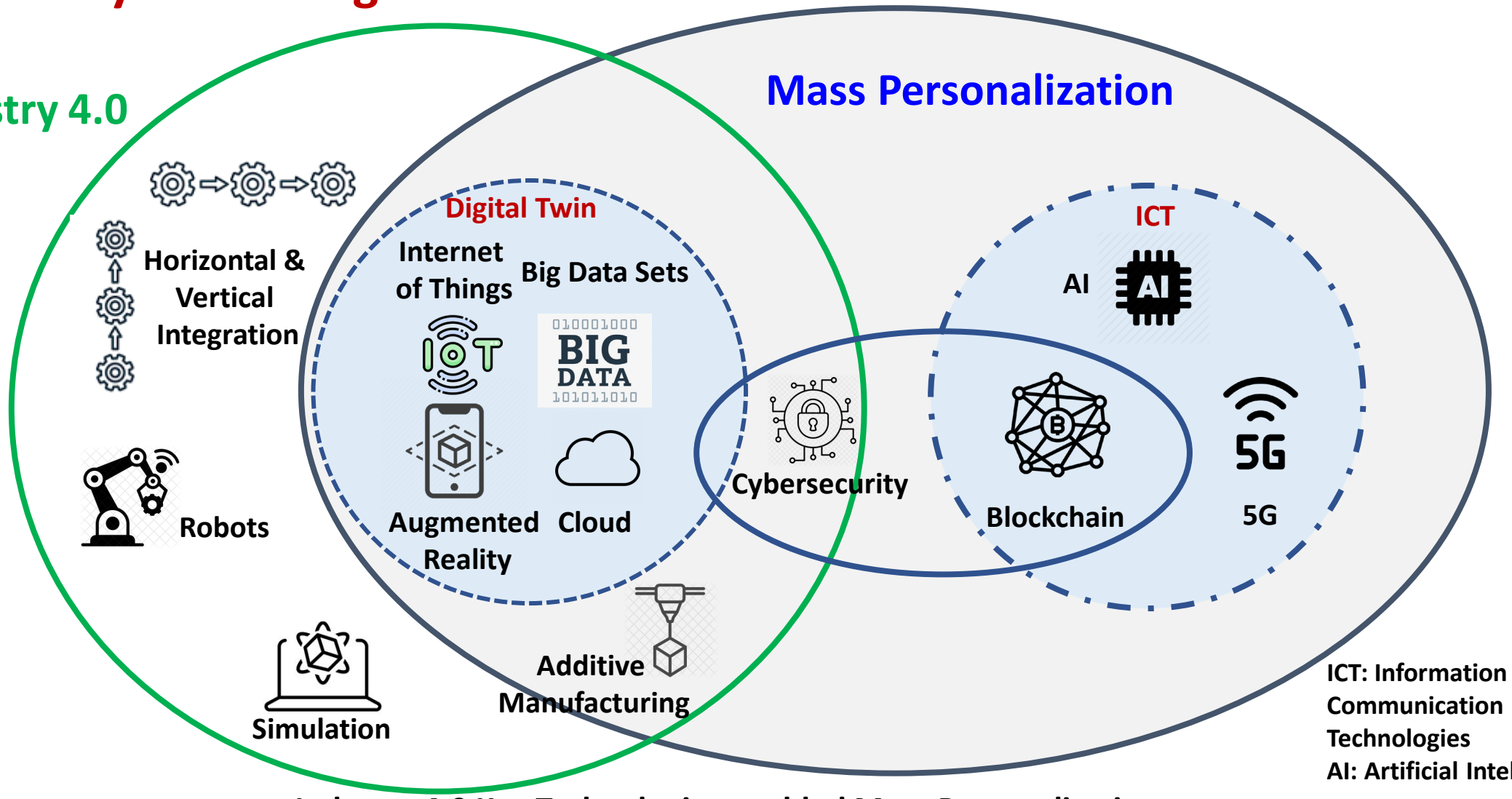
- **Synchronous Production**



[Source: ShapeDiver, 2022]

Mass Personalization

Industry 4.0 Key Technologies enabled Mass Personalization



ICT: Information and Communication Technologies
AI: Artificial Intelligence

Industry 4.0 Key Technologies enabled Mass Personalization [Source: Adapted from Aheleroff et al., 2020]

Importance of Internet of Things (IoT) in Industry 4.0

- By means of low-cost computing, the cloud, big data sets, analytics, and mobile technologies, physical things can:
  - share and
  - collect data

with minimal human intervention

- Hyperconnected world: digital systems can record, monitor, and adjust each interaction between connected things. The physical world meets the digital world—and they cooperate

What Technologies have made IoT Possible?

- Access to low-cost, low-power sensor technology
- Connectivity
- Cloud computing platforms
- Machine learning and analytics
- Conversational artificial intelligence (AI)

Internet of Things (IoT) Standards & Networks

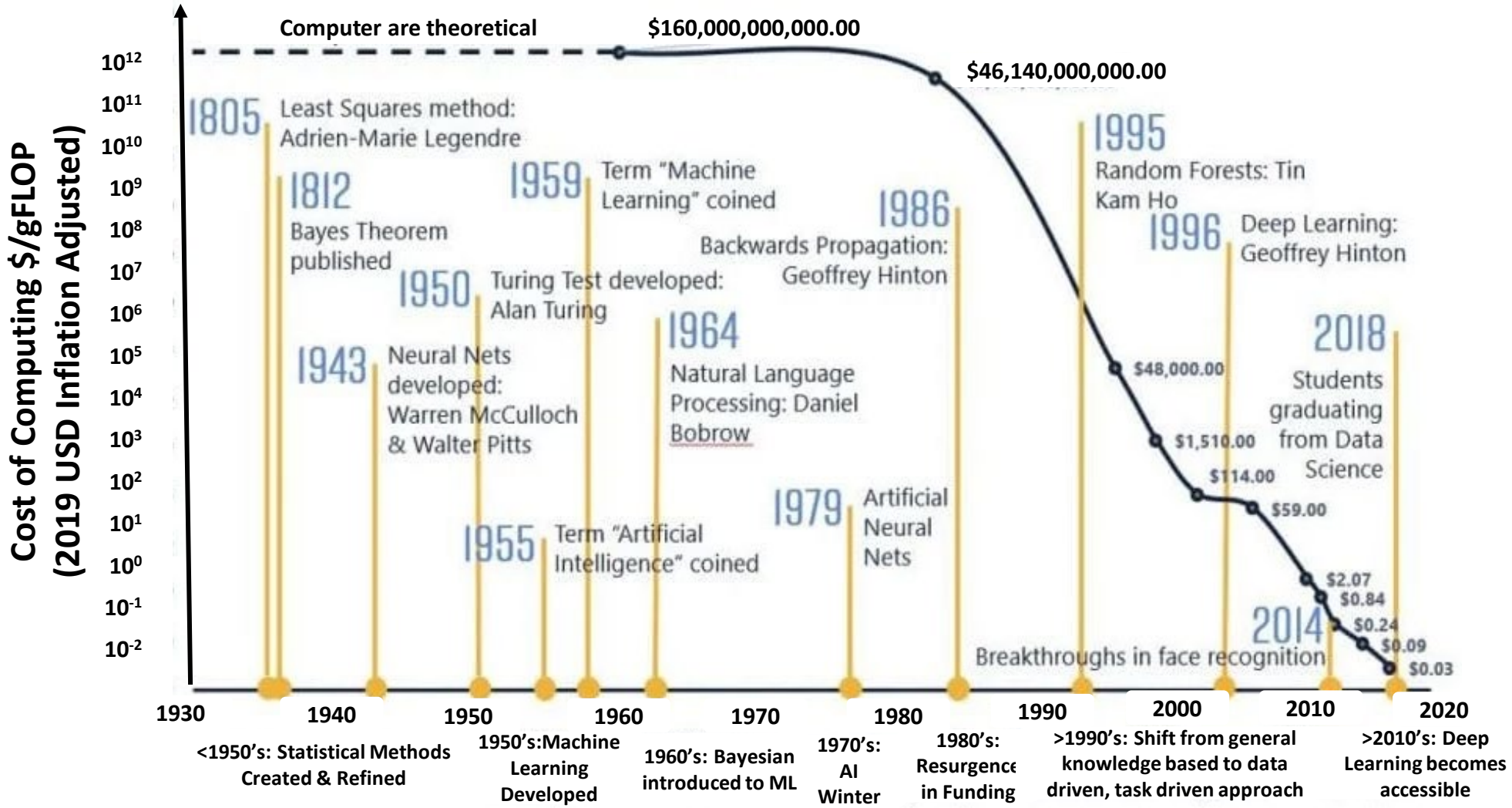
- **IPv6 over Low-Power Wireless Personal Area Networks (6LoWPAN)**
  - enables any low-power radio to communicate to the internet, including 804.15.4, Bluetooth Low Energy (BLE) and Z-Wave (for home automation)
- **ZigBee (based on the IEEE 802.15.4 standard)**
  - low-power, low-data rate wireless network used mainly in industrial settings
- **LiteOS**
  - Unix-like operating system (OS) for Wireless Sensor Networks (WSNs)
- **OneM2M**
  - machine-to-machine service layer that can be embedded in software and hardware to connect devices
- **Data Distribution Service (DDS)**
  - IoT standard for real-time, scalable and high-performance M2M communication
- **Advanced Message Queuing Protocol (AMQP)**
  - enables encrypted and interoperable messaging between organizations and applications
- **Constrained Application Protocol (CoAP)**
  - specifies how low-power, compute-constrained devices can operate in the IoT
- **Long Range Wide Area Network (LoRaWAN)**
  - support huge networks, such as smart cities, with millions of low-power devices

What about Standards?

[Source: Foote K., A Brief History of the Internet of Things, 2022]

The Rise of AI in Manufacturing

A perspective on the history of Artificial Intelligence (AI)



[Source: Adapted from Roy, 2020; Mittal S., 2020]

The Rise of AI in Manufacturing

From Smart Manufacturing (SMFG) towards Intelligent Manufacturing (IMFG)

Key Question: What relationship exists between SMFG and IMFG as well as Big Data and AI? How do they evolve?

AI evolution from the perspectives of content and control

DAI: Distributed Artificial Intelligence

AI 1.0: Symbolic AI

AI 2.0: AI – Machine Learning

AI 1.5D: Distributed AI

AI 1.5W: Web AI

IoS: Internet of Services

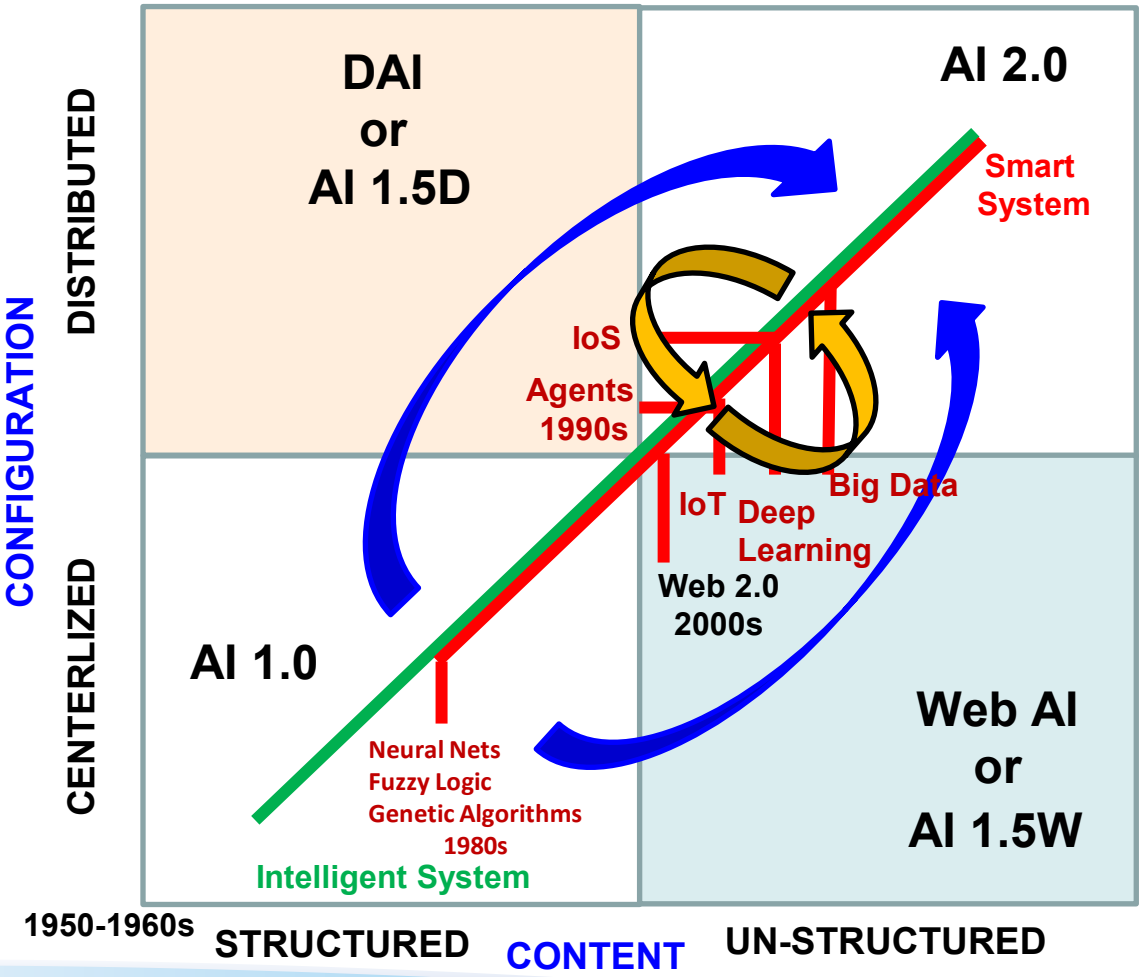
IoT: Internet of Things

DL: Deep Learning

NN: Neural Networks

FL: Fuzzy Logic

GA: Genetic Algorithms



DAI (AI 1.5D): evolution of collaborative multi agents (MAs), interoperability in messages and mutually learning from experience

AI 1.0: symbolic approaches characterized by structured contents and centralized control structures

A new version, called **Artificial Intelligence 2.0 (AI 2.0)**

Web AI (AI 1.5W): transition from 1.0 to 2.0 called 1.5X

[Source: Adapted from Yao, X., Zhou, J., Zhang, J., & Boër, C. R. (2017, September). From intelligent manufacturing to smart manufacturing for industry 4.0 driven by next generation artificial intelligence and further on. In 2017 5th international conference on enterprise systems (ES) (pp. 311-318). IEEE.]

The Rise of AI in Manufacturing

Definitions

SMART MANUFACTURING

- SMFG is the application of advanced smart technologies that enable rapid and stable manufacturing of new products, dynamic response to personalized product demands, and real-time optimization of production and supply chain networks
- SMFG platforms can integrate design, products, operations, and business systems that span shop floor, centers, factories, enterprises, and entire supply chains

[Source: Smart Manufacturing Leadership Coalition. Implementing 21st century smart manufacturing [Internet]. Schaumburg: Control Global; c2004–2020]

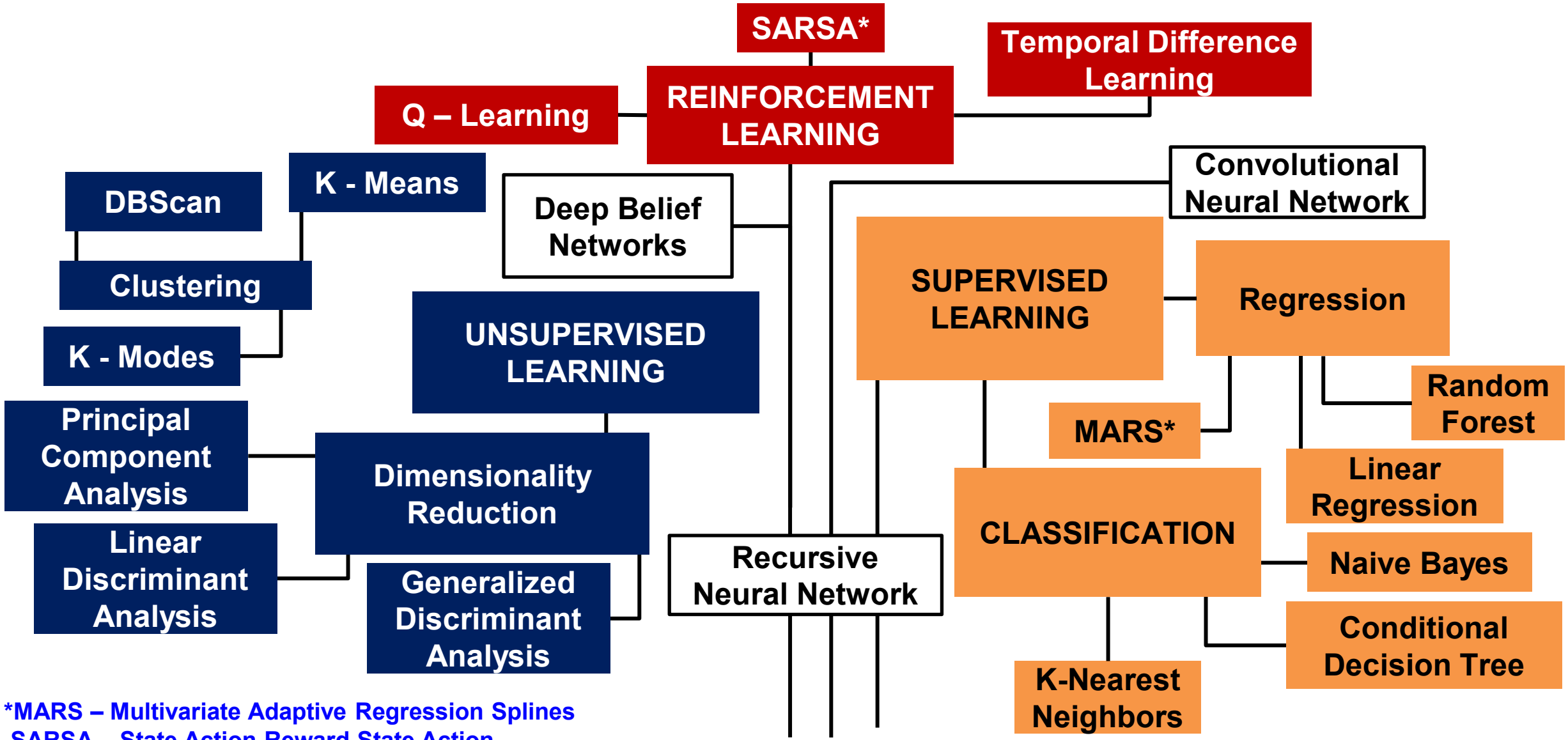
VS

INTELLIGENT MANUFACTURING

- IMFG automation performs manufacturing functions as if skilled humans are doing the task. IMFG systems utilize AI techniques to minimize human involvement and intervention into manufacturing activities and systems
- From a system integration view, IMFG combines manufacturing processes and systems with different degrees of machine intelligence, including AI-supported systems, AI-integrated systems, and totally Intelligent Manufacturing System (IMS)

[Source: Kusiak A. Computational intelligence in design and manufacturing. New York: John Wiley & Sons; 2000; Oztemel E. Intelligent manufacturing systems. In: Benyoucef L, Grabot B, editors. Artificial intelligence techniques for networked manufacturing enterprises management. London: Springer; 2010. p. 1–41.]

AI Algorithms in Manufacturing



*MARS – Multivariate Adaptive Regression Splines
SARSA – State Action Reward State Action

What is the potential of AI in Manufacturing?

Challenge 2:
Digitized Products

Mass Personalization Manufacturing Paradigm

Challenge 1:
The personalization of Mass Products

Challenge 3:
Compliance with Environmental Standards & Wastage

[Source: AI In Manufacturing, PwC, 2021]

AI & Mass Personalization in Industry 4.0

How Can Artificial Intelligence Be Applied in Manufacturing?

✓ AI and Machine Learning are giving manufacturers an unprecedented ability to:

1. improve throughput,
2. optimize their supply chain, and
3. accelerate research and development

✓ What's Driving the Urgency to Adopt AI?

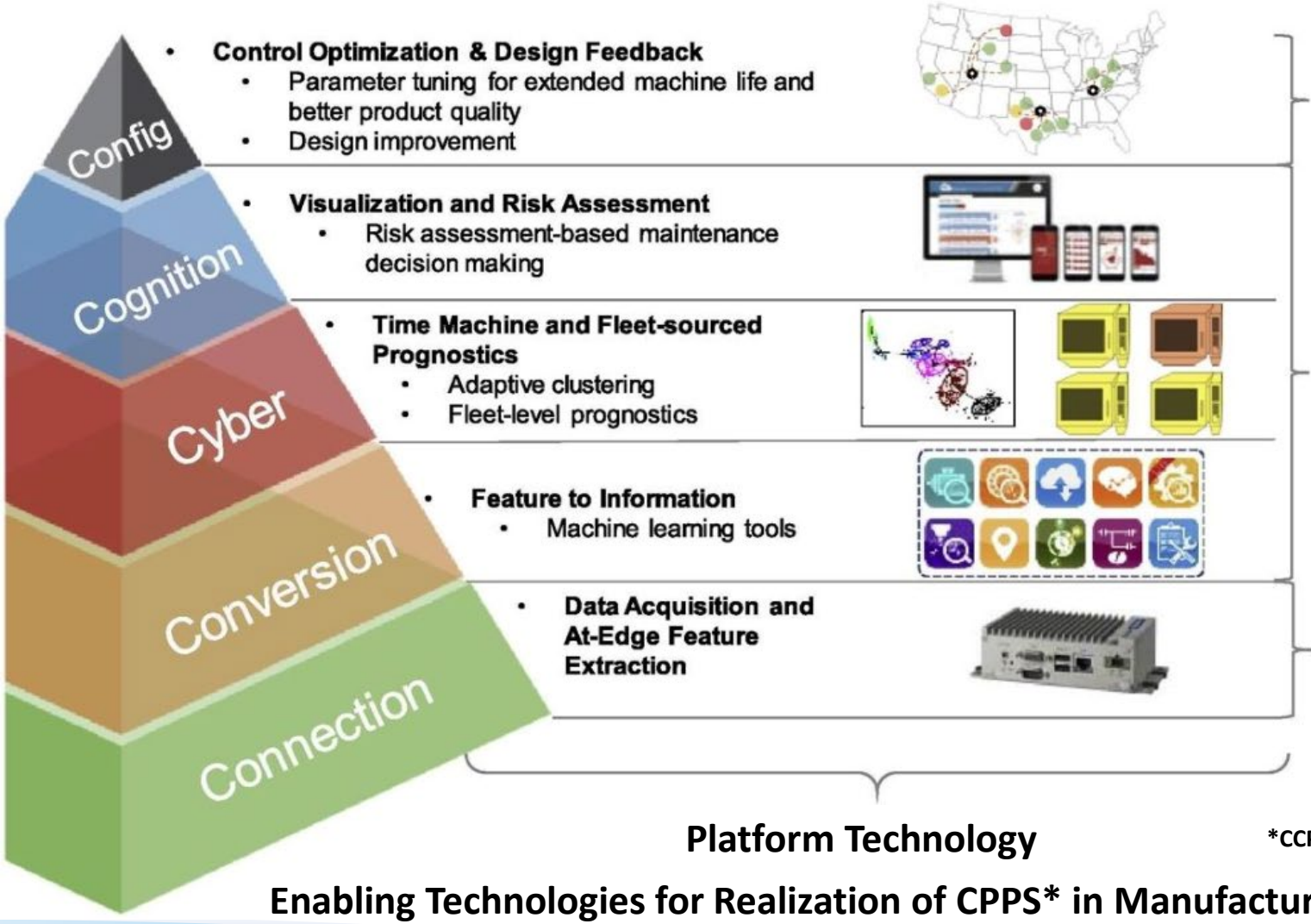
1. High revenue volatility
2. Need to continuously find cost savings
3. Short production times
4. Increased regulation and inspections
5. Learning and adaptability on the factory floor
6. Manufacturing capacity and supply chain demands
7. Increased need for small-batch and/or customized goods

[Source: Renner L. 2020]

AI & Mass Personalization in Industry 4.0

Industrial Artificial Intelligence can empower smart manufacturing

How Can AI Be Applied in Manufacturing?

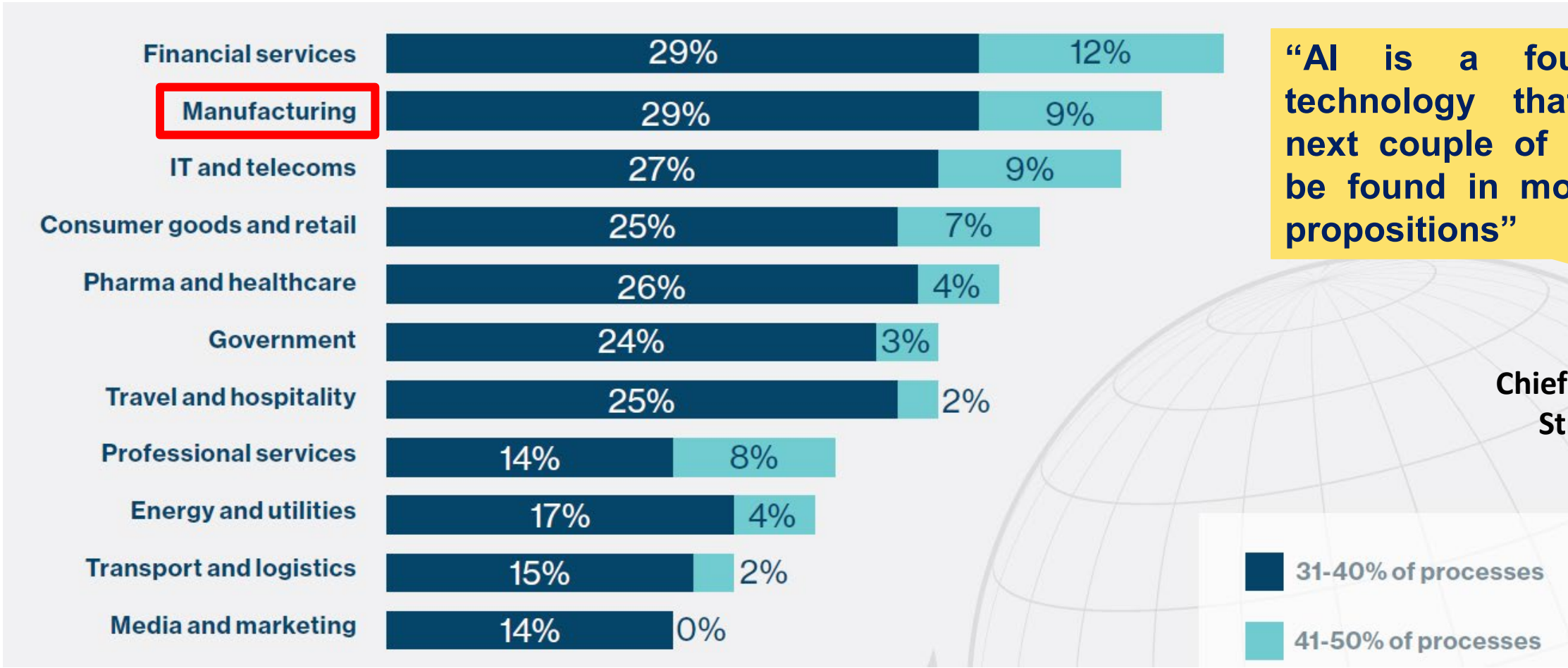


*CCPS: Cyber Physical Production Systems

Enabling Technologies for Realization of CPPS* in Manufacturing

[Source: Jay Lee et al., 2019]

Making Business Sense of AI



"AI is a foundational technology that in the next couple of years will be found in most of our propositions"

Jeroen Tas
Chief Innovation & Strategy Officer
Philips

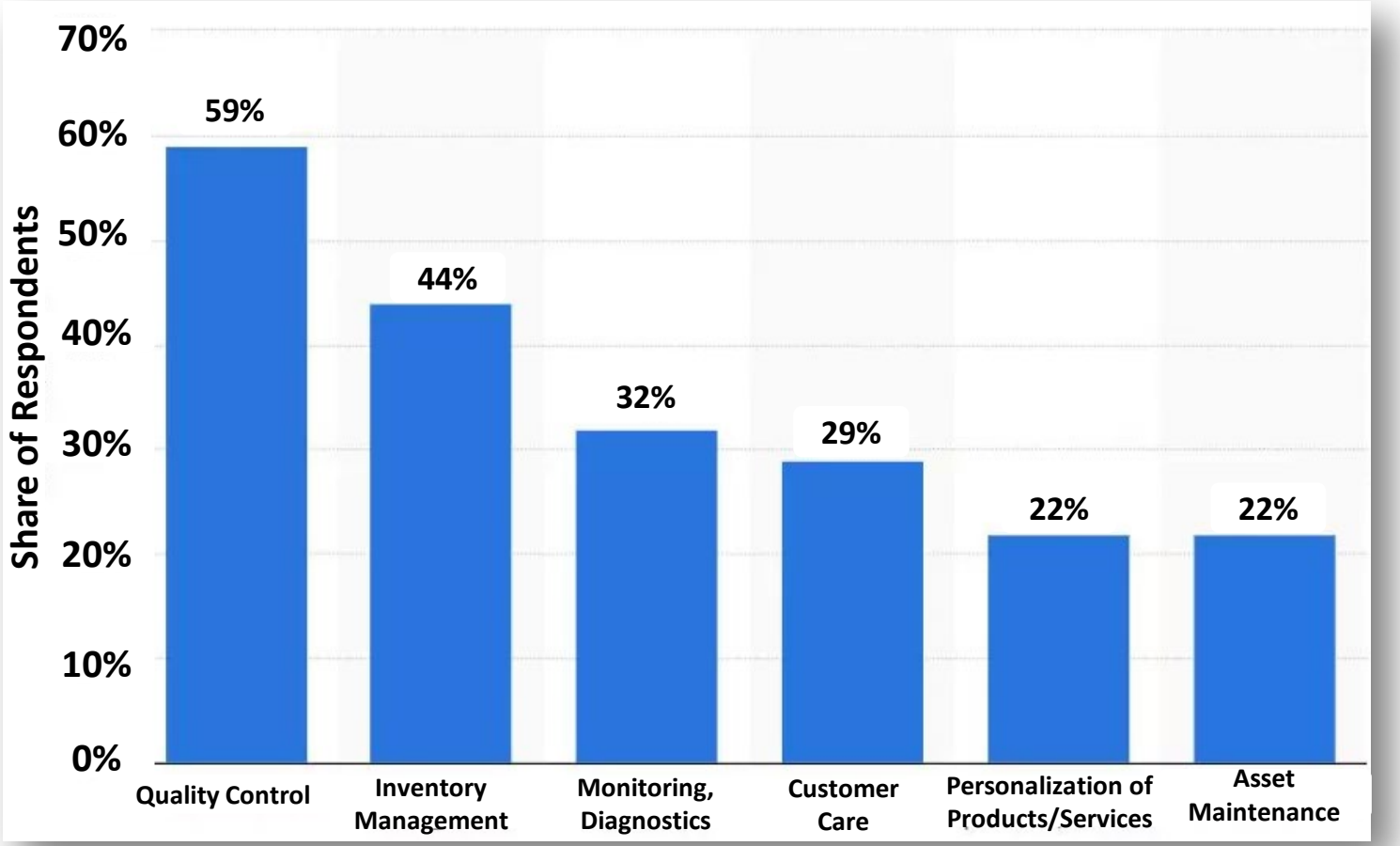
In 2023, approximately what percentage of business processes will use AI? (% of respondents)

[Source: MIT Technology Review Insights survey, 2020

The Rise of AI in Manufacturing

Why AI is Critical to the Future of the Manufacturing World?

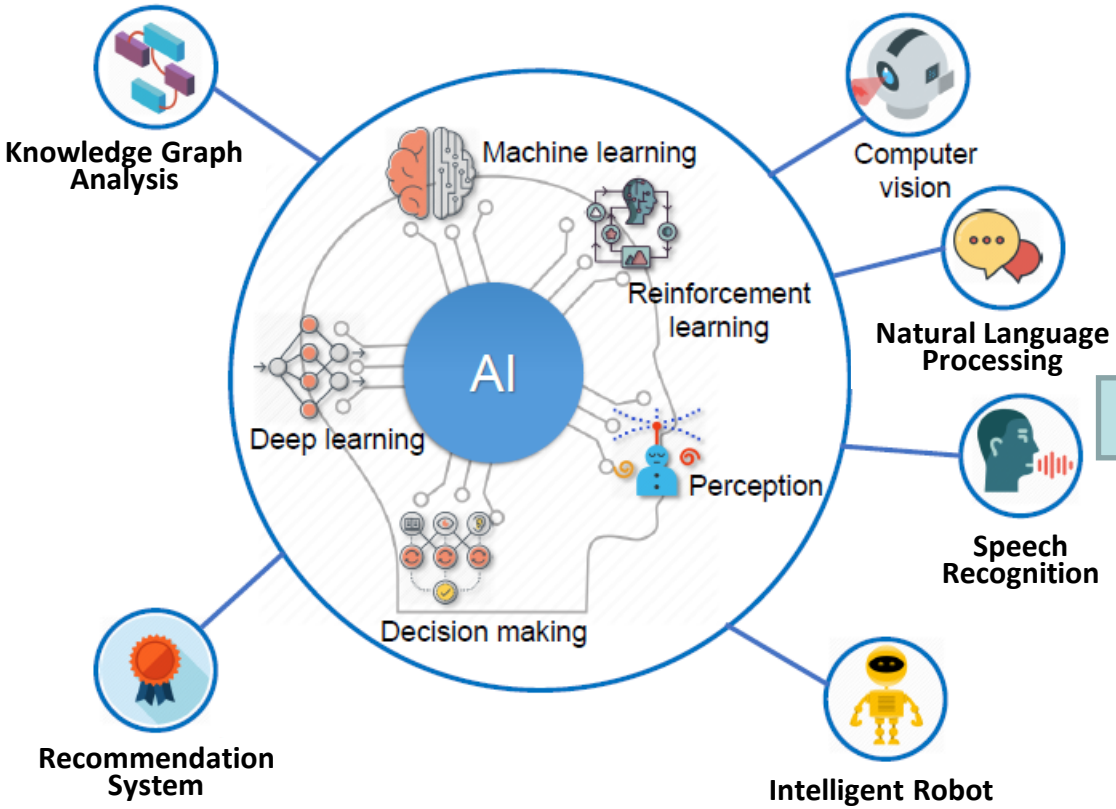
- According to MIT Survey (2020) ~60% of manufacturers are using AI to improve product quality, achieve greater speed and visibility across the supply chain, and optimize inventory management



[Source: Dilmegani C, 2022]

The Rise of AI in Manufacturing

Overview of AI Technologies in Industry 4.0



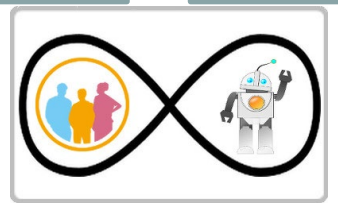
Customized Product Design	Customer Management	After-sales Service
Manufacturing Management	Customized Product Manufacturing	Market Analysis
Manufacturing Maintenance	Customized Product Logistics	...

Customized/Personalized Manufacturing

[Source: Adapted from Wang L., 2019]

The four types of AI in Mass Personalization

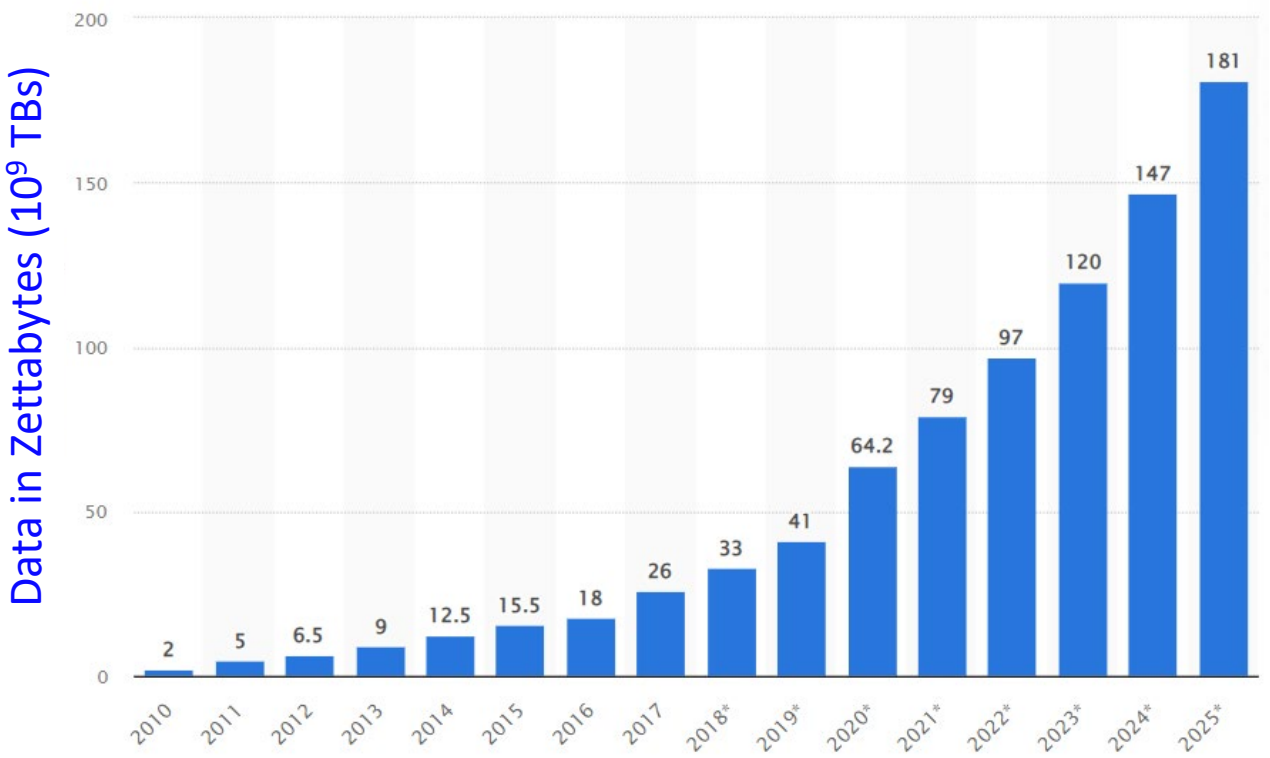
	Human in the Loop	No Human in the Loop
Hardwired/ Specific Systems	**Assisted intelligence** AI systems that assist humans in making decisions or taking actions. Hard-wired systems that do not learn from their interactions	**Automation** Automation of manual and cognitive tasks, both routine and non-routine. This does not involve new ways of doing things - it automates existing tasks.
Adaptive Systems	**Augmented intelligence** AI systems that augment human decision making and continuously learn from their interactions with humans and the environment	**Autonomous intelligence** AI systems that can adapt to different situations and can act autonomously without human assistance



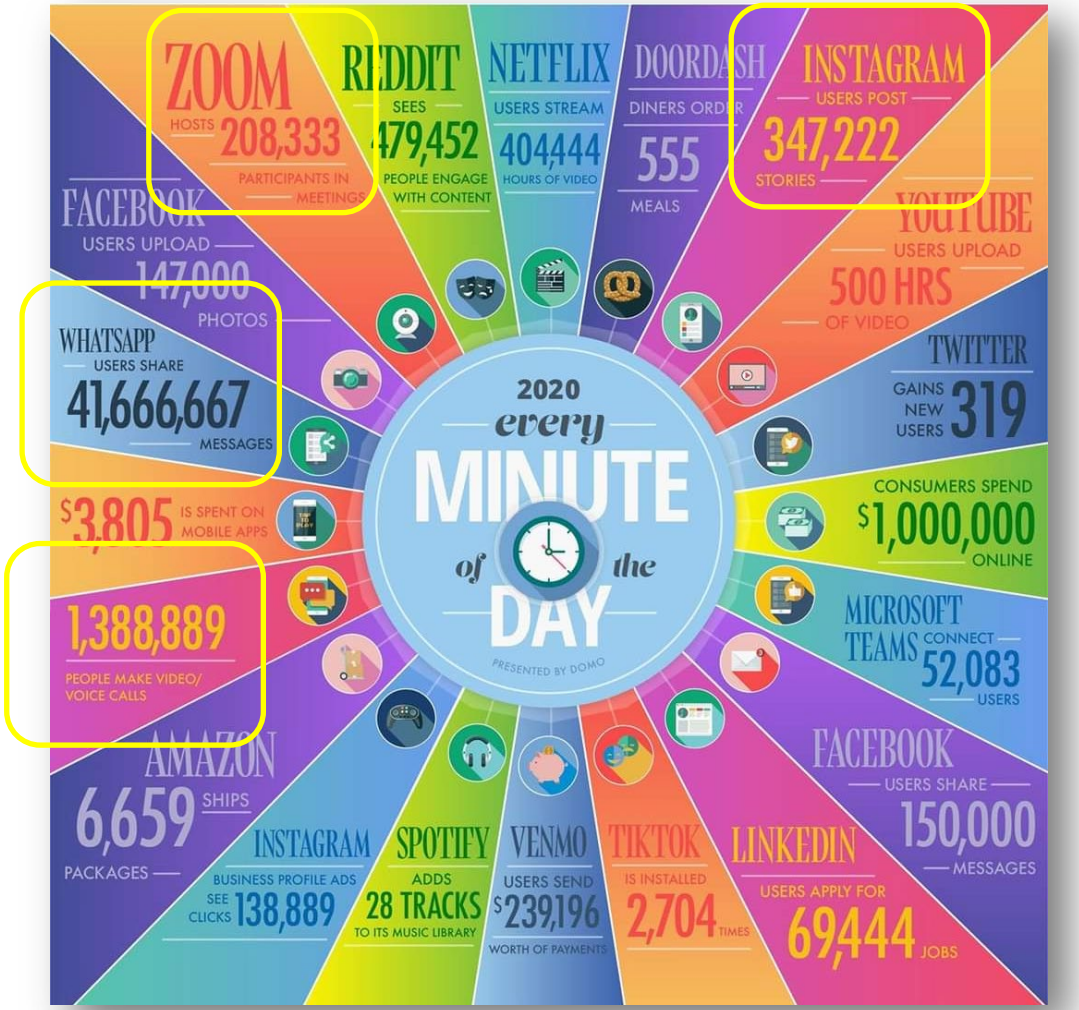
Industry 4.0 Key Technologies enabled Mass Personalization

Industry 4.0 – Big Data Sets

Big Data ≡ data that requires more processing resources to PRODUCE VALUE



[Source: https://www.statista.com/statistics/871513/worldwide-data-created//]



AI in Manufacturing: Examples

French food manufacturer Danone Group uses Machine Learning to improve its demand forecast accuracy Results:

- 20% decrease in forecasting errors
- 30% decrease in lost sales
- 50% reduction in demand planners' workload

[Source: Whiteside J., 2021]

Fanuc (Japanese automation company) uses robotic workers to operate its factories round-the-clock:

- Production of essential components for CNCs and motors
- Operation of all production floor machinery non-stop
- Facilitation of continuous monitoring of all operations

[Source: FANUC]

AI & IIoT Applications

AI in Manufacturing: Examples

Porsche

Use autonomous guided vehicles (AGVs) to

automate significant portions of automotive manufacturing

The AGVs take vehicle body parts from one processing station to the next, eliminating the need for human intervention and making the facility resilient to disruptions like pandemics

[Source: Porsche/Siemens]

BMW Group uses automated image recognition for:

- Quality checks, inspections, and
- Elimination of pseudo-defects (deviations from target despite no actual faults)

Result: high levels of precision in manufacturing

[Source: BMW Group, 2022]

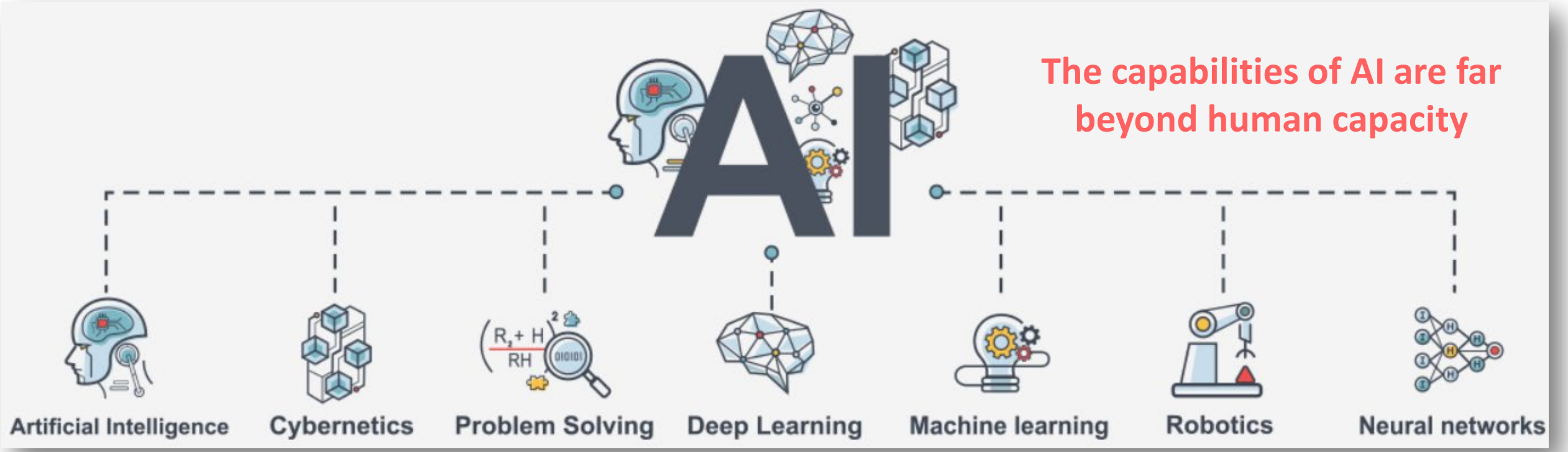
Personalization Trends for 2022

1. Increase in 1-1 Experiences
2. Personalized Mobile Customer Experiences
   - ✓ the share of mobile commerce in all e-commerce is around 73% by 2021
   - ✓ 79% of smartphone users have made a purchase online using their mobile devices in the last 6 months
3. Image Recognition
4. AI-Powered Personalization
5. Data Privacy and Cookieless Personalization
6. Personalizing Longer Customer Journeys
7. Increasing Importance of Customer Loyalty
8. Omnichannel Personalization
9. Anonymous Visitor Personalization

[Source: BCG Global AI Survey, 2018; BCG Analysis]

Discussion

The Basics of AI in Operations



7 BENEFITS OF AI IN MANUFACTURING

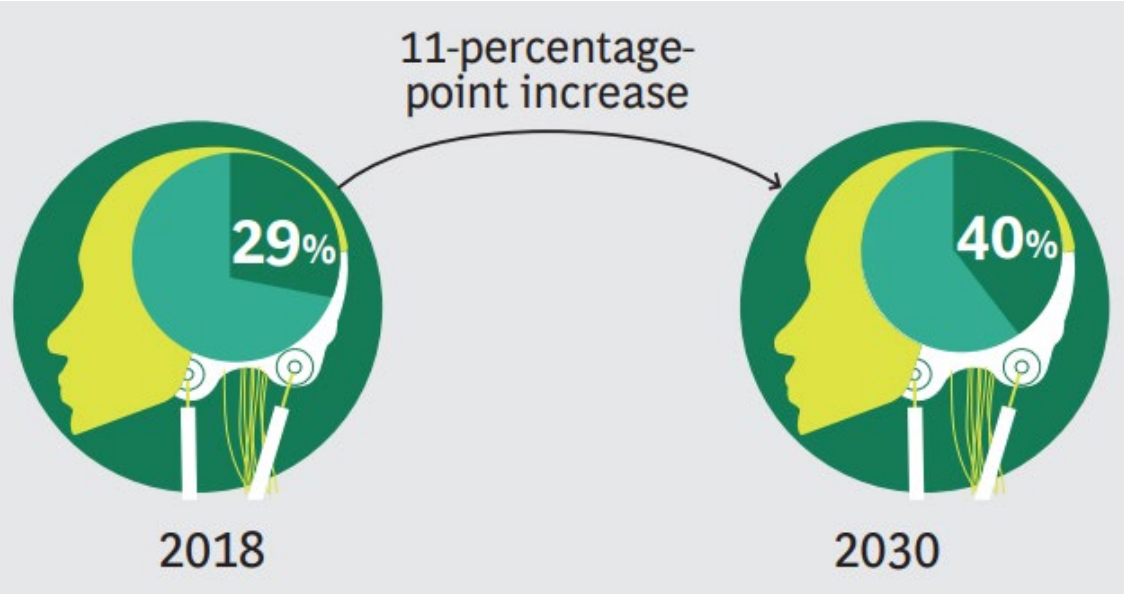
1. Direct Automation
2. 24/7 Production
3. Safety
4. Lower Operational Costs
5. Greater Efficiency
6. Quality Control
7. Quick Decision Making

[Source: King et al., 2019]

Discussion

AI will become Increasingly Important during the Next Decade

✓ Relevance to Improving Productivity



AI rated as the most important lever for productivity improvement

✓ Impact on Conversion Costs

Reduction in Conversion Costs enabled by Fully Implementing AI in operations

[Source: BCG Global AI Survey, 2018; BCG Analysis]

Why AI is Critical to the Future of the Manufacturing World

- ✓ Survey results about companies using AI conclude that:
  - Cost Savings
  - Revenue Growth

16% of those surveyed noticed a **10-19% decrease in costs**

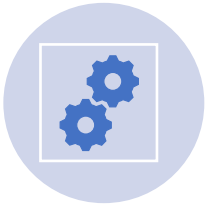
18% saw a **6-10% increase in overall revenue**

[Source: McKinsey 2020, The State of AI]

- ✓ AI can improve forecasting accuracy in manufacturing by 10-20%, which translates to a **5% reduction in inventory costs and a 2-3% increase in revenues**
- ✓ Benefits of AI in manufacturing include (among others):
  - Predictive maintenance to reduce unplanned downtime
  - Operate near-shore facilities using advanced manufacturing technologies (3D printers, robots) to reduce labor costs and stay resilient despite supply chain disruptions
  - Create optimal, AI-enabled generative design to ensure efficiency and reduce waste

[Source: BCG Global AI Survey, 2018; BCG Analysis]

The Factories of the Future Should…



Detect defects throughout the production process

The American Society for Quality estimates that for many organizations this cost of quality is as high as 15-20% of annual sales revenue, or billions of dollars annually for larger manufacturers

[Source: Wariach, Reinbacher, 2021]

Deploy predictive maintenance to reduce downtime

AI-based predictive maintenance can boost availability by up to 20% while reducing inspection costs by 25% and annual maintenance fees by up to 10%

[Source: McKinsey & Company, 2021]

Respond to real-time changes in demand across the supply chain

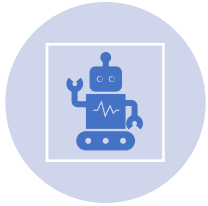
According to McKinsey, 61% of manufacturing executives report decreased costs, and 53% report increased revenues as a direct result of introducing AI in the supply chain. Further, more than one-third suggested a total revenue bounce of more than 5%

[Source: McKinsey & Company, 2019]

Validate whether intricate goods like microchips have been perfectly produced

According to a McKinsey study, the application of AI/ML use cases delivers the most value—about 40% in optimizing semiconductor manufacturing efficiencies. These use cases significantly improve the throughput of a Fabrication Plant (Fab). With consistent application, a Fab can expect cost-cutting to the range of 17%

[Source: McKinsey & Company, 2021]



Reduce costs of small-batch or single-run goods, enabling greater customization

By 2020, 85% of customer interaction in retail will be managed by AI, according to Gartner

[Source: Arthur R., 2017]

Improve employee satisfaction by shifting mundane tasks to machines

29% of US employees are engaged with their work and feel fulfilled by their duties, while another report states that 83% of US workers believe they could be more constructive if they had better productivity monitoring software to do so

[Source: Enlear Academy, 2021]

AI in Smart Factory Operations

✓ AI technologies have several applications in manufacturing operations:

Machine Vision

Sensing the production environment through visual, x-ray, or laser signals—for example, using a camera to classify parts and products

Speech Recognition

Processing speech and other acoustic signals—for example, using a virtual assistant similar to Alexa or Siri to process comments from operators about quality issues

Natural-Language Processing

Parsing text and interpreting its most probable meaning—for example, creating summaries from different performance reports

Information Processing

Extracting knowledge from unstructured text and retrieving answers to queries—for example, by searching in production-related text reports

[Source: Mewari and Kamath, 2022]

AI in Smart Factory Operations

✓ AI technologies have several applications in manufacturing operations:

Learning from Data

Predicting or classifying values on the basis of empirical production-related data—for example, using historical data generated by machines and processes to predict events

Planning and Exploring

Choosing a sequence of actions that maximizes a specified goal—for example, enabling an automated guided vehicle (AGV) to identify its best next movement

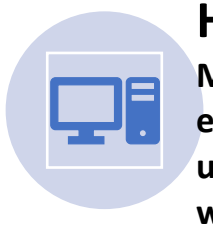
Navigation and Movement

Maneuvering through physical environments—for example, enabling an AGV to move and optimize its routes autonomously within a factory

Speech Generation

Communicating with humans via written text or acoustic speech—for example, reading instructions aloud

Handling and Control



Manipulating physical objects—for example, enabling robots to pick unsorted parts from a storage bin without requiring specific training

Supply Chain Optimization

Today's supply chains are super complex networks to manage, with thousands of parts and hundreds of locations. With machine learning algorithms, manufacturers can define the optimized supply chain solution for all their products.

[Source: Mewari and Kamath, 2022]

Discussion

Open Issues & Potential Solutions in AI through Machine Learning

Diverse & Unstructured Data	Potential Solutions	Effective Big Data Analytics
Heterogeneity of Systems		Large Number of Training Data; Diverse & Real-World Industrial Areas
Complexity & Computing Power		Use modern GPUs or FPGAs; Multiple Fog Devices; Parallel ML Algorithms
Security Threats		Software and Hardware Security Countermeasures

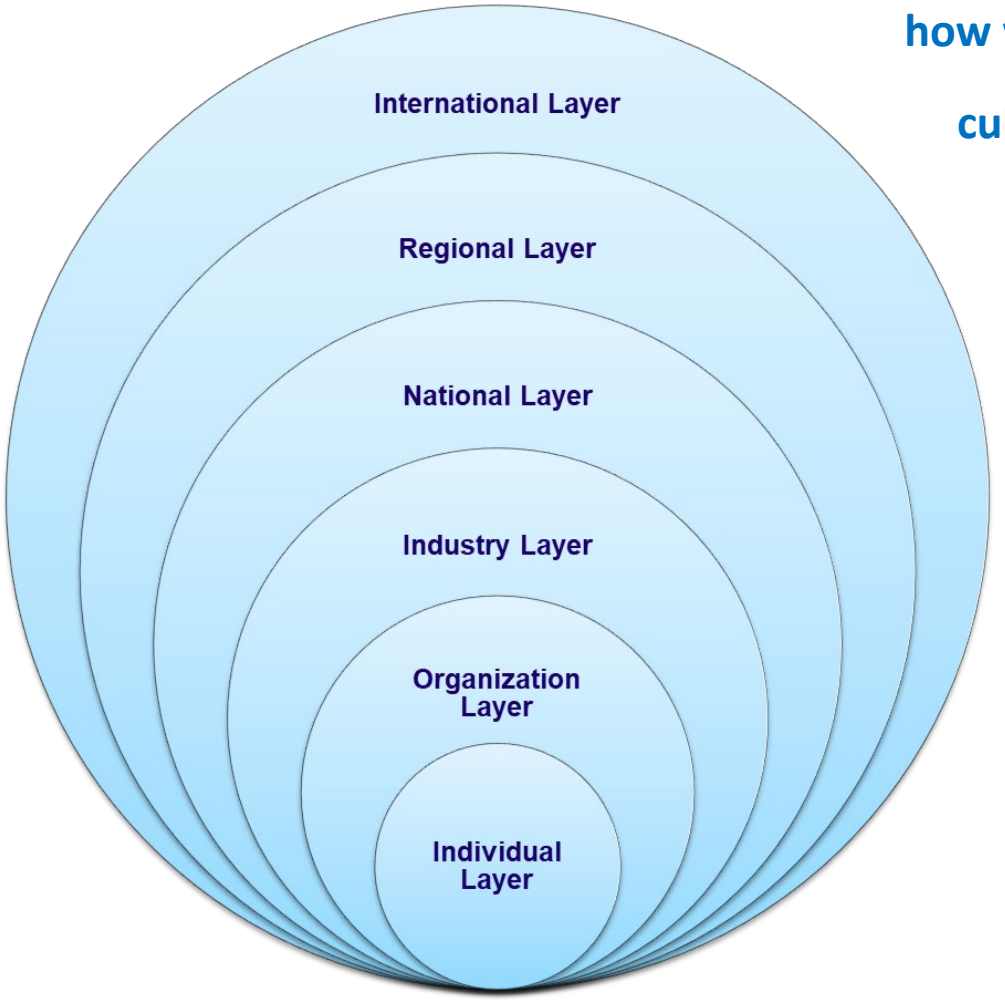
GPU: Graphical User Interface
FPGA: Field-programmable gate array
ML: Machine Learning

Open issues and potential solutions towards tackling faults in Industry 4.0 through ML

[Source: Angelopoulos et al., 2019]

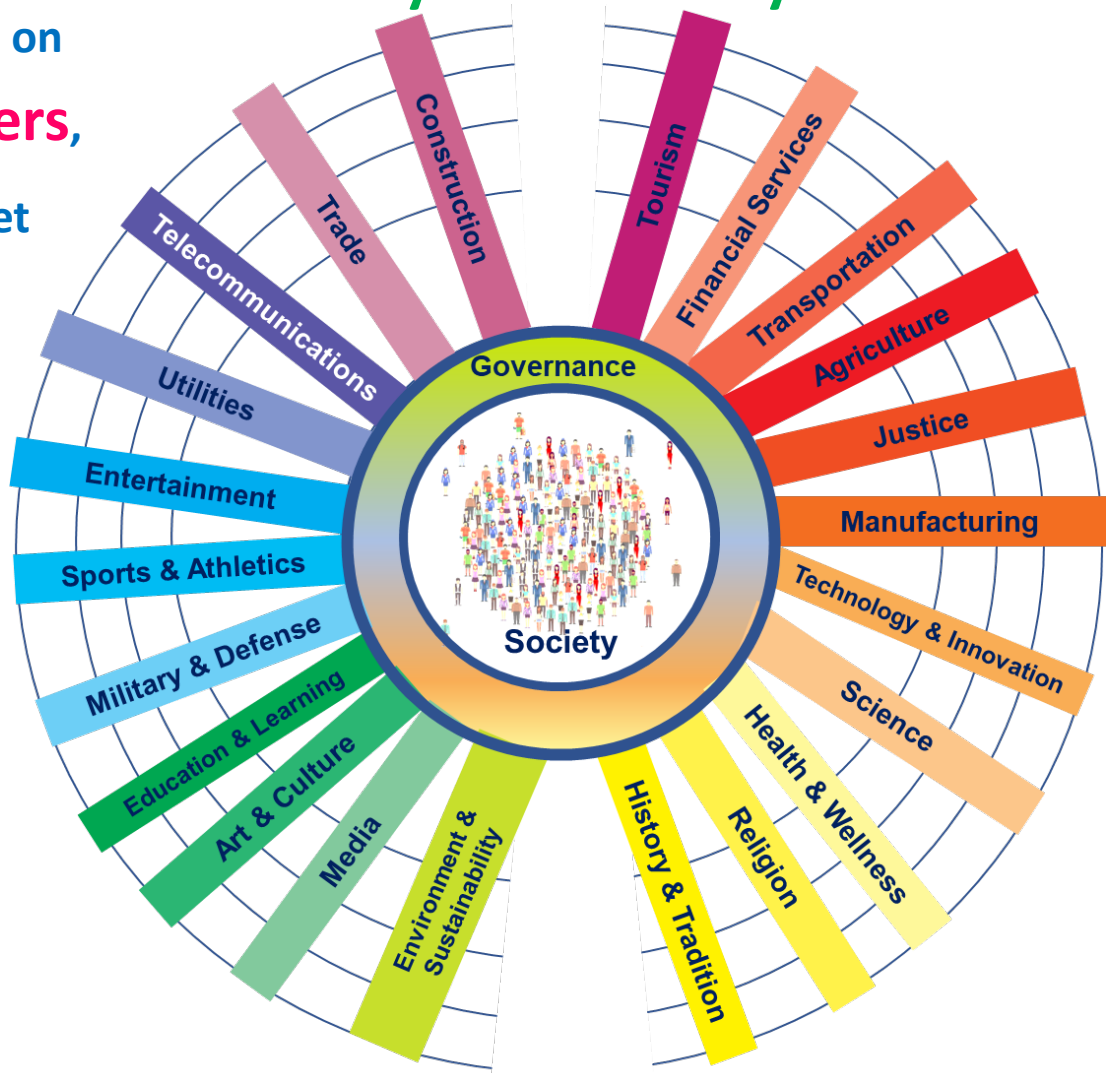
Looking Ahead – Society 4.0

Traditional Society



Universities should focus on how we develop our **careers**, cultivate our **skills**, meet people and nurture **relationships**

Industry 4.0 & Society 4.0



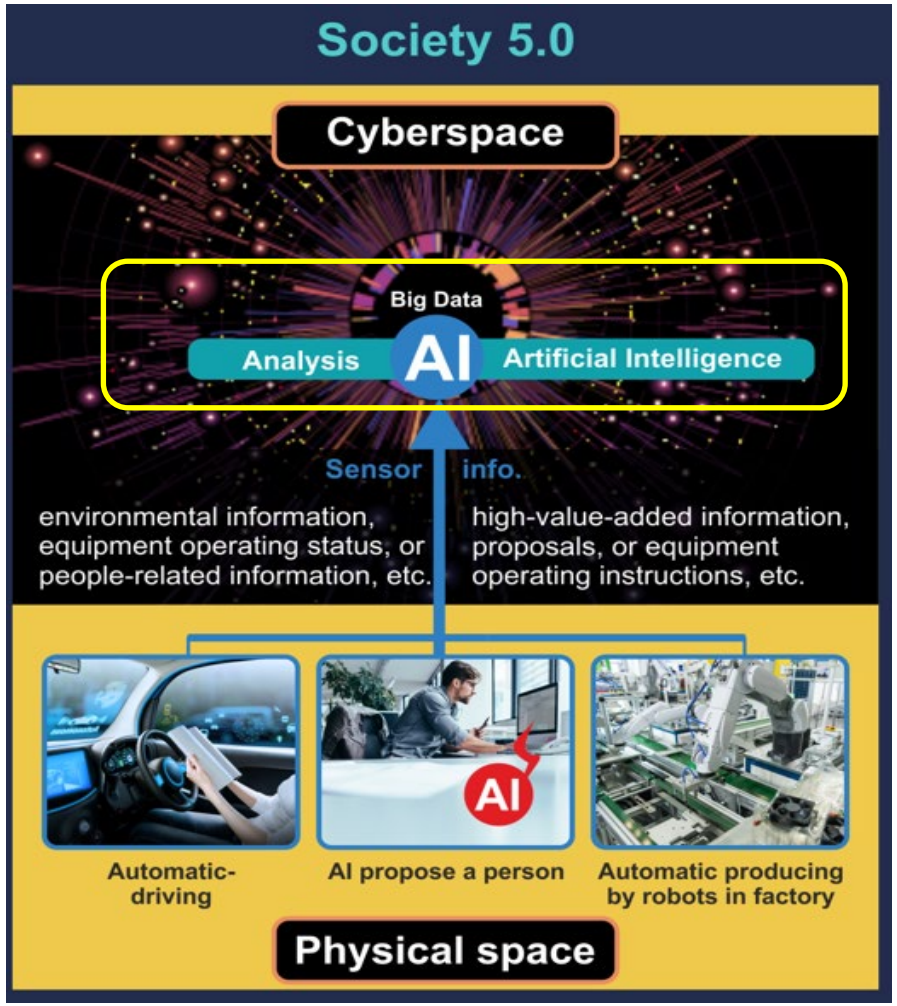
To fully collaborated and integrated systems

Looking Ahead – Society 5.0

Society 5.0 – Digital Platforms for Value Creation

New Skills are

REQUIRED



[Source: https://news.cgtn.com/news/2019-06-28/What-is-Society-5-0-at-the-G20-summit--HT4YQ8BXlC/index.html]

Looking Ahead – Society 5.0

Enablers for Integration of Society 5.0

- Japanese students may soon be saying **goodbye to traditional divisions** between grades and subjects in a new **focus on human skills to get the most out of technology**

"The essence of Society 5.0 is that it will become possible to quickly elicit the suitable solution that meets the **needs of the most individuals**"

[Japan's Prime Minister Shinzo Abe at the International Conference of the Future of Asia in 2017]

Educational Approaches

1. Make grade progression more **flexible**
   - ✓ **Ensure there are NO GAPS IN UNDERSTANDING**

2. Removing the barriers between **subjects** and **discipline**
   - ✓ Education system in which subjects like **math, data science and programming** are **BASIC REQUIREMENTS**, as are subjects such as **philosophy and languages**

[Source: https://foreignpolicy.com/sponsored/how-japan-is-preparing-its-students-for-society-5-0/.]

Looking Ahead: Industry 5.0 – Digital Platforms for Value Creation

Industry 5.0 – European Commission

- ✓ Aims beyond efficiency and productivity as the sole goals, and reinforces the role and the contribution of Industry to Society
- ✓ It complements the existing "Industry 4.0" approach by specifically putting **Research** and **Innovation** at the service of the transition to a **Sustainable**, **Human-Centric** and **Resilient** European Industry

Why Industry 5.0

- ✓ Industry 5.0 brings benefits for **Industry**, **Technicians** & **Society**
- ✓ It empowers Technicians, as well as addresses the evolving skills and training needs of employees. It increases the competitiveness of industry and helps attract the best talents

[Source: European Commission (2020https://ec.europa.eu/info/research-and-innovation/research-area/industrial-research-and-innovation/industry-50_en#publications]

Looking Ahead – Industry 5.0

Looking Ahead: Industry 5.0 – Digital Platforms for Value Creation

Human CENTRIC

RESILIENT

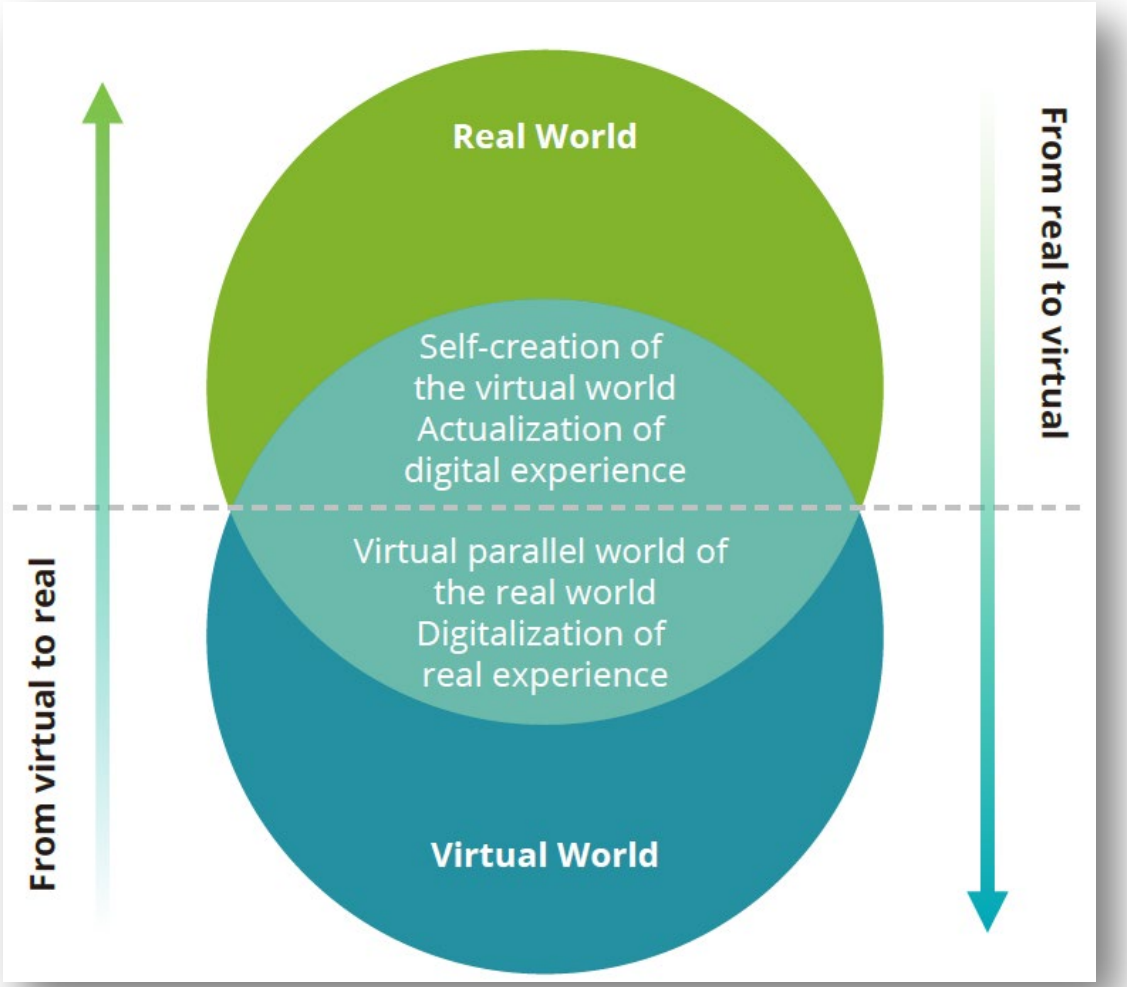
SUSTAINABLE

[Source: The 3 pillars of Industry 5.0 according to the EC – human-centric, resilient and sustainable]

Platforms for Value Creation: Metaverse

Definition

- ✓ "The concept of a fully immersive virtual world where people gather to socialize, play, and work"
- ✓ It is a simulated digital environment that combines Augmented Reality (AR), Virtual Reality (VR), Blockchain, and Social Media principles to create areas for rich user interaction that imitate the real world [Laeeq K., 2022]
- ✓ "A virtual environment where you can present yourself with people in digital spaces. You can kind of think of this as an embodied Internet that you're inside of, rather than just looking at" [Zuckerberg, Meta CEO]



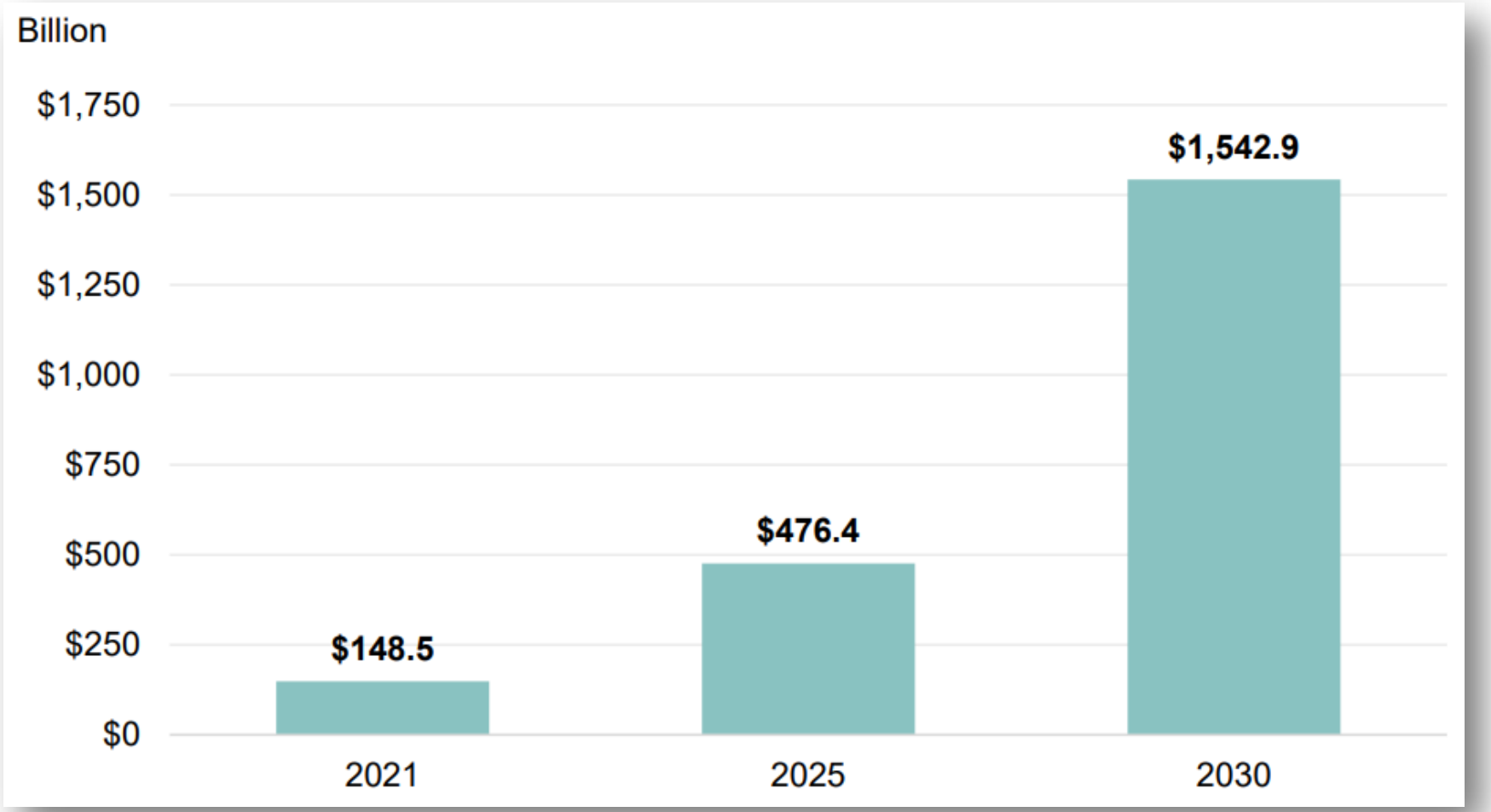
Two Development Paths of Metaverse

[Source: Deloitte Research and analysis, Global XR industry insight | Metaverse: unlocking imagination and embracing reality]

Looking Ahead - Metaverse

Platforms for Value Creation: Metaverse

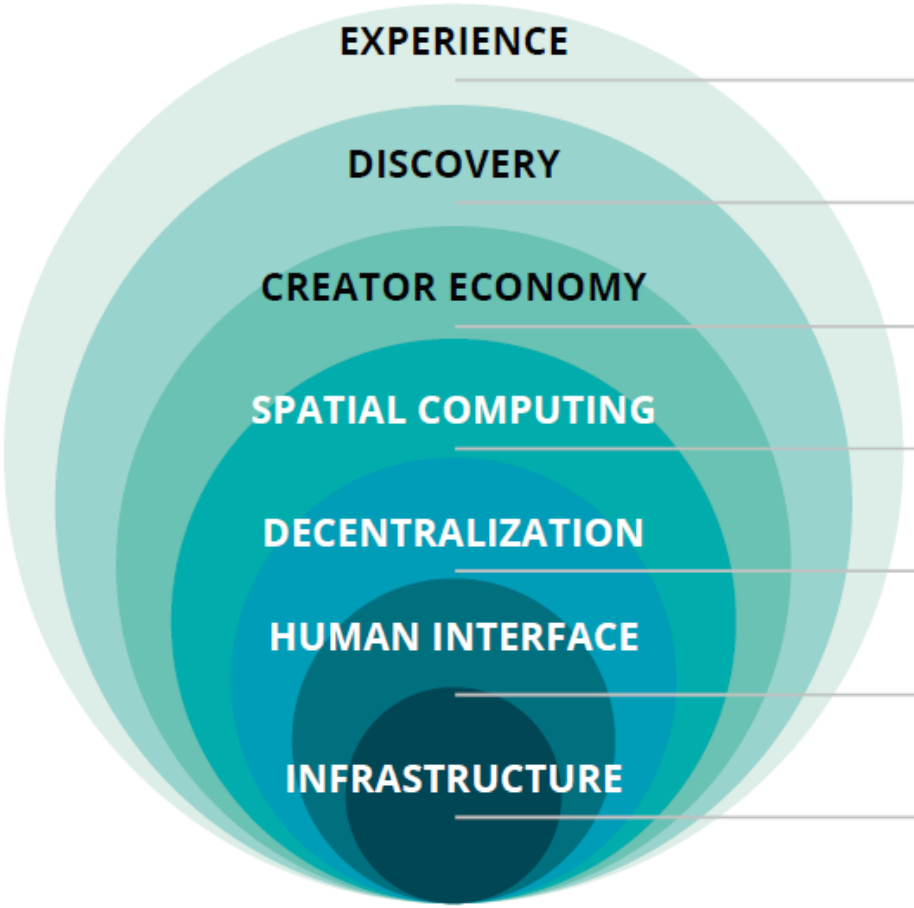
Market Size, 2021 - 2030



[Source: PWC, "To work for everyone, the Metaverse must be decentralized", Cointelegraph, November 2021]

Platforms for Value Creation: Metaverse

The Seven Layers of the Metaverse



Games, Social, Esports, Theater, Shopping	Application Products & Operation Ecosystems
AD Networks, Social curation, Ratings, Stores	
Design Tools, Asset Markets, Workflow, Commerce	
3D Engines, XR, Multitasking, Geospatial Mapping	Development Tools
Edge Computing, AI Agents, Microservices, Blockchain	
Wearables, Haptic Gestures	Infrastructure & Equipment
5G, WIFI 6, Cloud, chip technology, GPUs	

[Source: Deloitte Research and analysis, Global XR industry insight | Metaverse: unlocking imagination and embracing reality]

Looking Ahead - Metaverse

Platforms for Value Creation: Metaverse

Which are the Key Principles in the Metaverse?

Decentralized

Community-driven protocols, without central oversight and governance

Interconnected & Interoperable

Open standards enable real-time access to shared virtual worlds for unlimited users

Safe & Trustworthy

Ensuring safety, cybersecurity and data privacy from the start and throughout the metaverse

[Source: GSMA Intelligence, 2022]

Platforms for Value Creation: Metaverse

Opportunities and Applications

Which are the Key Enabling Factors?

5G Networks and Beyond

Wearable Technology

Artificial Intelligence

Avatars

Non-fungible tokens (NFTs)

[Source: GSMA Intelligence, 2022]

Conclusion

- **It is time to get personalized!**
  - Brands need to have the right personalization tool that is easy to use and comprehensive
- The trend towards personalization is not new, but it's **becoming an increasingly important part of businesses**
- As **AI progresses** and **models improve**, enterprises are building the unreal world
- Elevating **authenticity** within the organizations is very important
- Authenticity is the **compass** and the **framework** that will guide the marketplace to use **AI in a genuine way** across industries, use cases, and time, by **considering provenance, policy, people, and purpose**
- It will unlock **new attitudes towards and experiences with AI**, unleashing the benefits of the unreal world

Conclusion

AI as a building block of a resilient post-pandemic world

- All kinds of organizations are looking ahead to build **resilient systems** that can better withstand future disruptions such as pandemics, natural disasters, cyberthreats, and other destabilizing scenarios

The Pandemic Battle at hand

- "IBM" and "The Weather Company", has released the **Weather Channel Interactive Incidents Map**, which presents the latest COVID-19 data at the local level
  - **IBM Cognos:** IBM Global COVID-19 Statistics Dashboard - Robust tool for deeper analysis

Aiding overwhelmed help desks

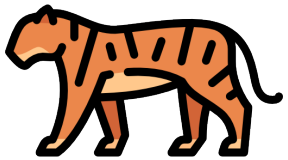
- IBM trained Watson Assistant on trusted information from the CDC and other sources and offered it at no cost for at least 90 days to governments, businesses, healthcare and academic organizations
  - **Tool: Natural Language Processing (NLP)**

Repairing broken supply chains

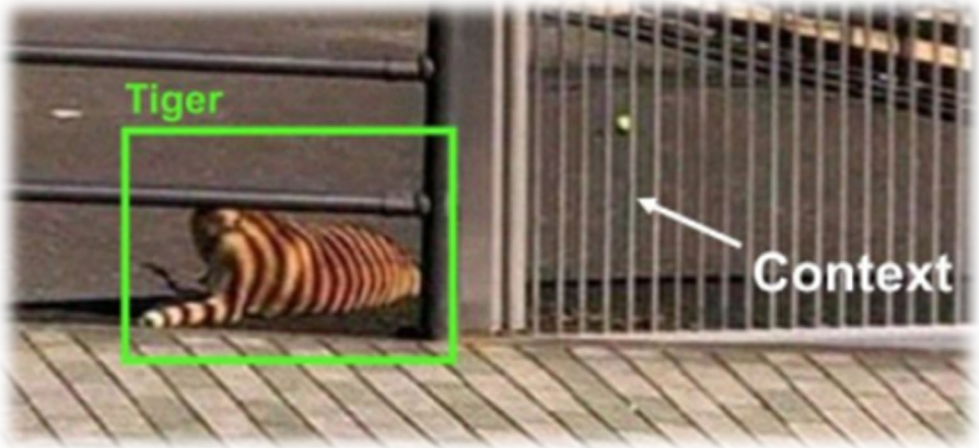
- Smarter supply chains powered by AI can be built for resilience and flexibility during such disruptions
- AI-infused supply chain is animated by sensors, RFID tags, actuators, GPS, news media data, and more
  - **Tool: Machine Learning**

Conclusion

Data without CONTEXT is just USELESS



From Tiger to Dog



Questions?

[Source: Twitter]

Key References

- Mourtzis, D. (2022). The mass personalization of global networks. In Design and Operation of Production Networks for Mass Personalization in the Era of Cloud Technology (pp. 79-116). Elsevier.
- Mourtzis, D. (2020). Simulation in the design and operation of manufacturing systems: state of the art and new trends. International Journal of Production Research, 58(7), 1927-1949.
- Jazdi, N., Talkhestani, B. A., Maschler, B., & Weyrich, M. (2021). Realization of AI-enhanced industrial automation systems using intelligent Digital Twins. Procedia CIRP, 97, 396-400.
- Mourtzis, D., & Doukas, M. (2014). The evolution of manufacturing systems: From craftsmanship to the era of customisation. In Handbook of research on design and management of lean production systems (pp. 1-29). IGI Global.
- ElMaraghy, H., Monostori, L., Schuh, G., & ElMaraghy, W. (2021). Evolution and future of manufacturing systems. CIRP Annals, 70(2), 635-658.
- Hu, S. J. (2013). Evolving paradigms of manufacturing: From mass production to mass customization and personalization. Procedia Cirp, 7, 3-8.
- Mourtzis, D., & Doukas, M. (2014). Design and planning of manufacturing networks for mass customisation and personalisation: challenges and outlook. Procedia Cirp, 19, 1-13.
- Yao, X., Zhou, J., Zhang, J., & Boër, C. R. (2017, September). From intelligent manufacturing to smart manufacturing for industry 4.0 driven by next generation artificial intelligence and further on. In 2017 5th international conference on enterprise systems (ES) (pp. 311-318). IEEE
- Aheleroff, S., Xu, X., Zhong, R. Y., and Engineering, M. S., 2019, "AnAgile Product Development Methodology for Mass Personalisation under Industry 4.0," Proc. Int. Conf. Comput. Ind. Eng. CIE, (350), p. 10.
- Aheleroff, S., Philip, R., Zhong, R. Y., & Xu, X. (2019). The degree of mass personalisation under industry 4.0. Procedia CIRP, 81, 1394-1399.
- Jin, X., Yu, S., Zheng, P., Liu, Q., & Xu, X. (2018). Cloud-based approach for smart product personalization. Procedia CIRP, 72, 922-927.
- Lee, J., Davari, H., Singh, J., & Pandhare, V. (2018). Industrial Artificial Intelligence for industry 4.0-based manufacturing systems. Manufacturing letters, 18, 20-23.
- Meet me in The Metaverse, Accenture 2022, TechVision
- Deloitte Research and analysis, Global XR industry insight | Metaverse: unlocking imagination and embracing reality
- Lee, J., Singh, J., & Azamfar, M. (2019). Industrial artificial intelligence. arXiv preprint arXiv:1908.02150.
- Angelopoulos, A., Michailidis, E. T., Nomikos, N., Trakadas, P., Hatziefremidis, A., Voliotis, S., & Zahariadis, T. (2019). Tackling faults in the industry 4.0 era—a survey of machine-learning solutions and key aspects. Sensors, 20(1), 109.
- Cloud AR/VR Whitepaper, GSMA Future Networks, 2019 and AI & Automation: An Overview, GSMA Future Networks, 2019
- Mass Customization, the Next Big Trend in eCommerce, https://www.shapediver.com/blog/mass-customization-in-ecommerce
- Appnovation, The Digital Consumer - Shifting Expectations and Digital Readiness, 2021, Link
- Clark Benedict, Personalize vs Customize: How are they Different?, Acquire 2022. Available at: https://acquire.io/blog/personalization-vs-customization/
- Personalization Technology: Landscape & Trends for 2021, https://www.yieldify.com/free-guides/personalization-technology/
- Rachel Arthur, 2017, Artificial Intelligence Dominates The Retail Conversation At Shoptalk Europe, Forbes, Available at: Link
- Mandeep Wariach, Thomas Reinbacher, 2021, Visual Inspection AI: a purpose-built solution for faster, more accurate quality control, https://cloud.google.com/blog/products/ai-machine-learning/improve-manufacturing-quality-control-with-visual-inspection-ai
- McKinsey 2019, Global AI Survey: AI proves its worth, but few scale impact. Available at: https://www.mckinsey.com/featured-insights/artificial-intelligence/global-ai-survey-ai-proves-its-worth-but-few-scale-impact
- Sebastian Göke, Kevin Staight, and Rutger Vrijen, 2021, Scaling AI in the sector that enables it: Lessons for semiconductor-device makers, Available at: Link
- How Artificial Intelligence is Impacting the Future of Employee Engagement, Enlear Academy, 2021, Available at: Link
- http://pascalobservatory.org/pascalnow/blogentry/news/being-human-era-fourth-industrial-revolution-and-ai
- https://www.rowse.co.uk/blog/post/7-manufacturing-ai-benefits
- https://www.360iresearch.com/library/research-report/global-personalization-software-market

Thank You!

For more information:

LMS
Laboratory for Manufacturing Systems & Automation

Professor Dimitris Mourtzis
mourtzis@lms.mech.upatras.gr