INDUSTRIE 4.0 – THE FOURTH INDUSTRIAL REVOLUTION MADE IN GERMANY

Prof. Dr.- Ing. Thomas Bauernhansl

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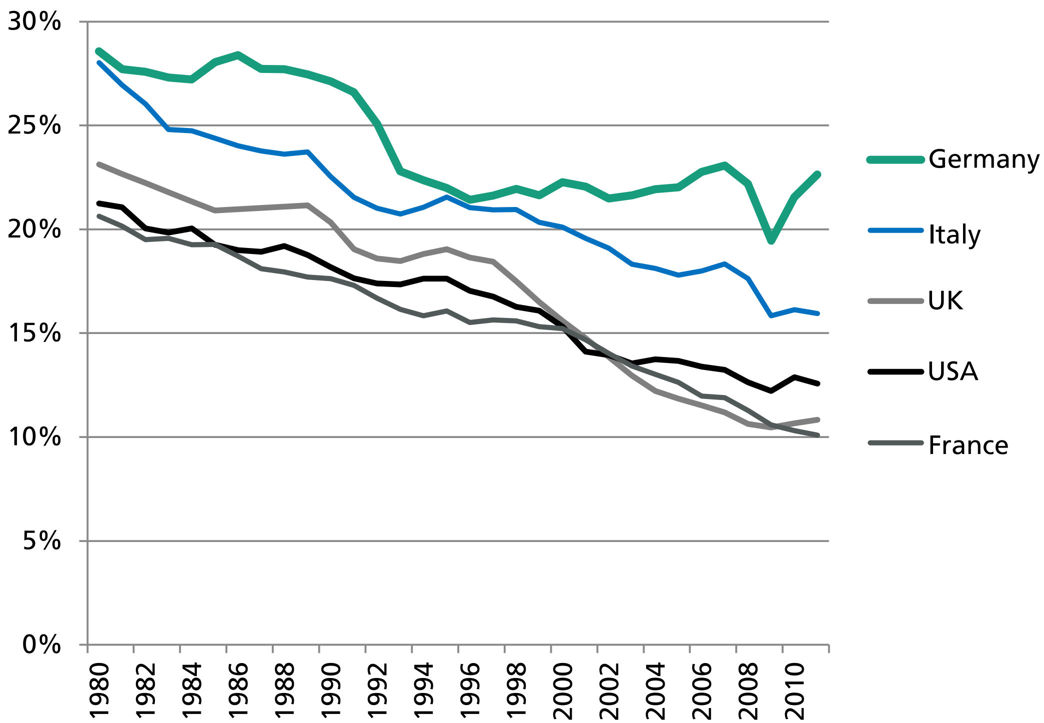
International Comparison – The competition has begun

The Renaissance of Manufacturing

Industry ensures growth and employment while financing the economy

Share of the manufacturing sector (including energy) in total GVA (gross value added)



source: UNData: Gross Value Added Manufacturing/Total Gross Value Added

Importance of the industry to the national economy

- **productivity contribution:** 30% productivity improvement over the last 10 years (twice as much as in the service sector)
- **innovation contribution:** €49.7 bn of R&D expenditure in 2010 (86.5% of overall economy)
- **export contribution:** €893 bn in 2010 (93.4% of total exports)

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Regional Manufacturing Conditions
Intensified competition for local value-added

USA
Re-industrialization

- Decreasing energy costs (shale gas/oil)
- Decreasing unit labor costs (2000 – 2014: +1,4% => –5% since 2009)
- Low interest rates
- Low exchange rates
- Applied research

Europe
Re-industrialization

- Increasing energy costs
- Unchanged unit labor costs (2000 – 2014: +1,8% => +3% in Germany since 2009)
- Low interest rates
- Decreasing exchange rates
- Horizon 2020

Asia (China)
Transformation of the industry

- Increasing energy costs
- Increasing unit labor costs (2003 – 2009: +10,9% => n/s since 2009
- Medium interest rates
- Increasing exchange rates
- Government subsides
- High investment in education/research

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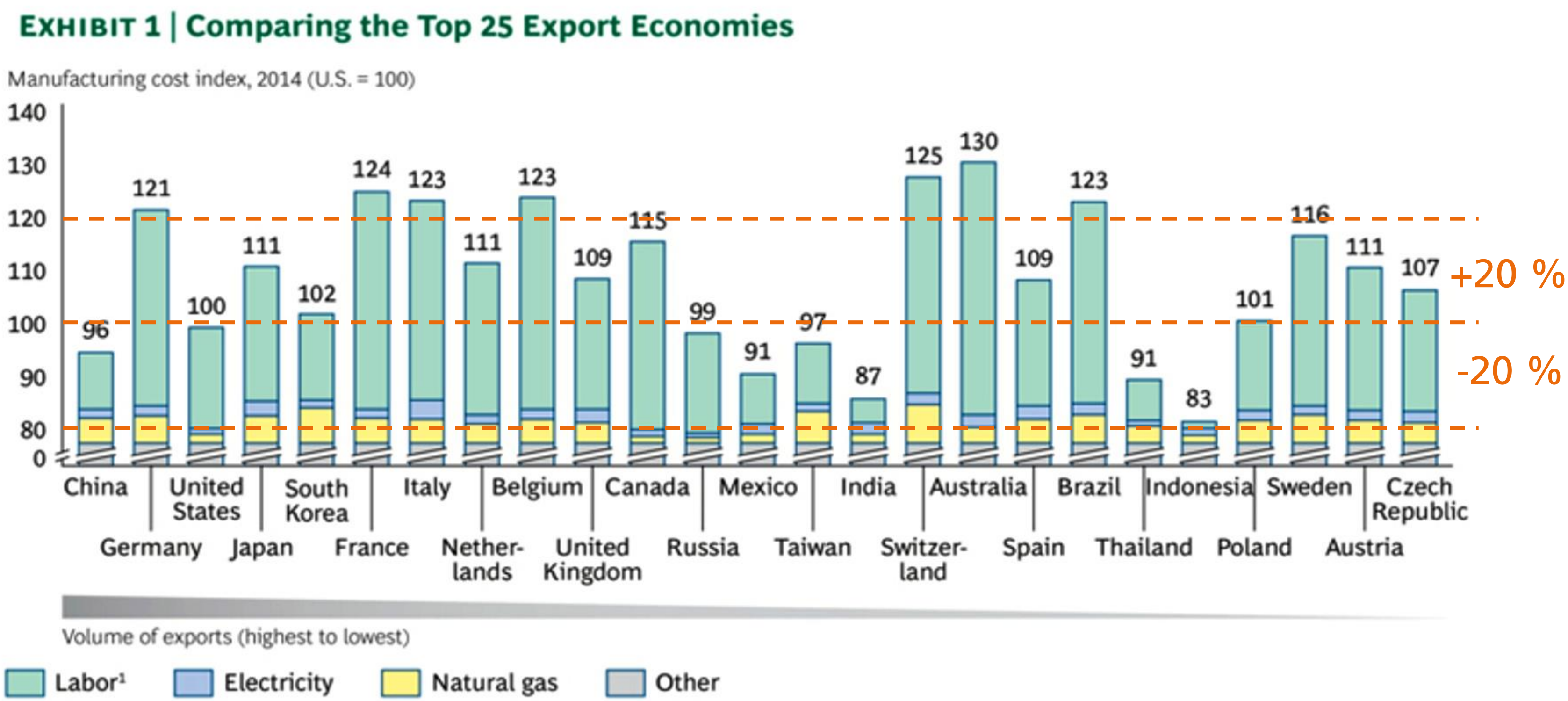
Manufacturing Cost Index 2014

The manufacturing costs continue to converge



Sources: U.S. Economic Census; U.S. Bureau of Labor Statistics; U.S. Bureau of Economic Analysis; International Labour Organization; Euromonitor International; Economist Intelligence Unit; BCG analysis.
Note: The index covers four direct costs only. No difference is assumed for other costs, such as raw-material inputs and machine and tool depreciation. Cost structure is calculated as a weighted average across all industries.
[1]Adjusted for productivity.

source: Boston Consulting Group 2014

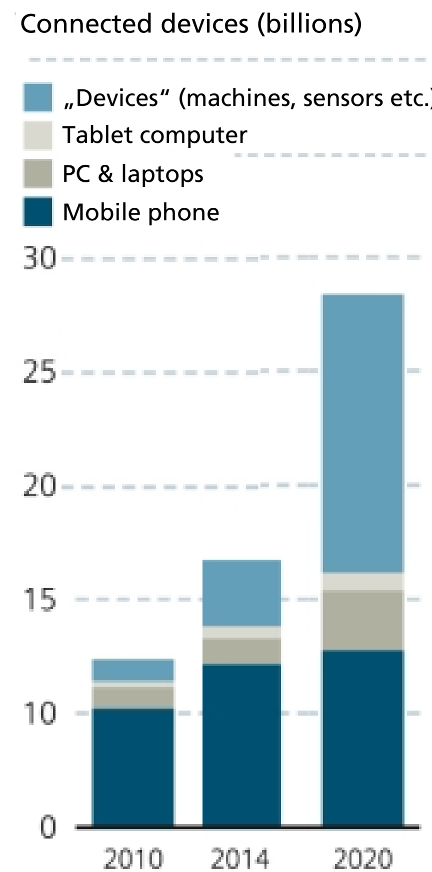
Digitization

The Digital World of Today and Tomorrow

Internet of Everything

Holistic global integration as base for new business ecosystems

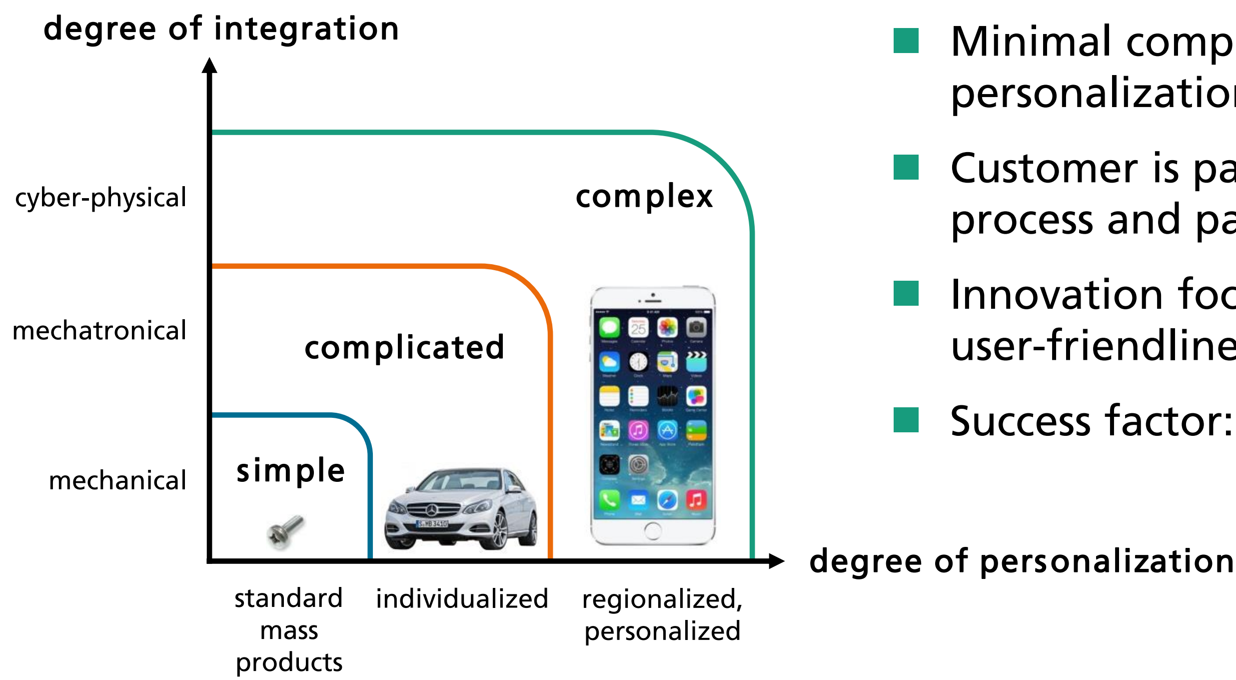
- 3 billion people used the internet in 2014
- 17 billion things were connected in 2014 via internet. In 2020 the number it expected to rise up to 28 billion.
- internet services are uncounted.
  example apple store: > 1 million apps were downloaded more than 75 billion times
- new economic activities arise:
  - shared economy
  - prosumer
  - Industrie 4.0/industrial internet…



source: The Internet of Things, MIT Technology Review, Business Report, Siemens

Change of Product Architecture

The ability to manage complexity effectively becomes a key competitive advantage



- Minimal complexity, maximum personalization and economies of scale
- Customer is part of the personalization process and pays for it
- Innovation focus: eco-system, user-friendliness, design
- Success factor: openness

sources: Wildemann, H.: Wachstumsorientiertes Kundenbeziehungsmanagement statt König-Kunde-Prinzip; Seemann, T.: Einfach produktiver werden – complexity im Unternehmen senken; Bildquellen: apple.de

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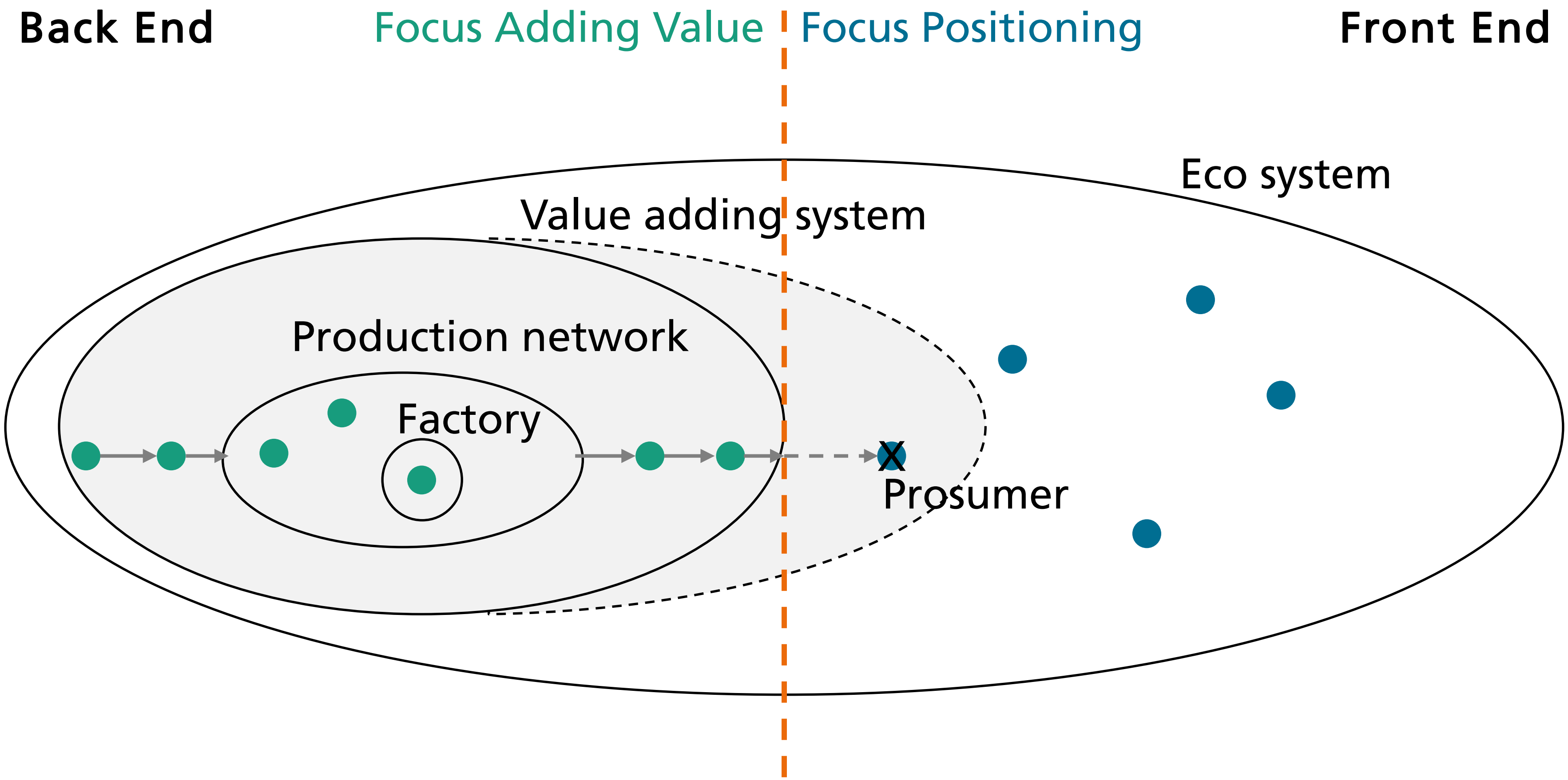
Classification within the Context of the Presentation

Adding value vs. positioning



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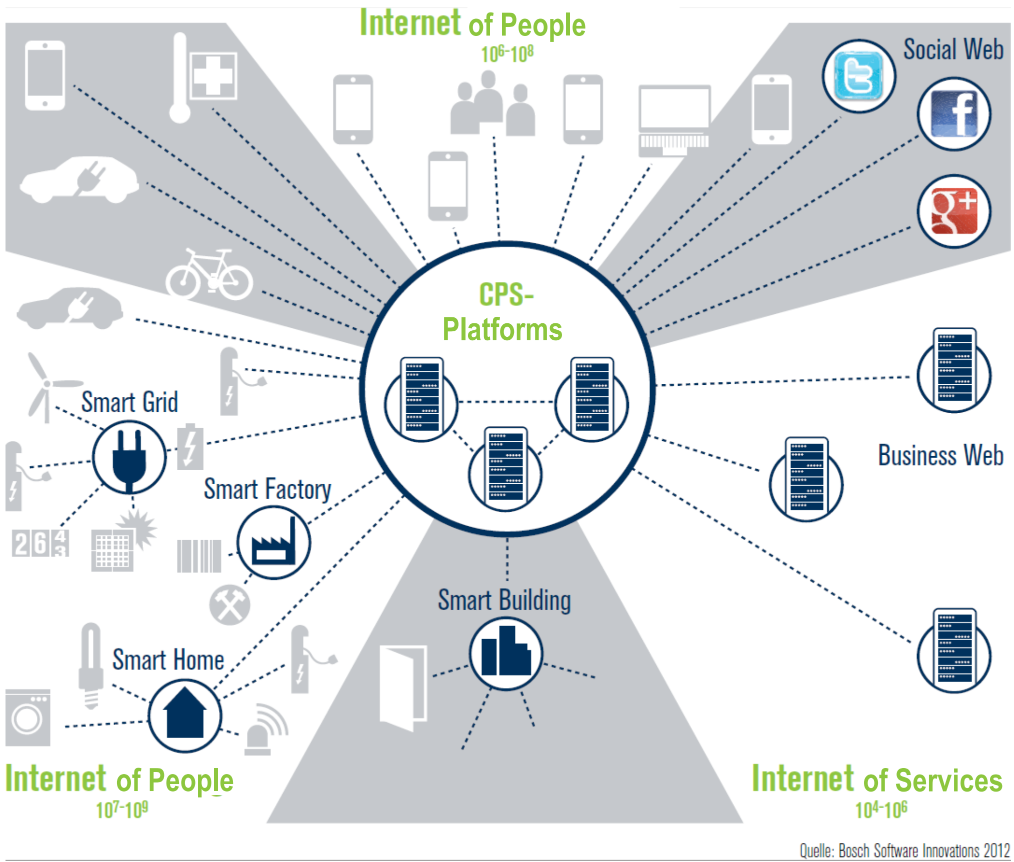
Digitization of Business Models

Everything goes smart and changes industrial branches



CPS Cyber-Physical System, **RFID** Radio Frequency Identification

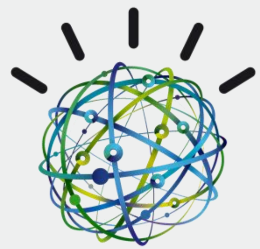
The Base: Processing Power and Connectivity

Moore and Metcalfe are proven right and define the scope and value of an enterprise

Connectivity

Metcalfe:

"The benefit of a communication system increases with the square of the number of participants."



Performance

Moore:

"Computer performance doubles every 18 months."

Ecosystems for Smart Business Models

Transparency

- cyber-physical systems
- Internet of Things and Services
- real time & at run time
- everything as a service

Knowledge

sources of pictures: wikipedia.de, ibm.com, abcnews.com

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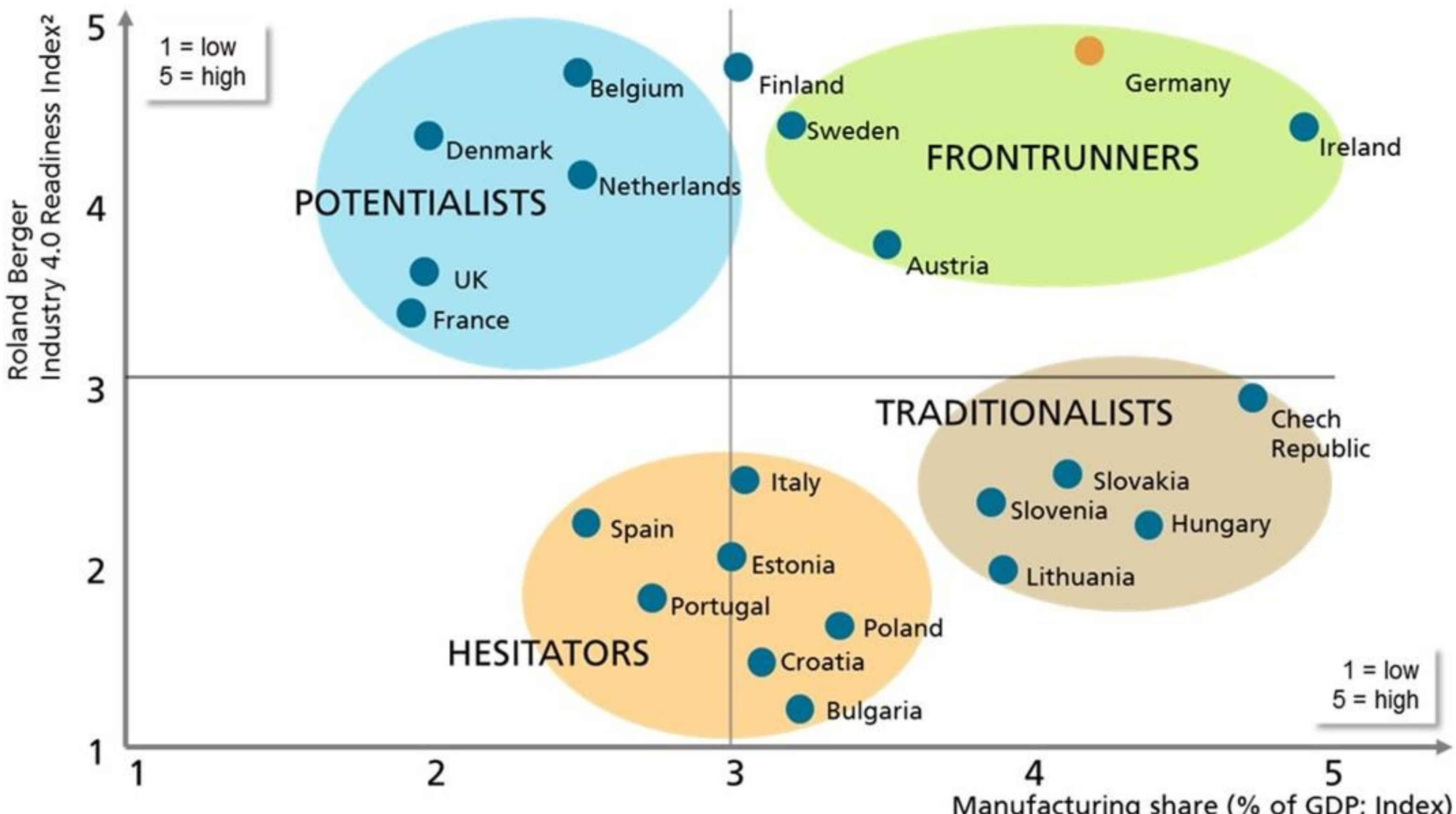
Assessment of the Industry 4.0 Readiness

Germany as frontrunner has the best position in Europe



source: Roland Berger, Strategy Consultants, March 2014

²Adjusted for outliers Cyprus, Latvia, Luxemburg, Romania, Greece

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Potential Economic Benefits by Industrie 4.0

Possible increase in gross value added from 15 % to 30 % by 2025*

- Bitkom/IAO expects additional annual growth of 17% by 2025
- John Chambers, CEO Cisco: „… 2% of additional annual growth for the Germany economy…“**
- German businesses are planning to invest €40 billion over the next 5 years***

Wirtschaftsbereiche	Bruttowertschöpfung [Mrd. €]		Potenzial durch Industrie 4.0	Jährliche Steigerung	Steigerung [Mrd. €]
	2013	2025*	2013-25	2013-25	2013-25
Chemische Industrie	40,08	52,10	+30%	2,21%	12,02
Kraftwagen- und Kraftwagenteile	74,00	88,80	+20%	1,53%	14,80
Maschinen- und Anlagenbau	76,79	99,83	+30%	2,21%	23,04
Elektrische Ausrüstung	40,27	52,35	+30%	2,21%	12,08
Land- und Forstwirtschaft	18,55	21,33	+15%	1,17%	2,78
Informations- und Kommunikationstechnik	93,65	107,70	+15%	1,17%	14,05
Potenzial der 6 ausgewählten Branchen	**343,34**	**422,11**	**+23%**	**1,74%**	**78,77**
Beispielhafte Hochrechnung für die Gesamtbruttowert-schöpfung in Deutschland	2.326,61	2.593,06**	+11,5%**	1,27%**	267,45**

* Bei den Hochrechnungen für 2025 wurde kein Wirtschaftswachstum berücksichtigt. Es handelt sich um eine reine Relativbetrachtung mit und ohne die Industrie 4.0-Potenziale für die sechs ausgewählten Branchen.

** Gesamtsumme enthält die Industrie 4.0-Potenziale für die sechs ausgewählten Branchen sowie die Hochrechnung der restlichen Branchen unter der Annahme, dass für diese ein Potenzial in Höhe von 50% des für die ausgewählten Branchen gilt.

sources: * Bitkom/IAO 2014, ** Sueddeutsche.de, *** PwC Studie 2014, wiwo.de

Research Funding in Comparison
The race for access to customers has started

- Advanced manufacturing partnership (AMP): +50 mio dollars
- Cyber security R&D and standards: +45 mio dollars
- Cyber-physical systems: +40 mio dollars
- National network for production innovation (NNMI): 1 billion dollars
- public-private partnerships, e.g. industrial internet consortium

- By 2015 1,2 trillion euros will be provided to reach the global technology leadership
- July 2014 founding of „*China Internet and Industry Convergence Innovation Alliance*"
  - Target: promote digitalization of distribution and usage of ICT in production

- Funding of several initiatives for implementing the internet of things into production
- More than 9 billion euros are available

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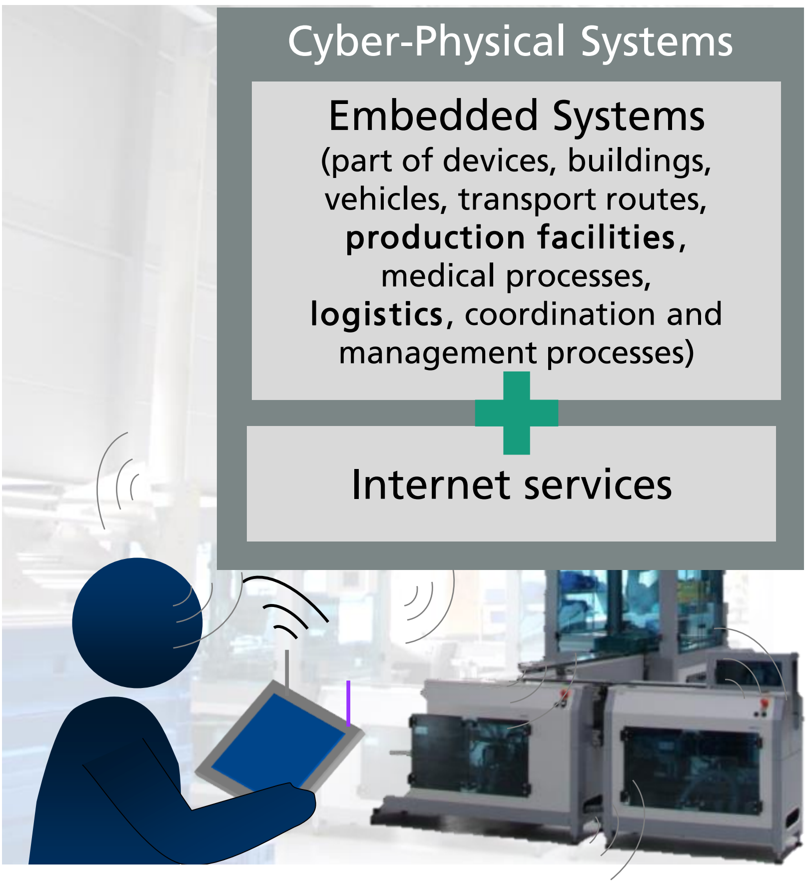
Smart Factory:
Concept and Potential Benefits

The Next Step of Decentralization

From fractal factory to cyber-physical production system



acc. to ACATECH, 2012

Features

- Acquisition of actual physical data by means of sensors
- Usage of worldwide available data and services
- Data analysis and storage
- Networking by means of digital communication technology
- Operation in the physical world by means of actors
- Usage of multimodal man-machine-interfaces

Context Management Replaces Operational Planning

Smart Factory organizes its own operations in a decentralized way

Cyber-physical systems (e.g. machines, facilities)

- Have an identity
- Communicate with each other and with the environment
- Configure themselves (plug and produce)
- Store information

decentralized self-organization

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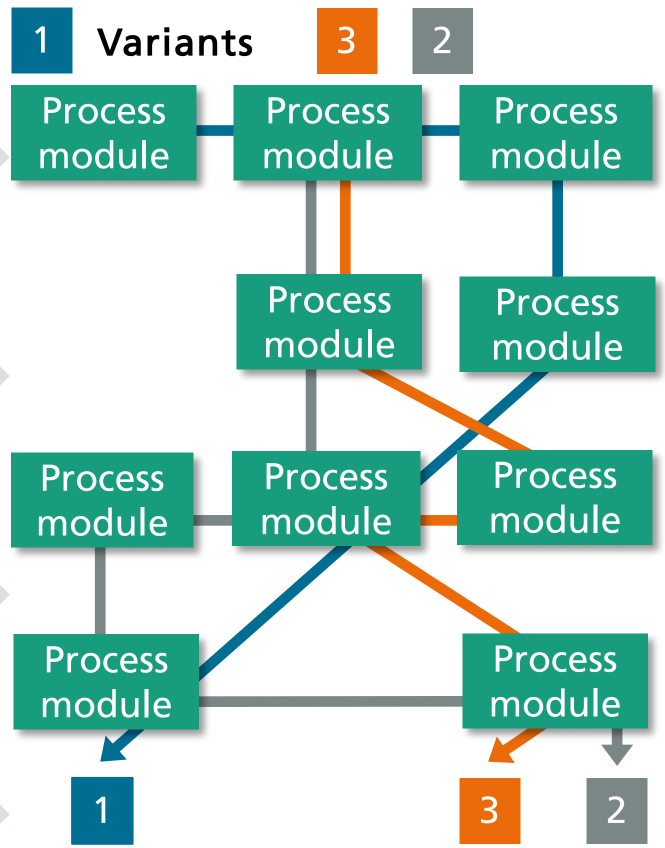
Automobile Production Tomorrow: Variable Logistics, Cycles and Throughputs

Assembly integrated manufacturing processes

Context-based planning and control via apps

Intelligent and self-configuring simulation models

Big Data based pattern recognition for optimization



Human robot cooperation

Automated guided vehicle systems and smart carriers

Control from the cloud/plug & produce

Augmented operator as conductor of value

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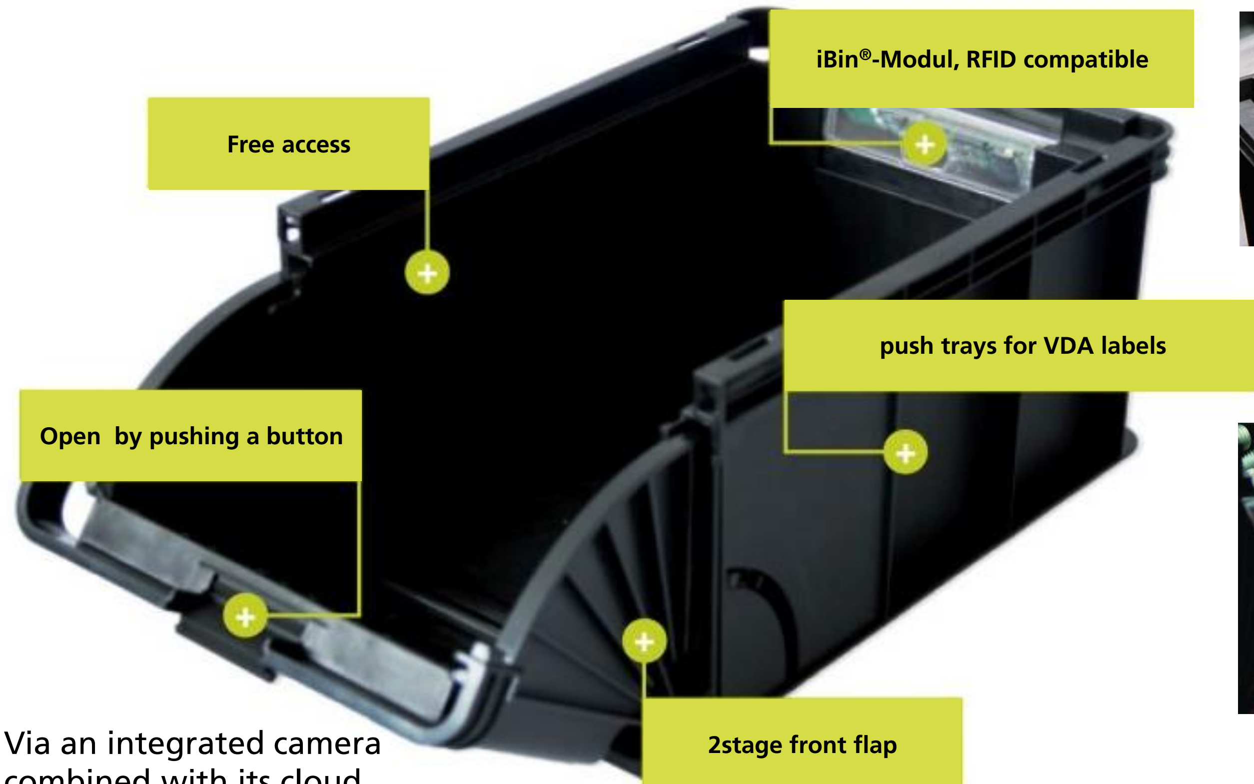
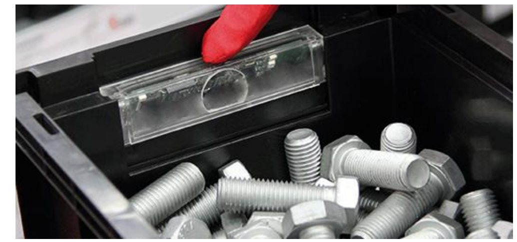
All Objects in a Factory will be Smart

iBin – Intelligent bins order their filling autonomously





Via an integrated camera combined with its cloud, iBin counts the parts enclosed in it.

WÜRTH

source Fraunhofer IML, Prof. Dr. Michael ten Hompel

All Objects in a Factory will be Mobile to a Large Extend

Example: swarm intelligence for logistics

source: Fraunhofer IML, Prof. Dr. Michael ten Hompel

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Robots will be mobile, flexible and safe

Example: SEW Eurodrive – freely navigating DTS (carries the robot for bin picking)

source: IPA

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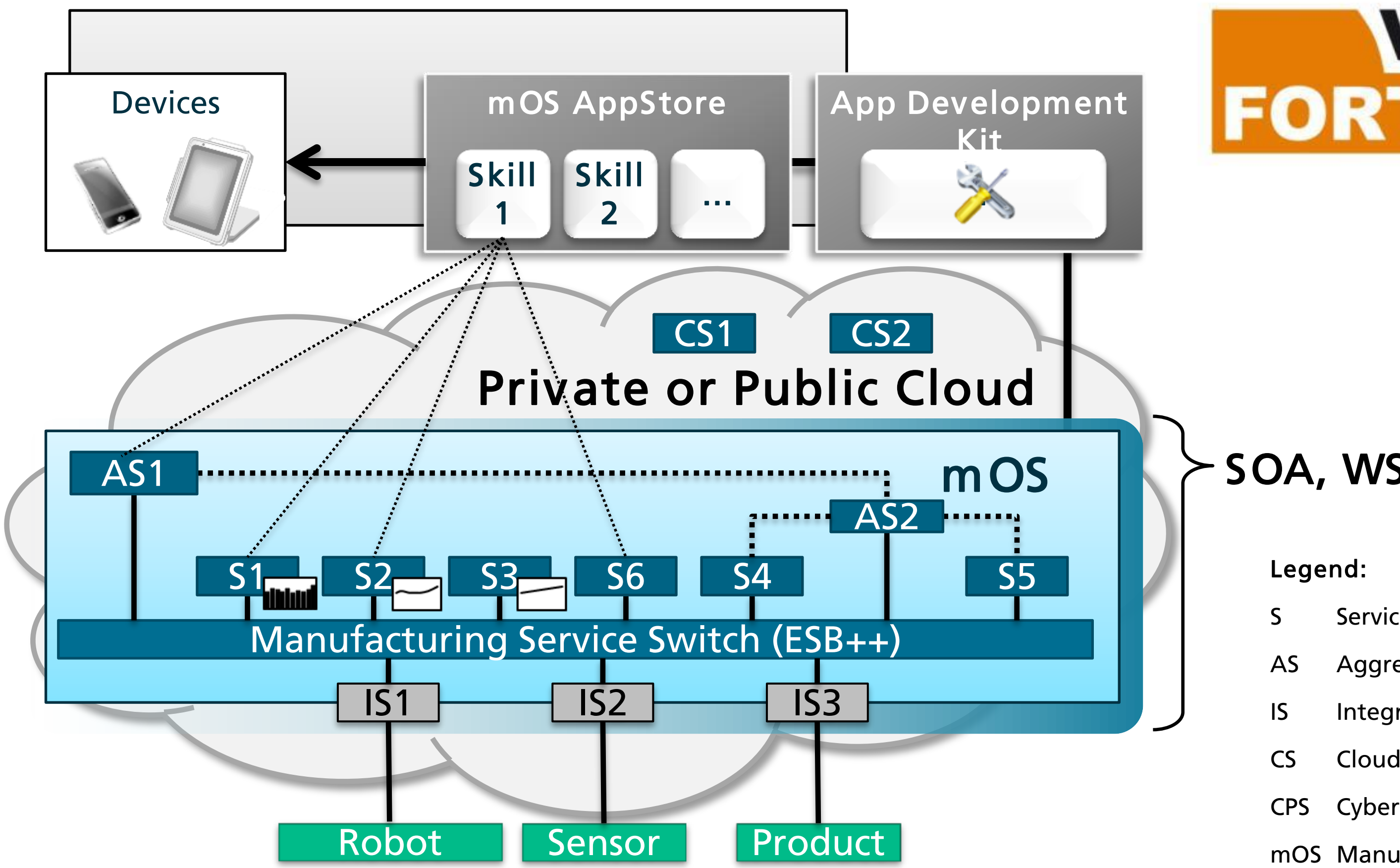
All Objects in a Factory will be Mobile as Far as Possible

Example: Audi R8 – freely navigating AGV (navigation as a service)

source: audi-mediaservices.com

Everything as a Service" (XaaS)

Use case Virtual Fort Knox – integration platform



VIRTUAL FORT KNOX

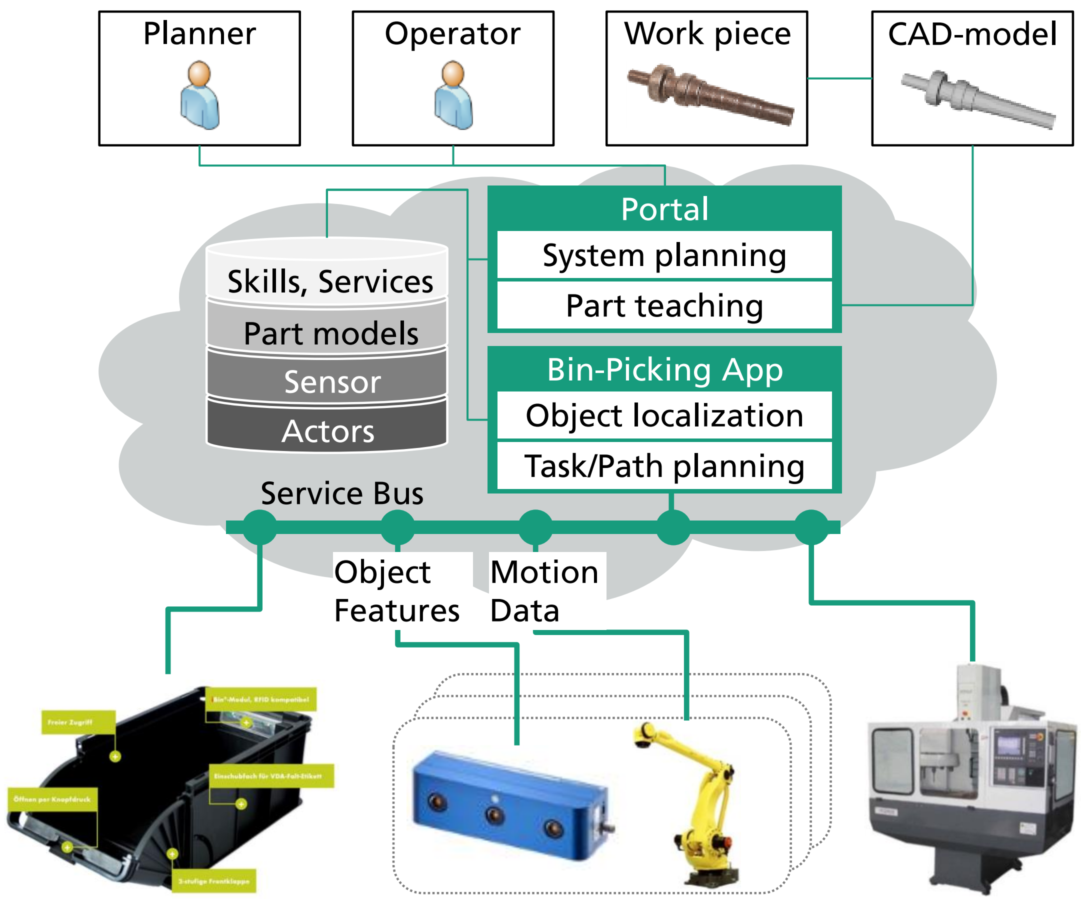
Legend:

S	Service
AS	Aggregated Service
IS	Integration Service
CS	Cloud Service
CPS	Cyber-Physical System
mOS	Manufacturing Operating System

Example 1: What if Bin-picking Came out of the Cloud?

Advantage

- externalization of skills, services, maintenance
- lean robot workcell ("lean client")
- centralized collection of data
  - optimization by statistical learning
- best practice solutions accessible
- to be displayed at HMI2015



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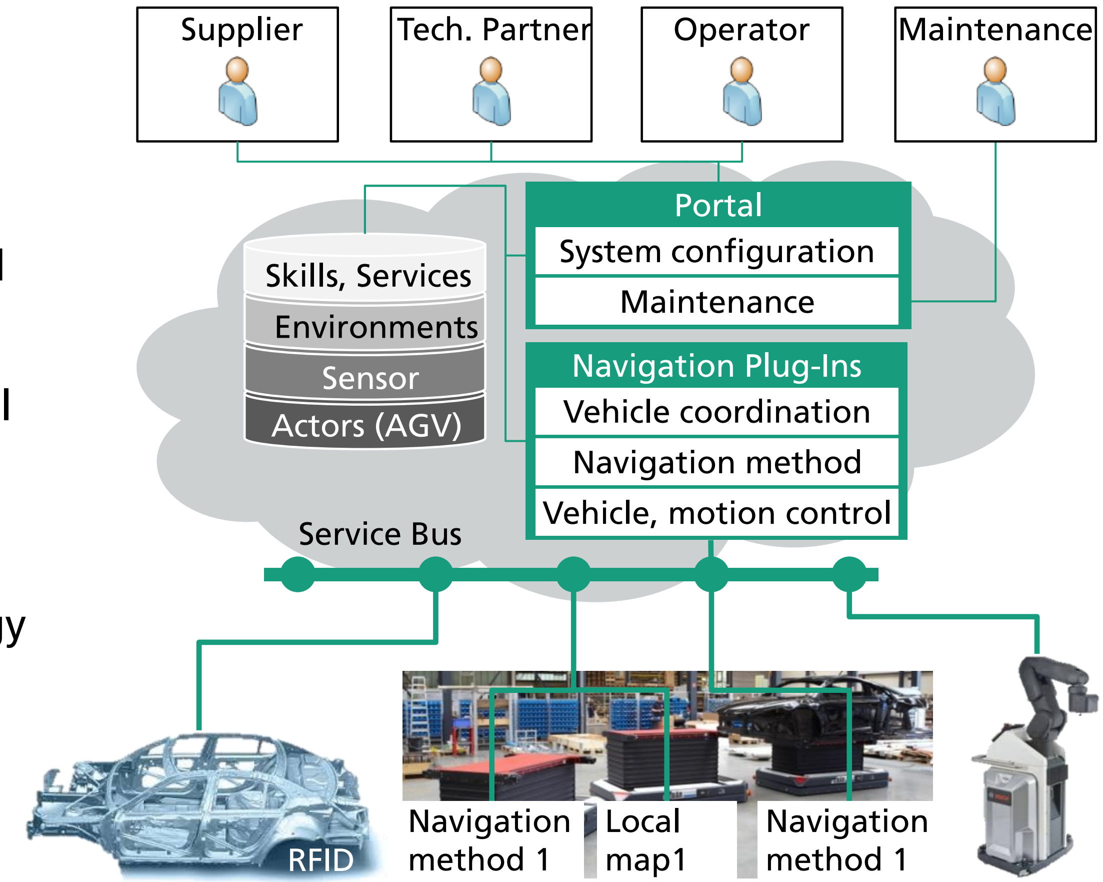
Example 2: What if there was a AGV Cloud Navigation?

Advantage

- logistics: centralized vehicle coordination (as is today)
- "Lean Client" AGVs; Navigation skills on demand
- centralized data collection
  - optimization by statistical learning (adaption of skills, condition monitoring)
- partnerships with technology providers, external services
- under development



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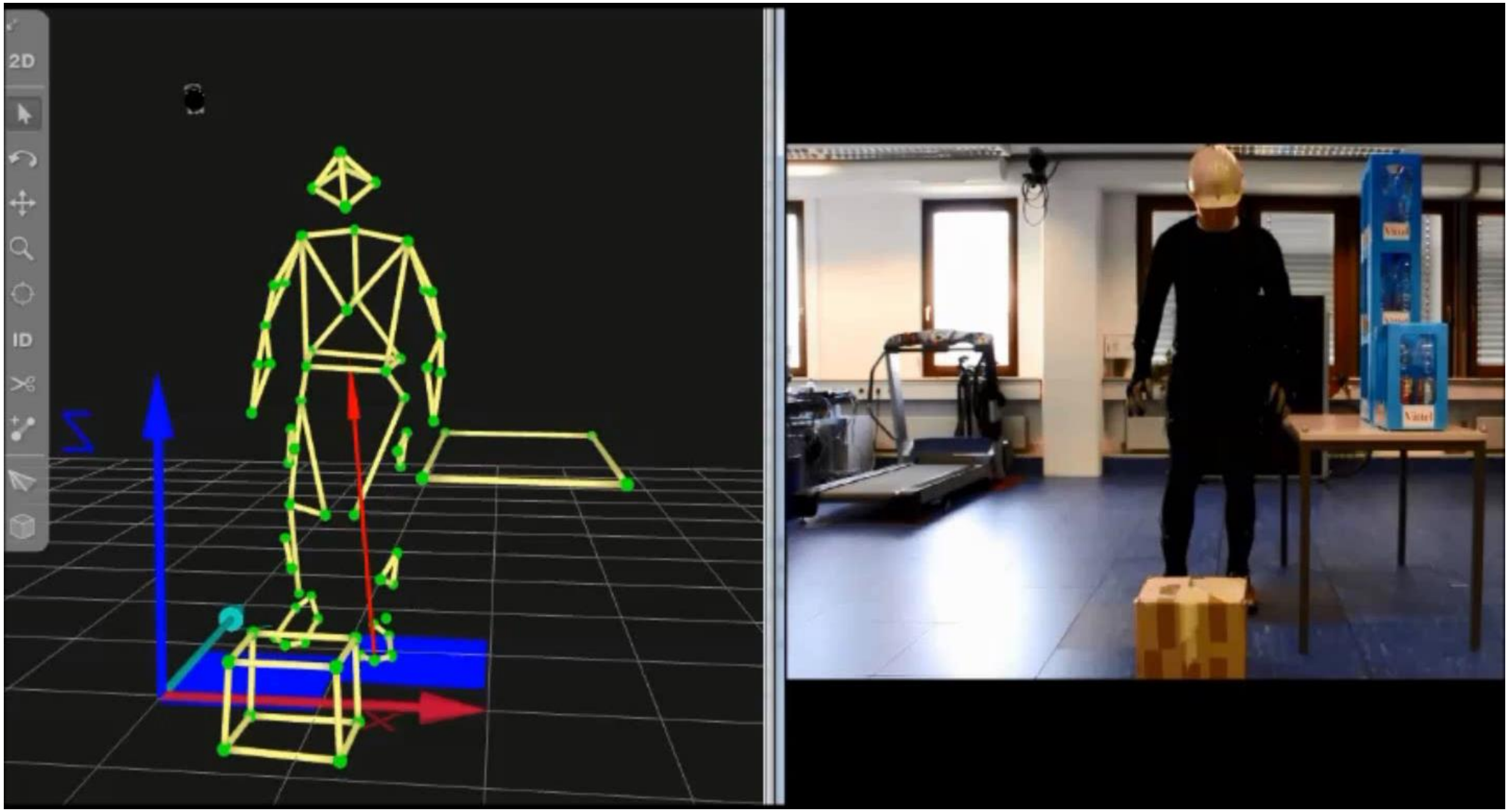
All Entities of a Factory have a Digital Shadow

Example: Motion Capturing for feed-back of real processes into planning models



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Challenges when Dealing with Big Data – Change of Perspective

Dealing with Complicated Contexts	Dealing with Complex Contexts
Complicated contexts are being systematically analyzed (root cause analysis)	Complex contexts are no longer being analyzed with regard to their causes (correlation replaces causality)
The complicated network is divided in small entities and correlations are being examined	Regularities are being derived from all available data (pattern recognition, e.g. customers' behavior patterns)
Random sample analysis, deductive approach	Complete data screen is being analyzed, inductive approach
The question is "why"	The question is "what"

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Business potential of Integrated Industry (Industrie 4.0)

Specialists expect an increase in overall performance between 30 to 50 % in value creation

Estimation of potential benefits

Costs	Effects	Potential
Carrying costs	■ Reduction of safety stocks ■ Avoiding Bullwhip and Burbidge effect	**-30 % to -40 %**
Manufacturing costs	■ Improvement of OEE ■ Process control loops ■ Improvement of vertical and horizontal staff flexibility	**-10 % to -20 %**
Logistics costs	■ Higher level of automation (milk run, picking etc.)	**-10 % to -20 %**
Complexitx costs	■ Wider span of supervision ■ Reduced trouble shooting	**-60 % to -70 %**
Quality costs	■ Near-realtime quality control loops	**-10 % to -20 %**
Maintenance costs	■ Optimization of stock levels ■ State-oriented maintenance (process data, measurement data) ■ Dynamic priorization	**-20 % to -30 %**

Pilot project at Bosch: Restructuring of complete distribution process based on an in-plant logistics center in an Industrie 4.0 project.

supplier

Automotive manufacturer

-10 % milkruns

+10 % produc-tivity

-30 % stock reduction

source: IPA/Bauernhansl, Bosch

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Key Factors of Success for Industry

Maximum proximity to customers combined with the highest productivity levels

- **Expanded value-added system**
  (ecosystem, business model, customer and supplier integration, customer-orientation)
- **Comprehensive transparency**
  (Vertical and horizontal interconnection in real time, focus on communication)
- **Rapid process capability**
  (big data, predictive analytics, qualification, focus on learning curves)
- **High level of flexibility and economies of scale**
  (everything as a service/ XaaS, decentralization, connectivity, service-orientation)
- **Maximum efficiency and synergies**
  (zero waste technologies, willingness and capability to change, autonomy, resource-orientation)
- **New security culture**
  (safety, security and privacy, risk-orientation)
- **Optimal framework conditions**
  (infrastructure, financing, research scene, lifelong learning)

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