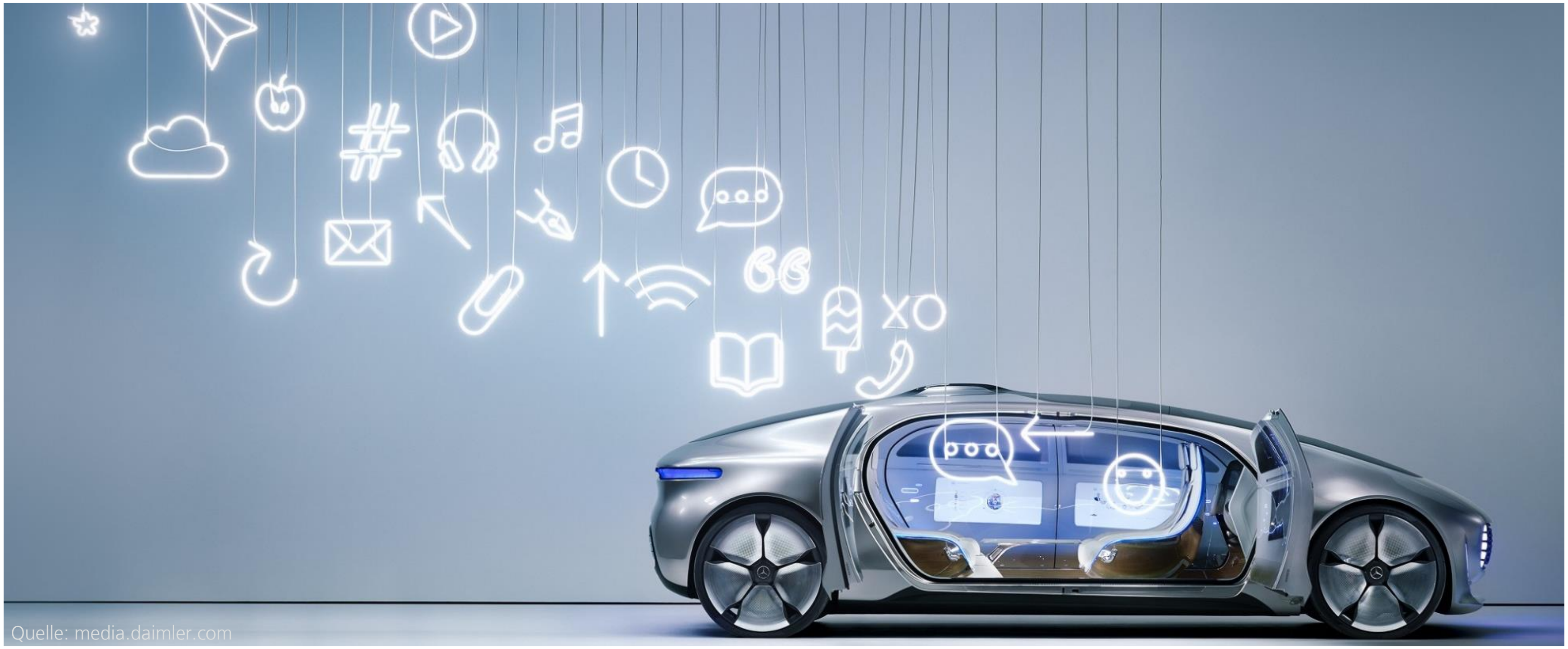
AUTOMOBILINDUSTRIE 4.0 – PERSONALISIERT UND SMART

Prof. Dr.-Ing. Thomas Bauernhansl
6. Februar 2018



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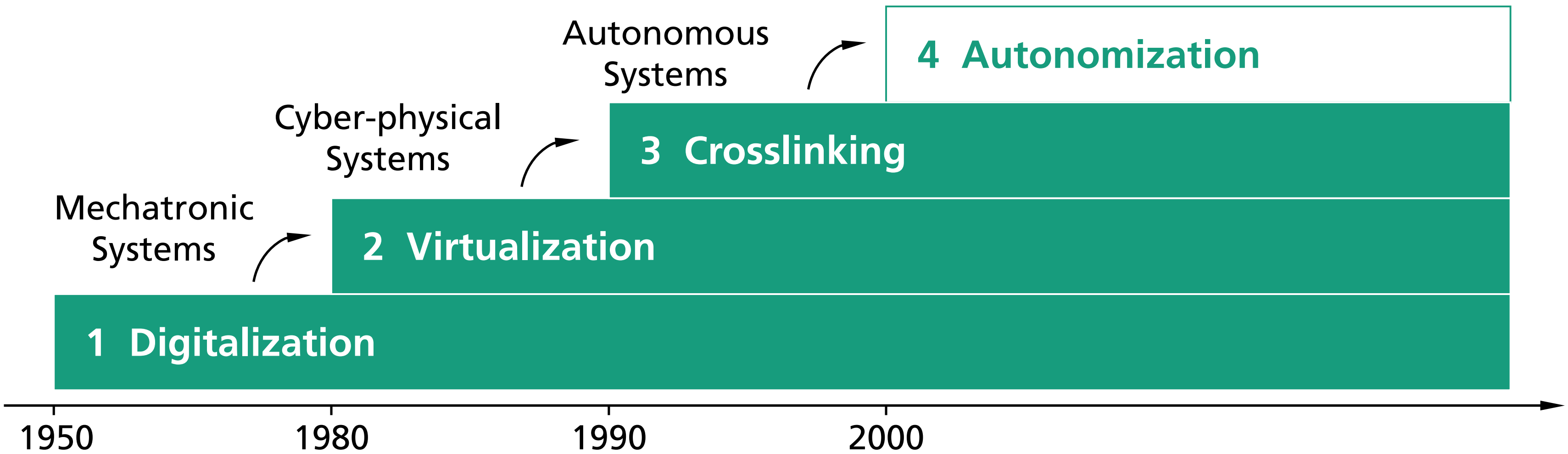
Development Stages of the Digital Transformation

From digital image to autonomous system



Digital image of analog processes (e.g. NC technology, 2-D CAD, MRP/ERP)

Digital modeling of processes (e.g. CAD/CAM, FEM, digital factory)

Integration of all value creation processes via broadband telecommunication (e.g. industrial IoT, cloud computing, CPS, 5G)

Combination of classic technologies and artificial intelligence create autonomous, self-organizing systems (e.g. autonomous transport systems, autonomous robots)

Quelle: Fraunhofer IPA

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Vertical Integration

Core elements of the fourth industrial Revolution

Infrastructure (physical, digital)

Cyber-physical System

Product Life Cycle (valuable = personalized + sustainable)

Interaction

Physical Systems (act, sense, communication) | **Human Beings** (decide, create, communicate)

Reflection

Digital Shadow (real-time model of everything)

Transaction

Software Service (machine skills, Apps for humans, platform services)

Interoperation

Cloud-based Platforms (private, community, public)

Prescription

Analytics (Big Data/machine learning)

Communication

Internet of Everything (human beings, services, things)

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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

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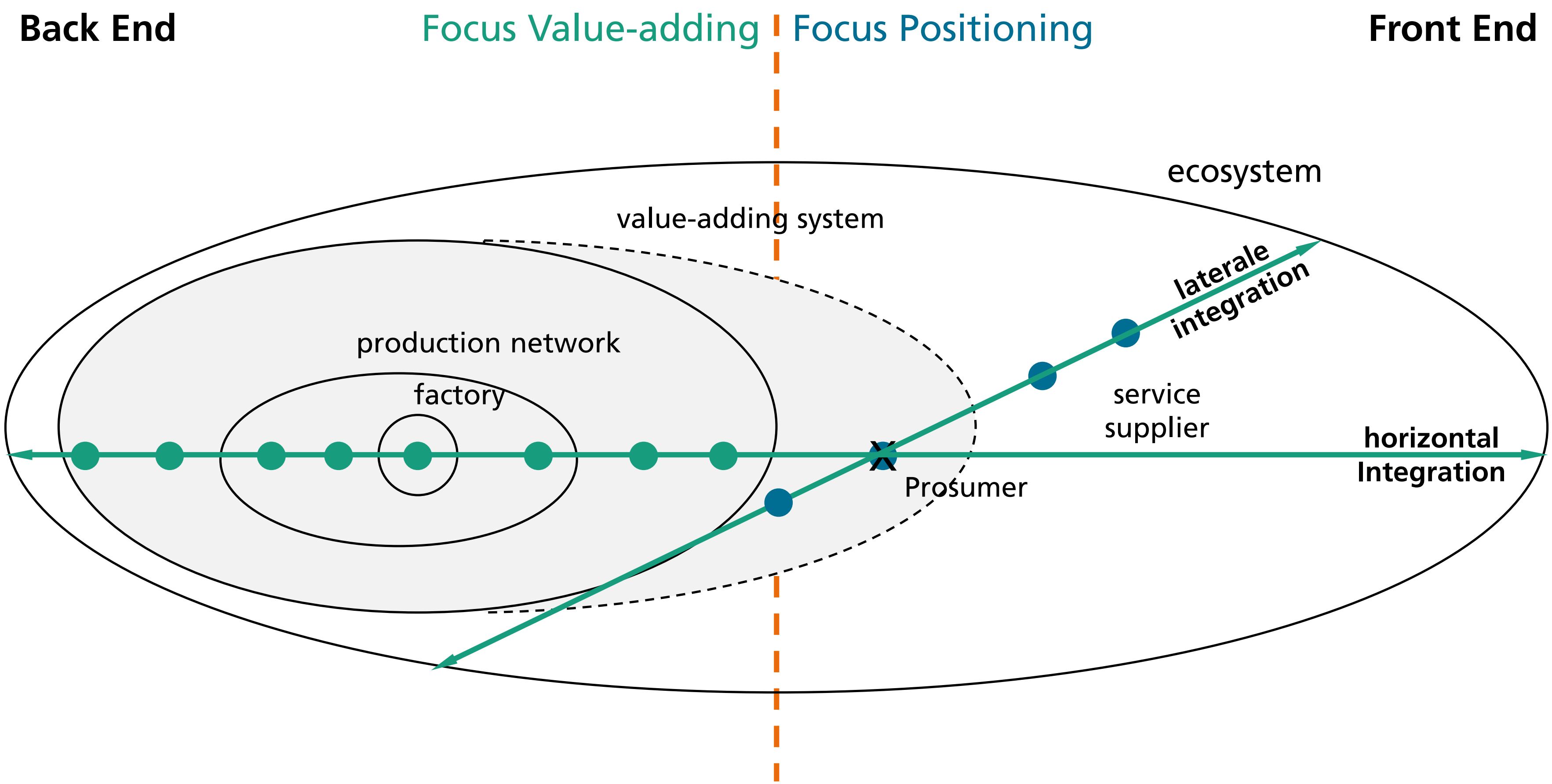
Horizontal and lateral Integration

From B2B and B2C to Business to User (B2U)



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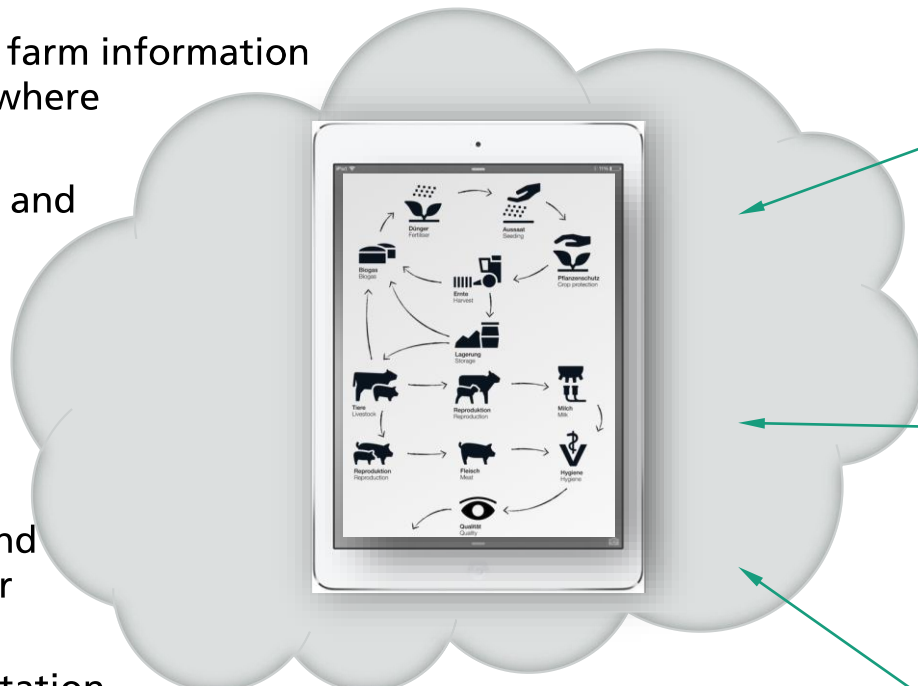
Business Ecosystems

»Farmnet 365« – an agricultural machinery initiative

365FarmNet

- **Online Tracking**
  Real time access to farm information any time from anywhere
- **Traceability**
  Digital, automated and complete documentation
- **Transparency**
  Integration of all farm processes
- **Efficiency**
  Decision support and knowledge transfer
- **Quality**
  Tracking, documentation and early warnings
- **Analytics**
  Prediction, Big Data processing



Machines

…

Equipment

…

Content

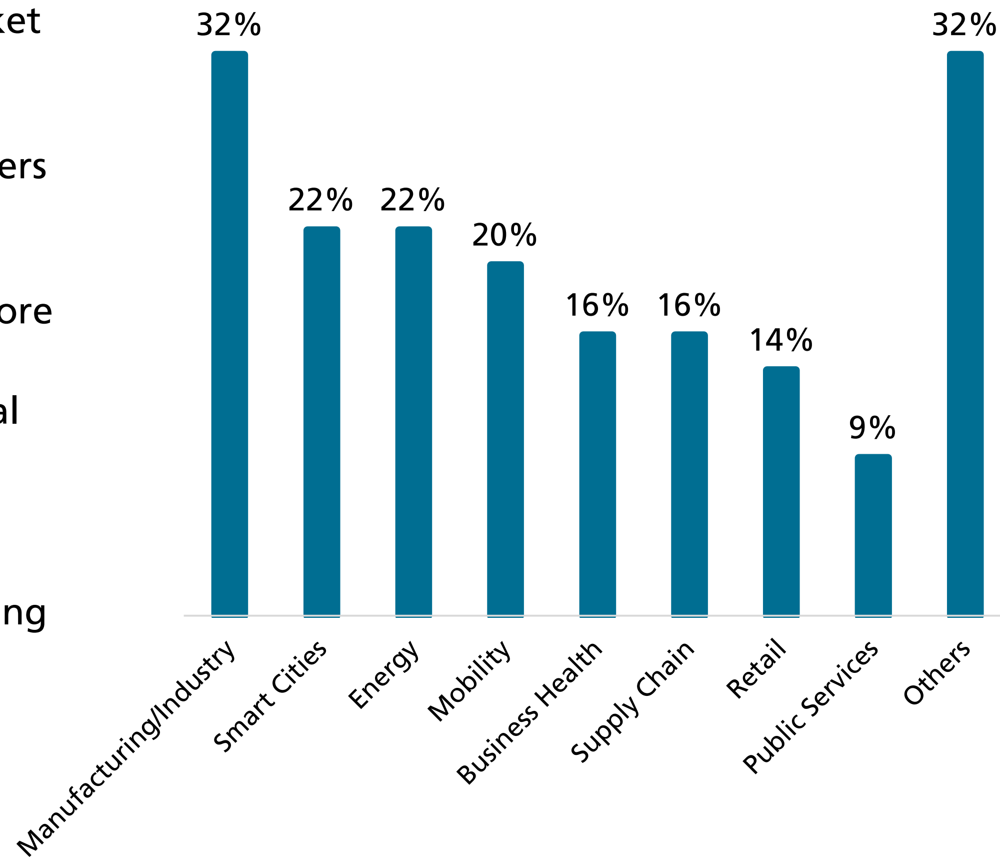
…

source: farmnet

IIOT Platforms Increase Massively

IT-backbone for new business models and ultra-efficient value-adding

- With more than 450 providers, the market of IoT-platforms remains highly fragmented.
- »In 2016 half of the IoT-platform providers generated a turnover of less than 1 Mio. USD.«
- The top providers record a growth of more than 50 %.
- Most platforms concentrate on industrial application areas (32 %).
- With 17 deals in 2016 alone the M&A-activity has notably increased.
- Compared to other branches the financing of startups play a rather minor role (2016: 330 Mio. USD).



source: Cisco, 2014, IoT Analytics 2017

Platforms as Core Element of Total Business Integration

Is one platform enough?

AXOOM

Horizontal Integration

- Supply Net
- Connectivity
- Logistic driven
- Transparency and speed

Laterale Integration

- Business Ecosystem
- Size
- Customer driven
- Value

365FarmNet

Virtual Fort Knox

Vertical Integration

- Cyber Physical System
- Hard Realtime Communication
- Production driven
- Productivity and Agiity

General Requirements

- Openess
- Safety, Security and Privacy
- XaaS
- Innovation
- Scalability

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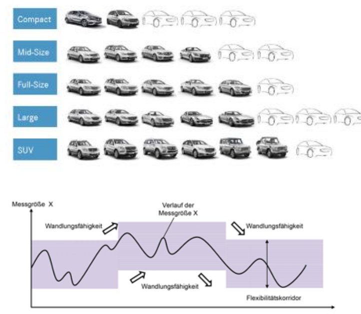
Trends in Automotive Industry

E-Mobility

- Change in powertrain value creation
- New market participants
- Lightweight construction

Volatile markets and product portfolios



- Adaptable factories
- Return of manual processes, lean automation
- Data driven approaches + QM

Autonomous driving

- New E/E architectures
- New vehicle concepts
- New interior concepts

Shared mobility, mobility systems

moovel

UBER

- New vehicle types
- Changed life cycle
- New business models

ARENA2036 – Stuttgart Research Campus
Active Research Environment for the Next Generation of Automobiles

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10 Guidelines for the Value-Adding System of the Future

How Industrie 4.0 will change automotive production

- **Guideline 1: Merge production and logistics system into one value-adding system.**
  Production and logistics systems act as integrated entity for reaching the enterprise goals.
- **Guideline 2: Dissolve line and cycle-time depending on product variety and workflow complexity.**
  Granularity of structures and processes is adapted to the complexity of the product programs and frame conditions.
- **Guideline 3: Setup processes and structures mobile and scalable.**
  Value-adding structures can be redesigned dynamically and economically when needed.
- **Guideline 4: Design intelligent systems.**
  Self-regulated subsystems contribute with their self-healing abilities to a robust overall system.
- **Guideline 5: Make support processes value-adding.**
  All support process (i.e. logistics) are either transformed into adding-value support processes or eliminated.
- **Guideline 6: Replace material flow with information flow.**
  Information is used effectively to reduce waste and stock and to support a downstream customization.
- **Guideline 7: Shift process complexity to where it can be handled most efficiently.**
  The value-adding system boundaries are flexible, integrating customers and suppliers as value-add partners in the value-adding system.
- **Guideline 8: Represent system elements and processes continuously in a digital shadow.**
  Accurate prediction and evaluation of upcoming events is made possible.
- **Guideline 9: Optimize production, based on data analytics.**
  In complex systems correlation is more important than causality.
- **Guideline 10: Focus the human role on design and optimization.**
  Humans use their skills to enhance value-adding and thus optimize the overall system.

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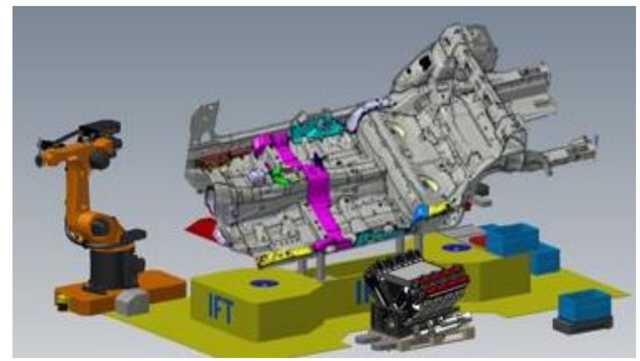
Guideline 1: Merge Production and Logistics System into one Value-adding System.

Production and logistics systems act as integrated entity for reaching the enterprise goals.

Fixed production today

- decoupled optimization of production and logistics
- competing target systems
- optimization of production results in higher complexity and higher costs in the logistics
- Separated production and logistics functions to ensure transparency

Changeable production tomorrow

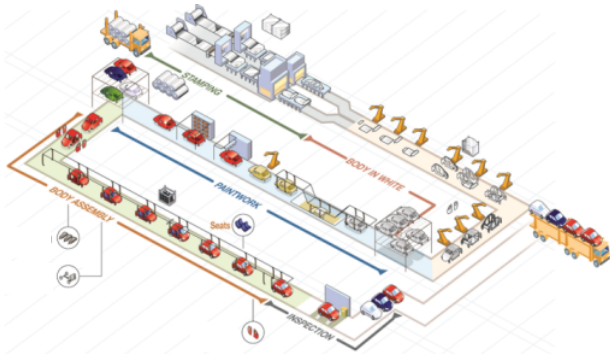


- global optimum instead of individual optimization
- transparency by self-descriptive systems
- no separation of productive and logistics areas
- changeable productive and logistics structures

Guideline 2: Dissolve Line and Cycle-time depending on Product Variety and Workflow Complexity.

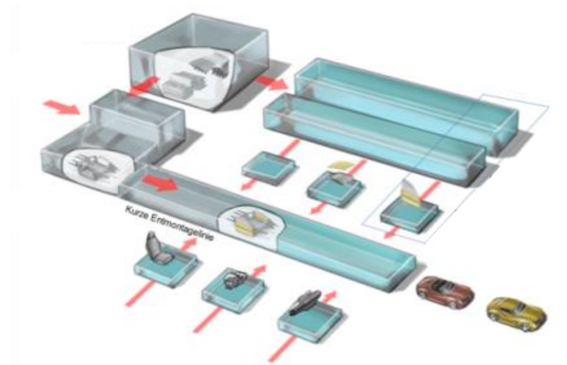
Granularity of structures and processes is adapted to the complexity of the product programs and frame conditions.

Fixed production today



- fixed chain of singular plant technology
- strict organizational split of section, lines and line sections
- fixed line balance
- fixed just-in-time sequence
- high efforts in control
- low possibility to adapt during product lifecycle
- changes interrupt the whole production

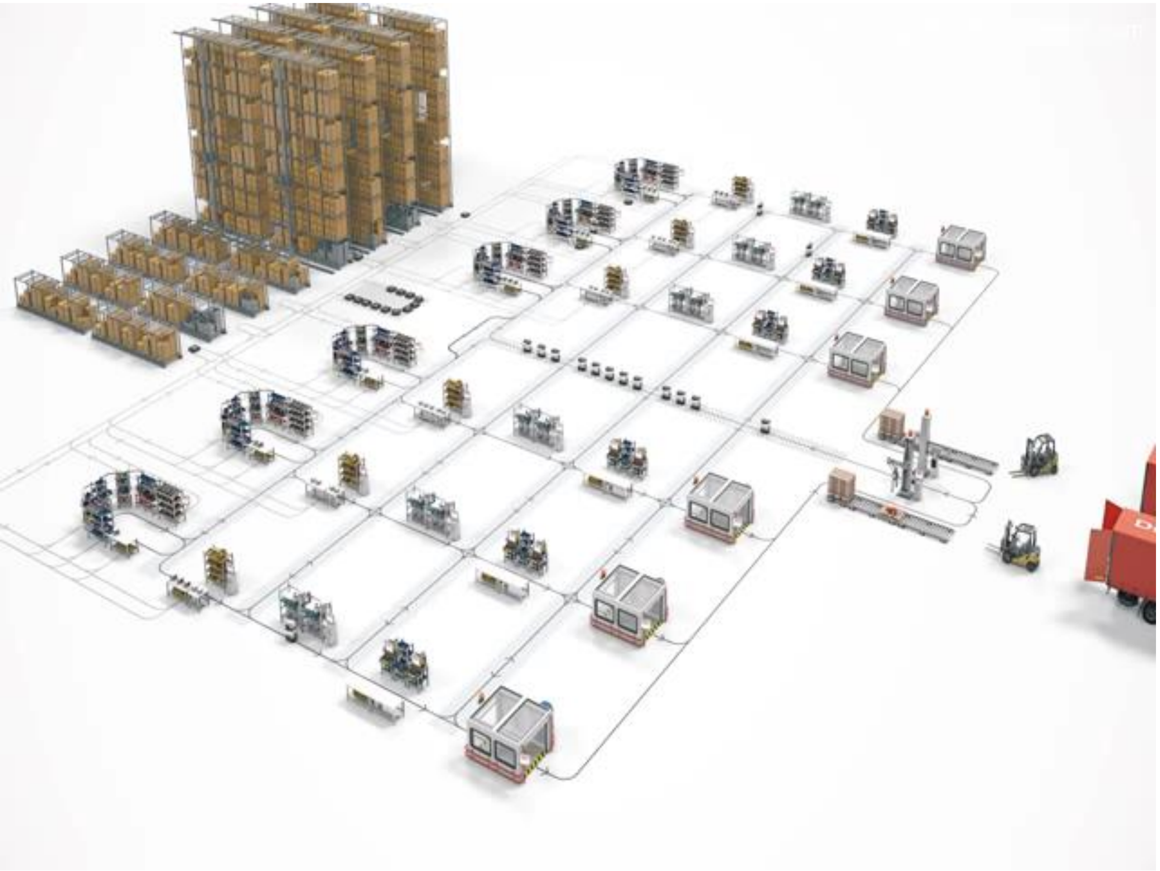
Changeable production tomorrow



- universal process modules
- interconnection of modules adapted to the situation
- routing flexibility inherent in the system
- self-similar systems-of-systems architectures
- dynamic reconfiguration subsystems
- no separation of body, paintwork, interior assembly
- no dissection of the overall organization

On the Way to Fluid Production

Example: SEW Eurodrive – merging of fluid logistics and partially automated U-Shape value-added cells



source: SEW Eurodrive

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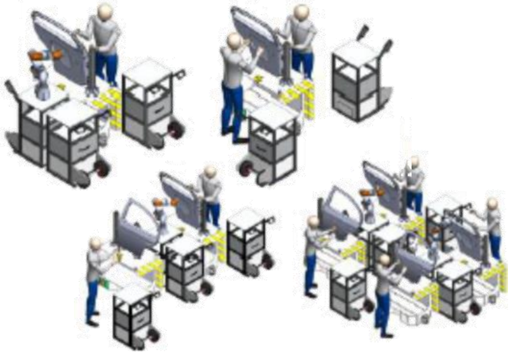
Guideline 3: Setup Processes and Structures Mobile and Scalable.

Value-adding structures can be redesigned dynamically and economically when needed.

Fixed production today

- fixed allocation of products to resources and to production tasks
- fixed layout
- safety fences between humans and machines
- fixed and investment-intensive automation
- resources dedicated to one specific operation

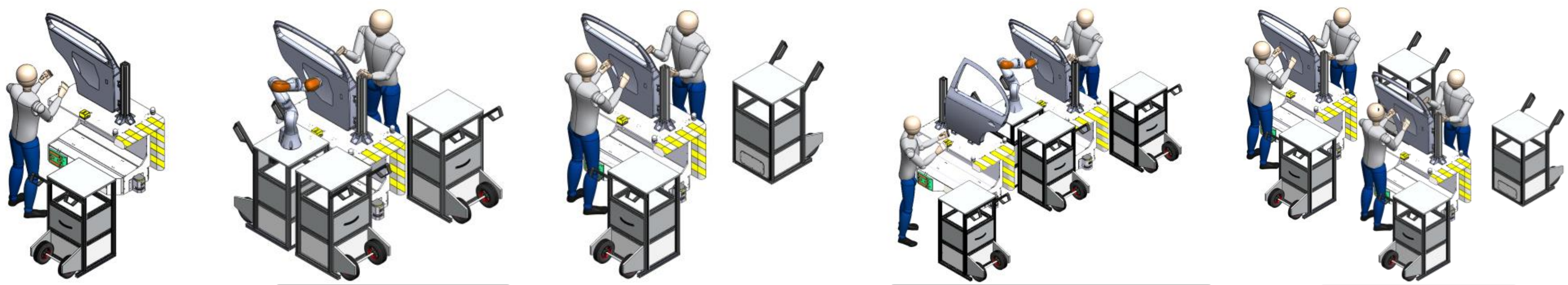
Changeable production tomorrow



- individual coordination of sequence and operation
- scalable automation
- human-robot-cooperation
- scaling and flow-orientated layout adjustment to daily production schedule
- system adjustment according to availability of resources

Output-oriented Configuration of Process Modules

Example: Assembly of a door module with HRC in ARENA2036



1 operator

1 operator, robot screws

2 operators

2 operators, 1 robot scres at 2 stations

4 operators at two stations

takt [sec]: 107 74 55 37 28

1 station | 2 stations | more than 2 stations

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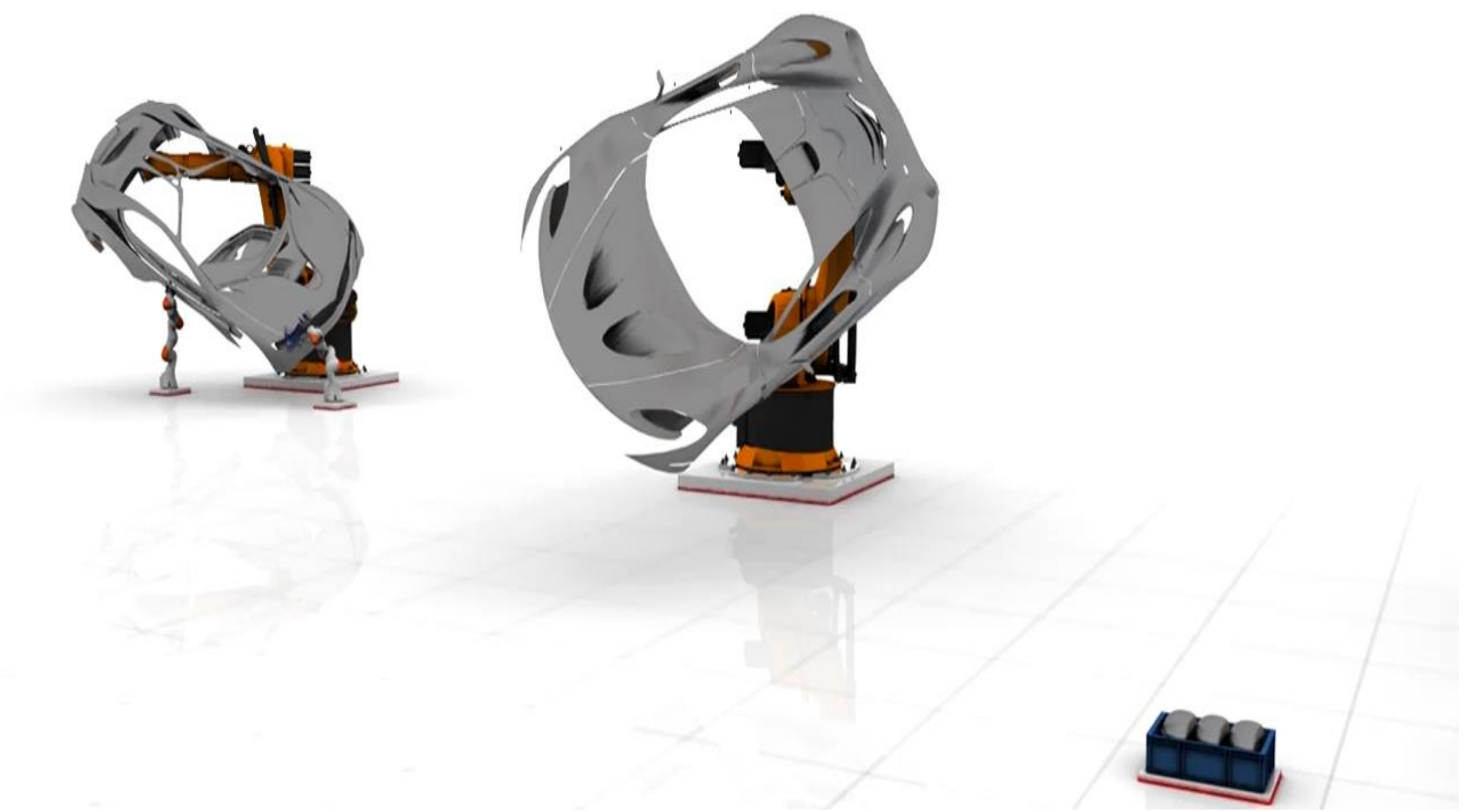
Fluid Production – Everything is Mobile and Scalable

Example: Active floor of Benjamin Logistics (start up company)



source: Benjamin Logistics

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Guideline 4: Design Intelligent Systems.

Self-regulated subsystems contribute with their self-healing abilities to a robust overall system.

Fixed production today

- centralized planning, controlling and optimization
- incorrect master data
- selective operating data recording
- manual commissioning, programming and optimization
- uncertain planning data
- planning, based on experience

Changeable production tomorrow

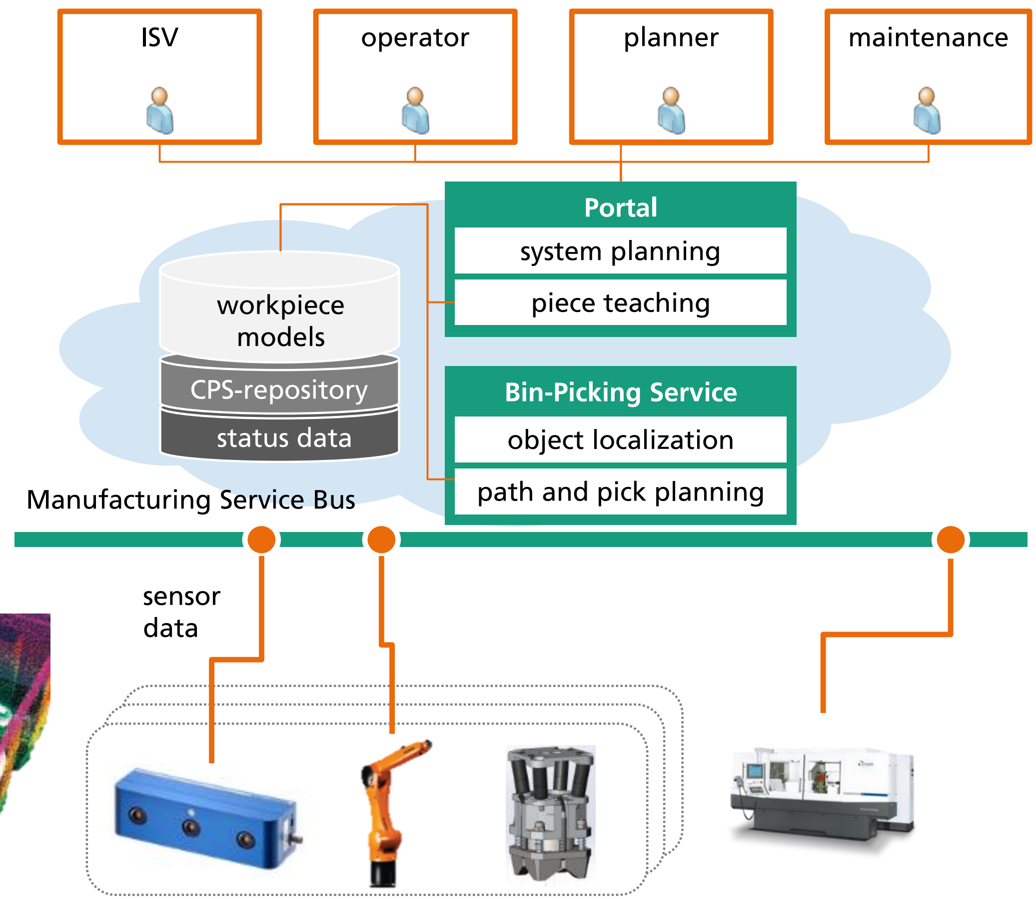
- intelligence shifted to decentralized entities
- plug-and-produce of system elements into systems of higher complexity
- self-description of CPS: always up-to-date information base
- cloud-based self-control
- changeable functional range of system elements
- virtual commissioning
- automated, self-optimizing operation planning

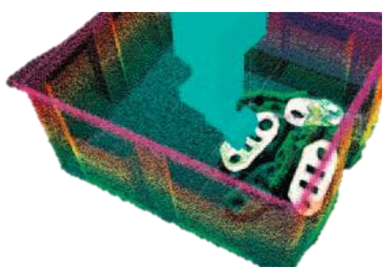
»Bin Picking« as Industrie 4.0 Application

Cloud Picking

Virtual Fort Knox

- shifting complex algorithms to the cloud
- process optimization through learning strategies
- lean robot system (»Lean Client«)
- business model e.g. »pay per unit/pick«





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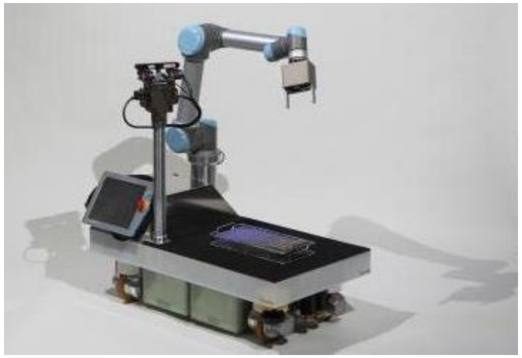
Guideline 5: Make Support Processes Value-adding.

All support process (i.e. logistics) are either transformed into value-adding support processes or eliminated.

Fixed production today

- fix installation of massive material flow systems
- complex supply chain network
- long-lasting planning horizon (forecast)
- high safety stock level
- material staging area is the bottleneck
- low time-share of value-add activities in total throughput time

Changeable production tomorrow



- innovative parallelization of assembly and logistics
- flexibility enabled by flexible material staging
- no material areas in production
- commissioning on tour
- assembly on AGV
- »best-fit« to avoid adjusting processes

Robots will be Mobile, Flexible and Safe

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

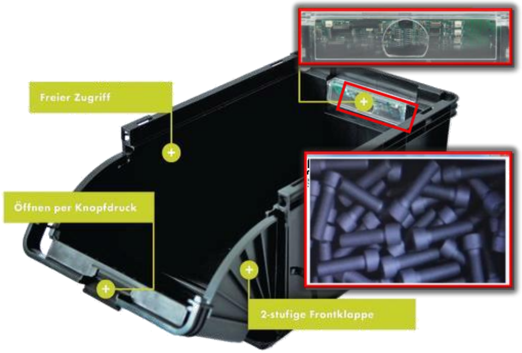
source: IPA

Guideline 6: Replace Material Flow with Information Flow.

Information is used effectively to reduce waste and stock and to support a downstream customization.

Fixed production today	Changeable production tomorrow

- Information flow is inflexibly linked to material flow
- lagged information flows
- information Overflow
- high level of buffer inventories to cope with insufficiencies



- real-time information access
- information flow adapted to actual needs
- intelligent integration of information
- simulation based on real time-data
- product differentiation through software variants

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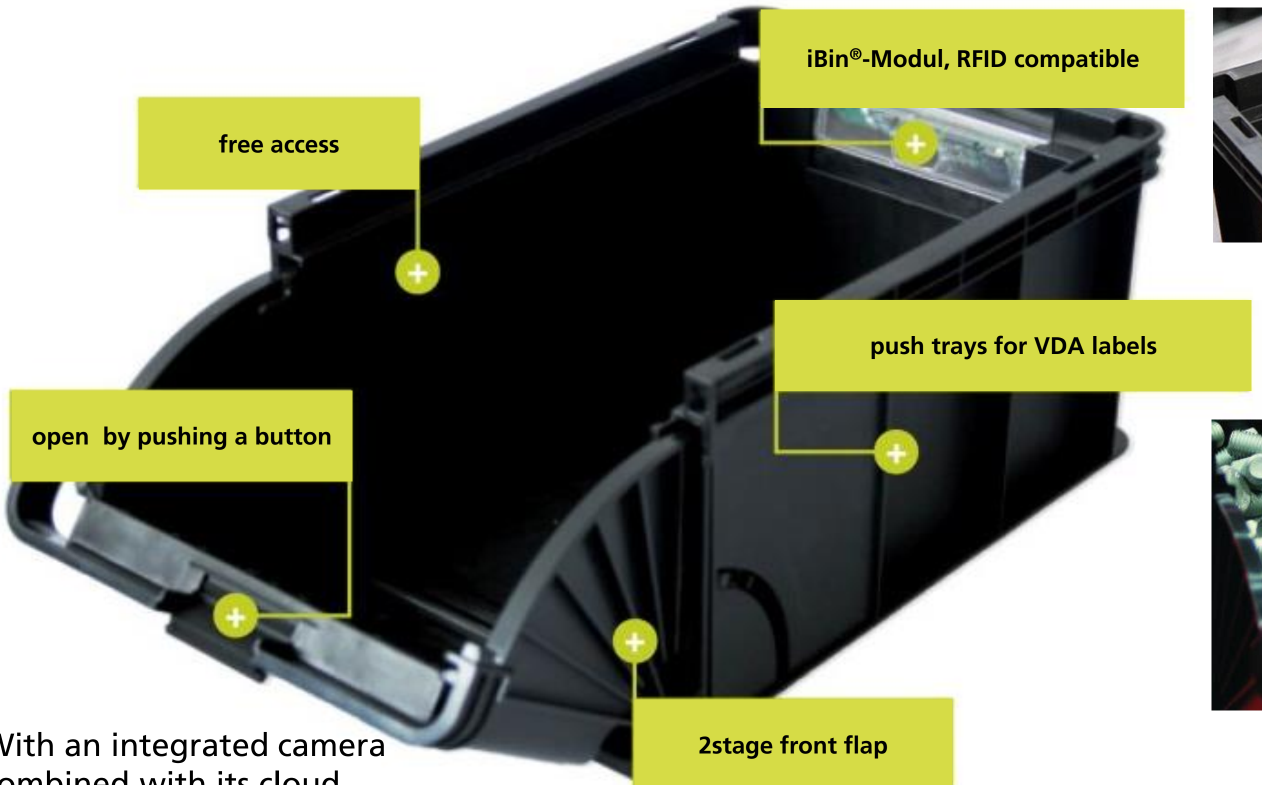
All Objects in a Factory will be Smart

iBin – Intelligent bins order their filling autonomously



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

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

WÜRTH

Replace Material Flow by Flow of Information

Example for personalized and urban production: Adidas Speed Factory

source: adidas

Guideline 7: Shift Process Complexity to Where it Can Be Handled Most Efficiently.

The value-adding systems boundaries are flexible, integrating customers and suppliers as value-add partners in the value-adding system.

Fixed production today

- predefined products with plenty of variants
- complexity of business processes and production must mainly be handled by OEM
- market risks and coordination efforts at introduction of new product designs
- system integration limited to core partners, due to cost and efforts
- many interfaces, partly standardized
- big networks of many small JIS-plants

Changeable production tomorrow

- active complexity management
- ad hoc configuration of value chains (MaaS)
- complexity of individualization managed by the customer as »Pro-Sumer«
- open source, open innovation and co-creation
- integration of additive manufacturing
- everything as a service
- just in realtime (JIR) delivery

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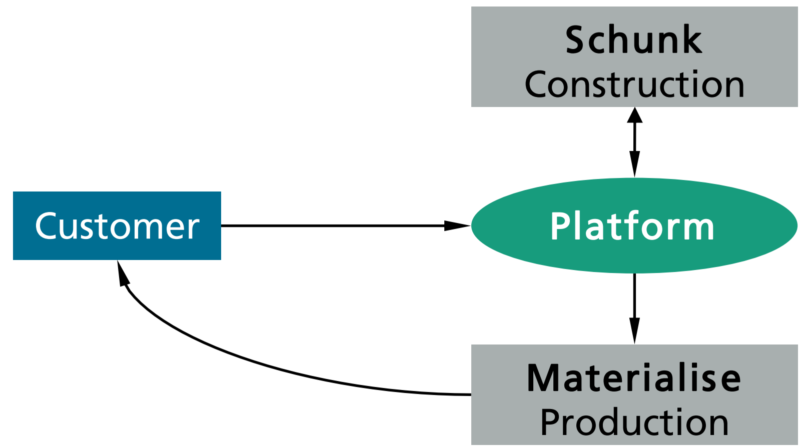
Business Model Innovation
Example Schunk eGRIP

Since 2015 suitable grippers can be ordered at Schunk, based on the CAD-Files of the parts that are transported.

- Reduction of order time and guarantee of high benefit for customers through integration of customers in the development process
- Communication via online platform
- The partner company Materialise takes over the 3D printing



source: Schunk GmbH; Materialise

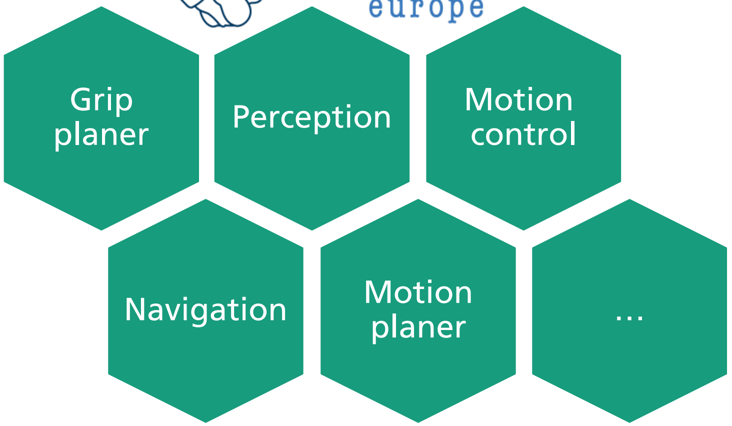
Open Source Communities as Enabler

Example: ROS for Industrial Robotics

Why Open Source?

- more than two million free open source software packages (FOSS) available
- robotics research available as bundled software components brings technology push
- increase of critical mass, quality, transferability etc.
- supports business models, especially for SME
- »rapid prototyping« of technologies
- cost advantage 33 % compared to new development[1]

Example: ROS industrial consortium europe



source: [1]N. Blümlein: Function-based System Engineering for Service Robot Prototypes (Diss Uni Stuttgart, 2013); [2]2014 Black Duck Software, Inc

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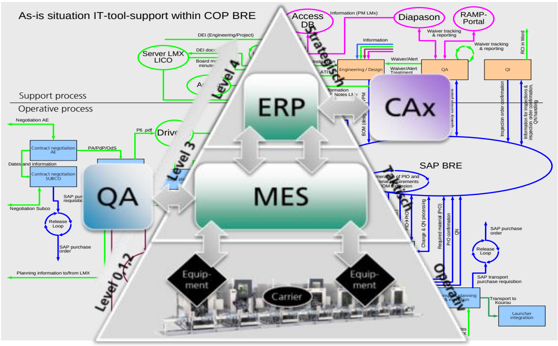
Guideline 8: Represent System Elements and Processes Continuously in a Digital Shadow.

Accurate prediction and evaluation of upcoming events is made possible.

Fixed production today



- unidirectional information flow from planning to »physical« operation level
- production planning and control as sequential processes
- inconsistent and incorrect data
- simulation with historic data
- high planning effort of planning in different phases

Changeable production tomorrow

- real-time system model for value-adding
- automated maintaining of master and dynamic data
- localization, supervision and forecast, based on live data
- production planning control based on real order situation
- transparency on current state makes prediction of future easier

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Networked Mobile Navigation in Industrie 4.0 Context

Cloud navigation

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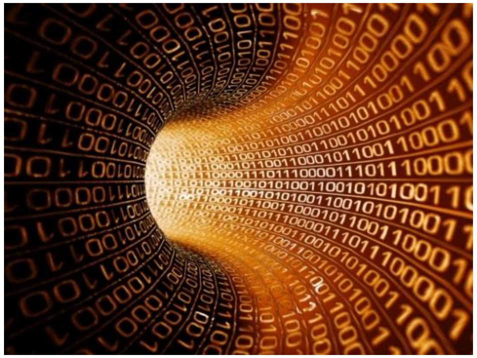
Cloud navigation for mobile robots
in intralogistics applications

source: https://www.youtube.com/watch?v=r7KjHMeic2I

Guideline 9: Optimize Production, Based on Data Analytics.

In complex systems correlation is more important than causality.

Fixed production today	Changeable production tomorrow
	

Fixed production today

- lean optimization (Six Sigma) of complicated systems
- search for root cause (Causality)
- problem solving by experts
- main question: WHY?

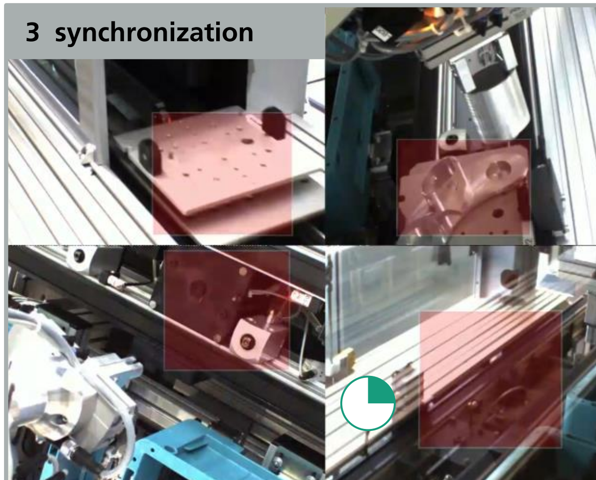
Changeable production tomorrow

- utilization of structured and unstructured data
- analytics with Big Data algorithms
- automated pattern recognition
- search for recipes (Correlation)
- main question: WHAT?

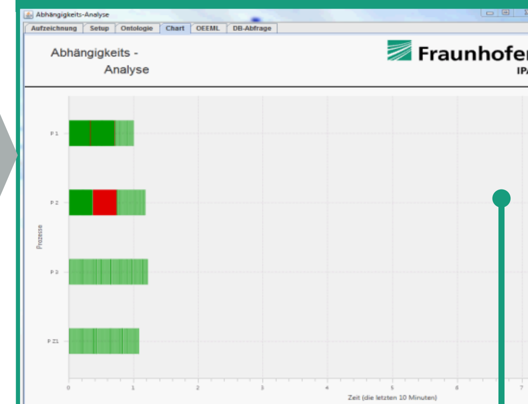
Detection of Anomalies: Smart System Optimization through Simultaneous Monitoring of all In-line Processes

set-up of cameras 1

3 synchronization



4 processing of the evaluation near real-time



2

teach-in of relevant features (approx. 5–20 per process)

extraction of all relevant data (smart data)

queries of semantic model and evaluation algorithms

- continuous evaluation of error effects, their causes and error propagation in chained systems >>who disturbs whom?<<
- evaluation of the dynamic shortage behavior
- visualization of single and chained effectivities
- detection of loss causes as potentials/chances

* Example with only one feature per process

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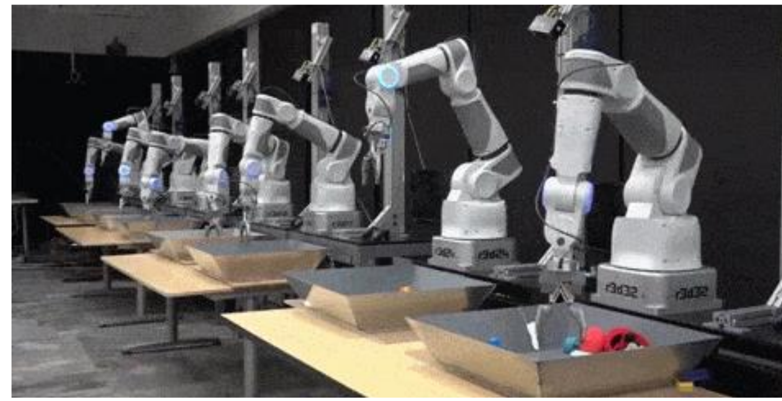
»Bin Picking« as Use Case for Industrie 4.0

Cloud Picking

Hand-Eye-Coordination with Robots (Google)

- 14 robots learned simultaneously within ~800.000 pick attempts to grasp varied objects from a bin; a monocular camera is used
- several robots exchange their experiences
- also unknown objects are being picked, deviations of camera position are being compensated due to the robustness of the used algorithms



source: https://i.ytimg.com/vi/H4V6NZLNu-c/hqdefault.jpg

Guideline 10: Focus the Human Role on Design and Optimization.

Humans use their skills to enhance the value-adding and thus optimize the overall system.

Fixed production today

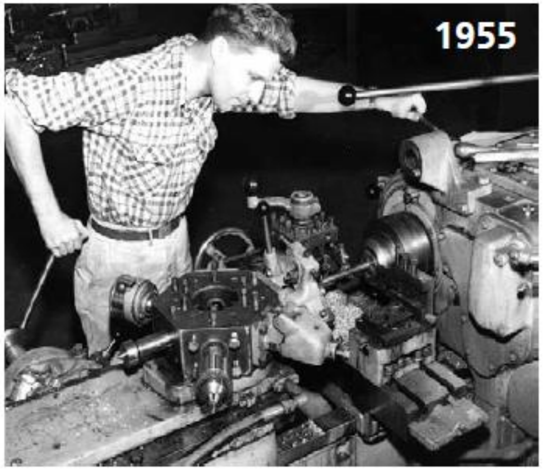
- separation of engineering and operations
- working cycle is forced by automated production system
- poor design and optimization autonomy of operators
- routine operations dominating human work

Changeable production tomorrow

- Reverse Taylor: merge engineering and operation
- automation of repetitive and standard work
- human intervenes when deviations occur
- design tasks and coordination are dominating human work

Change in Relationship between Human and Work Environment

Commander



Captain

Conductor

- Tasks of production workers and knowledge workers are merging (Revers Taylor)
- Routine tasks and simple technical and general work are taken over by machines
- New forms of cooperation and communication
- Increase of scope for decision-making and dispositive tasks
- New qualification demands: digital competence in all areas

source: Fraunhofer IAO

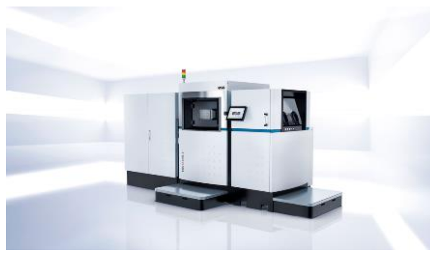
4 Archetypes of future Value-Adding Systems

Design depends on customer requirements and availability of production factors

GLOBAL

Regional Manufacturing for Global Markets

- Regional network of manufacturers
- Complex products
- Trust between the partners
- High level of knowledge-sharing
- High transport volume



REGULATIONS

Globally Integrated Value Networks

- Global manufacturing value network
- Make use of all regional benefits worldwide
- Highly integration of physical and virtual worlds
- Supply net excellence
- Restricted flexibility and adaptability

REGIONAL — DISTRIBUTION OF THE VALUE NETWORK — GLOBAL

- Manufacturing of the product near or by the consumer, using worldwide components, customized locally
- Very user-centered manufacturing
- Reduced transport volume
- Highly flexible

Urban Manufacturing

- Prosumer focus
- Short-term existence
- Extremely flexible
- Very focused and specialized
- Quality and security difficult to achieve and control

Virtual Value Networks

REGIONAL

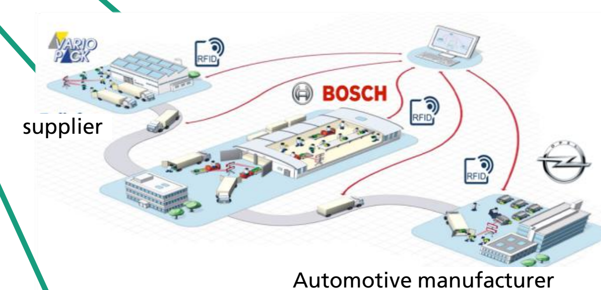
Business potential of Integrated Industry (Industrie 4.0)

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

Estimation of potential benefits

Costs	Effects	Potential
Stock costs	■ Reduction of safety stocks ■ Avoiding Bullwhip and Burbidge effects	**-30 to -40 %**
Manufacturing costs	■ Improving of OEE ■ Process control loops ■ Improvement of vertical and horizontal staff flexibility ■ Use of Smart Wearables	**-10 to -30 %**
Logistic costs	■ Higher level of automation (milk run, picking etc.) ■ Smart Wearables	**-10 to -30 %**
Complexity costs	■ Wider span of supervision ■ Reduced trouble shooting ■ Prosumer model ■ Everything as a Service (XaaS)	**-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.



-10 % milkruns

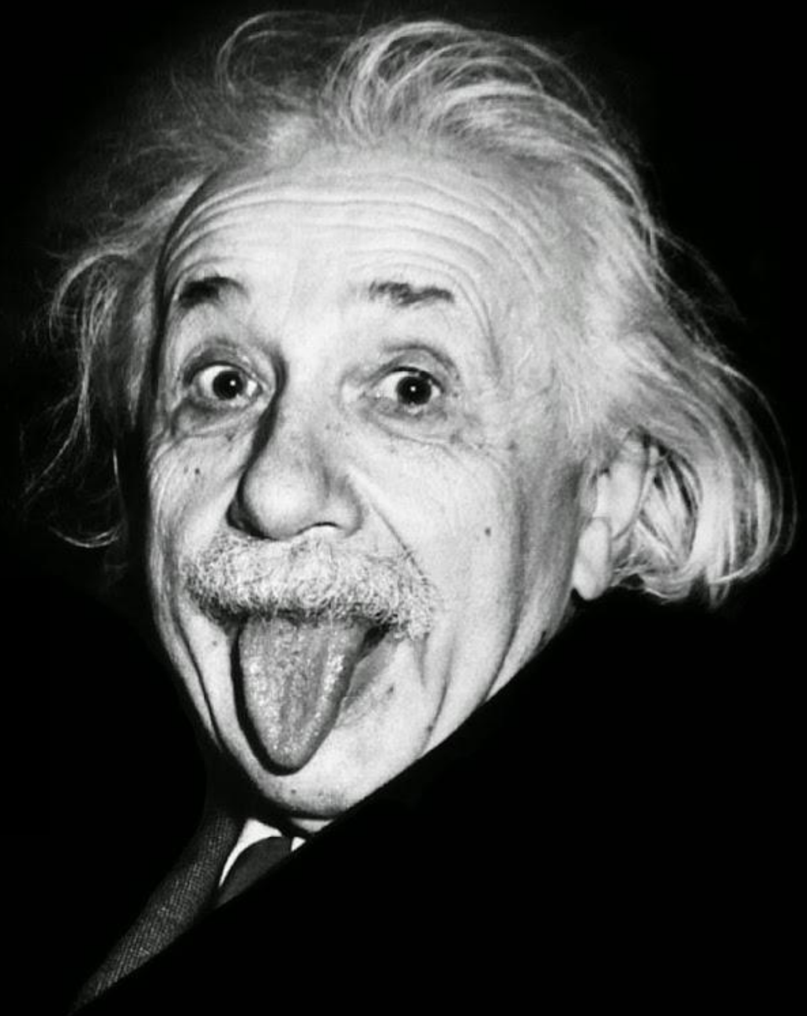
+10 % produc-tivity

-30 % stock reduction

source: IPA/Bauernhansl, Bosch

The definition of insanity is
doing the same thing over and over
again and expecting different results.

Albert Einstein



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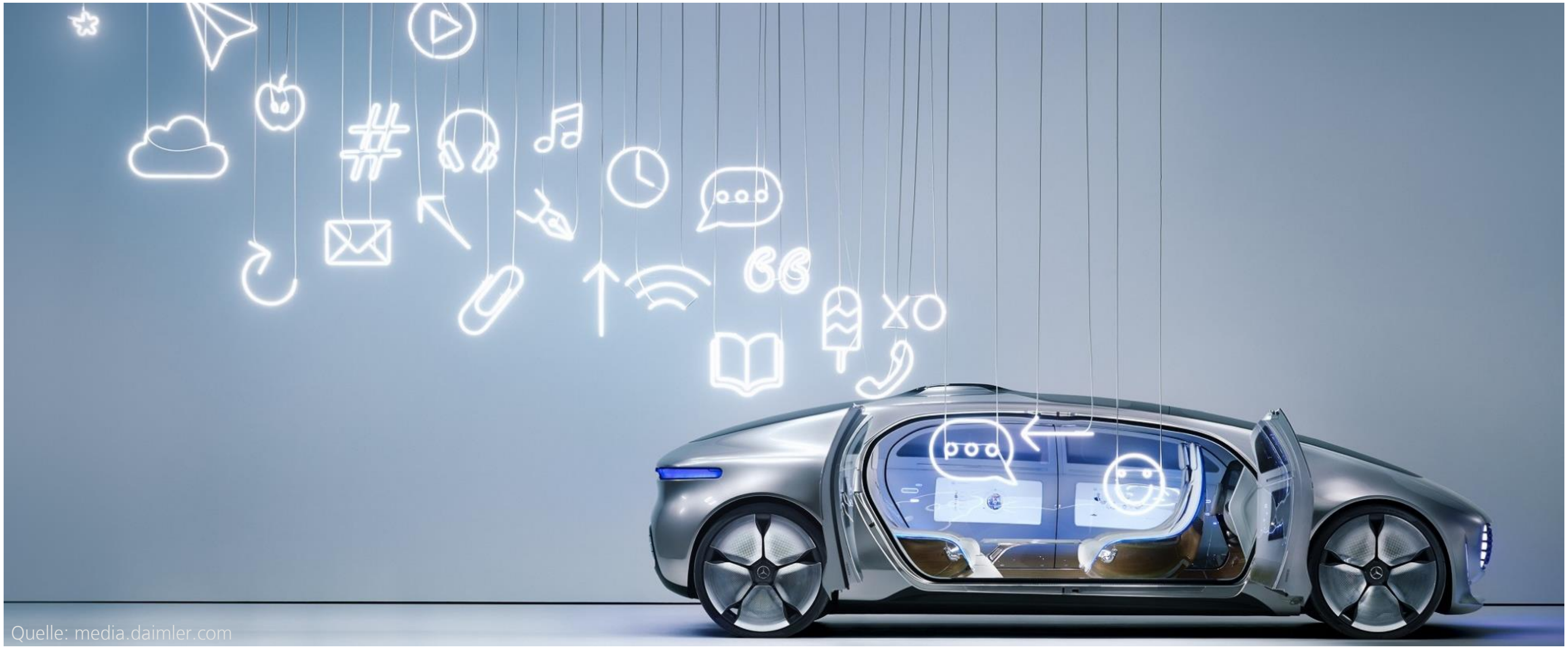
Prof. Dr.-Ing. Thomas Bauernhansl
6. Februar 2018



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