Definition of Smart factory concepts

Drivers for I4.0 implementation

1. Applying information and communications technology to digitize information and integrate systems into conception, development, manufacturing and use of products.
2. Increase innovation capacity.
3. Increase productivity.
4. Develop new standards and regulations.
5. New software technologies for modeling, simulation, virtualization and digital manufacturing.
6. Development of cyber-physical systems to monitor and control physical processes.
7. The evolution of 3D printers and additive manufacturing to simplify manufacturing.
8. Savings of raw materials and energy.
9. Decision support for human operators, the emergence of intelligent tools and assistance using augmented reality.
10. Integration of customer through network (cyber-physical systems).

Drivers for I4.0 implementation

11. Human-Robot Collaboration.
12. Raise up the employee technical and non-technical skills to adapt with new technology.
13. Digital Computing Assistance Systems and Virtual Training.
14. Decentralization: faster and data-driven decision-making.
15. Efficiency increases and cost reductions.
16. Role of government as enabler facilitator and policy makers.
17. Improving the work environment.
18. Decrease documentation and administration.
19. Increase traceability.
20. Increase people safety in the dangerous work places.

Enablers of digitalization and I4.0 implementation

What are digital enablers?

Important

1. **Digital enablers for the hybridisation of the physical and digital world**
   - Sensors and embedded systems
   - Advanced robotics
   - Simulation and digital twins

2. **Digital enablers for communications and data processing**
   - High processor power
   - Connectivity and mobility
   - Cloud Computing
   - Cybersecurity

3. **Digital enablers for intra-enterprise and inter-enterprise management**
   - Business solutions (software for CRM, ERP, etc.)
   - Intelligence and control solutions (BigData & Analytics)

Challenges and barriers for I4.0 implementation

1. Monetary - Financial

- Excessive monetary fees
- Business model variation
- Doubtful economic advantages/excessive funding

2. Social

- Personal issues (like sharing of personal information on internet)
- Monitoring of activities for gathering information (suspect)
- Resistance to change by shareholders
- Redundancy risk (Information Technology department)
- Unemployment increased due to automation, particularly for blue-collar workers

3. Political

- Forms of certifications and standards not fully developed
- Doubtful legal law for the protection of information

Challenges and barriers for I4.0 implementation

4. Organizational

- Information protection
- Machine-to-Machine (M2M) communication needs stability and reliability
- Power of product integrity
- Unexpected obstacle for IT should be avoided (network outage)
- Shielding (protecting) the industrial knowledge
- Adequate skills should be expedited
- Commitment of top management
- Qualification of personnel inadequate (Bag et al., 2021b)

5. Key challenges to Industry 4.0: technical skills, investment (cost, cybersecurity, privacy hazards, big data analysis, human-machine interaction, cyber-physical systems, data management and integration, knowledge-driven processes, capital, labour, education…

Challenges and barriers for I4.0 implementation

1. High Investment in Industry 4.0 Implementation.
2. Lack of Clarity Regarding Economic Benefit and excessive investments.
3. Challenges in Value-chain Integration.
4. Low Maturity Level of Preferred Technology.
5. Disruption to Existing Jobs.
6. Lack of Standards, Regulations etc.
7. Lack of Digital Skills.
8. Lack of Internal Digital Culture and Training.
9. Ineffective Change Management.
10. Resistance to Change.
11. Lack of Infrastructure.
12. Data security risks.

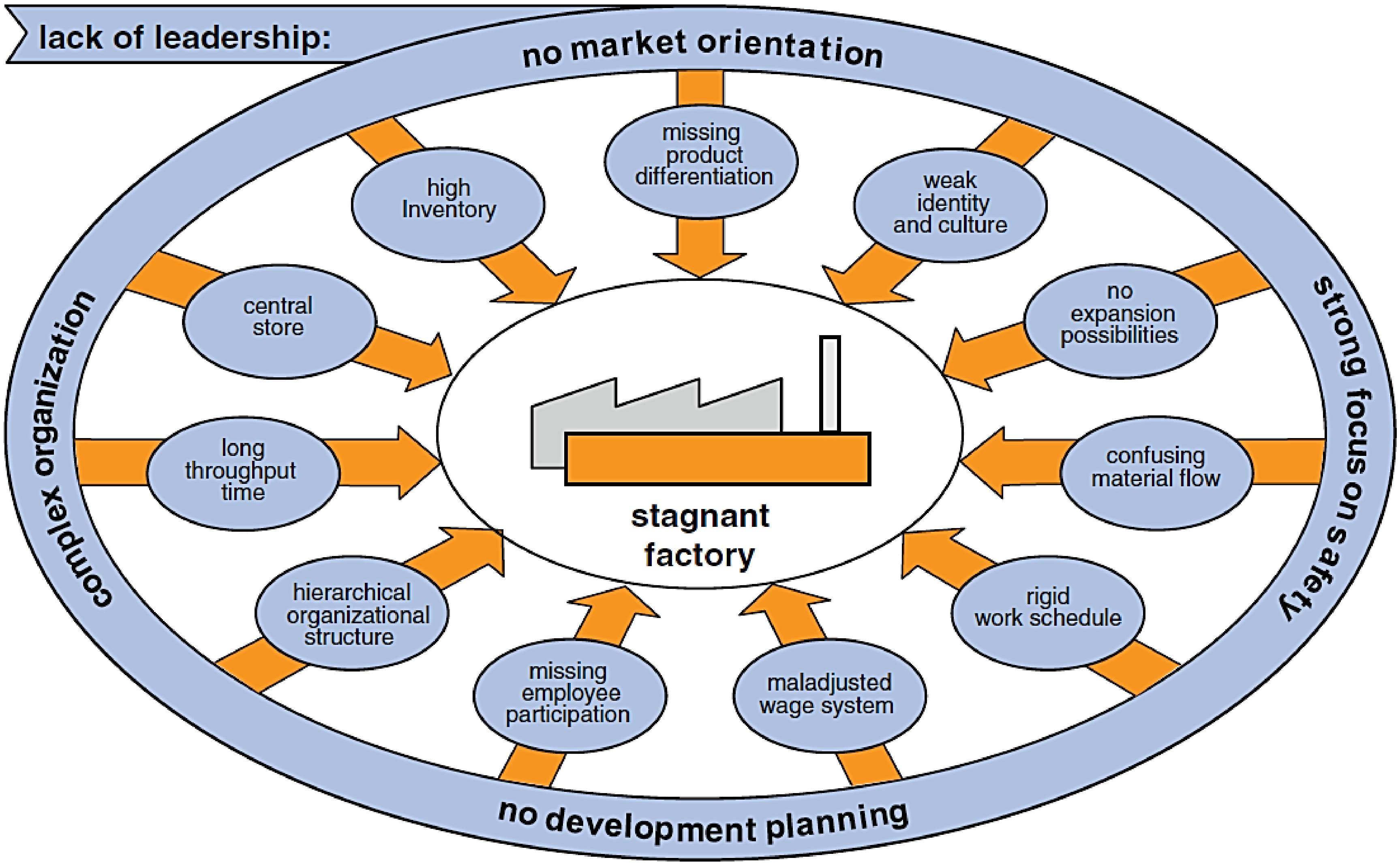
Challenges and barriers for I4.0 implementation

13. High Cost of Digital Technologies.
14. Insufficient qualifications of employees.
15. Lack of a clear digital vision.
16. Lack of data analytical capabilities.
17. Leadership Skill Gap.
18. Workforce Skill Gap.
19. Lack of a Digital Strategy Alongside Resource Scarcity.
20. Top management has no awareness in Industry 4.0.
21. Integration of new technology with old equipment.
22. Lack of formalized information on Industry 4.0 implementation.
23. Lack of methodical approach for implementation.

Traditional, stagnant production (factory)

The difference between traditional and Smart factory

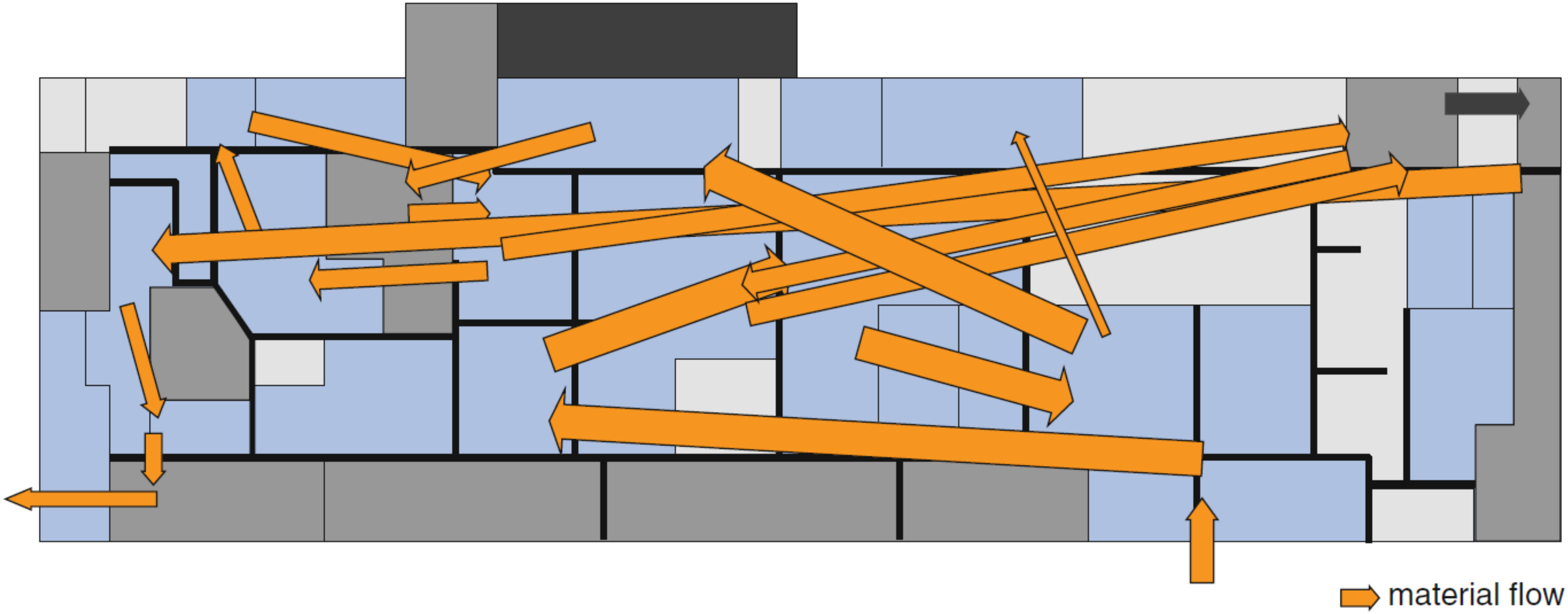
Important



Source: Handbook Factory Planning and Design; Wiendahl et al., 2015

Traditional, stagnant production (factory) Layout and material flow

LEAN



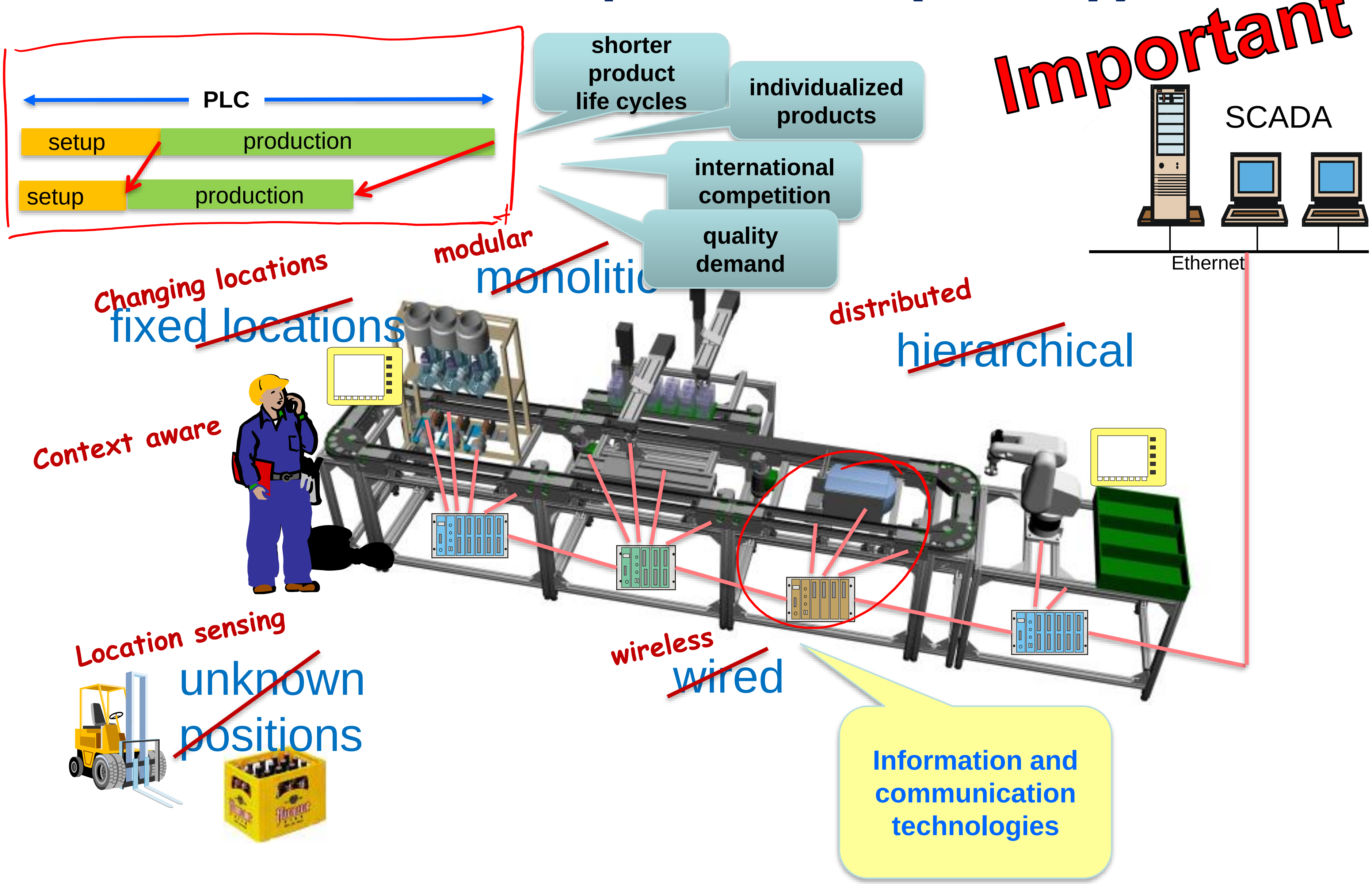
analysis results:

- strongly non-directional material flow
- production distances1300 m to 1500 m
- setup times up to 16 hours
- rework share 20%
- lead time app. 38 working days
- area deficit 1400 m ²

Important

Source: Handbook Factory Planning and Design; Wiendahl et al., 2015

Traditional vs. Smart production (factory)

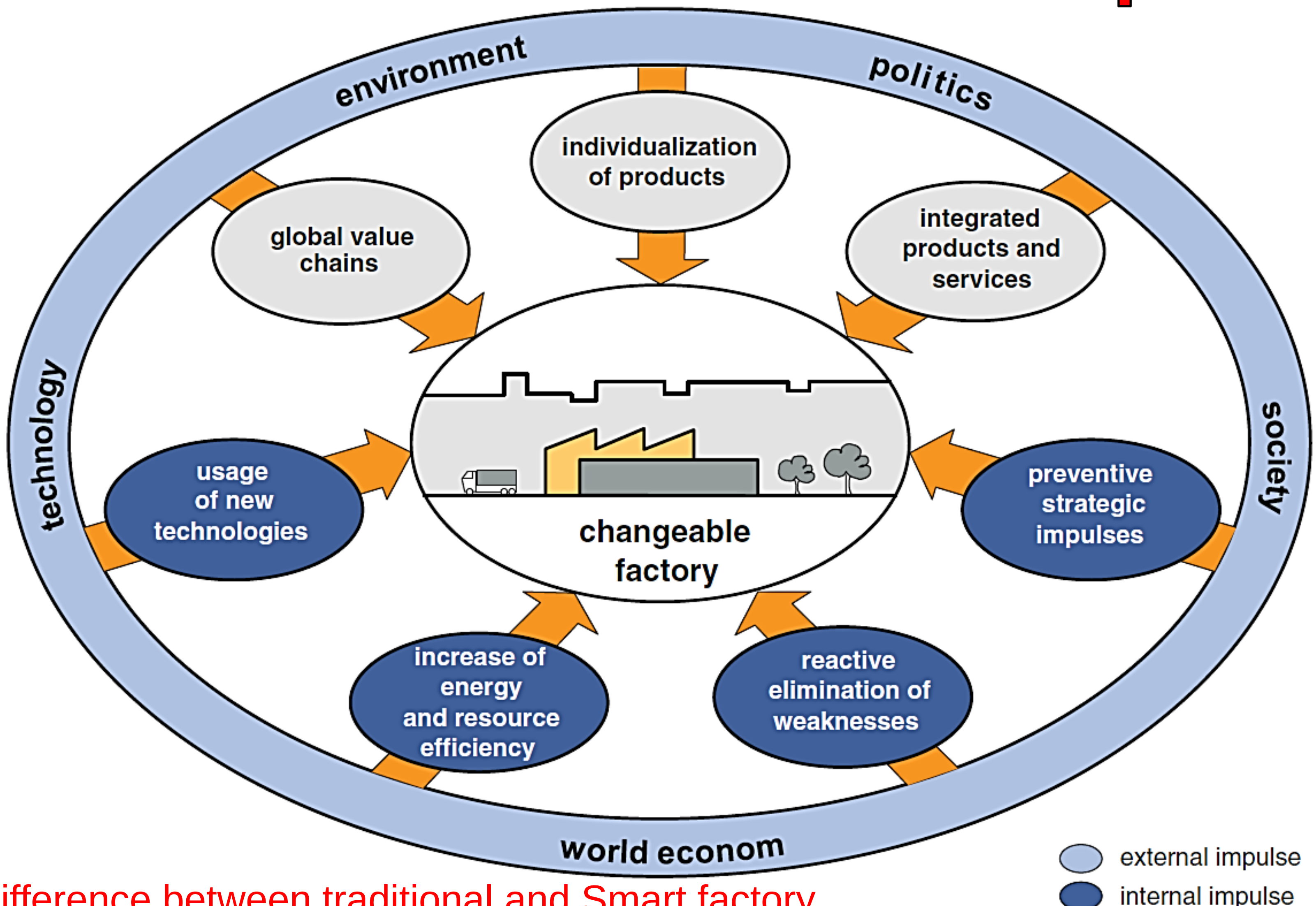


The difference between traditional and Smart factory

Source: Zühlke, Smart Factory

Internal and external change drivers for production enterprise

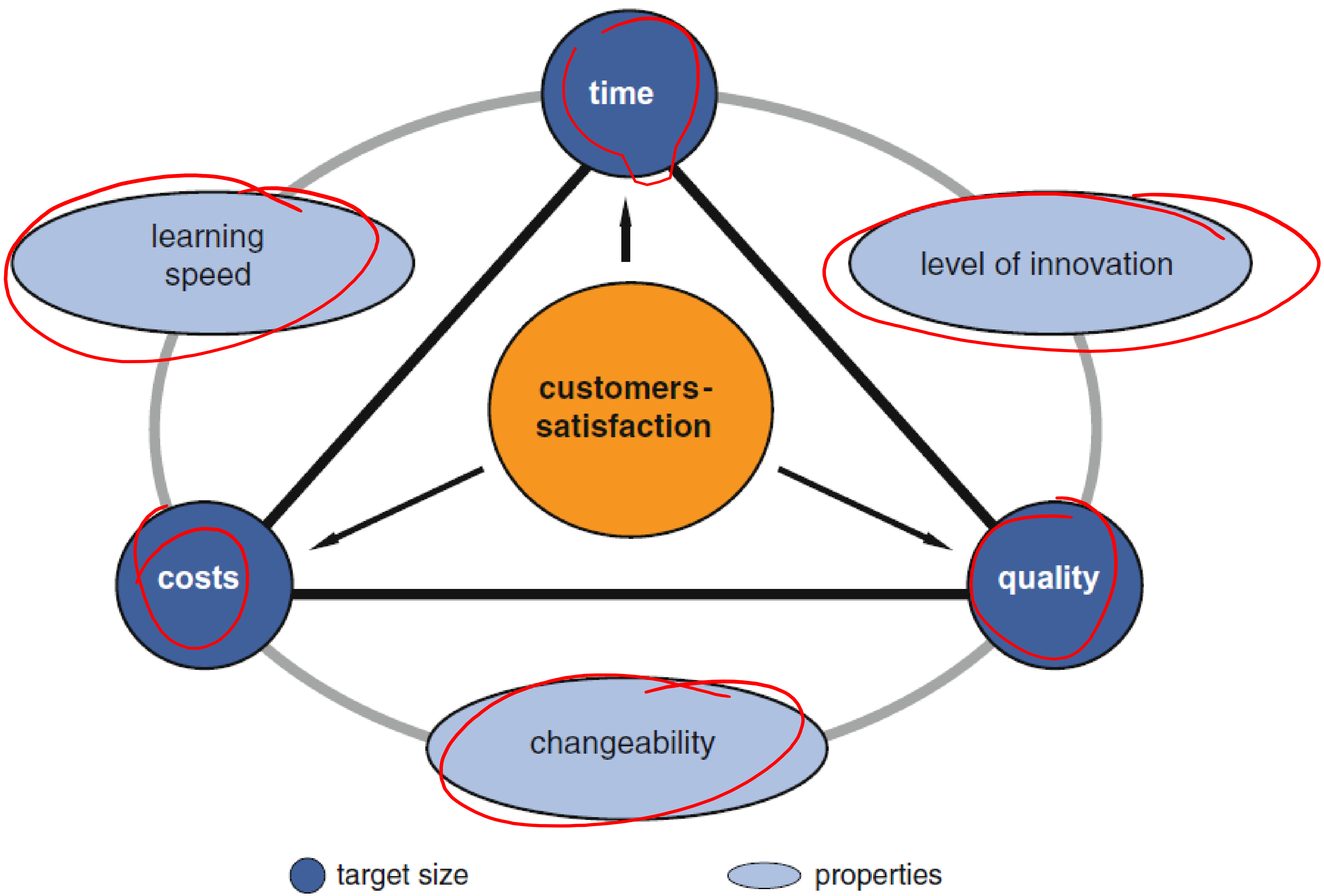
Important



The difference between traditional and Smart factory

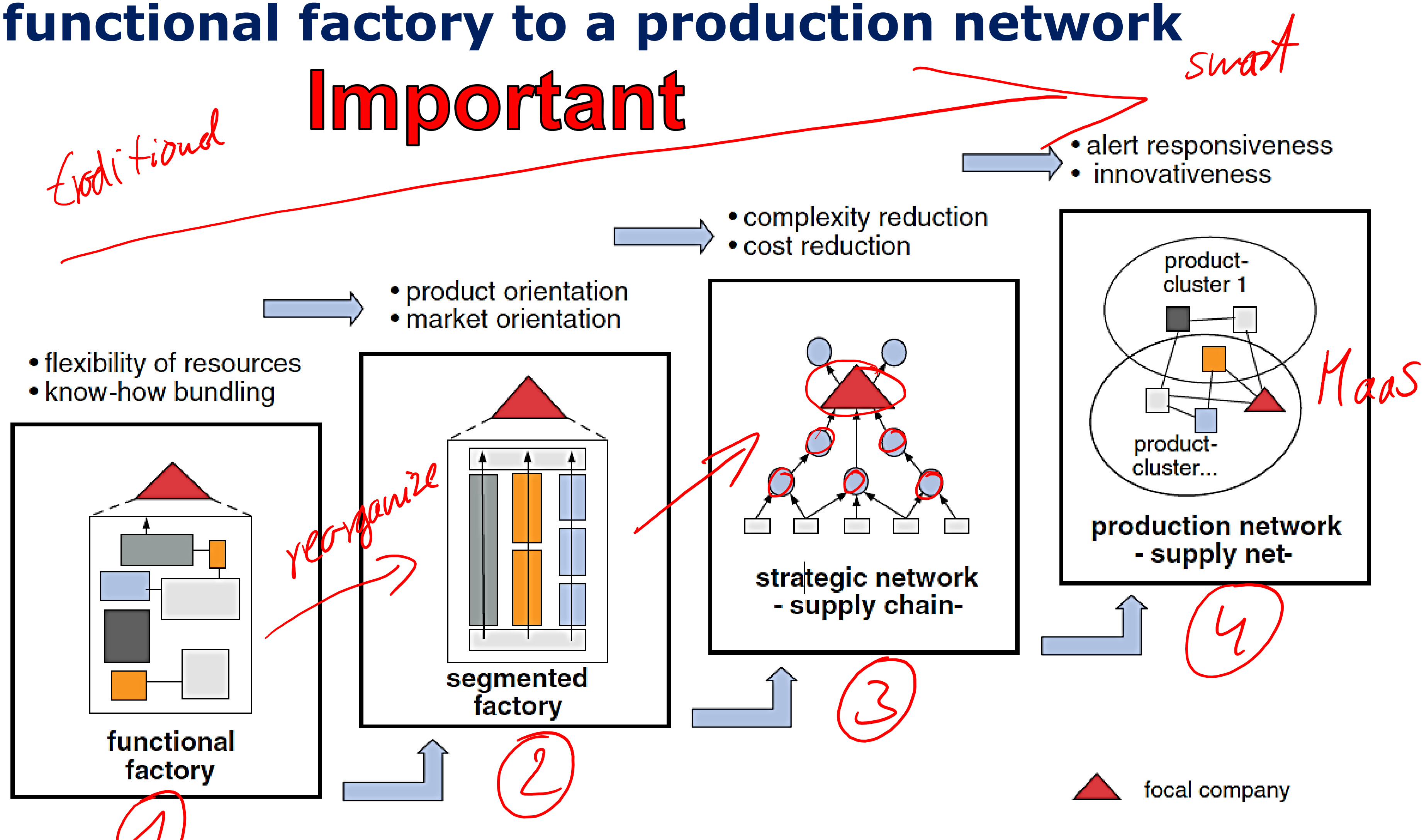
Source: Handbook Factory Planning and Design; Wiendahl et al., 2015

Competitive factors of (advanced) superior enterprise



Source: Handbook Factory Planning and Design; Wiendahl et al., 2015

The evolution of factory development – from a functional factory to a production network



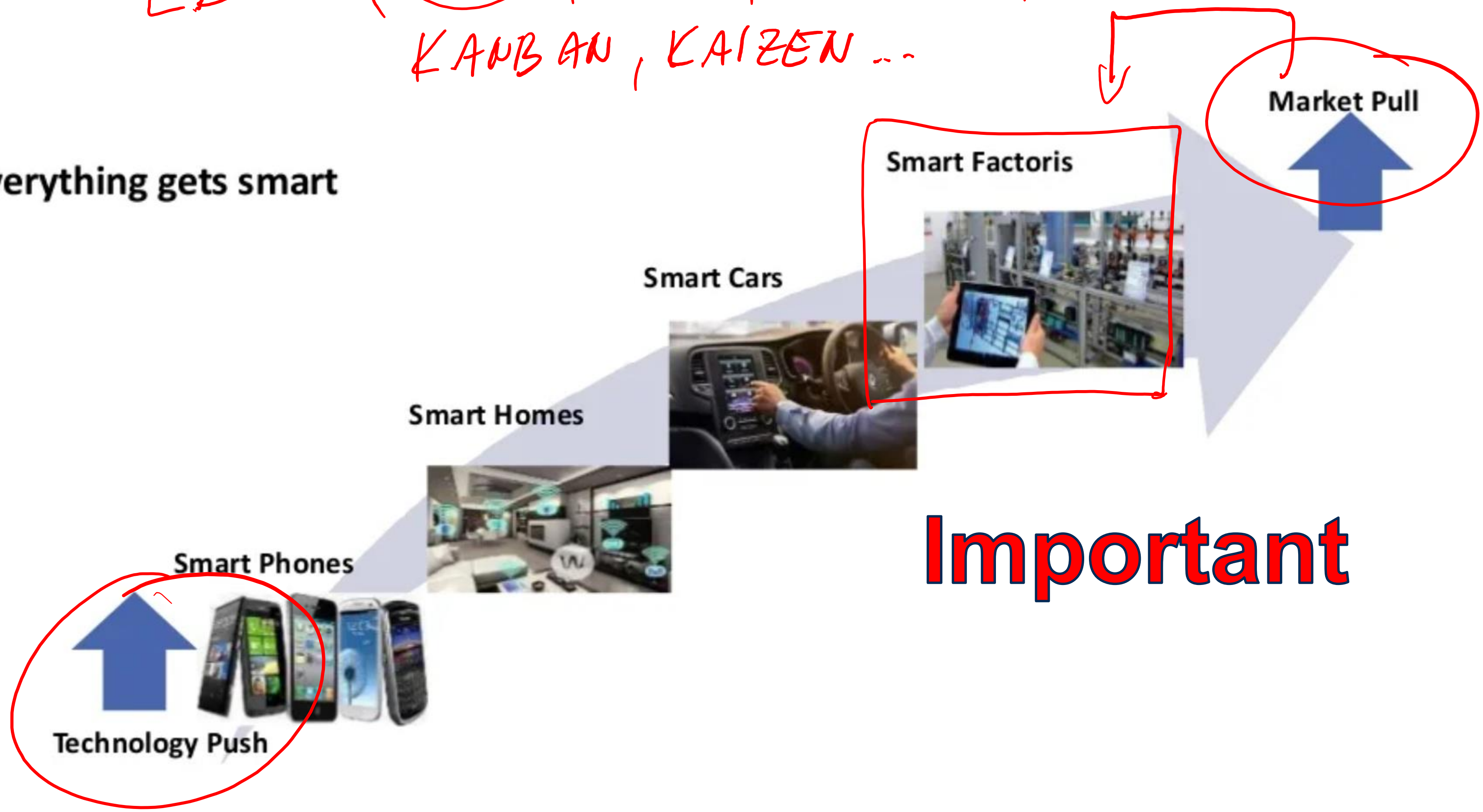
MaaS – Manufacturing as a Service

Source: Handbook Factory Planning and Design; Wiendahl et al., 2015

Smart factory should allow „MARKET PULL“ approach

LEAN (PULL, PUSH, VSM, 6σ, JIT, ...)
KANBAN, KAIZEN ...

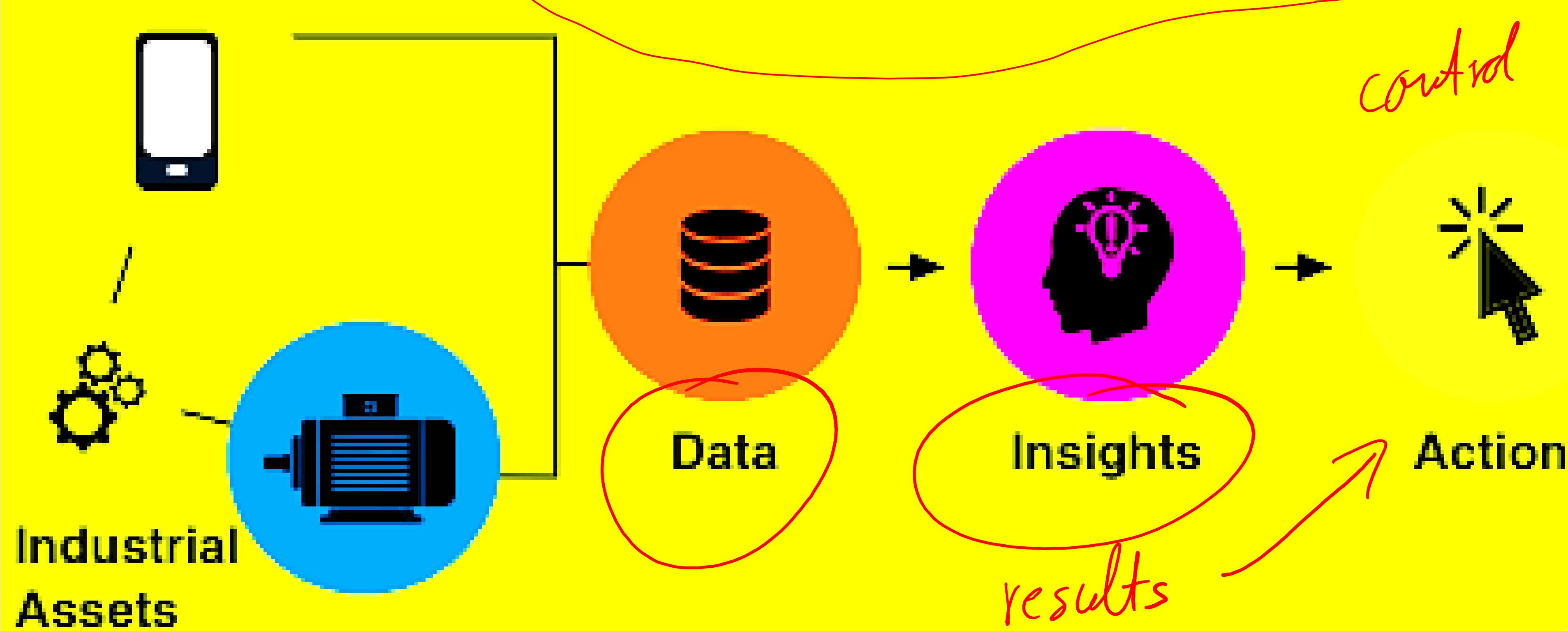
Everything gets smart



Important

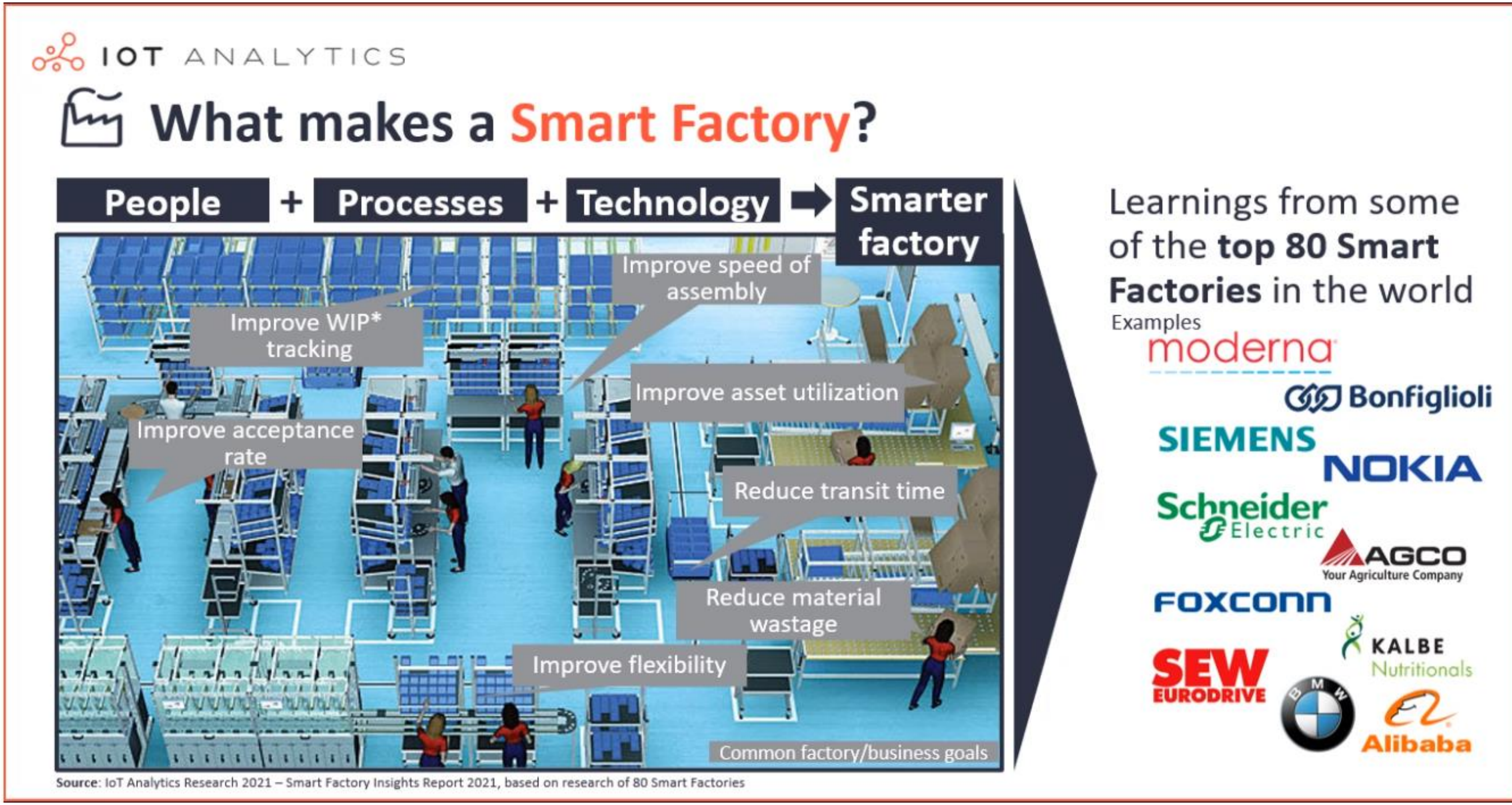
Smart Factory - definition

Digitalization (IoT, CPS, DT)
Transparency (data analytics, visualization)
Automation (without human present)
Self-awareness (automatic decisions, actions)



Important

Smart Factory - definition



Smart Factory - definition

What a smart factory really is – a definition

Based on several researches, **a smart factory is "the holistic transformation of people, processes, and technologies along with the use of data to achieve the intended performance/business goals of one or more production site(s)."**

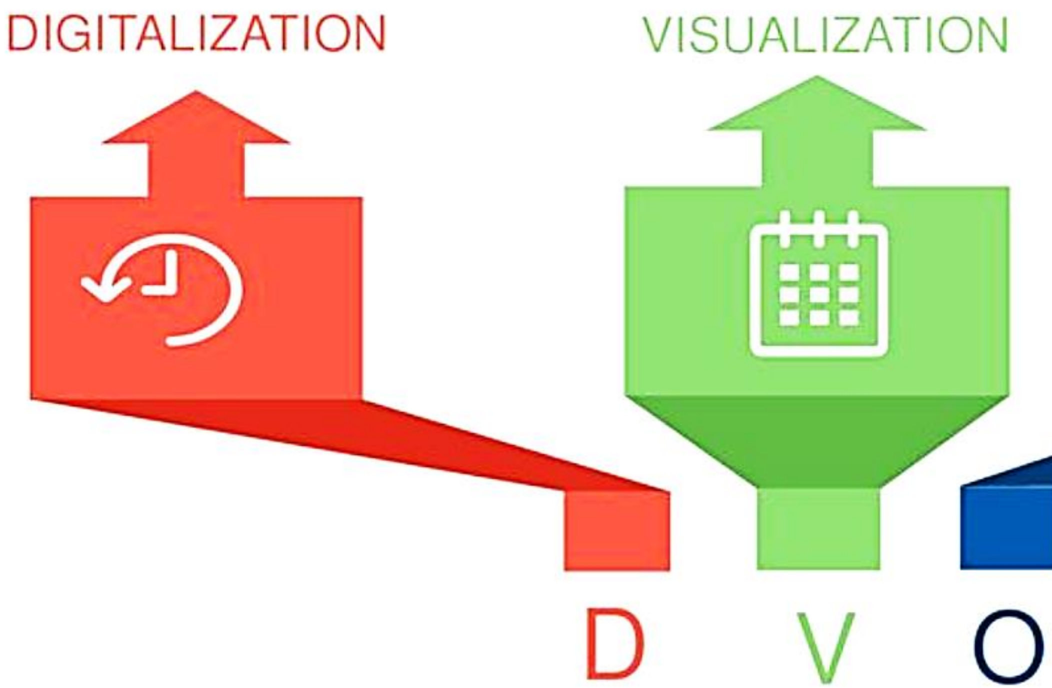
It is important to understand that a smart factory is not a destination or an end goal, but a journey that all manufacturing organizations can embark on at their own pace.

Important

Smart Factory – Vision

Connecting and digitalizing all machines, human and material processes to allow analytics and visualizations enabling self-correction, self-learning and self-optimization.

SCADA



advance algorith.

AI

- heuristics
- metaheuristics

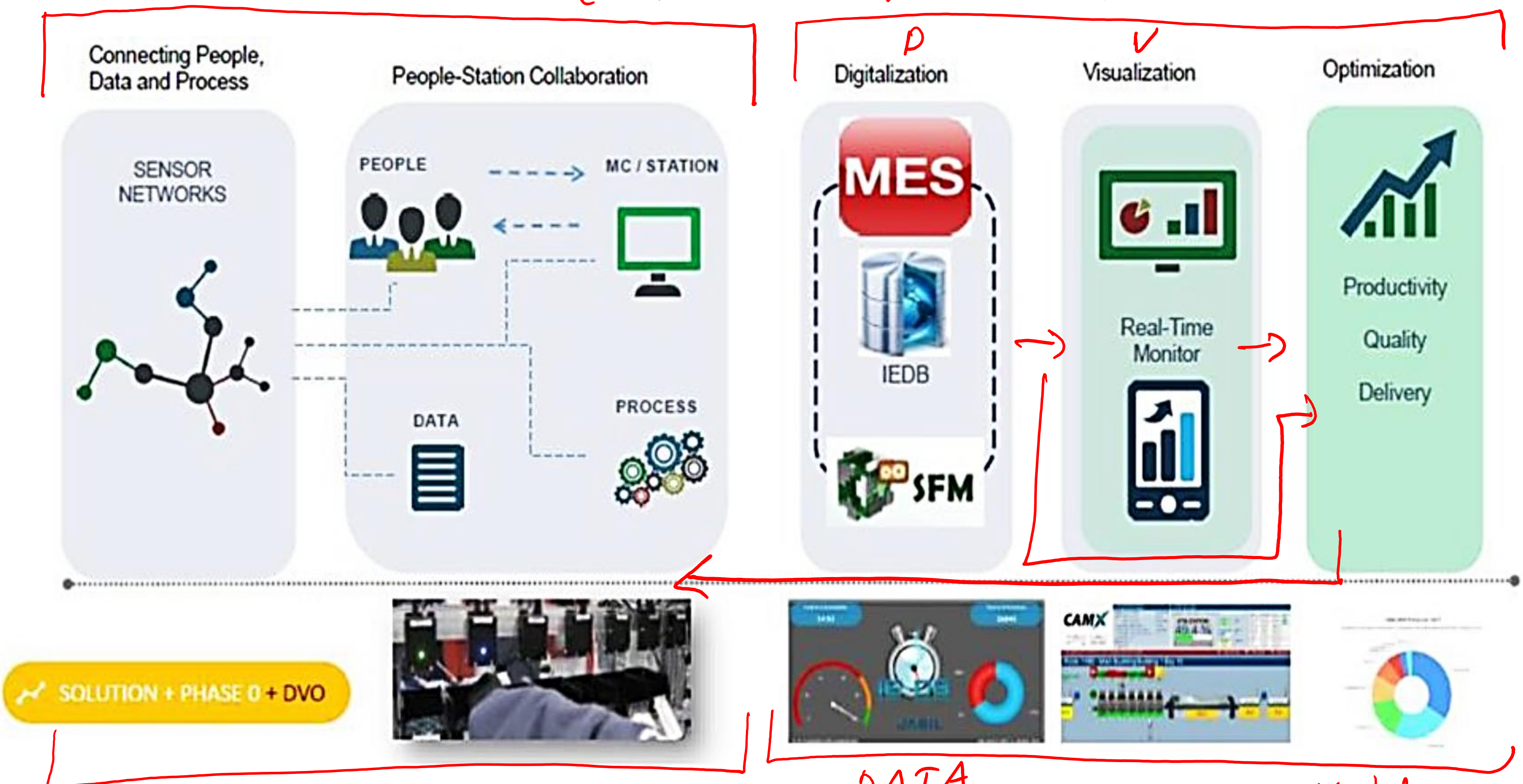
Important

Source: EOS, EMS Operations Services

Smart Factory – DVO Example

DT (DA)

real world CFS CFP virtual world

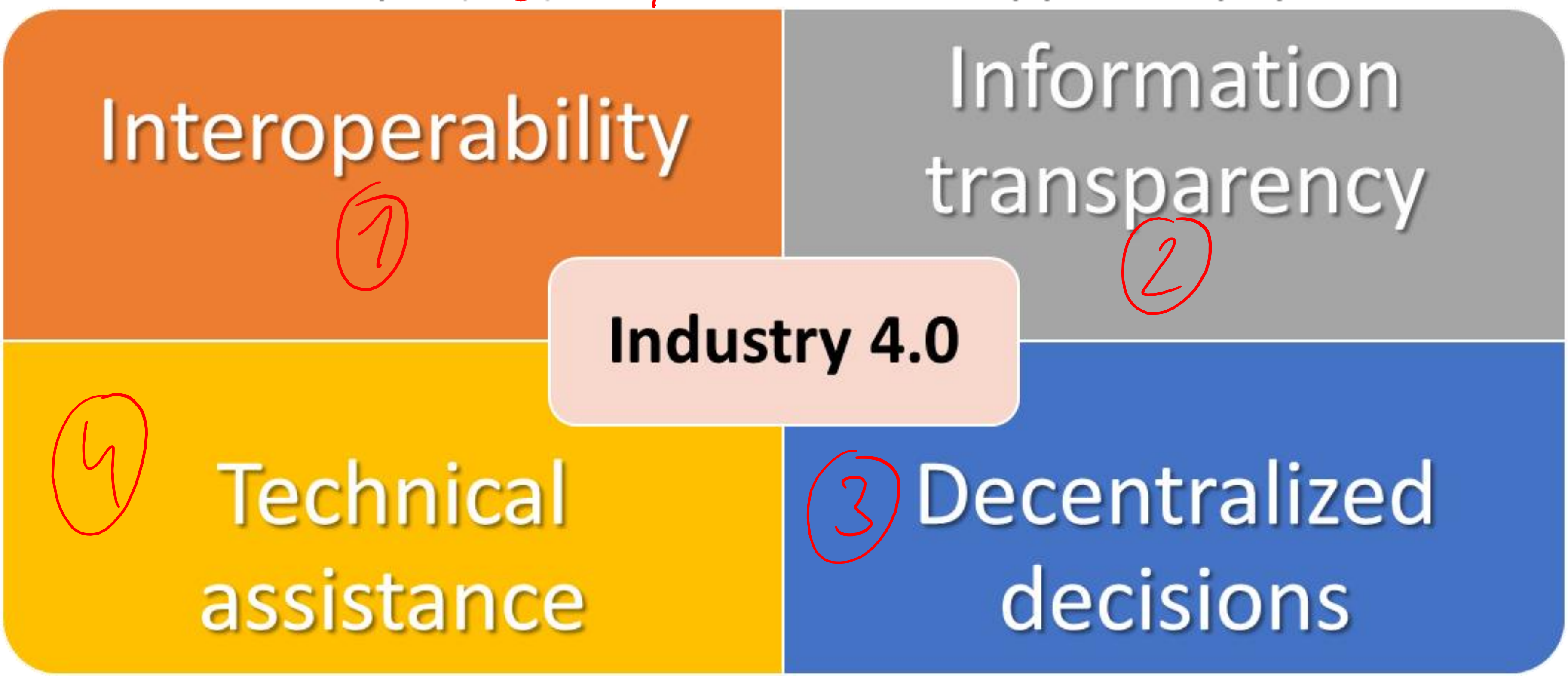


Important

Smart Factory – Design principles

Internet of Things (IoT)
Internet of People (IoP)

Digital plant models
virtual copy of the physical world

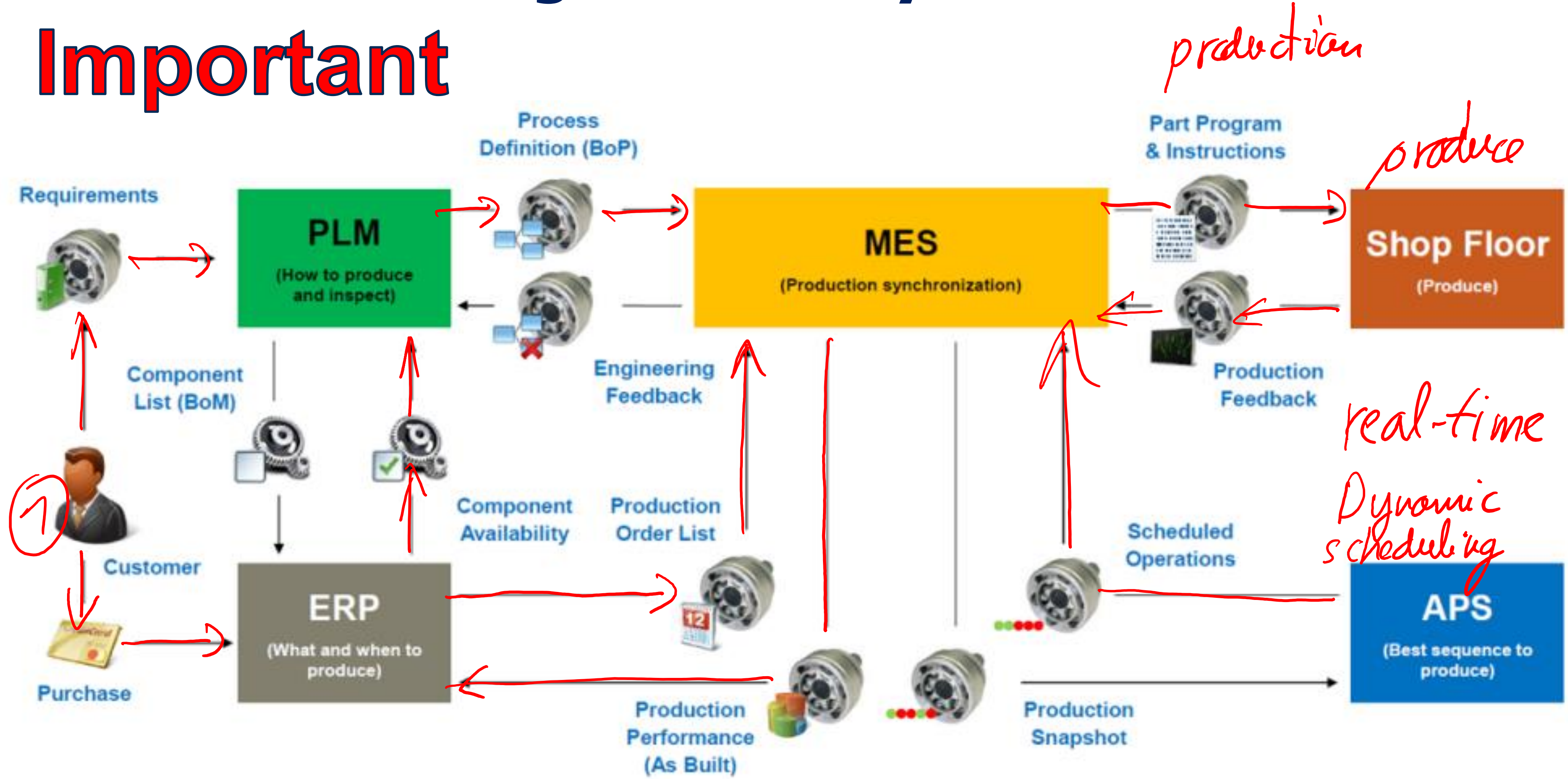


The ability of cyber physical systems to physically support humans by conducting a range of tasks.

The ability of cyber physical systems to make decisions on their own and to perform their tasks as autonomous as possible.

Digital Factory Flow

Important



Source: SNIC Solutions

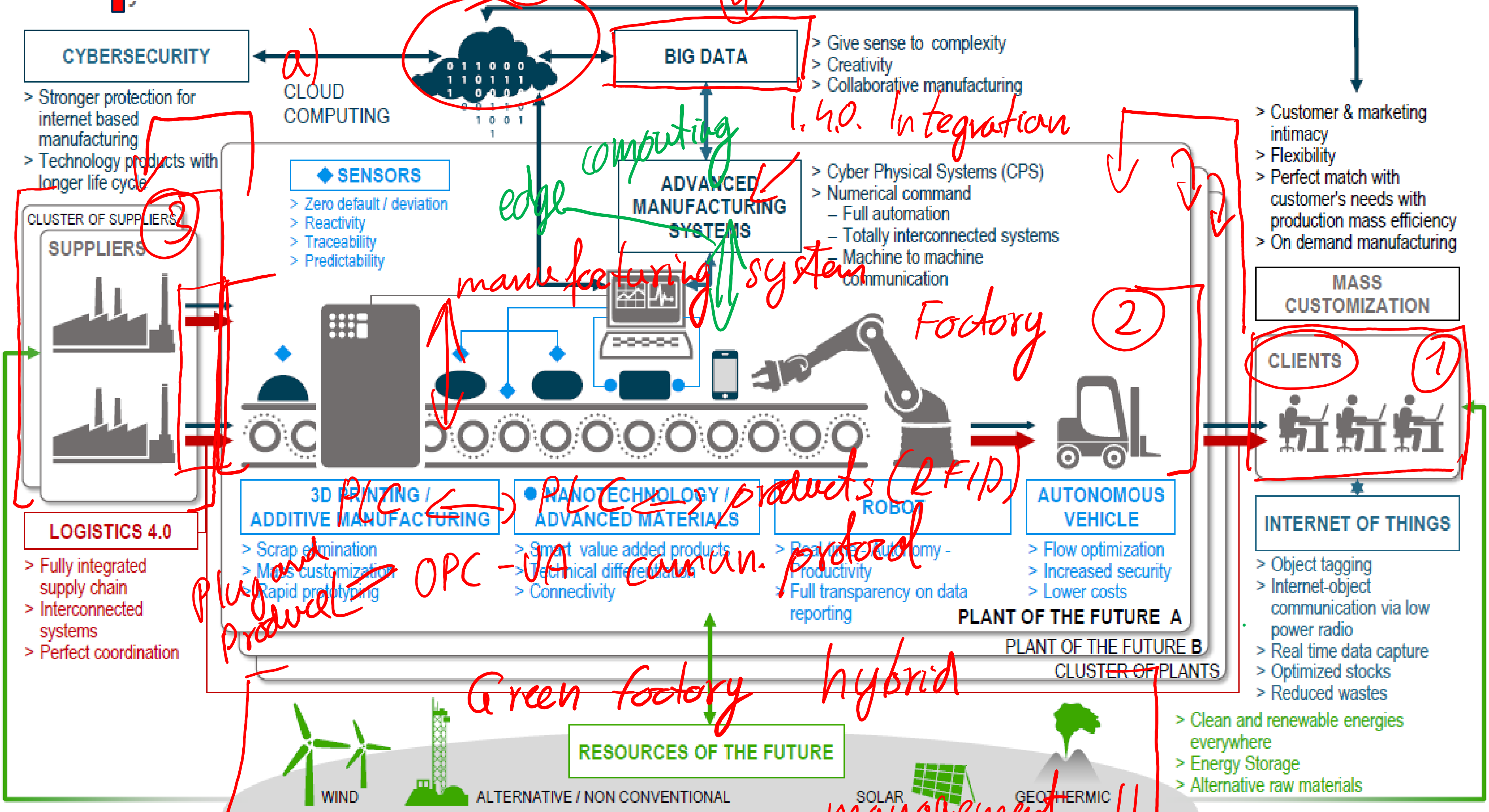
https://snicsolutions.com/blog/what-is-smart-manufacturing

MES: Manufacturing Execution System
MOM: Manufacturing Operations Management
APS: Advanced Planning and Scheduling
ERP: Enterprise Resource Planning
PLM: Product Lifecycle Management

https://suitecloud.vn/aps-va-erp-khac-nhau-o-diem-gi/

„Factory 4.0" – A smart factory defined by reconfigurability, flexibility, agility, efficiency and full digital integration

Important



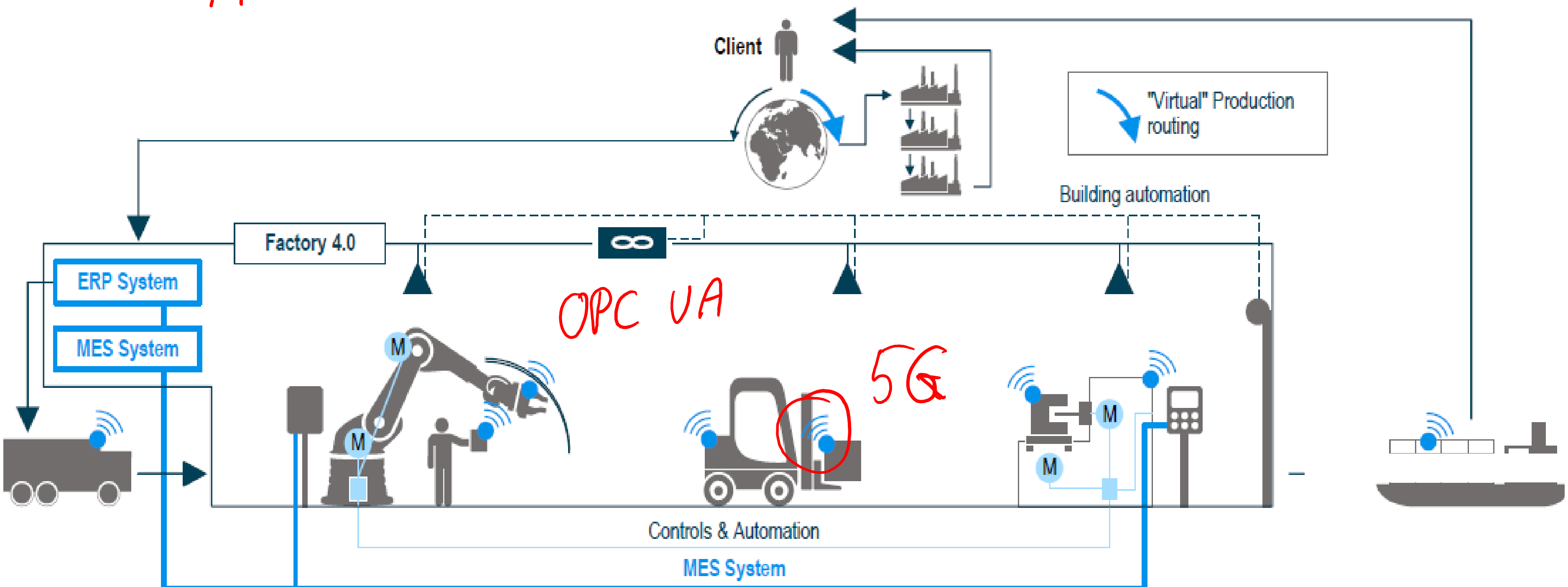
https://www.youtube.com/watch?v=7dU8unYYWjA

Source: Roland Berger

The backbone of the Smart Factory will be the data, digital twins, real-time communication – M2M communication, fast IoT → 5G network

5G Public network (security)
Private network (for industry)

Important



New players

	ERP System	MES System	Sensors/Automation	Building Automation	3D Data	Big Data Services
Data/ Funct.[1]	> All transaction data > Asset data > Price/cost data	> Shopfloor transaction data > Machine data > Maintenance data > Logistic data	> Sensor status like pressure, position etc., communication with other sensors > Machine control data	> Status of all building data, e.g. temp., light, access control, ventilation	> Product 3D data > Factory 3D data > PLM data	> Storage capacity > Algorithms and analytics > Connectivity

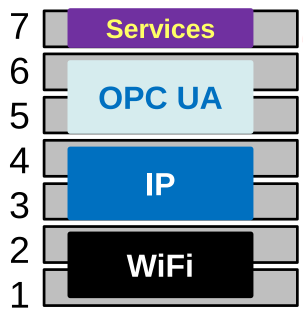
Source: Roland Berger

Production of the future - Future Products must...

main components

…have a standardized network interface

4



1 ID

…have a unique identity and memory (by birth)

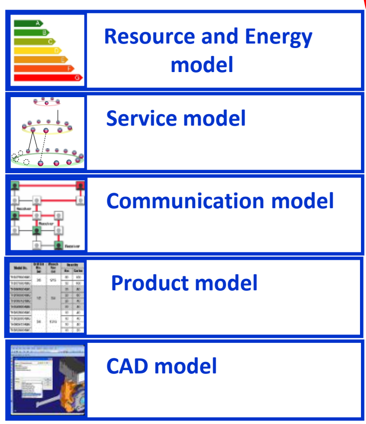
IP_{V6} [2001:0db8:85a3:08d3:1319:8a2e:0370:7344]

2

…offer autonomy

Important

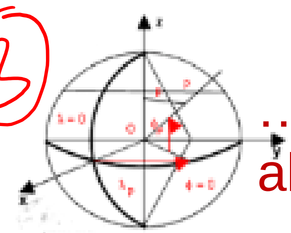
5



…be described by models

…be treated as abstract objects

3

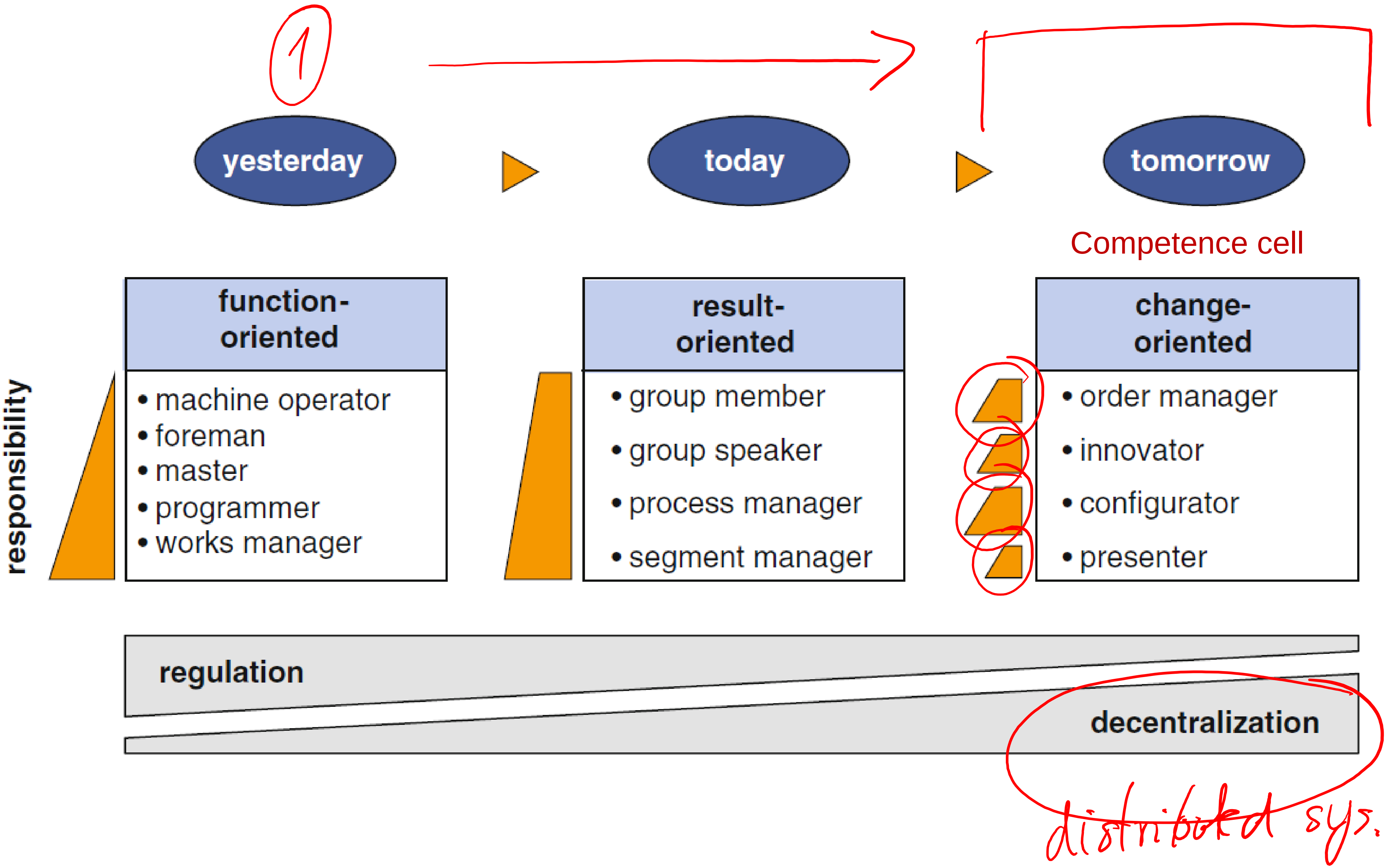


…be locatable at all times

Vir: Zühlke, Smart Factory, 2015

Changes in the role of employees

Important

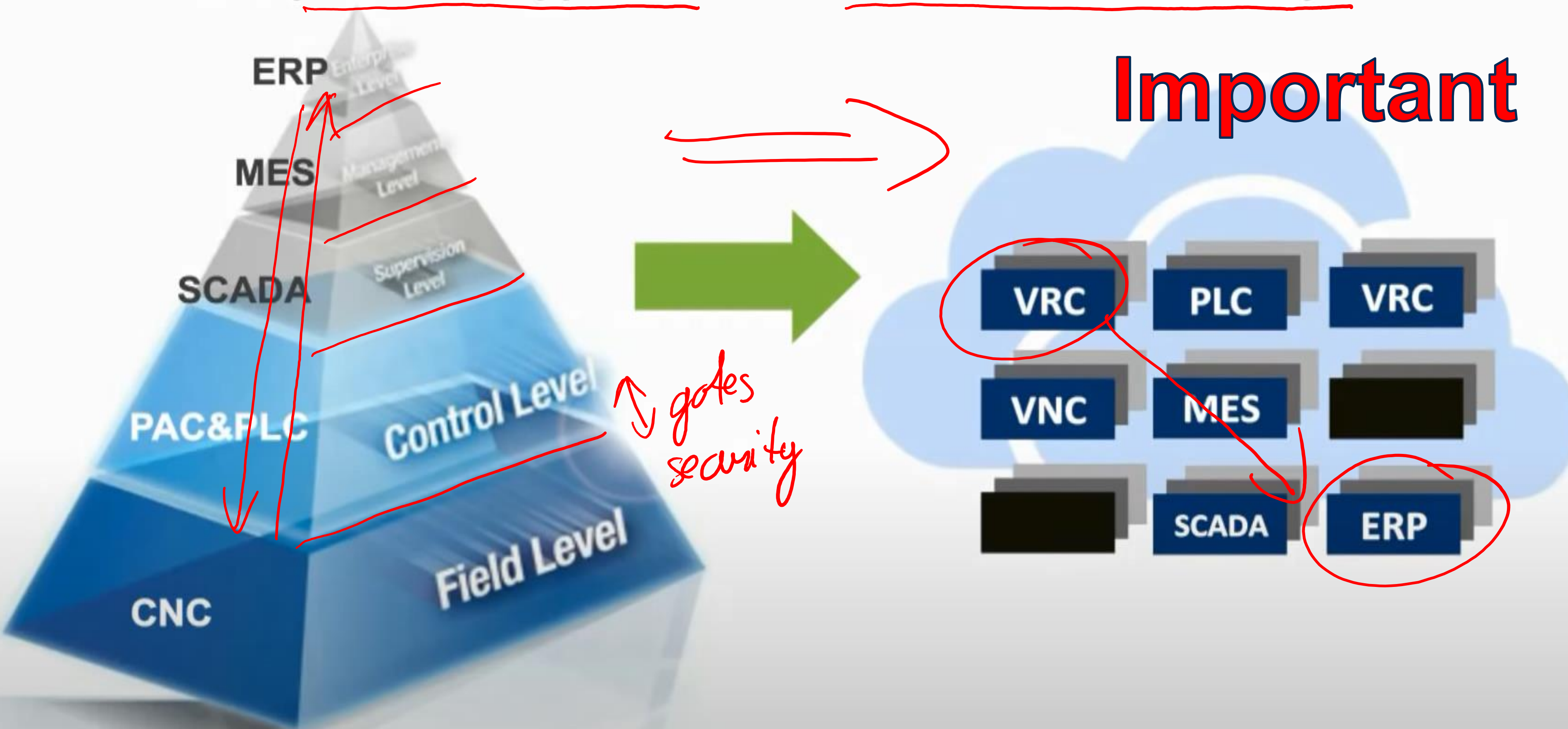


Source: Handbook Factory Planning and Design; Wiendahl et al., 2015

Paradigm Shift in Factory

From a classical 5 level factory automation pyramid

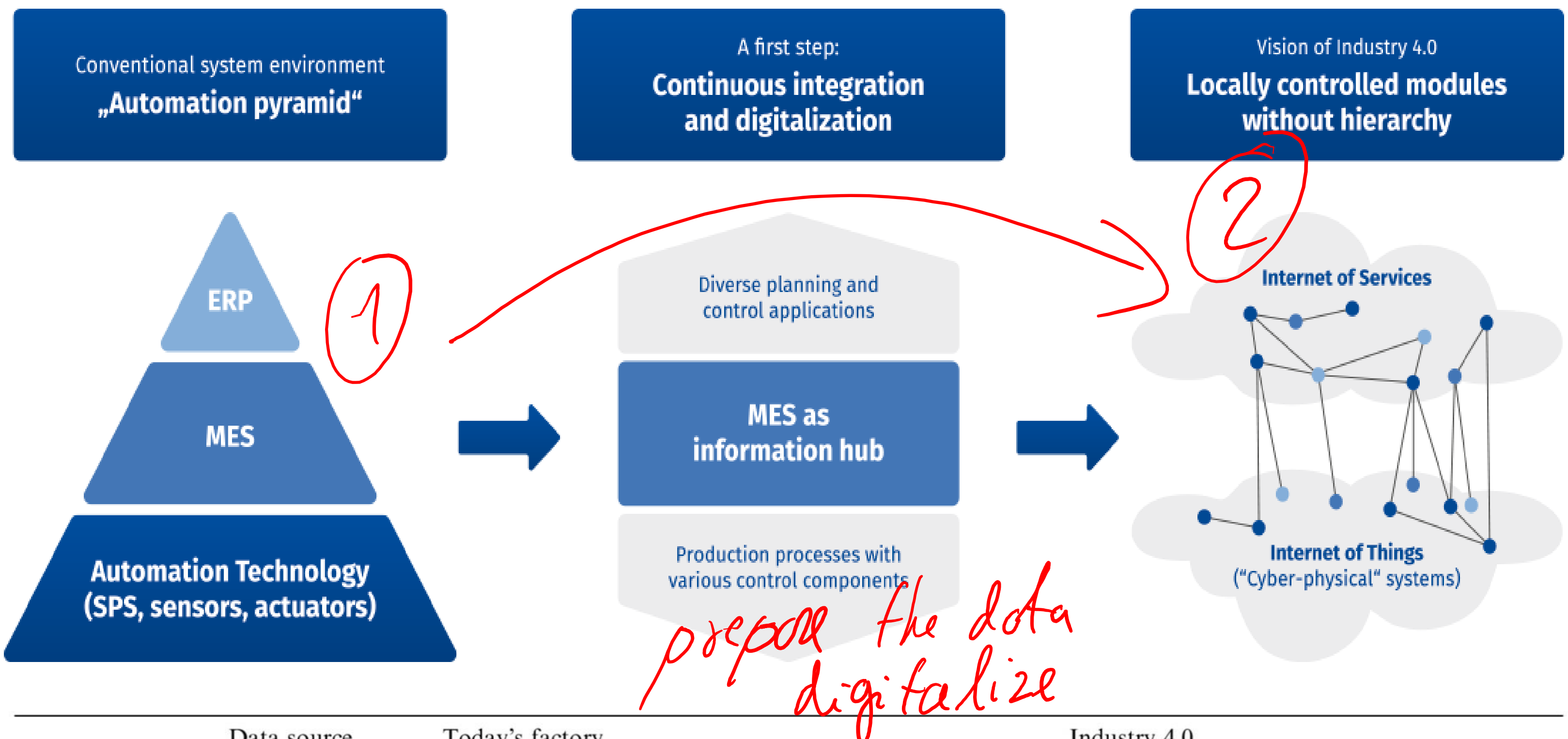
To a highly flexible connected cloud based smart factory



VRC – Virtual Robot Controller
VNC – Virtual Numeral Controller
MES – Manufacturing Execution System

CNC – Computerized Numeral Controller
ERP – Enterprise Resource Planning
SCADA – Supervisory Control and Data Acquisition

Today's factory VS. Industry 4.0



	Data source	Today's factory		Industry 4.0	
		Attributes	Technologies	Attributes	Technologies
Component	Sensor	Precision	Smart sensors and fault detection	Self-aware Self-predict	Degradation monitoring & remaining useful life prediction
Machine	Controller	Producibility & performance	Condition-based monitoring & diagnostics	Self-aware Self-predict Self-compare	Up time with predictive health monitoring
Production system	Networked system	Productivity & OEE	Lean operations: work and waste reduction	Self-configure Self-maintain Self-organize	Worry-free productivity

Source: Lee, J., Bagheri, B., & Kao, H. A. (2015). A cyber-physical systems architecture for industry 4.0-based manufacturing systems. Manufacturing Letters, 3, 18-23.

IoT Analytics – *Quantifying the connected world*

15 components of the smart factory of the future

Important

I 4.0

Suppliers

1 **Smart Supply network**
Transparency over supplier inventories and vehicle logistics allows for automatic and optimized supply decisions

Manufacturing

Software

2 **Next-gen manufacturing systems**
Manufacturing systems make automated and smart decisions (e.g., production scheduling), offer intelligent machine applications, seamless engineering integration and allow for remote visualization, monitoring, control, and alerts

3 **Cloud storage/ processing**
Data storage and application processing on secure cloud servers

4 **Data analytics**
Advanced decision algorit-hms & real-time analytics

5 **Cybersecurity**
Encrypted data and protection mechanisms against cyber threats

Shopfloor

6 **Intellig. sensors/actors**
Sensors deeply integrated in machines wirelessly stream data and have an own analytics engine (edge analytics)

7 **Cyber physical systems**
Interconnected systems and social machines control physical entities

8 **Smart maintenance**
Machine maintenance becomes integrated (autonomous) aided by predictive algorithms and remote assistance systems

9 **Mobile workforce**
Workers are equipped with mobile devices and augmented reality devices to process real-time information

10 **Self-driving vehicles**
Material is handled via autonomous vehicles and intelligent transportation units

11 **Intelligent products**
Products carry relevant information for machines to make decisions

12 **Additive manufacturing**
3D printing allows for rapid prototyping and rapid spare part printing

13 **Robotics**
Use of flexible robots augments intelligence, automates certain processes and creates new forms of worker-robot interaction

14 **Advanced materials**
New materials such as nano-materials as well as integrated computational materials engineering (ICME)

Customers

15 **Responsive manufacturing**
Individual manufacturing steps are designed for customer interaction so that products can be tailor-made for customers

IoT-related

Not IoT-related

Source: IoT Analytics

What is digital supply chain?

DIGITAL SUPPLY CHAIN IS AN INTELLIGENT VALUE DRIVEN NETWORK THAT LEVERAGES NEW TECHNIQUES & METHODS WITH DATA ANALYTICS TO CREATE VALUE AND REVENUE.

- DIGITAL PLANING
- DIGITAL SUPPLY
- DIGITAL MANUFATURING
- DIGITAL LOGISTICS

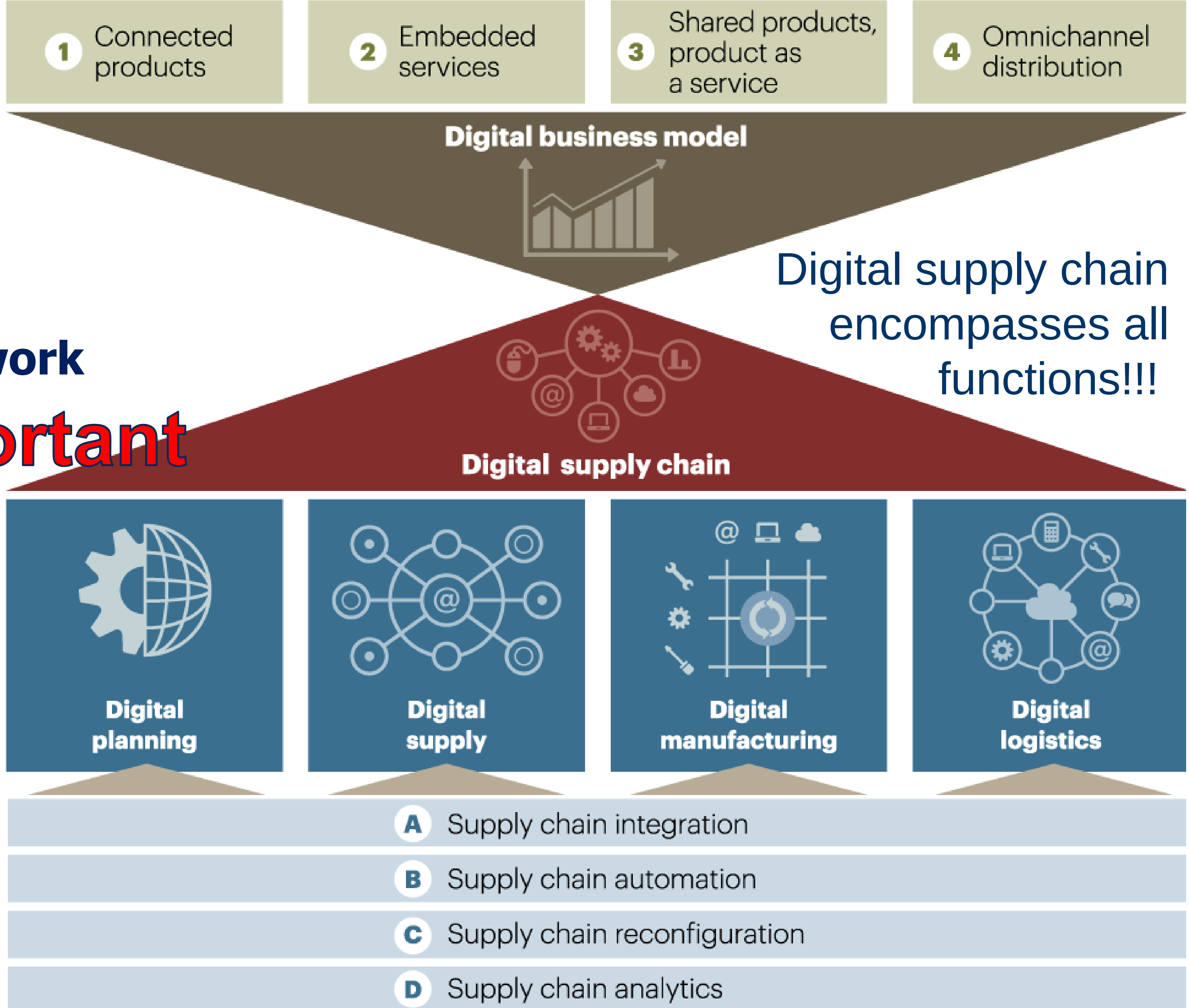
Important

Digital Supply Chain covers all goods and services – **Connectivity is the key**!!!

Source: Theme Work Analytics

Digital supply chain framework

Important



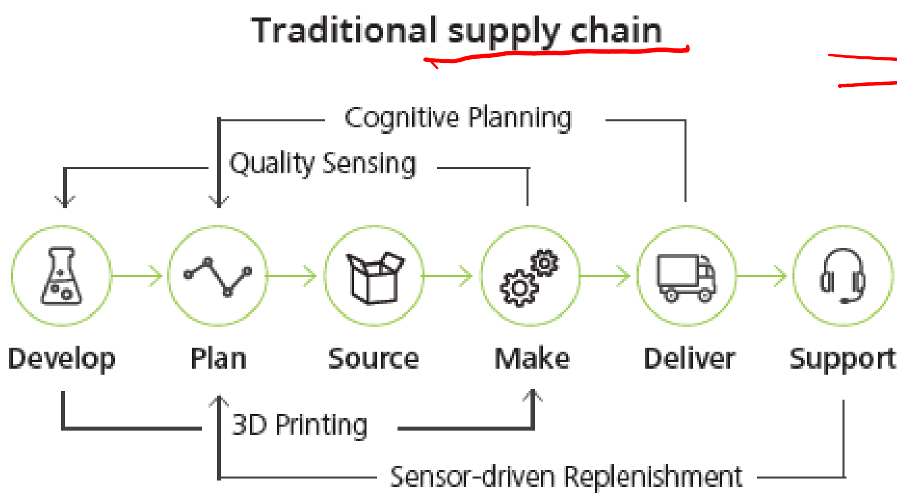
Digital supply chain encompasses all functions!!!

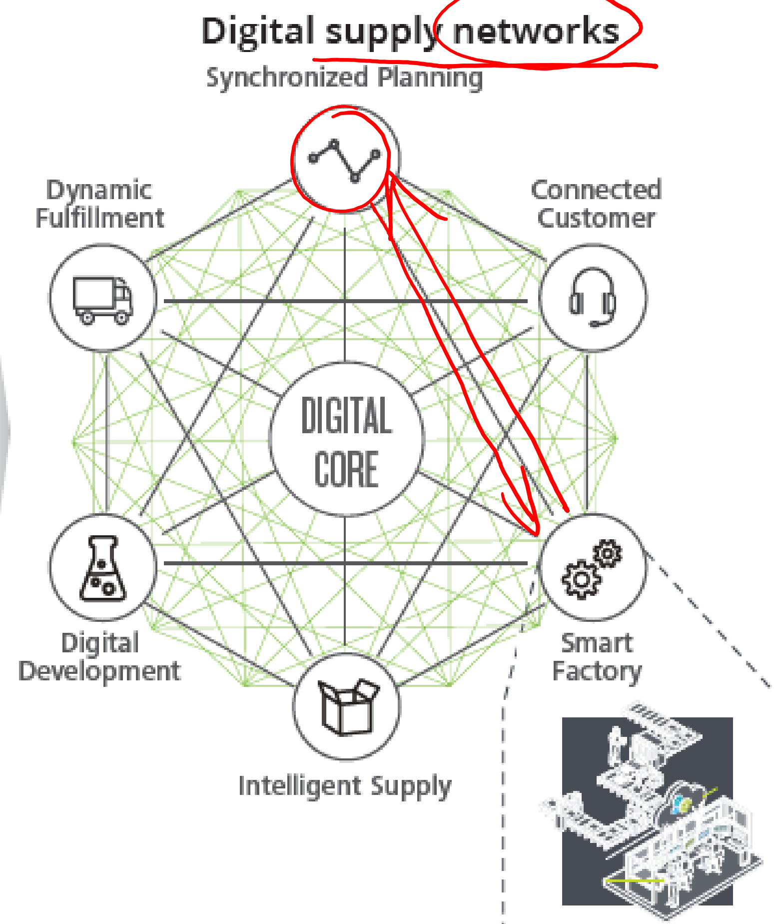
Source: A.T. Kearney Analitycs

Shifting from a traditional supply chain to a digital supply chain

interconnection

line sequence

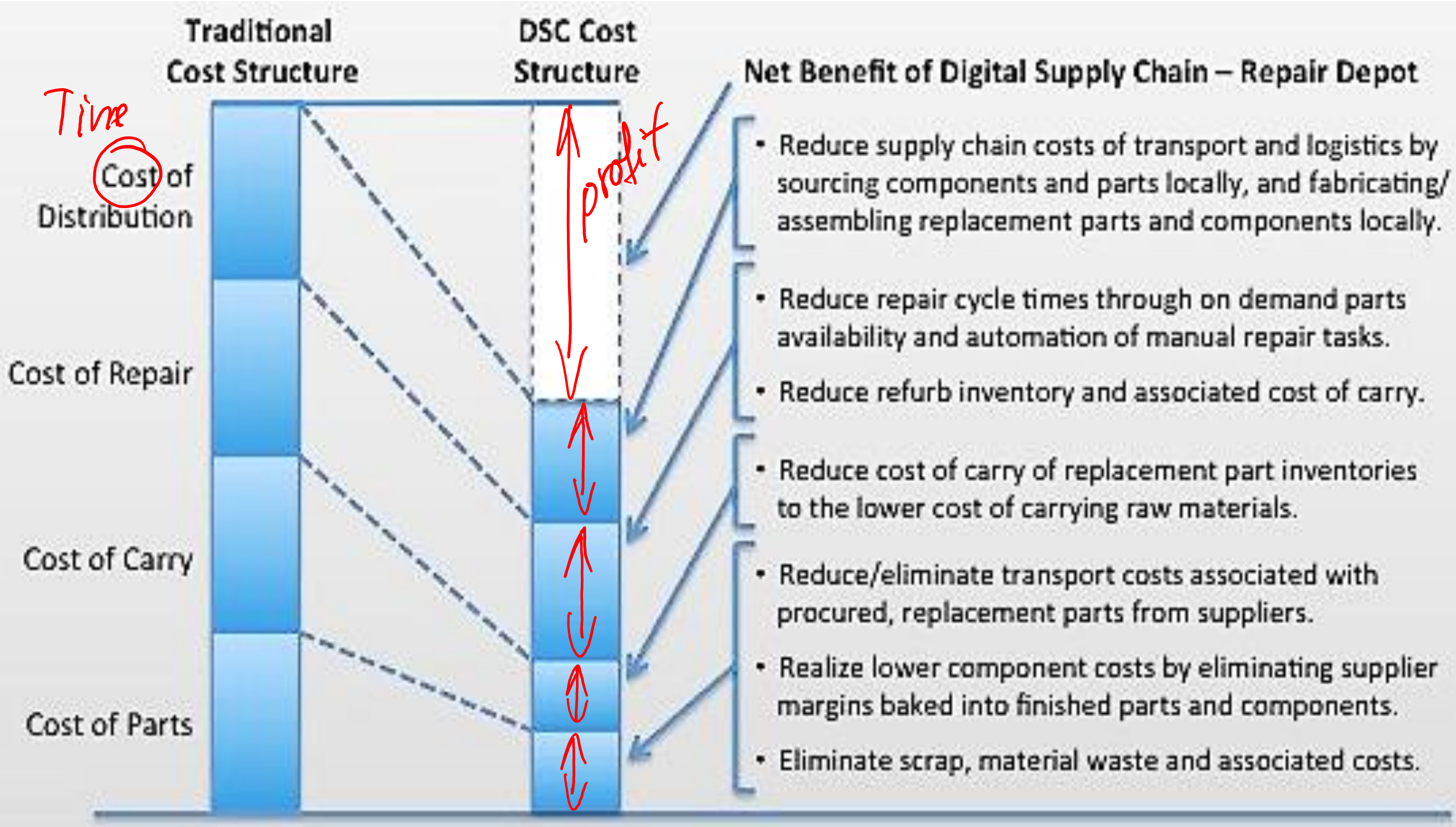




Important

Source: Deloitte analysis; Deloitte Universty Press | dupress.deloitte.com

Benefit Hypothesis of Digital Supply Chain



Digital technologies when combined, will result in dramatic cost reduction and service quality enhancement!!!

Source: Theme Work Analytics

Urgent activities in the Smart Factory