»Quo Vadis Logistik 4.0«
Changes and Future Trends in Transportation and Logistics

Transporeon Networking Event
Wolkenburg/Köln
March 17th, 2016

Univ.-Prof. Dr. rer. nat. Sabina Jeschke

IMA/ZLW & IfU
Faculty of Mechanical Engineering
RWTH Aachen University
Outline

I. Introduction – What is Transport-Logistics 4.0?
   - 4.0 – a revolution of artificial intelligence
   - About 4.0 breakthroughs and emerging mega trends
   - From Industry 4.0 to Logistics 4.0

II. The main competences of Logistics 4.0
   - Digitalization
   - Network collaboration
   - Service-level extension
   - Automation of supply chain

III. Future Perspectives & Summary
   - Robotization
   - Urbanization
   - 3D fabrication
   - The End!!
... leading to the 4th industrial (r)evolution...

**Breakthroughs - A new era of artificial intelligence**

**Communication technology**
- bandwidth and computational power

**Embedded systems**
- miniaturization

**Semantic technologies**
- information integration

---

- **Google Car** 2012
- **Watson** 2011

→ **Systems of “human-like” complexity**
... leading to the 4th industrial (r)evolution...

**Communication technology**
bandwidth and computational power

**Semantic technologies**
information integration

**Embedded systems**
miniaturization

**Breakthroughs - Everybody and everything is networked**

- Swarm Robotics
- Team Robotics
- Car2Infrastructure
- Smart Grid
- Smart Factory

IMA ZLW IfU

17.03.2016
S. Jeschke
... towards a networked world

The “Information Revolution”

Everybody and everything is networked. - Big Data & Cyber-Physical Systems

“Internet of Things & Services, M2M or Cyber Physical Systems are much more than just buzzwords for the outlook of connecting 50 billions devices by 2015.”
Dr. Stefan Ferber, Bosch (2011)

Vision of Wireless Next Generation System (WiNGS) Lab at the University of Texas at San Antonio, Dr. Kelley

Weidmüller, Vision 2020 - Industrial Revolution 4.0
Intelligently networked, self-controlling manufacturing systems

around 1750
around 1900
around 1970
today

1st industrial revolution
Mechanical production systematically using the power of water and steam

Power revolution
Centralized electric power infrastructure; mass production by division of labor

Digital revolution
Digital computing and communication technology, enhancing systems’ intelligence

Information revolution
Everybody and everything is networked – networked information as a “huge brain”
... towards a networked world

And how do these systems work?

Communication technology
bandwidth and computational power

Embedded systems
miniaturization

Semantic technologies
information integration

?? Steering - Controlling ??

Towards intelligent and (partly-) autonomous systems AND systems of systems

around 1750

1st industrial revolution
Mechanical production systematically using the power of water and steam

around 1900

Power revolution
Centralized electric power infrastructure; mass production by division of labor

around 1970

Digital revolution
Digital computing and communication technology, enhancing systems’ intelligence

today

Information revolution
Everybody and everything is networked – networked information as a “huge brain”

IMA ZLW IfU

17.03.2016
S. Jeschke
... towards a networked world
Not restricted to industry: cyber physical systems in all areas

Back to: “The earth converted into a huge ‘brain’ ”... (Tesla 1926)

Integrating complex information from multiple heterogeneous sources opens multiple possibilities of optimization: e.g. energy consumption, security services, rescue services as well as increasing the quality of life.

- Building automation
- Smart grid
- Smart environment
- Room automation
- Smart metering
- "House 4.0"
- "Power grid 4.0"
- "Logistics 4.0"
- "Mobility 4.0"
- "Health 4.0"
- "Education 4.0"
- "Room 4.0"
- "Smart metering 4.0"

... and more
What is Logistics 4.0?
How will be the future of logistics or Logistics 4.0?

Definition along two different time scales:

1. **short-term:**
   data-driven, highly networked processes between heterogeneous players (optimization, efficiency, transparency of processes, ...)

2. **medium-term:**
   autonomous systems and self-organization of systems of systems
From Industry 4.0 to Logistic 4.0
... and a more detailed one!

<table>
<thead>
<tr>
<th>Full digitalization</th>
<th>Big Data</th>
<th>Artificial Intelligence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network collaboration</td>
<td></td>
<td>Google Deepmind</td>
</tr>
<tr>
<td>Service innovations</td>
<td>Synchro-modal transport</td>
<td>Sustainable transport</td>
</tr>
</tbody>
</table>

Logistics 4.0

Autonomous driving
Automation of supply chain
Green Logistics
Outline

I. Introduction – What is Transport-Logistics 4.0?
   - 4.0 – a revolution of artificial intelligence
   - About 4.0 breakthroughs and emerging mega trends
   - From Industry 4.0 to Logistics 4.0

II. The main competences of Logistics 4.0
   - Digitalization
   - Network collaboration
   - Service-level extension
   - Automation of supply chain

III. Future Perspectives & Summary
   - Robotization
   - Urbanization
   - 3D fabrication
   - The End!!
Digitalization

Where do the data live?

Big Data Processing through Intelligent Cloud Solutions
Here, the term “cloud” is used in a maximum liberal style, namely as a solution for data storage and analysis somewhere outside of the place where the data are originally generated.

Cloud Functionalities

<table>
<thead>
<tr>
<th>Information integration</th>
<th>Complex data integrated and processed by platform services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooperation</td>
<td>Information exchange between cloud and teams</td>
</tr>
<tr>
<td>Granularity</td>
<td>Access to single data and aggregated information</td>
</tr>
</tbody>
</table>

The future of information access is service-oriented and omnipresent. “No access” is neither an option nor is it an allowed excuse...
Complexity of information is increasing exponentially.

In particular in logistics, the complexity is extreme due to the very heterogeneous players, that act globally.

Here again, players are not restricted to “humans” or “companies” but include also technological entities as web agents, autonomous trucks etc.

- How to know which information is available?
- Which quality?
- How to use all information to continuously optimize every process step (that is, to solve the algorithmic challenges)?
- How to restrict data against third parties?
- How to share information?
- …

Obviously, the concept of “platforms” plays in important role in managing and utilizing this complexity.

Here, the term “platform” is used in a maximum liberal style. Platforms can be centralized structures, but can also be federative-cooperative.
Digitalization

Big Data induce “intelligence”: from Big Data to Smart Data... 

Who the heck needs BIG data?  - Let’s make sense out of them...

The Big Data analysis pipeline...

<table>
<thead>
<tr>
<th>Acquisition / Recording</th>
<th>Extraction / Cleaning / Annotation</th>
<th>Integration / Aggregation / Representation</th>
<th>Analysis / Modeling</th>
<th>Interpretation / Prediction</th>
</tr>
</thead>
</table>

... transfers big data (many...) into smart data (meaningful data)

... accumulates intelligence from information fragments

... is a pipeline of aggregating (artificial) intelligence.

BIG DATA + SMART DATA ➞ INTELLIGENCE / DECISION / INSTRUCTION
Digitalization

Lateral thinking - what’s next?

Who is in the center of this development? Who is hosting the data?

What is the role of traditional logistics companies, and how / to which degree do IT- and cloud providers enter the scene?

Traditional logistics companies

(New) Cloud and IT companies
Decentralized systems are usually modelled by concepts all close to “Multi Agent Systems”

“A **multi-agent system (MAS)** is a (usually) computerized system composed of **multiple interacting intelligent** (and potentially heterogeneous) agents within an environment.

... **3 important characteristics:**

- **Autonomy**: the agents are at least partially independent, self-aware, autonomous
- **Local views**: no agent has a full global view of the system, or the system is too complex for an agent to make practical use of such knowledge
- **Decentralization**: there is no designated controlling agent (or the system is effectively reduced to a monolithic system)”

[Wooldridge 2002]
Network collaboration

2009: Truck robot platoons – distributed intelligence

→ The KONVOI project (several institutes from RWTH & industry partners)

- 2005-2009
- automated / partly autonomous transportation, e.g. by electronically coupling trucks to convoys
- several successful tests with trucks: Chauffeur, KONVOI, SARTRE (EU), Energy-ITS (Japan), ...

→ Adv. driver assistance system for trucks
→ short distances between vehicles of approx. 10m at a velocity of 80 km/h
→ Energy-ITS: 4m ! (2013)
→ KONVOI:
  - Car2infrastructure components!
  - Model of multi agent systems

→ expected improvements: beyond safety, reduction of fuel consumption and gained road space
Network collaboration

**Horizontal coupling (manufacturing/logistics) – to lot size 1**

→ **Organization forms on demand – individualized by client - initialized by product**

- Heterogenous player modeled as multi agent concept
- Models from biology and social sciences
- Basis on Autopoiesis & embodiment theory

Product agitates as “super-agent”:
- Plans production and transportation steps
- Requests service from agents
- Negotiates with other products for agent-resources

- Konvoi 2005-2009, RWTH with partners
- (partly) autonomous driving via convoys

© Daniel Ewert 2013
Network collaboration

Transfer of the agent idea to smart logistics

**macroscopic society design**

Matching of local optimization goals of agent and global optimization goals. Altruistic vs. egoistic behavior.

**microscopic agent and service design**

How to build agents that are capable of autonomous action in order to successfully carry out the tasks that we delegate to them?

Managed as a global network;
Community rules:
global optimization

→ Synchronize all supply chain actors and their different single services:
local optimization
Network collaboration

On the way to synchromodal network management

**From network collaboration to network integration: synchromodality**

Synchromodal transport can be described as an “extended version” of intermodal transport. It allows for the most efficient and flexible connections between all different existing transport networks, usually represented by different modes and different providers at a given time.

**Synchromodality:**
Combining intermodal transport with chain and network management

**The Multi Agent perspective:**
Very heterogeneous players have to be combined and synchronized, not only in their actions but in their common goals.
Network collaboration
Lateral thinking - what’s next?

Will there be a net of federal networks or one dominant „octopus“?

versus

I’m the BOSS

And who makes the rules?

What is the intelligence of the single entity, what is the intelligence of a node, what is the intelligence of the whole system? – Thus, what are the different roles, respectively?
Services become available and experts become obsolete!

As information becomes more and accessible, experts lose information power. This observation is inline with all earlier changes along the information chain, starting with the book printing …

Expert systems losing ground: Experts and service providers lose their unique selling proposition

Management of services: The new business model

Smartphone single point of contact for all information

Informed Customer

Profound Decisions
The customer gets powerful.

And: he/she expects services in business (B2B) to work in the same comfortable way as at home (B2C).

And – more again: the **digital native** is entering the scene. This guy does not even know what a fax machine is used for. Everything outside the internet does not exist!

Business units – such as marketing, sales, customer support – communicate with each other, but also directly and autonomously with the customer.

---

**Service Innovations**

**Expectation management – from B2C to B2B and the Generation Y!**

- The customer gets powerful.
- Business units – such as marketing, sales, customer support – communicate with each other, but also directly and autonomously with the customer.

---

**Key Points**

- Customer focused multi-channel communication
- Enabled by service-oriented business models
- Internal communication becomes more efficient
- Traditional enterprise Communication
- Sales
- Marketing
- Customer Support
- Business Customer

17.03.2016
S. Jeschke
Logistics 4.0 or „Logistics as a Service“ (LaaS)

The terminology is based on concepts as Software-as-a-Service (SaaS), Platform-as-a-Service (PaaS) .... up to Anything-as-a-Service (XaaS). It is sometimes referred to as "on-demand XY", without hosting or owning the necessary infrastructures and tools.

The philosophy behind it is: “Just do it – I don’t care how!”

Managing Platforms

Cloud Service Request

Carrier Request

Requests and Status Updates

Delivery Customer

Delivery Service

End Consumer

Mobile Apps

B2B relations still lacking generic services like in B2C relations
Service Innovations

A lot of new ideas are entering the field – fast!

DHL business model enables personalized delivery service, from delivery trucks into the trunk of a car.

Amazon: emerging to global dominance in the B2C market, enhancing its influence worldwide.

Also: the more services platform cover, the more they have the capability to cover even more (“platform dilemma”) ...
Which new business models are about to break through?

Will the product be delivered to the customer before it has been ordered, „Anticipatory Shipping“?

Send medicine before a disease spreads...

Who is ordering?

Which kind of foresight do Big Data Technology will come up with in the future?

GILD: “Roboter Recruiting”; selecting employees on a purely algorithmic basis.
The traditional division between logistics, intralogistics and production is outdated. What’s more: the whole differentiation between "inside" and "outside" is subject of debate.

1. Real-Time reaction on external events
2. Algorithms and data are “the same”!

Extension of the traditional supply to intra-logistics
Automation of supply chain

Intra-logistics goes mobile: The Festo Logistics League

Competitions robocup:
- 2012: 0 points in World Cup
- 2013: 4th in World Cup
- 2014: Winner of the GermanOpen
- 2014: Winner of the World Cup
- 2015: Winner of the World Cup

Critical factors for success:
- Totally decentralized
- No „hard coded components“
- Strong cooperation
- Re-planning during tasks

Competencies:
- localization & navigation
- computer vision
- adaptive planning
- multi agent strategies
- sensory & hardware

Mobile transportation robots from flexible routing
Automation of supply chain

Lateral thinking - what’s next?

Integrated Intra-Logistics

Drones as part of inner supply-chains

To which degree will the supply chain automate itself?

Will the product organize its transport on its own?

In case of a car, it may even drive itself to its new owner...

Cargo from the factory to the consignee

Autonomous Delivery

Credit: Kobi Shikar

Towards intelligent parcels

 RWTH AACHEN UNIVERSITY

17.03.2016

S. Jeschke
I. Introduction – What is Transport-Logistics 4.0?
   - 4.0 – a revolution of artificial intelligence
   - About 4.0 breakthroughs and emerging mega trends
   - From Industry 4.0 to Logistics 4.0

II. The main competences of Logistics 4.0
   - Digitalization
   - Network collaboration
   - Service-level extension
   - Automation of supply chain

III. Future Perspectives & Summary
   - Robotization
   - Urbanization
   - 3D fabrication
   - The End!!
Some even more “out of space” concepts

The new driver

„My colleague the robot…“

Again more: In a few years, automated driving might outcompete human drivers. Security issues, the demographic change, and the decreasing attractiveness of the job may add to a fast change.

Google

Daimler

DHL

Rolls Royce

rail-bound caps
Some even more “out of space” concepts

The third dimension

“In 2030, 70% of all humans will live in cities. Already then, about 10% will live in megacities (i.e., more than 10 Mio people). Escalating…”

Source: National Geographic Magazine

The megacities of the future

At a certain point, due to purely mathematical reasons, extended 3-dimensional building structures can not longer be served by purely 2-dimensional (street) networks.

---

Third dimension

Above ground

Below ground

Cities

Source: National Geographic Magazine

Hyperloop

Source: Cargo sous terrain, CH
Some even more “out of space” concepts

The new construction

„Digital warehouses are replacing physical spare parts storages“
[freestyle translation, source Logistik magazine]

„3D printing is on its way to leave the somewhat ‘restricted’ areas of spare part business, tool making etc. and is about to become a serious challenger for all traditional manufacturing models“.
[source Prof. Erman Tekkaya, TU Dortmund]

On-demand production

Water carbonators reaching high sales figures

3D printing of house (source Univ. of Southern California 2013)

3D print of pasta – Barilla (tests since 2015)

Harbor Rotterdam – 3D printer farm for metal printing (after piloting, now roll-out in 2016)

“plastics instead of parcels?” - UPS moving from logistics to 3D printing (tests since 2013)
Summary
... in four steps!

4.0: Revolution of a distributed artificial intelligence

4th Industrial Revolution

We are right in the middle of a 4th Industrial Revolution.

“Green is beautiful”

Logistics 4.0 – I: Data-driven revolution

- IT driven
- characterized by “everything is connected to everything anywhere anytime”

Logistics 4.0 – II: Automation-driven revolution

- New possibilities of optimization and business models are mainly data-driven.
- Globalization has its additional effects on speed and plurality...

... even if strict measures against “environmental bad guys” are rare today, there is an increasing pressure on everybody and all business models to cope with sustainability issues accordingly; and the “Generation Y” is adding to this effect.

- Autonomous carrier systems
- Fluent transition within logistics, intralogistics, and production
- New, intuitive intelligent interaction with humans...
Thank you!

Univ.-Prof. Dr. rer. nat. Sabina Jeschke
Head of Institute Cluster IMA/ZLW & IfU
phone: +49 241-80-91110
sabina.jeschke@ima-zlw-ifu.rwth-aachen.de

Co-authored by:

Dipl.-Ing. Max Hoffmann M.B.A.
max.hoffmann@ima-zlw-ifu.rwth-aachen.de

Dr.-Ing. Christian Tummel
christian.tummel@ima-zlw-ifu.rwth-aachen.de

Alexia Fenollar Solvay Ing. Ind.
alexia.fenollar@ima-zlw-ifu.rwth-aachen.de

Prof. Dr.-Ing. Tobias Meisen
Tobias.meisen@ima-zlw-ifu.rwth-aachen.de

www ima-zlw-ifu rwth-aachen de
<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1968</td>
<td>Born in Kungälv/Schweden</td>
</tr>
<tr>
<td>1994</td>
<td>NASA Ames Research Center, Moffett Field, CA/USA</td>
</tr>
<tr>
<td>10/1994</td>
<td>Fellowship „Studienstiftung des Deutschen Volkes“</td>
</tr>
<tr>
<td>1997</td>
<td>Diploma Physics</td>
</tr>
<tr>
<td>1997 – 2000</td>
<td>Research Fellow, TU Berlin, Institute for Mathematics</td>
</tr>
<tr>
<td>2000 – 2001</td>
<td>Lecturer, Georgia Institute of Technology, GA/USA</td>
</tr>
<tr>
<td>2001 – 2004</td>
<td>Project leadership, TU Berlin, Institute for Mathematics</td>
</tr>
<tr>
<td>04/2004</td>
<td>Ph.D. (Dr. rer. nat.), TU Berlin, in the field of Computer Sciences</td>
</tr>
<tr>
<td>2004</td>
<td>Set-up and leadership of the Multimedia-Center at the TU Berlin</td>
</tr>
<tr>
<td>2005 – 2007</td>
<td>Juniorprofessor „New Media in Mathematics &amp; Sciences“ &amp;</td>
</tr>
<tr>
<td></td>
<td>Director of the Multimedia-center MuLF, TU Berlin</td>
</tr>
<tr>
<td>2007 – 2009</td>
<td>Univ.-Professor, Institute for IT Service Technologies (IITS) &amp;</td>
</tr>
<tr>
<td></td>
<td>Director of the Computer Center (RUS), Department of Electrical</td>
</tr>
<tr>
<td></td>
<td>Engineering, University of Stuttgart</td>
</tr>
<tr>
<td>since 06/2009</td>
<td>Univ.-Professor, Head of the Institute Cluster IMA/ZLW &amp; IfU,</td>
</tr>
<tr>
<td></td>
<td>Department of Mechanical Engineering, RWTH Aachen University</td>
</tr>
<tr>
<td>since 10/2011</td>
<td>Vice Dean of the Department of Mechanical Engineering, RWTH Aachen</td>
</tr>
<tr>
<td>since 03/2012</td>
<td>Chairwoman VDI Aachen</td>
</tr>
<tr>
<td>since 05/2015</td>
<td>Supervisory Board of Körber AG, Hamburg</td>
</tr>
</tbody>
</table>