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LOGISTICS 4.0: GOALS, TRENDS AND SOLUTIONS

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Abstract: Logistics 4.0 generates a high number of new solutions. The scientific task is to generate an overview knowledge in this field and to show opportunities for the targeted further development. Research questions are: (1) What are typical goals and potentials of Logistics 4.0? (2) What current trends in ICT, production and logistics are influencing Logistics 4.0 solutions? (3) What are typical solutions of logistics 4.0? (4) In which areas do new research questions arise? The research is based on an analysis of new scientific publications and of own scientific projects according Logistics 4.0. Furthermore, the basis are also many years of scientific work and practical experiences in the area of logistics. The approach is based on the evaluation of the impact of trends on logistics solutions.

Keywords: *Logistics 4.0, Logistics service, Smart Logistics Zone, Trends, Research questions*

1. MOTIVATION AND INTRODUCTION

Logistics 4.0 designates the transfer of Industry 4.0 in the logistics field. This includes the fusion of logistics with digitization, networking and automation. Logistics service is realized by five types of logistics service providers, from 1PL to 5PL. (cf. [1], [2], [3]). Material flow processes and energy flow processes are mainly carried out by 1PL, 2PL and 3PL. Information flow processes are typical for all five logistics service provider types. Financial flow processes are realized as material flow processes or/and mostly as information flow processes. Energy flow processes are especially important for decentralized logistics solutions. Logistics includes integrating and safeguarding processes in the manufacturing company. Relevant literature differs Logistics 4.0 into Supply Chain Management, Information logistics, Corporate logistics, Trade logistics, Procurement logistics, Production logistics, Distribution logistics and sale, Reverse and Disposal logistics, Traffic logistics, Warehouse logistics and buffers, Transport logistics, Spare parts logistics and service, Intra logistics, Inbound logistics, Outbound logistics, and a lot of others logistics disciplines [4] (cf. [5], [6]). The various definitions show the challenge in creating an overview in Logistics 4.0 at whole.

Logistics 4.0 is more than digitizing traditional logistics. "However, the fourth industrial revolution is not only transforming processes in production and value creation, but also the world of work, organizational forms and structures in companies, and the competence and qualification requirements for employees." [7].

This paper aims to answer the research questions:

1. What are typical goals and potentials of Logistics 4.0?
2. What current trends in IT, production and logistics are influencing Logistics 4.0 solutions?

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3. What are typical solutions of logistics 4.0?
4. In which areas do new research questions arise?

It is important to emphasize that digitization and networking are only two criteria, albeit essential ones, for designing logistics processes and systems. Other important criteria are e. g: sustainability, resilience and safety.

2. METHODOLOGY

The research work is based on an evaluation of current scientific literature. A further source are own scientific projects and student projects in Logistics 4.0. The third component is the long year experience of the authors in the field of logistics.

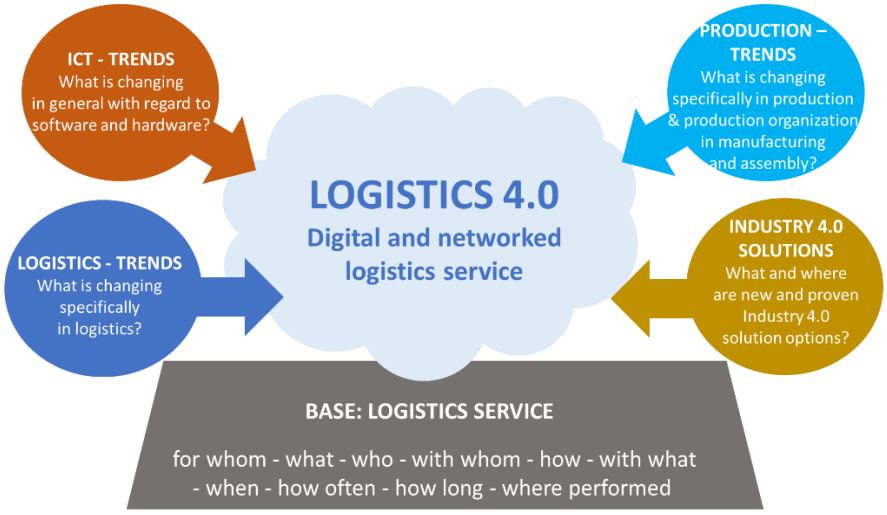

Figure 1. Logistics 4.0 is influenced by various trends (own editing)

The research work is approached from four sides (Figure 1.):

1. From the side of ICT Trends: What is changing in general with regard to software and hardware?
2. From the side of Logistics trends: What is changing specifically in logistics?
3. From the side of Production trends: What is changing specifically in production & production organization in manufacturing and assembly?
4. From the side of Industry 4.0 solutions: What and where are new and proven Industry 4.0 solution options? This characterizes the opportunities for new Logistics 4.0 applications.

These trends are described in terms of their impact on the logistics solution, which can be defined by the W/H question words. All four views are ultimately linked to holistically characterize the changes in Logistics 4.0 and to create an overview.

3. RESEARCH RESULTS

3.1. Result 1: Goals and potentials of Logistics 4.0

Typical goals for the implementation of Logistics 4.0 solutions are effectiveness, efficiency, time, costs, quality, flexibility, performance, safety, sustainability, communication/interaction, transparency, resilience, adaptivity and scalability. (cf. [8]) The following list is an open collection of examples of the goals with regard to Logistics 4.0 (cf. [9], [10], [11]):

- Reduction of costs through optimization of logistics processes (transport, picking, handling, storage, maintenance etc.) and service processes,
- Improvement of the resilience of the Supply Chain network,
- Increasing speed, flexibility, security and controllability of processes,
- Improvement of quality and transparency of data flow along supply chains,
- Reliable localization and tracking of logistics objects,
- Reduction of process times (loading),
- Continuous quality control of logistic objects,
- Reduction of errors (condition detection and continuous media and systems),
- Reduction of necessary personnel and extension of operating hours,
- Increased performance/productivity through adapted work tools,
- Increased communication and interaction with customers and suppliers (e.g. customer needs, sales forecasts, transparency in order fulfilment),
- Greater sustainability through e.g. optimization of resource use and implementation of climate protection measures,
- Minimizing energy consumption for logistics services and intelligent energy management.

In addition to the classic automation (replacement of manual activity by mechanized or automated activity) of Logistics 2.0 and 3.0, Logistics 4.0 solutions thus make a noticeable qualitative contribution by means of digitization and networking, e.g. in the areas of:

- Automated and continuous material flow,
- Automated and end-to-end flow of information,
- Automated and end-to-end financial flow,
- Automated and networked infrastructure,
- Reduction and optimization of energy flow required for logistics management,
- New business models and logistics services,
- Logistics by 5PL to handle global and complex Supply Chain networks,
- Automated and networked warehouse technology,
- Automated and networked commissioning processes and systems,
- Seamless identification and necessary status recording of logistical objects,
- Seamless digital documentation,
- Ergonomic and preventive employee support,
- Smart data analysis for planning, control and optimization,
- Digitized and networked processes,
- Process integration for all types of processes.

It is typical that Logistics 4.0 solutions in manufacturing companies consist of many individual solutions, which themselves are also constantly improved and reconfigured, but which ultimately only develop their full efficiency through their interaction.

3.2. Result 2: ICT Trends and what is changing in general with regard to software and hardware

Table I lists important ICT trends and characterizes their impact on logistics services.

Table I.
Influence of ICT trends according logistics service (compare only for trends [12, 13, 14, 15, 16])

Important ICT Trend	***Logistics service***									***Characterization of influence on Logistics 4.0***
	For whom	***What***	***Who***	***How***	***With what***	***When***	***How often***	***How long***	***Where***	
Digital market increases	■	■		■	■	■	■			As a business model, it pushes digitization across the board and customer channel.
Explore customers deep	■	■								Accurate analysis of customers requires the collection and preparation of data.
Homeoffice and Remote working places			■			■			■	Strong proliferation of home-based work and work that can be done from anywhere.
Demand for digital know-how			■		■					Require professional qualification and lifelong learning.
Cloud-platforms and cloud software				■						New offered services are infrastructure (IaaS), platforms (PaaS) and software (SaaS). Memory capacity, processing power and applications are provided by internet and do not installed local.
Edge Computing				■	■					Data processing is brought close to where it is needed.
Digital Twins				■	■					The virtual representation of a physical object or system is used to understand it, optimize it, predict it, control it, or repair it.

Continuation Table I.

Important ICT Trend	***Logistics service***									***Characterization of influence on Logistics 4.0***
	For whom	***What***	***Who***	***How***	***With what***	***When***	***How often***	***How long***	***Where***	
Increased data protection			■	■	■	■				Requires critical protection of sensitive data from corruption, compromise, or loss.
3D Printing	■	■	■	■	■	■	■	■	■	Changes the supply chains fundamentally. The product is first created at or near the customer.
Artificial Intelligence				■	■			■		Three group of methods are developed: Artificial neural networks, Fuzzy Logic and Evolutionary algorithm. It is possible to optimize f. e. logistical processes and systems (prescriptive analytics), quality control, prediction of failures and disturbances (predictive maintenance).
Benign AI-powered bots				■	■			■		Integration of bots into existing programs for e.g. evaluation of data, learning in decision-making situations and visualization of options for action and -effects.
Pattern matching Big Data Analytics				■	■			■		Increasing data volume requires efficient methods of processing. It is necessary to evaluate situations and do forecast.
Augmented & Virtual Reality				■	■			■		AR supported workstations e.g. picking with pick by vision.
Blockchain				■	■					The accounting of logistics activities can be realized automatically by using Blockchain technology (e. g. smart contracts).

Continuation Table I.

Important ICT Trend	***Logistics service***									***Characterization of influence on Logistics 4.0***
	For whom	***What***	***Who***	***How***	***With what***	***When***	***How often***	***How long***	***Where***	
Networking, Internet of Things										Internet of things (IoT) connects physical and virtual devices by using information and communication technologies. The task is now to develop the Internet of services (IoS).
Next-Generation Wireless										Concerns infrastructure, use of 5G networks with higher data rates, real-time transmission and short latency times.
Cloud & APIs										New offered services include infrastructure (IaaS), platforms (PaaS) and software (SaaS). Memory capacity, processing power and applications were provided by internet and do not installed local.
Sum	***3***	***3***	***4***	***14***	***14***	***4***	***2***	***5***	***1***	

It can be seen from (Table I.) that, in addition to new digital business models in logistics that affect the use of new technologies in logistics, ICT trends are primarily changing the way logisticians work (How) and the tools (With what) they use.

Only little influence exists on:

- The customers (For whom), only via Digital market and customer investigation,
- The actual logistics service itself (What),
- The person of the logistics service provider (Who, With whom), except for the required qualification.
- The time of the logistics service (When), shortened by software if necessary,
- The frequency of the logistics service (How often),
- The duration of the logistics service (How long) and
- The place where the logistics service is provided (Where).

The ICT trends can therefore be used for logistics like a checklist to verify whether an improvement is achievable for an existing task through AI, blockchain or via AR.

3.3. Result 3: Logistics trends and what is changing specifically in logistics

Table II lists important logistics trends and characterizes their impact on logistics services and on Logistics 4.0.

Table II.
Influence of Logistic trends according logistics service (compare only for trends [12, 15, 16, 17])

Important Logistics Trend	***Logistics service***									***Characterization of influence on Logistics 4.0***
	For whom	***What***	***Who***	***How***	***With what***	***When***	***How often***	***How long***	***Where***	
Supergrid Logistics	■	■	■	■	■	■	■	■	■	5 PL manage global networks.
Logistics Marketplaces	■	■	■	■	■	■	■	■	■	Allow transparent, flexible and easily configurable logistics services.
Sharing Economy	■	■	■	■	■	■	■	■	■	Changing business models; sharing of logistics resources.
Servitization	■	■	■	■	■	■	■	■	■	Change in business models to a combined offering of product and service.
Silver Economy	■	■	■	■	■	■	■	■	■	New logistics services by satisfying the health and life needs of the elderly.
Space Logistics	■	■	■	■	■	■	■	■	■	Specialized area, impact only on a few logistics companies.
Dual sourcing Multi sourcing			■							Networks and chains with multiple suppliers.
Omnichannel Logistics	■	■								Integrated view of all customer channels.
Mass Personalization	■	■								Linking individualization with mass production for all customer channels.
Fresh Chain	■	■	■	■	■	■	■	■	■	Special logistics for refrigerated and perishable goods.
Smart Containerization		■		■						Intelligent containers change cargo shipping up to the last mile.

Continuation Table II.

Important Logistics Trend	***Logistics service***									***Characterization of influence on Logistics 4.0***
	For whom	***What***	***Who***	***How***	***With what***	***When***	***How often***	***How long***	***Where***	
Rethinking Packaging		■								Rethinking packaging forms.
Sustainable Logistics	■	■	■	■	■	■	■	■	■	Innovations and evaluation of the entire logistics service, combines economy, ecology and social issues.
Next-Generations Security				■	■					Potential hazards are predicted and eliminated.
Resilience in SCM		■	■	■	■	■	■	■	■	Risk management of rare, serious events.
Future of Work			■	■	■	■	■	■	■	New demands on working life.
Smart infrastructure				■	■					Mobility infrastructure e.g. charging infrastructure for e-mobility and cargo bikes; 5G projects e.g. communication for mobility and communication for factories.
New professions in logistics			■	■	■					E.g. data specialist, drone pilot, robot coordinator, digital transport manager, global supply chain manager.
Decentral organization and self-organization		■	■	■	■	■	■	■	■	Allows multiple interactions in the logistical zone, have often a strong dynamical non-linearity.
Sum	10	14	13	15	14	11	11	**11**	**11**	

Logistics trends influence all aspects of logistics performance. This ranges from new business models, new logistics objects, logistics processes and systems, and logistics infrastructure.

3.4. Result 4: Productions trends and what is changing specifically in logistics

Table III lists important production trends and characterizes their impact on logistics services and on Logistics 4.0.

Table III.
Influence of Production trends according logistics service (compare only for trends [12, 16, 17, 18, 19, 20])

Important Production Trend	***Logistics service***									***Characterization of influence on Logistics 4.0***
	For whom	***What***	***Who***	***How***	***With what***	***When***	***How often***	***How long***	***Where***	
Individualization of customer wishes and -requirements		■					■			Leads to "lot size 1" and possibly to dynamic lot sizing, increasing variety of variants.
Globalization		■	■						■	Global supply networks and globally distributed markets, global production sites.
Regionalization ***Production relocation***		■	■						■	Disruptive events in SC lead to rethinking in procurement and SCM, production is shifted to the market, new partners and forms of collaboration.
Production disruption		■	■							Traditional business models, products, services and technologies are modified or displaced.
Demographic change and securing skilled workers		■	■							Affects the conception and design of workplaces (performance change).
Migration		■	■							Conception and design of workplaces (performance change).

Continuation Table III.

Important Production Trend	***Logistics service***									***Characterization of influence on Logistics 4.0***
	For whom	***What***	***Who***	***How***	***With what***	***When***	***How often***	***How long***	***Where***	
Sustainability, Environmentally friendly production and resource efficiency		■		■	■				■	Influences in particular the material and energy flows.
New technologies and materials (e.g. lightweight construction, 3-D printing, biological transformation)	■	■	■	■	■	■	■	■	■	Changes logistics supply chains.
Shortened innovation and technology life cycles							■			Planning periods are shortened, modularity instead of complete solutions, can be exchanged and supplemented more easily.
Industry 4.0				■	■					e.g. Internet of Things and CPS, cf. (Table IV.).
Self-Driving Vehicles ***Unmanned Aerial Vehicles***				■	■					Objectives are to improve the energy efficiency and to increase the capacity of the transport mode and space. They support e.g. transportation and delivery processes, handling of tools and parts, assembly, quality control and maintenance.
Robotics & Automation				■	■					Increasing automation, human-technology combinations.

Continuation Table III.

Important Production Trend	***Logistics service***									***Characterization of influence on Logistics 4.0***
	For whom	***What***	***Who***	***How***	***With what***	***When***	***How often***	***How long***	***Where***	
Bionic Enhancement				■	■					Changes the conception and design of workplaces.
Higher reliability and safety requirements (product/counterfeit protection)				■	■					This influences the logistics solutions in terms of condition detection and transparency.
Integration of production and service processes		■								Hybrid products change the logistics service portfolio.
Higher demands on creativity, competence, knowledge and innovative ability of planners and controllers; broad engineering qualification			■							Requires special education and training, permanent learning.
Integration of production area and office									■	Changes the conception and design of workplaces.
Sum	***1***	***9***	***7***	***7***	***7***	***1***	***3***	***1***	***5***	

Logistics services are strongly influenced by production trends. This affects all aspects of logistics services, but specifically what, who, how and with what is executed.
Production trends are reflected in logistics and in Logistics 4.0.

3.5. Result 5: Solutions of Industry 4.0 and what is changing specifically in logistics

Table IV lists important solutions of Industry 4.0 and characterizes their impact on logistics services. There are various approaches for a systematization. In [21], for example, the transformation in enterprise logistics and SCM is subdivided into technology, people, organization and information, which could also be used to classify the solutions if necessary. In Table IV, the aspect-based view of the Smart Logistics Zone is used for classification. (cf. [8, 22] This is divided into business models, objects, processes, systems and infrastructure.

Table IV.
Important solutions of Industry 4.0 according logistics service (compare only for typical solutions [16, 17, 21, 22, 23, 24])

Important solutions of Industry 4.0	***Logistics service***									***Characterization of influence on Logistics 4.0***
	For whom	***What***	***Who***	***How***	***With what***	***When***	***How often***	***How long***	***Where***	
Digital Business models										New business models expand the portfolio of large logistics service providers and also lead to start-up.
Smart objects										Use of e.g. smart material, smart part, smart product, smart packaging, smart loading unit, smart pallet, smart box and, smart container.
New software-integrated processes										Facilitate and automate the logistical processes of goods movement and all business processes e.g. purchase processing and payment.
CPS and HTO system										Driverless, autonomously operated logistics operators, Cyber-physical material handling modules, New work aids (assistance robots, data glasses and gloves, intelligent clothing and intelligent contact lenses).
Smart infrastructure										Environments that promote and facilitate primary logistics operations
Sum	***1***	***3***	***1***	***2***	***3***	***0***	***0***	***0***	***0***	

The Smart Logistics Zone model enables a systematization of Industry 4.0 / Logistics 4.0 solutions and spans a solution space. At the same time, it enables the derivation of a large number of research questions. Examples include:

1. What new business models arise with digitization and networking?

2. How can the digital business models themselves be suitably designed through digitization and networking?
3. How intelligent do logistics objects need to be and how can intelligence be generated technically?
4. Where are intelligent and where are "dumb" objects advisable?
5. How can logistics processes be improved through innovation and digitization/networking?
6. Which CPS and MTO systems can be used for technical implementation? (Best practices)
7. Where is further need for action in the development of CPS and MTO systems?
8. Which scenarios are conceivable in order to be able to install a nationwide/worldwide smart infrastructure?
9. How should the charging infrastructure in cities/regions/nationally be planned for individual means of transport (e.g. for e-mobility)?
10. What intelligence should be transferred to the infrastructure for autonomous driving?

For further research questions on intelligent infrastructure (cf. [17]).

3. SUMMARY

The industrial revolution, referred to as Industry 4.0, has a major impact on logistics solutions. In order to span the field of Logistics 4.0 holistically, the research work was drawn up from four sides: From the side of ICT trends, from the side of Logistics trends, from the side of Production trends, and from the side of Industry 4.0 solutions. These trends and solutions are described in terms of their impact on the logistics service fulfilment and specifically on Logistics 4.0. The impacts were briefly explained in tabular form for this purpose. The tables represent open collective lists that can be constantly modified and supplemented. As a result, summary notes are provided. For example, the ICT trends can be used purely as a checklist to identify potential through digitization and networking. Research questions are posed.

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