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Logistics as a Science – Central Research Questions in the Era of the Fourth Industrial Revolution

Position Paper of the Scientific Advisory Board of Bundesvereinigung Logistik (BVL)

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Introduction

In view of the fundamental changes in the economy and society resulting from the so-called Fourth Industrial Revolution ("Industry 4.0"), it is necessary to reposition logistics as a discipline and a science – because it is a central element in, and the driving force behind, this development. Logistics has developed from being a pure service-providing activity – delivering the right goods to the right place at the right time – to become a key driver of digital and societal change. Topics like the Internet of Things and Services, big data or autonomous driving are inseparably intertwined with logistics today. In this process, logistics as a science and an economic sector drives not only the application but increasingly also the development of basic methods, algorithms and technologies.

In 2010, the Scientific Advisory Board of BVL outlined in detail its understanding of the scientific discipline of logistics in a position paper[1]. Building on this paper, it now appears a matter of urgency to underline the central role of logistics in the context of Industry 4.0 (referred to hereinafter as "Logistics 4.0) and to reflect on the key challenges facing logistics research. With this Position Paper, the Scientific Advisory Board of BVL would like to define the central questions regarding the future of logistics in the era of the Fourth Industrial Revolution with the aim of making a fundamental contribution to the discussion, organisation and further development of Logistics 4.0.

In this endeavour, the Scientific Advisory Board draws on two central preconditions or core elements of Industry 4.0 that will also be essential for the future of Logistics 4.0: on the one hand, this concerns digitisation, decentralisation and interconnection, and on the other, a fundamental shift towards autonomous control and organisation, symbolised by the Internet of Things and Services. It was in this context that the coming of the Fourth Industrial Revolution was proclaimed at the time of the Hannover Fair in 2011. Frequently described as a "Copernican revolution", this is a priori knowledge – in other words, a logically deduced realisation, but one for which comprehensive empirical proof is not yet available – that was quickly shared by major sections of the international scientific community.

In a single sentence, this realisation can be roughly described as follows:

> In tomorrow's world, it will be possible to organise logistics more efficiently based on autonomous entities[2], and the degree of corresponding decentralisation and self-organisation will grow parallel to the complexity and dynamic development of logistics value added systems.

The resulting change is fundamental in nature and will affect all sectors and disciplines in logistics – from planning and technical organisation through to management.

Against this backdrop, we can derive three core hypotheses for Logistics 4.0.

Core hypotheses

Logistics plays an absolutely central role in the all-encompassing digitisation of the economy and society. This means it is even more important as a subject of research than was already the case – because without adequate logistics the Fourth Industrial Revolution is simply inconceivable. Logistics is the backbone of these developments. The goal is to create flexibly interconnected, complex, distributed systems based on a continuous and autonomous exchange of data and information between human actors and physical, technical objects. Within the context of the Fourth Industrial Revolution, the aim is to develop industrial systems and networks to the stage where they can extensively control themselves within a certain technical and organisational framework while adapting as flexibly, efficiently and effectively as possible to continually changing circumstances.

The implementation of Industry 4.0 without Logistics 4.0 is just as unthinkable as the globalisation of the economy without logistics networks that span the world. The primary tasks of logistics include not only network management but also the structuring and control of these networks – both from a scientific point of view and in the areas that call for hands-on organisation. This leads us to recognise that:

- Logistics is the prime mover of the Fourth Industrial Revolution.
- Logistics is both the driver and the basis of the Fourth Industrial Revolution.
- Logistics calls for a joint theoretical foundation for technology and the economy as well as for strategy and operations.

In view of these hypotheses, it is absolutely essential that we intensify research into the topic of Logistics 4.0. The hypotheses also give rise to a whole number of central research questions, and finding answers to these questions poses a major challenge to logistics research. The following pages outline some of the questions that are of central importance and address the more specific considerations in greater detail.

Research questions

Structural and methodological change as a result of Logistics 4.0

1 Like Industry 4.0, Logistics 4.0 is based on a priori knowledge. One research question that is still wide open concerns the verifiable effects that Industry 4.0 induces in logistics in terms of efficiency, flexibility and availability.

2 Do the conventional ways of developing, assessing and launching product, service and business model innovations in the market constitute an obstacle to Logistics 4.0? What new approaches can be identified in this context, and what are the resulting potentials?

3 How will the normative and operational levels (planning and control) be organised in future? Will there be separation of these two levels in future?

4 What change will there be in the KPIs for logistics optimisation?

5 How will the targeted control and planning of interconnected autonomous groups of actors with special interests be regulated?

6 How must the goals and rules be defined, transferred and implemented in the distributed and autonomous systems of Logistics 4.0?

7 What will the transition from classic, deterministic, hierarchical supply chain planning and control to heterarchical, probabilistic ad-hoc planning and control activities in Logistics 4.0 look like?

8 Will Logistics 4.0 result in different principles for resource utilisation (“share economy”)?

Logistics 4.0 as a sociotechnical system

9 Humans and autonomous machines will in future interact in (social) networks as equal partners and cooperate in natural environments. What will the sociotechnical systems of Logistics 4.0 look like?

10 How will risk and responsibility be shared and distributed (“machine responsibility”)?

11 What qualifications and competencies does Logistics 4.0 require? How will they be individually fostered?

1 Like Industry 4.0, Logistics 4.0 is based on a priori knowledge. One research question that is still wide open concerns the verifiable effects that Industry 4.0 induces in logistics in terms of efficiency, flexibility and availability.

The vision of digitisation is penetrating all areas of logistics process chains – from production, through procurement, to distribution – and therefore driving expectations and ideas concerning the possibilities associated with the future organisation and implementation of processes, installations and systems. At the same time, however, there are widely differing views on how digitisation will create value added.

This is an area in which comprehensive interconnection of information technology rapidly and directly opens up new opportunities. And although the absolute data volume in all sectors of the economy has been growing apace for quite some time, the front-to-end recording and processing of all company-related process data remains a key challenge – and one that, with few exceptions, has not yet been successfully mastered. Without recourse to all too visionary ideas, it is easy to recognise the benefits of the availability of faster, more comprehensive and above all error-free information. Information that is available at short notice and suitably processed represents knowledge, and enables the recipient to respond more quickly, for example, to detect wear at an early stage or to predict failures – just some of the central skills needed by an agile and efficient company. Moreover, it is undisputed that data as such constitutes a value – increasingly so in the context of Logistics 4.0. This value can be increased both by exchange and by processing. Machine learning of the kind employed in Logistics 4.0 for the analysis of large data volumes (e.g. predictive analytics) or the control of cyber-physical systems (e.g. image and speech analysis, gesture recognition) further increases the value of the data. The systematic interconnection of intelligent process modules lays a promising foundation for the interconnection of distributed information to create a knowledge base with the help of suitable algorithms – although this is a hypothesis for which solid evidence is still needed.

The general consensus is that the key value added provided by Logistics 4.0 is that it permits the systematic exploitation of the performance capability of digital modules in order to shift operational decisions such as the allocation of orders or the creation of sequences directly to the process level. This paradigm shift towards the autonomy of machines, equipment and objects such as workpieces and goods will be a key competence in the endeavour to master volatile and highly individualised procurement, production and distribution activities in years to come.

This type of system architecture is associated above all with two main properties: namely high efficiency and great robustness. Despite the potential, these properties do not come about by themselves. In the case of decentral solutions, efficiency is based on the assumption of higher performance capability, as the systems (can) react dynamically to changes. However, in most cases dynamic behaviour will not be sufficient to offset the absence of a global system perspective (status overview).

Due to the high degree of parallelity, it is often also assumed that autonomous, decentral systems possess great robustness (against failure). This is true, for example, where the failure of a monolithic control system directly leads to overall system failure. A decentral control system may be able to largely compensate for the failure of individual components. However, one of the factors that is of interest in this connection is the time needed to react to failures. Depending on the underlying design concept, notification of failure information by means of sequential communication of individual system participants is characterised by systemic inertia.

Topical individual questions therefore include the following:

- What scope of decentral decision-making is meaningful and expedient? Which global information should be kept available in order to permit efficient system operation, and under what boundary conditions?
- How does fault information act in decentrally controlled systems, and what level of dynamic behaviour does a locally interconnected system exhibit?
- Which rules are to be defined for the necessary system reactions, and how can a differentiated assessment of the performance characteristics at different performance points within the system be assured?
- How can decentrally controlled systems be modelled in terms of methodology and transparency in order to permit valid scientific assessment of their expected properties? Is supplementing suitable models from information science with a physical perspective (including no copying, no deleting of objects) a suitable approach?

2 Do the conventional ways of developing, assessing and launching product, service and business model innovations in the market constitute an obstacle to Logistics 4.0? What new approaches can be identified in this context, and what are the resulting potentials?

Digitisation has already resulted in far-reaching changes to value added chains and business models in many different sectors. It is frequently the case that entirely new actors outside the established companies are the ones who analyse and question the existing value added processes in light of the new options offered by digitisation and interconnection. One of the key characteristics of these changes is the high speed of innovation. Prototypes are created and developed in rapid succession. Products are launched on the market at an early stage with a core functionality, and much of the development of additional functions takes place after the market launch at the request or on the initiative of customers. Detailed milestone and work package planning is replaced by agile planning methods like "scrum"; microeconomic assessment is based on long-term business cases. The necessary start-up phase is financed by venture capital investors interested in value appreciation.

In contrast, innovative logistics technologies, solutions and services are generally developed on the basis of proven processes and methods for the development of products and services and with the help of economic efficiency calculations. Although development processes have become ever faster in recent years, the aim has always been to only bring logistics technologies and services onto the market when they have reached a high degree of maturity. Innovative logistics services are in turn often developed in collaboration with pilot customers as value added services (contract logistics) and require the individualised, customer-specific bundling of different logistics services, something that generally involves a greater depth of integration. One of the elements of these kinds of value added services is the close interlinkage of planning and control systems – and also of ICT systems – between the relevant actors.

The outsourcing of value added services by shippers involves wide-ranging cost efficiency calculations that address not only the cost factor but also the performance, and in particular the quality standards of a logistics service provider, and that also entail a process of risk analysis. This applies in similar fashion to logistics service providers, who make sometimes considerable (up-front) investments in assets – often based on customer specifications. The durations of the contracts often differ from the amortisation periods of the investments. As a result, the establishment of logistics business relationships is often accompanied by classic and generally very time-consuming microeconomic review mechanisms (e.g. market analysis [products, customers and competitors], forecasts, business cases and investment and cost efficiency calculations).

Business ideas developed in connection with Logistics 4.0 often exhibit different characteristics. They may, for example, be based on a new device, a new app or new software. The primary focus is not on the (new) outsourcing of comprehensive physical logistics services or the creation of new logistics process chains. Instead, decentral intelligence in logistics objects permits rapid reaction to changes in the logistics environment. This paves the way for the replacement of high-powered planning processes with smart control mechanisms. Development and market launch are often a matter of just a few weeks or months. The predictability of the increased benefit for the actors in question is also highly limited, however – particularly against the backdrop of the strong technological momentum. One of the reasons market segments become blurred is that digital products and services cannot be classified using conventional segmentation criteria.

This means that classic processes for product and service development and microeconomic review mechanisms are at odds with the characteristic features of Logistics 4.0 solutions. Development and market launch take too long, and the use of traditional review mechanisms may result in a situation in which product, service and business model innovations from the world of Logistics 4.0 have no prospect of market introduction if the classic review mechanisms are applied.

Using the above as a starting point, we can identify the following urgent individual questions:

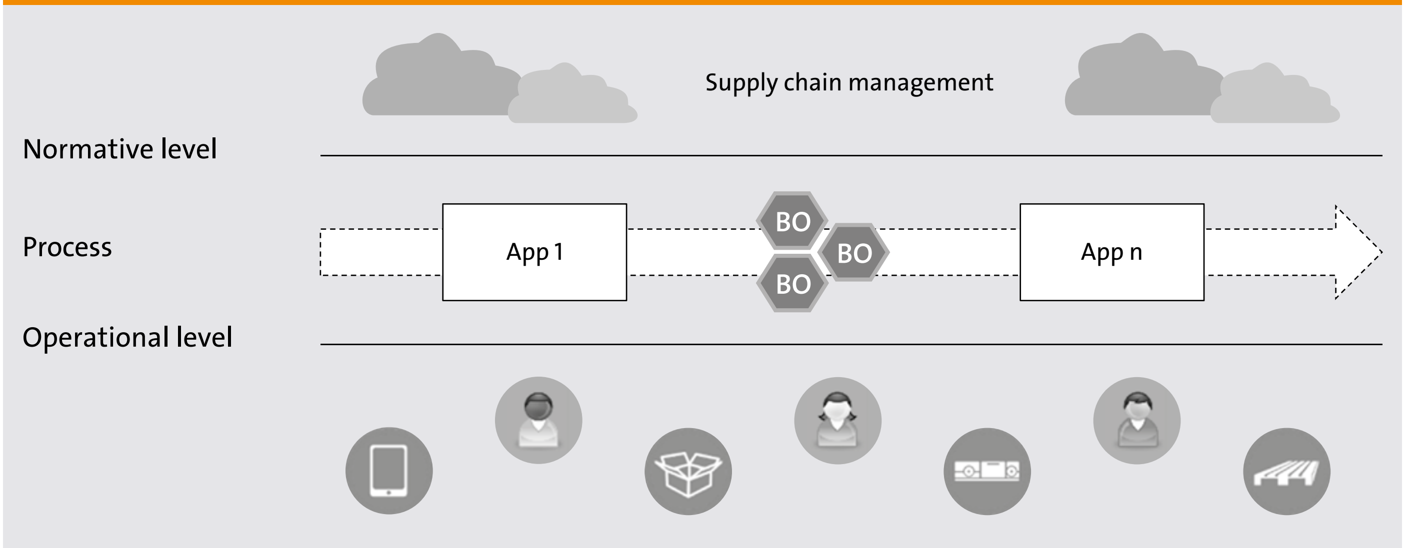
- Will we see a fundamental change in the value added model, and will this be sufficiently taken into account by the available approaches to the development, assessment and market introduction of logistics innovations?
- Do more recent agile approaches based on the trial-and-error principle create greater flexibility and increase the market prospects of product, service and business model innovations?
- How do these new approaches have to be organised in order to integrate agility and quality demands and to build bridges between the actors of digitisation and classic logistics service providers as well as shippers – to the benefit of both sides?
- How must alternative review mechanisms be organised to ensure not only rapid market launch but also adequate risk provisioning for the actors in question? How can new review mechanisms of this kind be put in place?

3 How will the normative and operational levels (planning and control) be organised in future? Will there be separation of these two levels in future?

At its core, the Fourth Industrial Revolution is inseparably linked to the introduction of autonomous, self-organising entities. This is designed not only to pave the way for Production 4.0 but also to promote the emergence of "self-organising adaptive logistics"[3] (Logistics 4.0).

Following on systematically from this a priori knowledge, we arrive at the conclusion that the operational, near-realtime control level will in future make its own decisions, eventually leading to self-organisation in the more distant future. Logically, this would result in the decoupling of near-realtime operations within logistics systems and networks.

Fig. 1: Decoupling of normative and operational (near-realtime) levels



In order to make decisions on an operational level, it is in particular at this level that application-specific information must be stored and propagated. This information includes, among other things, the topology and the layout of material flows and networks, strictly defined rules and semantics, and ultimately all information that permits decentral, autonomous, targeted decisions within the system in question. The goal is to achieve greater flexibility and changeability on operational level. At the same time, the decoupling of the operational and normative levels creates much improved options for the standardisation of supply chain management. This benefit appears evident but has not yet been verified in vivo to date.

There are a number of basic individual questions in this context, including:

- How can targeted, strategic and efficient action be achieved in the distributed systems of Logistics 4.0 (based on a high number of autonomous entities), and how must the (operational) framework for action and the target systems of decentral entities be organised to achieve favourable properties in the overall system?
- Can business objects, functions and processes be standardised on the normative level in an application-neutral way by decoupling the operational level?
- What follows classic logistics process chain management if processes are implemented on an ad-hoc basis?

4 What change will there be in the KPIs for logistics optimisation?

For some time now, the dynamic nature of modern logistics processes has led to a situation in which isolated monitoring of individual KPIs is increasingly problematic and, above all, in which the static assessment of fixed, company-specific target figures can be highly misleading. In supply chains that had previously been optimised all too systematically, the disruption of supply chains due to occurrences such as environmental disasters has resulted in severe production losses. Unforeseen changes to the load profile or in the structure of goods have even resulted in significant efficiency losses in intralogistics systems that were geared with high efficiency towards a specific load scenario.

It was not least this factor that gave rise to the realisation that the definition of target values must be more comprehensive on the whole and, above all, be case-specific and flexible. In view of the imminent paradigm shift with a departure from deterministic decision-making structures and largely pre-planned routines in production and distribution, this development will pick up even greater pace.

Current KPIs, concepts and organisational approaches will not be simply transferrable to the new control models and philosophies that are being discussed across a broad front. It will only be possible to generate the targeted value added if, alongside the interconnection technology, the logic for decision-making processes such as the determination of priorities or starting times is also optimised and developed further. This opens up a whole new area in which our current knowledge is only rudimentary.

As is to be expected, the efficiency of decentral and autonomous decision processes also depends on the required time response. An overly rigid advance timing schedule would probably provide little leeway for the creation of effective ad-hoc organisations or value added networks. Another factor that deserves in-depth analysis is the provision of buffer times (and also physical buffer positions) and the interplay with the required system flexibility. On the whole, therefore, it is to be assumed that additional KPIs will have to be incorporated in the process and that this will lead to a shift in the established weightings.

Logistics planning and control have always gone hand in hand with multi-criterion optimisation. The currently dominant underlying and overriding parameters – namely, throughput time, stock volume and capacity utilisation – must therefore be supplemented by additional parameters, including flexibility-focused KPIs. The goal is to identify suitable assessment scales that can depict the interplay between the contradictory indicators in the desired manner.

Two of the topical questions in this area are:

- Which models and concepts can be used to arrive at a comprehensive assessment of the interplay between new technologies and new KPIs or requirements?
- Which relevant KPIs should be included in this process in future? What is the relationship between classic KPIs like stocks and throughput time on the one hand and flexibility indicators like the dimensional or service spectrum?

5 How will the targeted control and planning of interconnected autonomous groups of actors with special interests be regulated?

To date, the discussion of the topic "Industry 4.0" has primarily focused on concepts in the area of big data and the Internet of Things. The merging of information logistics and physical logistics in cyber-physical systems opens up totally new technical perspectives for the organisation and operation of complex, flexible value added networks. In contrast, there has been far less emphasis on questions concerning the organisational structuring and the management of these systems – but it is the interconnection of widely differing resources and actors that constitutes the very core of Industry 4.0.

All this is based on the idea of flexibly interconnected, decentral production capacities, autonomously communicating and acting objects and infrastructures, and the front-to-end integration of physical and information-based systems. These kinds of developments increase the complexity of the systems exponentially, however. As a result, established, conventional methods for the planning and control of production and logistics systems are reaching the limits of their capability. This applies not only to intralogistics but also and in particular within the context of cross-company supply chain management and the development of logistics infrastructures. Conventional logistics systems must be developed into "logistics service value networks" – and this poses fundamental technical and organisational challenges.

In value added networks, autonomous actors work together to produce and distribute components of complex services that are combined (in modular fashion) to generate the benefit for the customer. The design and coordination of these kinds of distributed service systems is one of the major challenges for logistics in the interconnected industry of the future. Against this backdrop, one of the key questions concerns the development of interaction between humans and technology in logistics in this changed environment. Human (inter-)action will continue to be a decisive factor, particularly in decentral and increasingly (IT) technology-driven logistics systems.

The development and utilisation of the potential offered by distributed ("virtual") logistics systems is driven by the intra-company and, to an even greater degree, the cross-company coordination of the utilisation of distributed resources, capacities and processes as "services" by (vertical and horizontal) value added partners, based on highly developed and typically web-based information and communication systems. The central challenges lie in the "neutral" design of platforms for the common and decentrally coordinated utilisation of these kinds of distributed resources and in the definition of rules and processes for the organisation of these platforms. Logistics service providers can play a central role in this process, in which the integration of IT and physical logistics will be key. The economic characteristics of these systems with their many widely differing and sometimes competing stakeholders will determine the acceptance and success of these systems. Logistics 4.0 will be the central element in this respect.

This raises numerous individual questions – which to date have only been addressed tangentially at most – on the structural and procedural nature, the rules, the mechanisms and the criteria of such systems. For example:

- How can "market mechanisms" and the governance of multiple stakeholders be organised and implemented as the central precondition for efficient business models in Logistics 4.0?
- How can standardisation and modularisation be employed to master the complexity of informational and physical logistics structures and processes?
- In view of decentrally available information, how can economic concepts and coordination mechanisms be developed for horizontal logistics collaborations and marketplaces that can be applied in real-life decision-making situations with wide-ranging restrictions and that are geared towards the targeted improvement in the utilisation of logistics resources?

6 How must the goals and rules be defined, transferred and implemented in the distributed and autonomous systems of Logistics 4.0?

The development of hierarchically planned and centrally controlled logistics systems towards coordinated, decentral and self-controlling autonomous systems fundamentally changes the relationship between the strategic (or normative) and the operational level. The targeted coordination of decentral systems requires the stipulation of rules and mechanisms to ensure that the decisions that are made decentrally complement each other to form a consistent overall concept. Here, the aim is to define rules on the normative (planning) level that ensure coordination of the operational and decentral decisions of the autonomous actors (and objects) with the aim of achieving agreed, overriding objectives (control). The decentral actors must accept these overriding rules, as they are the prerequisite for effective coordination. This presupposes agreement on their characteristics.[4]

Target criteria and rules have already been developed in many technically dominated, distributed logistics systems using multi-agent systems, above all in the field of intralogistics. The concept of swarm intelligence and learning-capable autonomous logistics systems is also increasingly the subject of research and is already being successfully applied. The more, however, that cross-company logistics systems with distributed resources and processes as well as multiple actors with potentially diverging economic objectives come into play, the greater the challenge of developing economic goals and rules and of ensuring the economic functionality of distributed logistics systems – regardless of technical effectiveness and efficiency – in the organisation and control of Logistics 4.0 systems. The efficiency and effectiveness potential of distributed logistics resources, and above all the flexible use of these resources on demand, can only be exploited on the basis of agreed economic rule systems.

In recent times, above all in the field of macroeconomic research, major importance has been attached to developing so-called market mechanisms, which are used in many forms based on the concept of "market design". There is major potential here, specifically for the design of distributed logistics systems. Agreeing on these types of market mechanisms is a complex process, particularly in complex value added networks with multiple, economically independent actors with potentially diverging objectives and interests; at the same time, however, it is precisely this agreement that constitutes a central element in the success of Logistics 4.0 .[5]

Against this backdrop, the following individual questions concern some of the basic issues that need to be addressed:

- Which actors will take up the initiative in the development of these regulating systems and define the criteria for participation and the proper functioning of the regulating mechanisms?
- How can we succeed in ensuring the compatibility of the heterogeneous objectives of the participants in distributed logistics systems?
- How can the potential conflict between central objective and rule definition on the one hand, and decentral autonomy on the other, be handled and structured using economic principles and models?

7 What will the transition from classic, deterministic, hierarchical supply chain planning and control to heterarchical, probabilistic ad-hoc planning and control activities in Logistics 4.0 look like?

The traditional idea of planning, controlling and monitoring logistics networks holistically (hierarchically) is designed to achieve the optimum overall outcome across company borders. The extreme case of integration – from the raw material supplier all the way through to the consumer – is geared towards the centralised planning and coordination of all entities involved in the value added process. However, the resulting complexity above all negatively impacts on the robustness of the systems. It is almost impossible to neutralise system failures, which can then threaten overall functionability. Structural disruptions and economic crises result in increased volatility, uncertainty and complexity, and reduce the predictability of logistics operations. In order to ensure efficient logistics even in the highly dynamic and volatile scenarios encountered in Industry 4.0, one factor that also needs to be investigated is the situation-specific need to reduce the level of integration of all too narrowly and rigidly coupled systems and of the resulting highly vulnerable value added networks – and thereby to determine whether measures such as targeted risk management designed to decouple logistics systems are more likely to achieve the goals of increased robustness, resilience and agility[6].

In this context, logistics management aims to create value added networks to organise the systems of autonomous actors that are geared towards the exchange of information and collaboration and that are only loosely connected. The answer to the question of which degree of coordination and integration is to be targeted and is meaningful depends on the specific situation in the value added networks. A principle of total integration is neither desirable nor practicable.

In this connection, particular importance is attached to increasing adaptivity. Value added networks must be seen as complex adaptive systems with intensive communication and interdependencies between their entities, processes and resources. Associated system characteristics include non-linearity, complex multidimensional behaviour, evolutionarity and self-organisation. But these systems need coordination and decision mechanisms in order to permit adaptive and collective behaviour in autonomous, decentralised contexts. It is no longer possible to achieve the inherent complexity of these kinds of networks through maximum possible integration, in other words centralised planning and control. It is only logical that what is required is a paradigm shift in logistics systems towards the decentralised control of "intelligent" objects in heterarchical structures – rather than, following the traditional mindset – the centralised control of "non-intelligent" objects in hierarchical structures.

The reorientation of logistics in science and practice towards intelligently coordinated, distributed, more decentrally organised constellations of autonomous subsystems constitutes a not inconsiderable change in focus of logistics organisational principles and criteria. Nonetheless, there are already a wide range of research approaches, albeit with very different designations, that are based on similar principles and that can serve as valuable points of reference for the further research and development of complex adaptive logistics systems.

The central individual questions in this regard include the following:

- How can contrasting strengths and weaknesses, potentials and risks of integrated and distributed systems be assessed more effectively in the context of Logistics 4.0, and what would an optimum situation-dependent balance look like?
- How can logistics systems be organised and controlled as complex adaptive systems at the interface of technology and the economy?

8 Will Logistics 4.0 result in different principles for resource utilisation ("share economy")?

Logistics systems have always been geared towards increased efficiency. The operation of logistics systems often entails high investment (e.g. for facilities such as warehouses or hubs as well as transport fleets comprising vehicles, conveying systems, aircraft, rolling stock, locomotives, ships etc.). Whether efficiency targets can be achieved therefore also largely depends on the degree of utilisation of existing capacity.

As a result of a wide range of system-internal and system-external framework conditions (such as volatility of demand, social legislation, imbalances and information deficits), it is almost impossible to avoid idle capacities in traditional logistics systems. Although electronic freight exchanges promote the rapid matching of supply and demand in road freight transport and therefore improve capacity utilisation at specific points, they are nevertheless focused on the utilisation potential of a resource that can be assigned to exactly one owner. There is no provision for the common, overriding optimisation of resources belonging to multiple owners.

The failed city logistics projects from the 1990s show that the joint use of logistics resources (in this case, above all trucks and storage space) has, for various reasons, not been a success to date. The issue of how close to real time it is possible to compile a status overview of orders and available resources was not the only question that remained unanswered. What was also unclear is what logic is needed to assign existing orders to available (transport) resources of different owners / actors, and how the corresponding "contribution mechanisms" should be designed. As a result, traditional optimisation approaches still focus on utilisation of in-house resources.

With the help of realtime data and using cyber-physical systems, Logistics 4.0 permits interruption-free, interconnected communication within flows of goods and products.

Communication in Logistics 4.0 concerns people (e.g. drivers, schedulers, management personnel in the logistics sector), logistics objects (e.g. goods and products, containers, packaging, pallets), logistics processes (e.g. transport, transshipment, storage, order picking), logistics vehicles and logistics facilities (e.g. terminals, hubs). Containers are fitted with digital equipment, rendering status information globally available in real time. In the field of road freight transport, shipment-based scheduling systems are linked up to vehicle-based telematics. The intelligent processing, interlinking, evaluation and utilisation of data for logistics decisions (big data) is seen as the enabler of Logistics 4.0.

This means that the preconditions for a "share economy" in logistics appear to be in place: ICT solutions permit common access to data by business partners (e.g. logistics service providers, shippers, subcontractors) via the cloud in real time. This data can include sender-related and recipient-related order statuses as well as available resources – all on the relevant timelines. This creates the tools needed to align orders to the available resources of different actors.

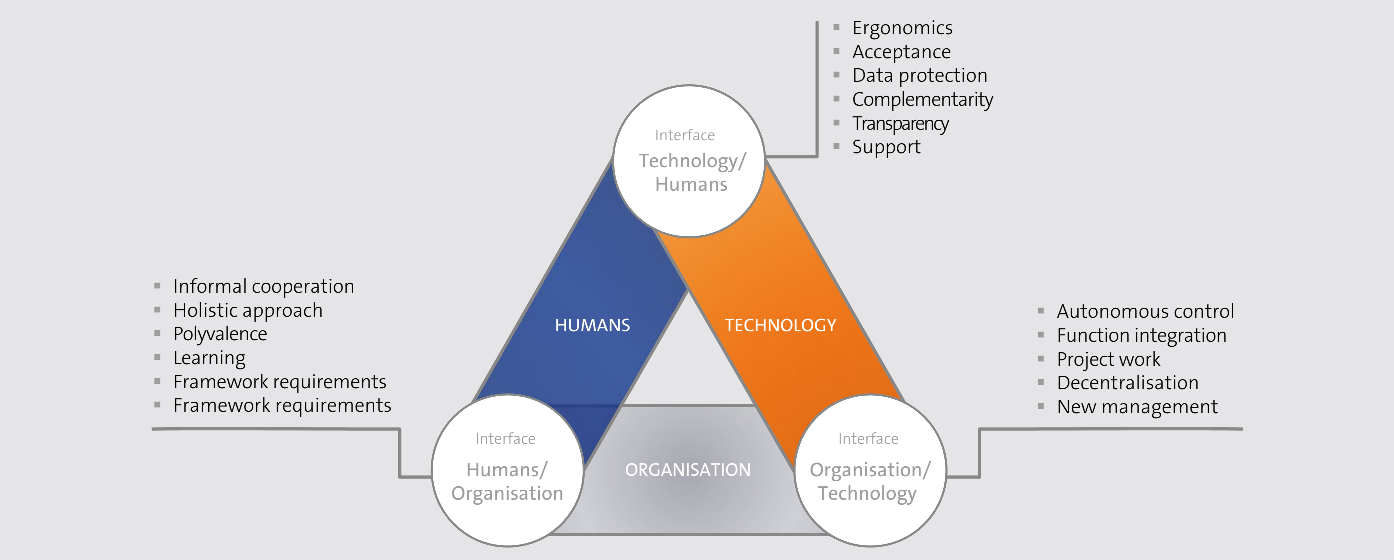
However, many individual questions still appear to be unresolved in connection with the stable implementation of a "share economy":

- How can quality/service standards be ensured if logistics services are created with "distributed" resources?
- Which priority rules are suitable for deciding which resource should be used for which order and when, and how are these rules to be applied?
- Which governance models can be used to operate a "share economy" in logistics? In particular, it must be borne in mind that operation of the platform (including the decision on the distributed use of resources) directly affects resource utilisation and therefore the economic success position of the actors.
- What standards need to be met by a "contribution system" based on the provision of logistics services for a "share economy", and how can such a system be structured?
- Which areas/logistics services are particularly predestined for a "share economy"?
- What criteria does compliance have to fulfil in a "share economy" in logistics? Where are the weaknesses – with regard to data access and data protection, for example?
- What is the nature of the trade-off between the sharing of information ("privacy") and efficiency gains? What does this trade-off depend on? In the case of large-scale reciprocal effects: what does this mean for the distribution of public sector and private sector tasks?

9 Humans and autonomous machines will in future interact in (social) networks as equal partners and cooperate in natural environments. What will the sociotechnical systems of Logistics 4.0 look like?

It is particularly in this field that technological developments open up major potential for innovation. A further aspect of equally central importance is that, based on general understanding, Logistics 4.0 involves the interconnection and digital penetration of processes but not necessarily the all-encompassing automation of these processes. On the contrary, the expectation is that we will see widely diverging developmental perspectives for digitised work. Automation technologies will by no means determine the organisational nature of work but will always be associated with a certain amount of creative leeway.[7]

Fig. 2: Dimensions and interfaces of the sociotechnical system of Logistics 4.0[8]



The changes to the working world due to interconnection and digitisation that are gradually emerging in industry, trade and logistics already happened some time ago in other sectors – in the financial world, for example, with its high-frequency stock market. In recent years, employees in these sectors have come to terms with the new situation, just as major parts of society as a whole have become accustomed to the use of digital devices and social networks as a matter of course.

This development opens up new perspectives and opportunities, not only for the structuring and optimisation of processes but also for integration of the work performed by humans. Simple examples already exist in the form of individual instructions or the performance-based and knowledge-dependent management of people in the work process. Today, the increasing integration of sensor technology in handling equipment and the direct integration of this technology in the work process permit hybrid workplaces without the previous strict separation of work spaces or the temporary shutdown of the corresponding automatic functions. Among other things, this exploits the potential to master problems and challenges in the area of societal development (demographics) – by relieving people of the need to perform physically demanding or monotonous tasks, for example. In other applications, however, human activities can also be transformed into process-monitoring or problem-solving tasks. The goal is to establish systems for skill development as well as for informal learning that anticipate the individuality of the person in question and his or her cognitive qualities and skills ("cognitive ergonomics"). This is the only way it will be possible to utilise the individual creativity and flexibility of human beings in the sociotechnical context of Logistics 4.0 in a socially acceptable manner. The acceptance of a new "man-machine" interaction concept in the vein of Logistics 4.0 will ultimately determine its long-term success. However, this acceptance cannot be promoted or even forced on people from the outside but must grow gradually over time.[9]

The resulting individual questions concern the three essential interfaces of the sociotechnical system of Logistics 4.0 (cf. Fig. 2 above), for example:

- The technology/human interface: which activities are meaningful and socially acceptable within the framework of Logistics 4.0 and how are they to be automated. People and machines act in different time frames; how can an understanding of dynamic system behaviour and an understanding for autonomous behaviour be promoted (on both sides)?
- The organisation/human interface: what is the right, individual scope of management by the system? How can human beings be meaningfully integrated in decision-making processes?
- The organisation/technology interface: Logistics 4.0 is based on decentralisation and new principles of autonomous control and self-organisation; how can these principles be formulated in a technology-compliant manner? Which methods and algorithms should be adapted or developed for this purpose?

10 How will risk and responsibility be shared and distributed ("machine responsibility")?

In Logistics 4.0, affordable and high-powered sensors, actuator technology and information processing enable the machines not only to communicate with people but also to interact, as well as to interpret and ultimately anticipate human behaviour. Interpretation of gestures and speech or the measurement of the human pulse based on analysis of a video signal are just as much part of the current state of the art as eye trackers in cars or fitness bracelets complete with motion analysis. Techniques and algorithms of artificial intelligence and machine learning are increasingly gaining ground, and their development points in the direction of autonomous action by machines.

Machines will become "equal" partners in the social networks of Logistics 4.0. Avatars and software agents will represent humans in the virtual world created by these novel social networks (cf. Hypothesis 9)[10]. In future, "man-machine interaction" (MMI) will increasingly resemble interaction between humans. As logistics is a sector with a wide range of manual tasks, it will be affected by this development to a particularly high degree.

In Logistics 4.0, the corresponding technical developments will initially extend to relatively simple systems like intelligent containers and shelves, smart devices and swarms of driverless transport vehicles that will have the ability to interact with humans via speech, gestures and the interpretation of physiological parameters. In the longer term, these systems will be joined by cyborgs, autonomous trucks, robots or complex machines.

One topic that is closely related to this question is that of context-based learning. Once again, this will concern both parties – humans and machines. On the one hand, this will be about how individual experience-based knowledge is preserved and imparted by humans. On the other hand, there is the question of how machines learn in the context of natural environments and in interaction with humans (e.g. artificial intelligence techniques).[11]

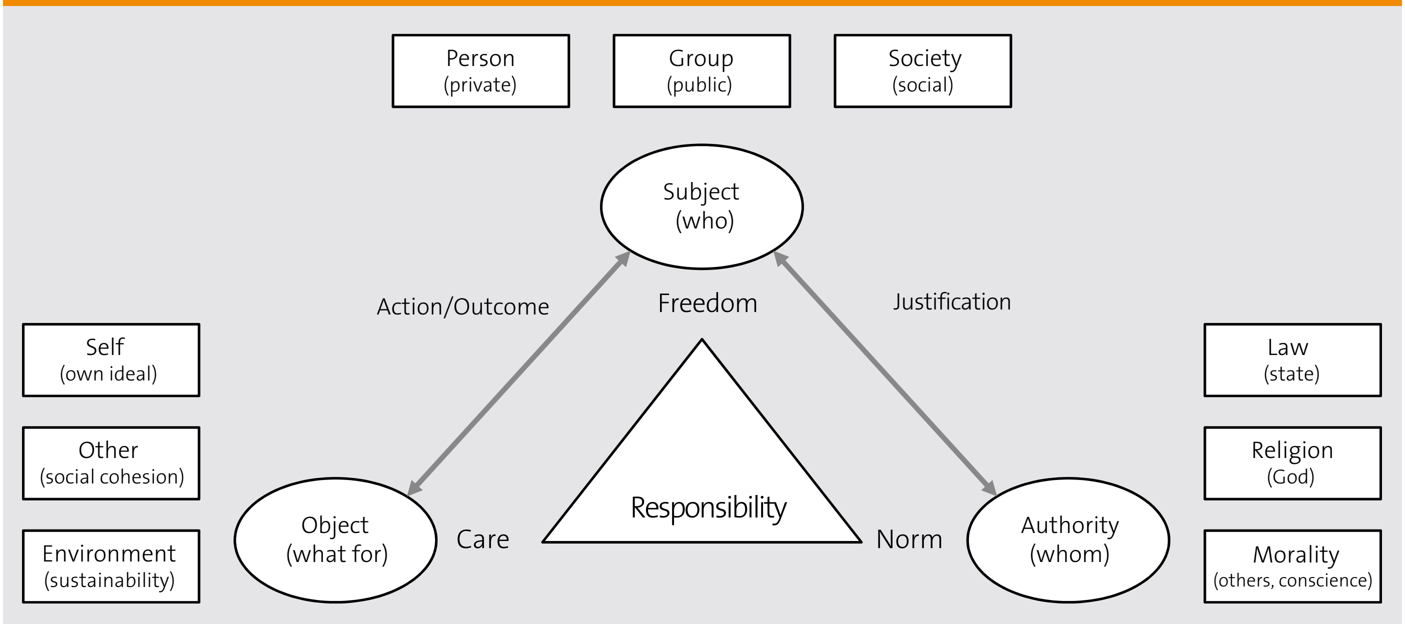
It would be negligent, however, to interpret a positive vision of the future interaction between humans and machines as a merely technical development. Interaction with (partially) autonomously acting machines raises questions concerning acceptance, legal assessment and the restructuring of the sociotechnical system up to and including the ethical perspective.

"While MMI applications will make many injuries and fatalities preventable in future, it is equally likely that these applications will also cause harm to some people.[12] In this connection, the scientific literature also discusses the ethical and legal implications of scenarios in which a (partly) autonomous machine has to decide between harming two people or groups of people – between its own passengers and other traffic participants, for example, or between multiple other traffic participants.[13] The faster reaction times of MMI applications basically means that more "damaging events" will be avoidable, and this raises two questions: that of the legitimacy and possibly even the legality of decisions not to use MMI solutions; and, secondly, the question of whether this may result in restrictions on human options for action." [14]

The following questions are among those that need to be answered in an interdisciplinary scientific discourse:

- How will responsible and targeted action in the interaction of humans and machines by structured and organised in the common social networks of Logistics 4.0?
- What is the normative standard that machines have to submit to in their interaction with one another and with humans?
- What is the categorical imperative of Logistics 4.0?

Fig. 3: Basic relationships of responsibility[15]



11 What qualifications and competencies does Logistics 4.0 require? How will they be individually fostered?

Increasing digitisation and interconnection in Logistics 4.0 creates major challenges for employees and management personnel. With the increasing application of advanced information and communication technologies in logistics and production, existing work, organisation and management structures will be called into question by new technological concepts. Added to this are the effects of demographic change and the differing aptitudes, values and attitudes of the different generations.[16]

In Logistics 4.0, simple rule-based work routines are increasingly automated. Humans and machines work together. The employees are still responsible for organisational, creative decisions. Smart devices like smartphones, tablets, 3D glasses or wearables enable the employees to manage the glut of information and to enter into a novel dialogue with intelligent machines and products.

What are the resulting specialist and methodological requirements of this development with regard to the people employed in the logistics sector? One general specialist element will be the integration of production and logistics knowledge on the one hand and up-to-date IT skills on the other. This calls for additional qualification measures in the area with the lower skill levels. Concrete requirements will largely depend on the function of the employees in question, although age will also play a decisive role, as younger employees are far more comfortable when it comes to using digital technologies.

Qualification measures for personnel in the era of Logistics 4.0 must take account of all groups of employees – in other words, not only blue-collar staff but also commercial employees and management personnel, and the requirements will be different in each case. As a result of increased automation, for example, blue-collar employees will sometimes be faced with the challenge of performing new tasks. Commercial personnel will have to learn the necessary skills that enable them to handle a more highly automated, decentral planning and control approach. For their part, management executives need holistic business process and IT expertise in order to identify and exploit the potential of Logistics 4.0 for their company – as well as high-level skills in the area of change management and modern employee leadership. They must help older employees to understand the benefits of Logistics 4.0 while simultaneously arousing the interest of employees from Generations Y and Z (the so-called digital natives) in their company and managing these younger employees in an appropriate manner. Moreover, they must create a framework for the productive cooperation of older and younger employees.

The resulting qualification needs must be individually determined for all employees and management personnel, followed by the organisation of suitable further training and development programmes. Ongoing digitisation in the educational field also opens up attractive new options for companies, such as online courses, gamification or knowledge platforms. It goes without saying that training content must also be rapidly established in the areas of school, vocational and university education. At the same time, however, it is precisely the process of digitisation that also paves the way for the development of competencies on independent initiative outside the conventional education pathways. This aspect should be taken into account in the development of concepts for the documentation of the individual qualification status for Logistics 4.0.

In view of the above, the following are just some of the individual questions that need to be asked:

- What specialist and methodological demands will Logistics 4.0 make on employees in logistics – in general and in terms of specific tasks and functions?
- How does digitisation affect employment in logistics, and how will this impact the supply and demand for specialists and management personnel?
- How can the different knowledge statuses and working practices of the different generations be combined in a productive way and optimally utilised?
- How does the further training and development system need to be adapted in order to address these issues?

Conclusion

The Fourth Industrial Revolution is fundamentally changing the face of industry and society, creating major challenges for logistics in the reorganisation and restructuring of value added systems. Established business models and success factors are being called into question, and there is a need for new ideas and concepts.

Industry 4.0 is unthinkable without logistics. It is the prime mover of the Fourth Industrial Revolution and the core element of all successful concepts. Logistics will be the key competitive and locational factor for industry in the international competition between new business models in the area of autonomisation and digitisation. More than ever before, logistics research is therefore called upon to answer the fundamental research questions arising on the road to Logistics 4.0.

The research questions outlined in this Position Paper underline the importance of logistics and IT as the central knowledge areas for the implementation of the Fourth Industrial Revolution. The wide-ranging interrelationships between these two disciplines make it expedient to focus above all on interdisciplinary concepts. A further aim is to create a common theoretical foundation for technology and economy in the concept of Logistics 4.0.

These challenges can only be mastered, however, if logistics research receives the necessary support. Laying the scientific foundation for the logistics of the future, establishing it as a science within the context of a new “logistics” research initiative, and systematically promoting logistics as an independent discipline for the first time is a national task. The decision-makers in the field of research policy are called upon to pledge their commitment to this societal task and to lend it their long-term support.

In this connection, we also refer readers to the Position Paper of the Board of BVL on digitisation, which contains more details regarding the association’s position on the particular importance of information technology in logistics.

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