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A Vision of Digitalization in Supply Chain Management and Logistics

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Abstract

Digitalization requires a new form of management to master the transformation process of corporations and companies. The Dortmund Management Model structures the focus areas of the digital transformation along the management tasks goal, planning, decision, realization and monitoring as well as the common socio-technical subsystems technological, organizational and personnel - enriched by a fourth dimension: information. Additionally, the acceleration factors transformation, migration and change management are taken into account.

This paper embraces a vision for a persistent management of production and supply chain networks in order to achieve a holistic Management 4.0. The emerging developments of technology, methods, tools and models in production and supply chain research are connected and merged into a big picture of digital supply chain management and logistics. The interfaces between management tasks show specific characteristics of digital business processes in particular, which are hereinafter exemplarily outlined:

New business models and value-creation networks are based on adaption intelligent production systems, which are interconnected with digital models for continuous planning and reconfiguration. At the shop floor and between sites orders are completed by autonomous guided vehicles (AGV) with intelligent load carriers. Decentralized negotiations and decisions across company boundaries concluded with smart contracts are enabling reasonable and sustainable distribution of the value creation processes. Humans are still in the center of action – abilities are developed by integrated competence management, new learning approaches and human-centered assistance systems coupled with AI-based decision-making support. New types of organizations allow a synergetic collaboration of humans and machines. The benefit of integrating new production and transport technologies becomes assessable and accelerates the ongoing renewal of existing networks.

This paper provides an overview of possible potential and connecting factors by linking different technological developments towards supply chain, logistics, production and management research and shows further research demands.

Keywords

Plattform economy; Silicon Economy; Management 4.0; Individualization

1. Introduction

Individualized customer requirements are increasingly driving the diversity of variants in Supply Chain and Productions Systems – the ‘lot size one’ is a continuous tendency. Industry 4.0 holds the promise for highly customized processes while maintaining the productions costs of mass productions systems. How has a

vision of future value-chain networks, process chains and technologies have to look like, to fulfil this objective properly? There are certain requirements that are already clearly noticeable. And all companies and industries in logistics and supply chain management are obliged to meet them. Same-Day-Delivery without additional shipping costs in almost all product categories is already a unique selling point and a differentiating characteristic of large trading platforms. Processes and structures have to adapt to fulfil these promises, while using the current technological developments in a human-centred and economical modality. One key challenge of the management is the goal-orientated design of the transformation process in their company. This paper describes a vision of digitized logistics and supply chain management. Research results are combined to give a complete picture of future supply chains, from the shop floor to the control of operational processes, from human-machine collaboration to autonomous supply chains. Afterwards, the 'Dortmund Management Model' is briefly presented, which structures the transformation process holistically and the need for further training for the management of digital transformation is illustrated. Finally, the development towards platform economics is presented and limitations and further research are outlined.

2. A Vision of Digitalization in Supply Chain Management and Logistics

The image of distribution centers in Logistics and supply chain management is characterized by miles of conveyors and giant sorters guiding parcels through the system. These large, fixed units are designed for a steady and high capacity utilization with long-term forecasted standardized processes to operate economically. These two requirements are no longer present [1]. The prospective supply chain systems are obliged to handle quantities and processes economically, which are unknown figures at the point of investment. In conclusion, significant changes on the shop floor are necessary. Fixed steady conveyors, which run a preconfigured route are not adaptable enough. Especially warehouse-location decisions for distributions centers are not possible to conclude for a number of decades. Changes within the range of products are more frequent due to shorter product life cycles and are influencing the necessary and reasonable locations. These changes create new requirements for the supply chains of the future and their components.

2.1 Infrastructure-less logistics

Forthcoming logistics systems not only have to be mobile and adjustable. At best, they have to be without any infrastructure at all. That does not mean it has to be without technology, but characterizes a vision of a capacity, which is fast to set up and dismantle. Research projects already describe concepts for a distribution center, which is ready for operation within a few weeks [2,3]. Crucial parts of this concept are automated guided vehicles (AGV). They not only fulfil the tasks of traditional unsteady conveyors like forklifts, they also replace conveyors. AGV systems are already able to realise transport relations on the shopfloor without being dependent on determined routes. Furthermore, they are also able to react directly on changes. If products, load carriers or storage locations change, the vehicle calculates a new route to navigate efficiently through the system. Capacities do not have to be expanded by long-term investments, the need for upscaling to compensate a larger job load is obsolete. The modularity of the systems makes it possible to compensate increasing demands by complementing the system with additional AGVs temporarily or permanently. A proper example for this kind of transportation systems are cellular transport systems. These systems act autonomously and are capable of driving on the shop floor as well as in storage racks [4]. This said, a handover form storage and retrieval machine to carriers is rendered mandatory. The capacity for moving goods in and out of rack systems no longer has to be set at the point of investment, but can be controlled by the deployment of cellular transport systems. It is possible, that in future warehouses shelves are no longer present. Innovative AGVs have the ability to pick a single small load carrier out of a stack located on the floor. In conclusion, simple stacks of small load carriers are sufficient to gain direct access on the whole inventory [5].

2.2 Decentralized control in production and logistics

Planning and control of this kind of adaptable systems influenced by fluctuating capacities requires new concepts. So far, strictly hierarchically organized and centrally arranged production planning and control is possibly no longer suitable for volatile market conditions. Mathematical problems induced by capacity planning and scheduling are solvable in a reasonable period using heuristics, but using the flexibility of the system by decentralized decision-making may be the more favourable option. The uprising challenge is to proof the decision quality of decentralized planning and guaranteed on-time delivery for customers. The necessary advancements are aiming for a connection between flexibility and decentralized autonomous control and the obligation of centralized approaches. Also, the expansion of planning steps of autonomous control in upstream processes and operations across company boundaries have to be addressed. [6–8] Planning in partnership-based collaborations of maintenance and production will be a critical requirement for smart-production systems [9]. By using sensory and operational data, impending machine failures can be predicted [9,10]. Spare parts can be produced right at the place of demand by the use of 3D-printing technology [11]. Decentralized intelligence of machines enables an autonomous reaction, for example rescheduling of jobs in context of critical system conditions [12]. These are just a few examples of intelligent assistance systems that will support logistics tasks in the years ahead.

2.3 Social Networked Industry

Prospectively, nearly every workplace will be characterized by digital technologies and interaction with intelligent systems will be everyday practice. The work still has to be human-centered to create an adequate working environment and a sustainable and competitive economy [13]. Intelligent assistance systems relieve humans from monotonous and physical tasks. For example, AGVs can follow the worker automatically [14] while exoskeletons are reducing the workers physical distress while handling heavy goods [15]. In the vision of the social networked industry, humans and machines are working hand in hand. Like in social networks, entities communicate with each other and keep interchanging [16]. But not only the information exchange is enhanced, physiological and psychological constitutions of the workers are taken into account. The intelligent shelf recognizes the workers condition, for example the exhaustion level and proposes breaks accordingly [17]. The AGV shows its condition or ‘mood’ by easy interpretable symbols [18]. Considering the technological evolution, the realisation of this synergetic relationship among human and machine requires not only the inclusion of physiological parameters, but also the involvement and active design of cognitive aspects [19]. The development of corporations in this direction additionally includes the aspect of the organisation. Individual and fast changing customer and market requirements are leading to different activities and in conclusion to inconstant team compositions. Including social factors in the change process is more important than ever [20]. Virtual planning environments will be used to increase the participation in change processes and results inevitably in the inclusion of the process expertise of all employees [21]. Additionally, the demands upon the employee’s competences are going to change. The comprehension of the overall process and problem solving becomes more relevant and has to be measured and developed by a consistent competence management [22]. Competence requirements of the workers are evaluated and deviations from the competence profile are going to be levelled out using individual qualification measures. In doing so, new learning concepts are utilized: Game based approaches like serious games in further training and gamification in training measures will be integrated to increase self-learning competence and motivation of employees [23]. Intelligent assistance systems will also support the learning progress of employees. VR- and AR- technologies enriched by eye-tracking and AI are able to trace the learning success of the employees [24]. The necessary digital support during training and the level of difficulty for competence measures will be set individually and in real-time. The described changes in different logistics systems also affects the cooperation in networks in which new coordination and cooperation procedures become necessary.

2.4 Autonomous Supply-Chain networks

Especially the transition in corporate networks poses the question for automated and even autonomous conclusions of contracts between intelligent systems. The technology for negotiations of rates, but also the trigger of payments or mandatory orders are smart contracts based on distributed ledger technology. The immanent immutability of datasets using this technology ensures not only the manipulation security, but also audit secure accounting. The legal basis for autonomization of the financial flows, which is besides the material and the information flow significant in supply chain management, is currently investigated by the 'Recht-Testbed'-Project. [25].

Artificial Intelligence and logistic assistance systems are also supporting the strategic and operational decisions in supply chain networks. Nowadays, simulation software is utilized to predict disturbances on the transport routes and used to choose the best possible option [26,27]. While planning value chain networks, not only cost and performance are taken into account. Targets concerning energy efficiency, for example warehouse locations problems and means of transportation are taken into consideration, too [28]. Future productions systems will be fully modular and will be dynamically plan- and optimizable by using assistance systems [29]. Decentralized controlled supply chain networks of the future will integrate the necessary intelligence for control, assessment of alternative options and communication already in the handled objects itself. A container recognizes delays on its path, works out alternative means of transport, commissions a service provider and handles the payment on pick-up [30]. Logistics 4.0 realized in this way requires the consistent and near real-time digital image of the enterprise's resources. This challenge is called digital twin or digital shadow. Due to a digitalized and reality-synced image of the company and the related processes, the transparency of the present state is increased and also renders effects of possible measures calculable or simulateable [31]. These options contribute to automated adjustable production and logistics systems - the first step to adaption intelligent systems [8]. The challenge of the coming years will be to design the change in the direction of the possible future vision outlined above. The change of companies will not happen overnight and technologies and research findings must be evaluated, selected and implemented step by step in a targeted manner.

3. Management 4.0 – shaping the transformation process

As for digitalisation in logistics and supply chain management, the is still a long way to go. It requires a company-specific objective and a systemic approach. The D Management Modell offers an overview for the necessary tasks of the needed management 4.0. In contrast to other transformation models or management models, the Dortmund Management Model focuses on a domain and explicitly on the change in industry 4.0 (for a comparison of the models, see [32]).

The Dortmund Management Model is a framework to support management in the digital transformation of companies and is to be understood as a universal model. The challenge lies in an integrative management process that analyses the corporate culture, the corporate organization and the value-added processes and at the same time promotes process and technology innovations and must be operationalized individually under consideration of the individual needs of people.

In order to advance the transformation of a company to industry 4.0, three acceleration factors are integrated into the model: transformation, migration and change management. Transformation focuses here on an agile organization, made possible by the use of suitable technologies and organizational learning to adapt to changed framework conditions [33]. Migration describes the step-by-step introduction of technologies in companies and their processes [34].Change management covers all activities that aim to bring about far-reaching, cross-functional changes in the implementation of new strategies, structures, systems, processes or behaviours in a company [35,36].

In addition, the framework of the Dortmund Management Model structures the management of digital transformation in two dimensions: a management dimension that describes the relevant (standard) tasks of management ('goal', 'planning', 'decision', 'realization' and 'monitoring') [37,38], and an organizational design dimension in the form of four pillars.

The integrated view of the Dortmund Management Model is reflected in the four pillars 'technology', 'role of man', 'organization' and 'information', which are equally included: This comprehensive organisational design approach is based on the MTO concept according to Ulich and includes the characteristics 'human', 'technology' and 'organisation' [39]. The increasing quality and quantity of digital data available in real time offers new possibilities for companies within the framework of industry 4.0. By combining digital and real processes in the sense of digitization, companies automatically or autonomously generate amounts of data at their disposal. The information resulting from this data, for example from cross-company value creation networks, is a valuable asset for innovative data-supported business models and thus a central asset in industry 4.0. This leads to a self-optimizing organization that enables autonomous and timely adaptation to the changing conditions in the business environment [33]. Consequently, a fourth feature is added to the MTO model: Information (I) (MTO plus I). [36]

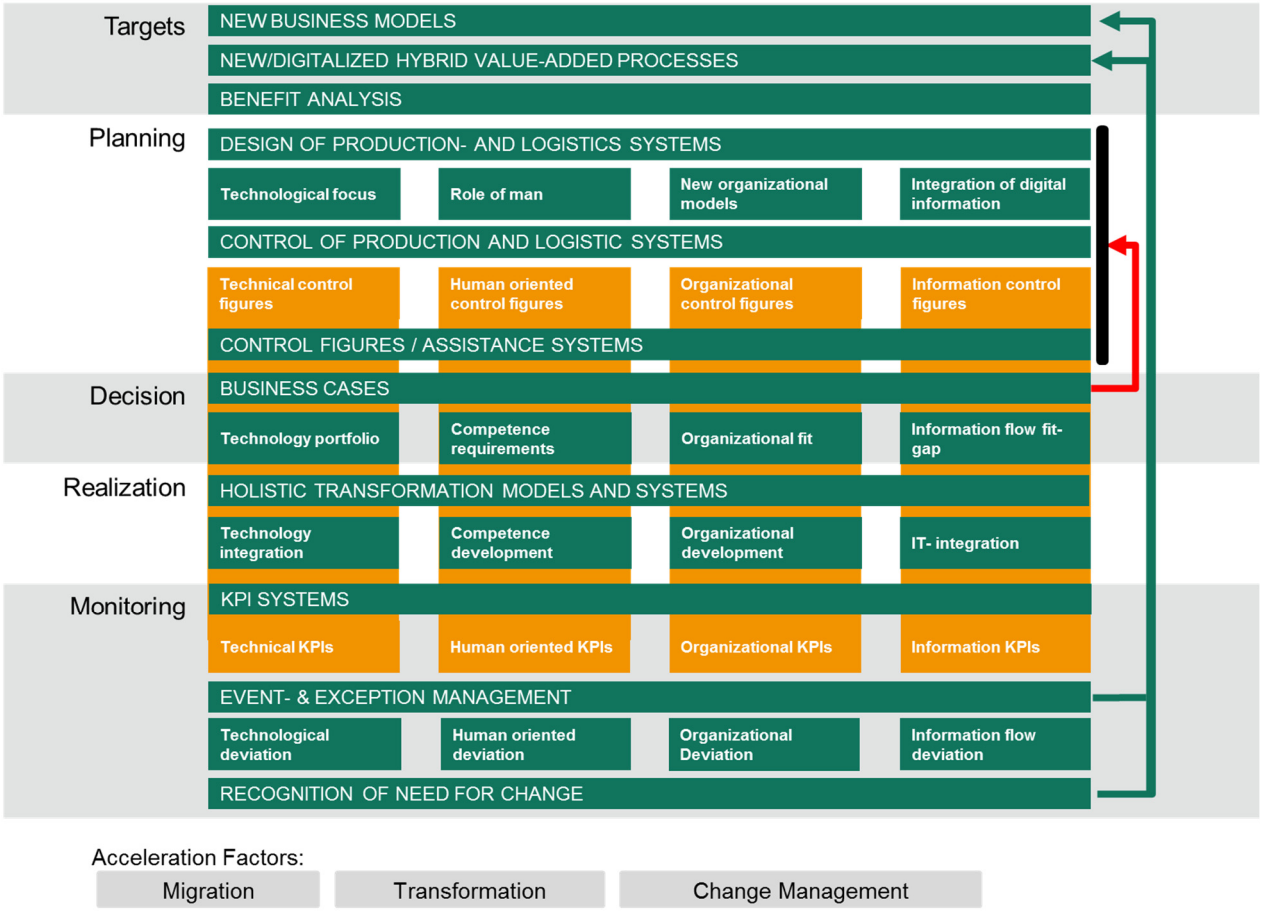

Figure 1: Dortmund Management Model

On the basis of the framework, necessary fields of action for the management of digital transformation can be described along the management tasks and their interrelations with the pillars of the organizational design dimension. Consequently, it enables management to merge isolated technological solutions into an integrated management model by using the design principles of supply chain management. The model can thus be used by companies to structure the digital transformation process and include all necessary perspectives.

For concrete transformation projects, the individual tasks must be operationalized with appropriate methods. Various company case studies in which industry 4.0 technologies have been implemented in transfer and implementation projects have shown that the challenges that have arisen are explicitly addressed by the management model [40]. However, the employees, especially those responsible for transformation, must design the process and consider the pillars integrated.

Thus, the management of the digital transformation has to be seen as an interdisciplinary field of activity across company boundaries, which is currently animating new responsibilities and in conclusion new job descriptions like 'digital transformation manager', 'chief digital officer' or 'digital transformation architect'. The competence profiles of these new job descriptions are nearly the same. For 99% of the companies, features like the will to change, handling complexity, communication and especially lifelong learning are the field where most action is required. In contrast, more than half of the questioned companies have no actual strategy for the development of these special digital skills. Simultaneously, over 74% of the employees desire more further training opportunities in the field of digital transformation. [41,42]

Under the lead of the Fraunhofer Institute for Material Flow and Logistics IML the project associates of the Center of Excellence Logistics and IT [43] in Dortmund, Germany, and the Fraunhofer Academy are developing a modular training format for the management of the digital transformation on the basis of the Dortmund Management Modell.

4. Outlook – Silicon Economy

The necessary technology for the given examples already exists. Objects like load carriers with sensors and micro computers may work energy self-sufficient for several years, and not only track their own movement, but being localized through 5G and communicate without the need of further infrastructure [44]. They are able to post payments via smart contract platforms in digital currencies and book logistics services independently. The linkage of the intelligent physical objects (IoT-broker), blockchain based transactions (blockchain-broker) and logistics services (logistics-broker) generates a new platform economy for the B2B-sector – the silicon economy [45]. The continuous connection of all necessary resources for a reasonable movement of things enables totally new business models [46,43]. The crucial data exchange between objects and companies will be bound to the purpose of use, based on the principle of data sovereignty, and is therefore trustworthy and secure [47].

The Dortmund Management Model is a contribution to structuring the task of digital transformation. The model is constantly being further developed and various methods for operationalization are still the object of research [32]. The task of the companies will be to develop a vision of digitalized logistics and supply chain management for themselves. One success factor will be the qualification of the employees for the transformation.

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Biography

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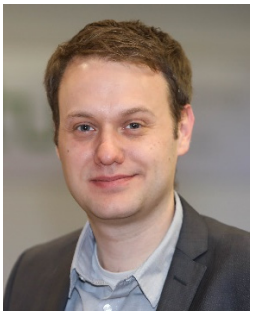

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