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The Role of Artificial Intelligence in Revolutionizing Supply Chain Operations

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ABSTRACT: In 2010, the German Logistics Association (BVL) formed an interdisciplinary working group that presented a proposal to establish logistics as an academic discipline. Due to the positioning of this group and the successful interdisciplinary collaboration, the decision was made to create another working group called "Future Topics of Logistics". The main goal of this group is to address current and future scientific and business challenges in the field of logistics, as well as identify potential strategies for overcoming these challenges. The main question is whether the principles that have led to successful logistics development in the past three decades still apply, or if new and innovative logistics concepts should be considered in light of current and future challenges.

This study is derived from the findings of the working group, which also introduced the theme "Coordinated Autonomous Logistics Systems" at the 6th International Scientific Symposium on Logistics organised by the German Logistics Association (BVL) in Hamburg on June 13-14, 2012. The study serves as a benchmark and initial step to instigate the essential modifications in both the scientific and business realms to address present and future logistics difficulties. The study is structured as follows: Section 2 categorises current and future issues for logistics based on their relative similarity or originality compared to previous general conditions for logistics. Section 3 introduces and conceptualises a new notion called "Cloud Logistics." It adheres to the main progression towards more collaborative, decentralised, self-governing logistics systems. The concept applies the fundamental principles of Artificial Intelligence to the field of logistics in order to facilitate the effective and efficient management of dispersed logistics resources, particularly in unpredictable and intricate settings. A future research agenda is proposed to address the problems in advancing the conception and implementation of Cloud Logistics. The paper is concluded in Section 4.

I. PRESENT AND FORTHCOMING OBSTACLES IN THE FIELD OF LOGISTICS

1.1 Megatrends

The functioning of logistics and goods traffic is contingent upon the overall progress of the economy, specifically the production and trade of goods. These activities are intricately linked to the megatrends of globalisation, demographic development, urbanisation, technological innovation, and sustainability. In addition, governments establish a regulatory framework at both the national and international levels for these advancements. Significant policies have lately been issued in the domains of competition, energy supply, and environmental and climatic matters. To determine the current and future difficulties for logistics, we will examine each mega-trend and its impact on logistics.

Globalization

Globalisation refers to the process of increasing interconnectedness and interdependence among countries, economies, and societies worldwide.

Globalisation refers to the phenomenon of a growing interconnectedness of economies, where the sourcing, manufacturing, and distribution of commodities are spread around the world in order to take advantage of variations in labour and resource expenses, as well as tax and regulatory environments. The concurrent rise in the specialisation of tasks enhances economies of scale and scope, necessitating cost-effective and efficient logistics systems. The "BRIC"3 countries have had highly dynamic growth during the previous two decades due to decreasing transaction costs, especially in transport and communication services, together with stable political conditions, technical advancement, and inexpensive labour. Firstly, a portion of recent growth can be attributed to a "globalisation bubble" caused by unrealistic expectations of high returns from globally distributed production networks.

Relevance for logistics

The relevance of logistics in the context of globalisation lies in the complex and interconnected nature of the supply chain. With the geographically dispersed division of labour, there are numerous entities involved, including individuals

and organisations. This leads to the development of multi-staged and highly integrated logistics systems, which in turn results in an increased number of potential delay points. Consequently, there is a greater need for coordination, communication, and monitoring. According to Manuj and Mentzer (2008), managing these supply chains is becoming increasingly challenging in today's competitive world, as highlighted by Christopher and Lee (2004). The escalating uncertainties in supply and demand, the global expansion of the market, the ever-decreasing lifespan of products, and the growing reliance on manufacturing, distribution, and logistics partners, which in turn leads to intricate international supply network relationships, have resulted in heightened vulnerability to risks in the supply chain.

Demographic Shifts

The global population is forecasted to increase from 6 billion in 2008 to 8.7 billion in 2030. However, this growth is not evenly spread among different regions. Africa is expected to experience the largest growth rate at 55%, followed by Asia at 24% and Latin America at 23%. If forecasts are accurate, India is projected to become the most populated country by 2025, with a 28% increase compared to 2008 (Kritzinger et al., 2010). Conversely, in certain advanced nations, the population remains stagnant or decreases, leading to a demographic transition characterised by a rise in the old population. This change is mostly caused by lower birth rates and longer life spans, as observed in countries like Japan and Germany. However, estimates about population growth heavily rely on assumptions about migration patterns and advancements in the prevention and treatment of HIV/AIDS (United Nations, Department of Economic and Social Affairs, Population Division 2009).

Urbanization

Urbanisation refers to the process of the growth and development of cities, including the increase in population and the expansion of urban areas. Roughly 50% of the global population presently resides in urban areas. According to the United Nations, Department of Economic and Social Affairs, Population Division 2008 and the European Commission: Directorate-General for Energy and Transport 2009, it is projected that by 2050, renewable energy sources would account for two-thirds of worldwide energy production. In Europe, this proportion is predicted to reach 84% (compared to 72% in 2007), while in China it is projected to reach 90%. In developing and emerging nations, urban migration has resulted in the formation of "mega cities" such as Shanghai. Over the past 50 years, the city's population has doubled and currently stands at 15.7 million inhabitants. It is projected to reach 19.4 million by 2025, according to the United Nations' Department of Economic and Social Affairs, Population Division (2008). So far, these cities have seen unregulated growth, resulting in significant geographical expansion. To meet the demands of residents in major cities, it is necessary to use sustainable urban development approaches, such as polycentric growth along predetermined axes.

Technological Innovation and Digitalization

Technological innovation refers to the development and implementation of new or improved technologies, whereas digitization involves the conversion of analogue information into digital form.

The advent of technical innovation, particularly in recent decades, has resulted in substantial enhancements in productivity, hence driving economic expansion and amplifying trade volumes and the corresponding logistics operations. While incremental technological progress, such as Moore's law, has been reliably predicted, major disruptive innovations, like the introduction of the first transistor, have not been anticipated in the same way. Consequently, conversations regarding forthcoming technological changes are largely conjectural. However, according to Nefiodow (2006), a futurologist, the main areas where technical advancements are expected to occur include bio or nanotechnology, medical devices, aiding systems, energy and environmental engineering, networks and information technology, knowledge society, and social networks. In the realm of energy and environmental engineering, the primary obstacles can be clearly defined as heightened resource efficiency and the adoption of renewable energies. Examples include Google's comprehensive capture of the entire world through "Google Earth," the utilisation of computer-aided-design (CAD) or enterprise resource planning (ERP) tools in manufacturing and corporate operations, and the digitalization of books. Consequently, a parallel digital universe is formed over time, as described by Mattern (2003). This leads to an increasingly large and constantly expanding volume of data, as the modelling process grows more intricate. In addition, the total volume of data is also expanding due to an increasing number of physical objects that have the capability to automatically generate data. These objects are equipped with small computers that are connected to the internet, such as RFID tagged goods. The term used to describe this concept is the "Internet of Things" (IOT). In his work published in 2010, Fleisch asserts that the Internet of Things (IOT) primarily focuses on detecting and monitoring the physical environment. It offers a cost-effective framework for accurately measuring the physical world. The rate at which more data is produced has consistently risen thus far and is projected to continue increasing. Although the number of "smart" things generating data is projected to increase at an even quicker rate. Therefore, inquiries related to automated data storage and processing are expected to become more significant.

The relevance of technological innovation and digitization for logistics is significant and has a wide-ranging impact. Product life cycles, particularly for technology-intensive products like mobile phones, flat screen TVs, and laptops, are becoming increasingly shorter. As a result, highly efficient logistics systems have been developed. Although these systems demonstrate satisfactory performance in stable conditions, their performance tends to significantly deteriorate in the event of disturbances, indicating vulnerability (Tang & Tomlin 2008).

Simultaneously, logistics systems are being operated and controlled in a progressively automated manner. The Internet of Things serves as the conceptual foundation for this. The data gathered from intelligent items, such as pallets fitted with RFID tags, serves as the foundation for managing and regulating movements and occurrences in the tangible realm. To achieve an effective decentralised and partially autonomous control of systems, it is necessary for the virtual world to be closely synchronised with events in the physical world. This synchronisation provides reliable input data for control mechanisms.

Decentralised production structures, specifically in intralogistics, offer a conceptual framework to address these difficulties. One solution is through the use of standards outlined in the Electronic Product Code (EPC). Data is typically generated in these systems at each production step and at the interfaces between production phases. Material flows are tracked using Auto ID techniques. Given the substantial volume of data in these systems, it is customary to consolidate the data into useful indications and display them on information dashboards.

Sustainability

The concept of "sustainability" was introduced by the Brundtland Commission in 1987 and is defined as "development that satisfies the current needs without jeopardising the ability of future generations to satisfy their own needs." (United Nations, World Commission on Environment and Development 1987) Sustainable development encompasses the three aspects of economic, environmental, and societal development. The issue of environmental sustainability has garnered considerable attention in light of the initial signs of climate change caused by human activity, specifically the excessive release of greenhouse gases. To mitigate the impacts of climate change, policymakers have implemented legislation to incorporate the external costs associated with the pollution of clean air, which is a public benefit.

Significance in logistics: The logistics sector, particularly transport operations, plays a substantial role in the release of greenhouse gases. The EU Commission has identified several issues in transport policy, including the imposition of restricted CO₂ budgets for the transport sector (European Commission 2011). To attain the desired 60% decrease in emissions by 2050 (compared to 1990 levels), various measures are suggested. These include providing financial support to encourage advancements in transport technologies, implementing strategies for carbon-free mobility (such as "zero-carbon urban logistics 2030"), and enacting policies to account for external impacts, such as emission trading schemes. The European Union Emission Trading Scheme (EU ETS) was initiated in 2005 and began including the airline industry in 2012, as stated in DIRECTIVE 2008/101/EC. While it is uncertain whether all initiatives will be implemented due to the need for support from all 27 member states of the EU, the EU Commission's strong emphasis on climate change highlights the growing recognition among EU industrial nations that environmental sustainability will provide a competitive edge for EU countries in the global market in the long term.

1.2 Exploring Structural Breaks and Economic Crises Beyond Mega Trends

Disruptions in the structure

Megatrends cause gradual changes in both the environment of logistics systems and the logistics systems themselves. Therefore, systems have the ability to adjust and modify themselves gradually in response to shifting circumstances. On the other hand, structural fractures lead to sudden and disruptive problems, typically causing a rapid and significant decrease in logistics performance. However, there are certain problem clusters that can be recognised, such as political upheavals witnessed in Tunisia, Egypt, or Libya, as well as terrorist activities, local military conflicts, and economic recession, which have the potential to abruptly and unexpectedly disrupt global supply chains. Anthropogenic produced environmental catastrophes, such as oil spills, nuclear or chemical accidents, can cause similar repercussions.

Financial downturns

Economic crises are not solely attributable to external disruptions, such as natural catastrophes or armed wars, as assumed in traditional economic theory. Recently, there has been a consensus in the field of economics that oscillations in the business cycle are mostly caused by human behaviour and decision-making (Keynes 1994; Schumpeter & Röpke 2006). The most serious crises to date have emerged from the financial sector, including the Mississippi Bubble in 1720, the Great Depression in 1929, and the global financial and economic crisis in 2008. Although the fundamental components that influence development have been extensively studied, accurately predicting the exact timing of crises

remains an insurmountable challenge. This phenomenon occurs because fundamental economic indicators and collective behaviour exhibit distinct patterns before each crisis, rendering current indicators of crises irrelevant. Roubini & Mihm (2010) argue that the duration of a period of prosperity directly correlates with the severity of subsequent crises. In shorter economic cycles, recurrent downturns offer greater potential for innovation and the transformation of outdated structures, as described by Schumpeter & Röpke (2006) as "creative destruction". In light of this context and the recent worldwide financial and economic crisis, it is necessary to assess various scenarios outlined in long-term economic forecasts. There are three distinct scenarios that are identified (Rothengatter et al. 2010; OECD/ITF 2009):

- The term "bounce back" refers to the phenomenon when the global economy reverts to its original trajectory of growth within a span of five years. This scenario is highly desirable for the economy, but it also has significant risks. There is a strong likelihood that behaviours will remain constant, which might potentially lead to the occurrence of another catastrophe.
 - "Retrenchment," which refers to a prolonged state of pessimism, hampers economic growth and the progression of globalisation, as well as the movement of products. This possibility is only plausible if there is a significant and dramatic shift in international relations.
 - The concept of "Schumpeterian creative destruction" refers to the phenomenon where a crisis leads to the emergence of new market structures, particularly in the financial sector, as well as innovation in the production of sustainable products and processes. Therefore, in this situation, companies must enhance their adaptability and reduce the time it takes to complete tasks in order to promptly react to shifting circumstances.
- Therefore, it is probable that novel forms of collaborative logistics will arise, either through contractual agreements or auctions, with the aim of distributing risks, enhancing adaptability, and upholding service standards.

II. IS THE CLOUD PARADIGM THE FUTURE OF LOGISTICS?

2.1 The Influence of Restricted Foreseeability on Logistics Systems & Strategies

Megatrends, structural discontinuities, and economic crises amplify volatility, uncertainty, and complexity, hence constraining the ability to forecast logistics with precision. However, the primary guiding principle for logistics systems in the past twenty years has been efficiency in terms of costs. This has been made possible, in large part, by rapid advancements in information technology (Christopher & Peck 2004). Tang & Tomlin (2008) assert that executives made efforts to enhance their financial performance by implementing activities aimed at increasing revenue (such as expanding product diversity and frequently introducing new products) and reducing costs (such as using cost-cutting measures). The implementation of strategies such as reducing the supply base, adopting just-in-time (JIT) systems, and implementing vendor-managed inventory (VMI) has resulted in a decrease in assets, such as outsourcing manufacturing. However, these strategies have also led to the development of longer and more intricate global supply chains, which are more susceptible to disruptions in business operations. Additionally, Tang (2006) argues that while cost efficiency is achieved through these strategies, there are also significant hidden costs that arise in the event of a disturbance (Lee 2004). The increasing occurrence of business disruptions caused by economic crises, political instability, volcanic eruptions, earthquakes, and tsunamis has prompted scholars and professionals to devise techniques for sustaining supply chain performance under unpredictable conditions. The predominant method suggested is Risk Management.

According to Miller (1992) and Juttner et al. (2003), risk is defined as the lack of predictability or fluctuation in company results, such as supply chain performance. The presence of uncertain external variables that impact company outcomes leads to an escalation in risk. The purpose of risk management is to mitigate risk by decreasing either its likelihood or severity, or both. According to Miller (1992), there are five organisational responses to uncertainty, and four of them are applicable to logistics: avoidance, control, cooperation, and flexibility. One way to enhance supply chain flexibility is by expanding the number of providers for a certain input factor or implementing decentralised warehouses that allow for rapid adaptation to local demand fluctuations. Tang (2006) provides a concise overview of the risk management process, which consists of three main steps: identification, assessment (including both probability and impact), and the formulation of measures to mitigate the identified risks. Zsidisin et al. (2004) offer a comprehensive examination of various methodologies for evaluating supply risk, as demonstrated by their extensive analysis.

Beforehand. In addition, Tang (2006) asserts that due to the lack of accurate estimates regarding the likelihood of a significant disruption, many companies struggle to conduct cost/benefit or return on investment analysis to support certain risk reduction programmes or contingency plans. Consequently, alternative approaches to risk management have been suggested.

"Robust" supply chain solutions allow organisations to effectively handle frequent changes in normal situations and assist them in maintaining their operations in the event of a significant disruption (Tang 2006). Robustness in supply chains can be attained by using certain design strategies such as strategic stock, additional de-coupling points, or delay. In addition, strong tactics can also help in developing resilient supply chains.

Surana et al. (2005) and Choi et al. (2001) propose a different viewpoint, suggesting that supply chain networks can be classified as complex adaptive systems (CAS) due to their high level of communication and interdependence among entities, processes, and resources.

Delfmann et al. (2010) assert that logistics is an interdisciplinary academic discipline that utilises and modifies methods from other research fields, such as mathematics or engineering. These methods can serve as a conceptual framework to address present and future challenges in logistics. Artificial Intelligence is a potential technology that has emerged in the world of computer sciences.

2.2 Change in fundamental beliefs or principles:

Applying the concept of Artificial Intelligence to the field of logistics.

Artificial Intelligence refers to a new and developing approach for providing and using computing resources as a service, which is based on Service Level Agreements (SLA). So far, numerous definitions have been presented. One of the most prevalent definitions is provided by Vaquero et al. (2008), who describe clouds as a substantial collection of readily available and quickly accessible virtualized resources, including hardware, development platforms, and services. These resources have the ability to be reconfigured in real-time to accommodate varying levels of demand, enabling efficient utilisation of resources. The pool of resources is commonly utilised through a pay-per-use approach, where the Infrastructure Provider offers assurances through customised Service Level Agreements (SLAs). The Department of Commerce National Institute of Standards and Technology (NIST) defines Artificial Intelligence as a model that allows for easy and widespread access to a shared pool of customisable computing resources, such as networks, servers, storage, applications, and services. These resources can be quickly provided and released with minimal management effort or interaction with service providers. The cloud model consists of five fundamental characteristics, three service models, and four deployment models. A condensed explanation of these components, based on the NIST definition, is presented in the following three paragraphs.

The rapid flexibility of Artificial Intelligence is a result of providers' ability to swiftly add or release resources to effectively meet variations in client demand. This occurs imperceptibly to the consumer, so creating the illusion of limitless and readily accessible computing capabilities, regardless of quantity or duration. Kuperberg et al. (2011) provide a thorough analysis of this attribute and specifically differentiate between scalability and elasticity. Scalability refers to a system's ability to sustain its performance goals or service level agreements (SLAs) even as its workload rises, up to a specific limit. An elastic system is capable of dynamically adding or removing resources as the demand for services increases or declines, accordingly. Therefore, elasticity introduces a dynamic element to scalability.

Measured Service: To efficiently manage and optimise resource usage, a metering capability is implemented for each service. Service utilisation is closely monitored, regulated, and documented. Consequently, both providers and consumers have clear visibility into the actual utilisation of resources, enabling a pay-per-use payment model.

Artificial Intelligence services are classified into three service models based on the sort of capacity offered to the consumer. Infrastructure as a Service (IaaS) involves providing essential computing resources, such as storage or processing power, that may be used by the user to deploy and operate various software, such as operating systems. Platform as a Service (PaaS) offers consumers an environment for hosting applications, allowing them to deploy applications developed using a certain programming language, such as Java or Python. Software as a Service (SaaS) enables users to utilise the applications provided by a service provider on a cloud infrastructure. These applications are typically accessed through web browsers or other lightweight client interfaces on various devices, including mobile devices.

Artificial Intelligence has identified four deployment models, each with a specific feature determining who has the right to consume the underlying cloud infrastructure resources. Private clouds offer dedicated cloud infrastructure exclusively for a single organisation, while public clouds give infrastructure publicly to the general public. A community cloud refers to the provision of cloud infrastructure to a specific group of organisations that share common issues. A hybrid cloud architecture consists of a minimum of two separate cloud infrastructures that are linked together by an interface. This interface enables the transfer of data and applications between the two infrastructures. This requirement is commonly known as cloud interoperability.

Put simply, the Artificial Intelligence model addresses the essential logistical challenge of delivering the appropriate goods or services, in the correct quantity and quality, to the designated consumer, at the specified location and time, and at the appropriate price, such as computing resources. However, the model and its associated features, service, and deployment models described above can also be analysed in a more abstract manner in order to uncover the underlying concepts. Artificial Intelligence employs three service models, which are constructed by implementing the principles of resource abstraction, virtualization, and subsequent encapsulation in services. From a theoretical perspective, these notions have the potential to be applied to any kind of resource. The set of underlying notions of Artificial Intelligence shall be referred to as the "cloud paradigm" in the following.

- For instance, Xu (2012) applies the cloud paradigm to the industrial field. Cloud Manufacturing is a new concept that incorporates recent trends in shifting from production-oriented to service-oriented manufacturing. It also draws on existing manufacturing approaches that involve distributed resources, such as networked manufacturing, manufacturing grid (MGrid), virtual manufacturing, and agile manufacturing.
- Günthner et al. (2010) assert that while the mechanical components of production systems have been extensively modularized, the control of these modules remains centralised. The growing complexity of systems, driven by factors such as the tendency towards individualization, leads to a rise in operational risk (ten Hompel, 2010). There is a requirement for intra-logistics. Efficient material flow systems should include of smart infrastructure, compact transport modules, and operate in a manner analogous to computer networks: decentralised, cooperative, adaptive, and devoid of hierarchy. The Internet of Things offers a conceptual framework for these systems. Scholz-Reiter et al. (2007) contend that complete self-control is unnecessary for every logistics system. The ideal level of self-control is primarily determined by the logistical performance targets, as well as the complexity and extent of self-control required. Logistics performance in complex systems is enhanced when self-control is increased up to a maximum level, after which it begins to decline with additional increases in self-control.

2.3. Implementing the Cloud Paradigm in Logistics:

An analysis and evaluation of the ability of a paradigm to adapt and adjust.

Like Cloud Manufacturing, the concept of applying the cloud paradigm to logistics involves incorporating and enhancing existing logistics strategies to address current limitations and enhance logistics performance in unpredictable and complex environments. The integration of the cloud paradigm into the logistics domain will be referred to as "Cloud Logistics".

The concept of Cloud Logistics is still in its early stages of development. There is currently no widely agreed-upon meaning for this term, although there are some well-thought-out suggestions in the literature. The working group "Future Topics of Logistics" of the Scientific Advisory Board of the BVL defines Cloud Logistics as "an environment of "virtual" systems that facilitate supply chains' overall coordination and use of distributed resources, capacities, processes, and services from supply chain partners. These systems are based on advanced information and communication technologies that leverage modern Internet services." (German Logistics Association (BVL) 2012) Under the term "Supply Chain as a Service", Leukel et al. (2011) provide a more detailed conceptualization of Cloud Logistics, covering, amongst others, a model to describe a supply chain exclusively through services, cloud scalability and potential constraints resulting from the physical heterogeneity of logistics resources, and the role of SLAs. The conceptualization of Cloud Logistics proposed in this paper picks up on these contributions. It details them further and, more importantly, discusses whether the characteristics of Artificial Intelligence can be preserved in the logistics domain – explicitly taking into account the specific properties of logistics, say, the flow of physical goods in physical networks. The following discussion is structured along the elements (i.e. essential characteristics, service and deployment models) of the NIST definition of Artificial Intelligence.

Artificial Intelligence offers broad network access as well as on-demand self-service to computing capabilities. However, these characteristics can be partially preserved only for Cloud Logistics. Logistics capabilities (services) cannot be accessed or provided over the internet but are always associated with a physical flow of goods in physical networks. Nevertheless, the business initiation, definition of scope of services and contract closure can be performed online, for example, via an electronic data interchange (EDI) or via a specialized Cloud Logistics platform. With regard to on-demand provision of logistics capabilities, Cloud Logistics preserves the characteristic of Artificial Intelligence with the minor difference that the time gap between service request and provision may be larger in Cloud Logistics. Moreover, on-demand provision of logistics capabilities is common business practice if procured from an external provider, for example, a pick-up by an express courier can be scheduled on needs basis. However, logistics capabilities

cannot be provided as a self-service. Human interaction between the shipper and the respective logistics service provider or sub-contractor will always occur.

- In the first pooling scenario, a logistics service provider manages a pool of resources to meet service requests from multiple customers. By pooling resources, the logistics service provider can achieve efficiency gains through economies of scale and scope. This is similar to the pooling scenario in Artificial Intelligence, where one provider pools resources and dynamically assigns them to serve multiple customers.
- In the second pooling scenario at least two logistics service providers pool their resources in order to serve their combined customer base or customers of a third party. Providers will decide on those resources or services that will also be accessible to other providers. As a consequence, resource pooling requires horizontal cooperation between logistics service providers. Yet, this type of cooperation does not imply an ongoing commitment between suppliers as in, for example, strategic alliances. It is rather a transient short-term cooperation which ends automatically after an agreed service has been fulfilled. To add, cooperation in Cloud Logistics differs from sub-contracting in such a way that terms and conditions are pre-defined, use utility prices and are not subject to (constant re-)negotiation between providers. Anticipated efficiency gains will then arise from the improved utilization of currently underutilized resources of the cooperating logistics service providers. This scenario can be considered as an extension to the first as it implies that each cooperating logistics service provider already operates an own resource pool and it emphasizes the principle of “self-similarity” of logistics (Delfmann et al. 2010). As multiple companies have already outsourced logistics to specialized service providers this precondition seems to be generally fulfilled. Thus, Cloud Logistics offers a potentially interesting method to improve efficiency through cooperation.
- A third way to pool resources arises if arbitrary companies in an arbitrary industry cooperate horizontally and share resources which are directly connected to logistics resources, for example inventory in warehouses. Cooperating companies may have either outsourced the management of the associated warehouse or manage it themselves. Zhao et al. (2005) “analyze a decentralized dealer network in which each independent dealer is given the flexibility to share his inventory [...] each dealer faces his own customer demand with high priority, and inventory-sharing requests from other dealers with low priority.” Dealers’ sharing behavior and system performance is analyzed pertaining to incentives, subsidies and transshipment fees. Thus far, the authors of the paper in hand are aware of one example in apparel industry in which this type of resource pooling has been implemented successfully. Consider this simplified workflow of order generation, handling and invoicing: A shoe manufacturer operates an online shop, incoming orders are offered to the dealer located closest to the customer, the dealer accepts and delivers the shoes; the manufacturer pays the dealer and invoices the customer.

In Artificial Intelligence three distinct service models have been proposed. Thus far, no comprehensive service model for Cloud Logistics has been proposed. Service models generally depend on the resources types and their capabilities. Consequently, the Cloud Logistics service model covers basic transportation, warehousing services, but also associated value added services such as packaging or customs clearance. These services usually require some sort of physical handling of goods. Yet, also services without direct physical manipulation are conceivable; hence some of them may be accessible over the internet. Information or financial services such as shipment tracking or billing belong to this class.

2.4 Heading towards Cloud Logistics: Anticipating the Upcoming Challenges

The fundamental principles for conceptualising Cloud Logistics have been established. However, there are still several unresolved difficulties that need to be addressed in order to successfully construct a genuine Cloud Logistics system. The following paragraphs provide a brief overview of prospective areas for future research.

It is necessary to create a comprehensive service model that relies on logistics resources. Service compatibility, particularly in terms of data interfaces, will be crucial to ensure the ability to mix services from many logistics providers into solutions. Existing concepts, for example, from Cloud Manufacturing are likely to be applicable to logistics too. In light of this service model, it needs to be understood if and how logistics providers need to adapt their current service portfolios to offer Cloud Logistics services.

Analysing these theories in the context of existing 3PL/4PL structures can serve as a foundation for comprehending the effectiveness of Cloud Logistics in an actual business setting. Leukel & Kirn (2011) propose to utilize the theories of New Institutional Economics, say transaction costs theory, agency theory, and property right theory to evaluate “Cloud Value Systems”. Applying these theories to existing 3PL/4PL structures could be a starting point to understand the performance of Cloud Logistics in a real business environment.

III.CONCLUSION

A potential solution to the challenges faced by logistics in a complex, uncertain, volatile, and unpredictable environment can be found in adaptive, coordinated, distributed, and autonomous logistics systems. These systems rely on decentralised self-control mechanisms, known as Cloud Logistics. However, there is still a long way to go before successfully implementing such a system. The wide range of challenges ahead highlights the diverse nature of this research field, both for academic and research. An adequate answer to the challenges for logistics arising from an increasingly complex, uncertain, volatile and less predictable environment seems to be found in principle by means of adaptive, coordinated, distributed, autonomous logistics systems based on de- centralized self-control mechanisms in sense of Cloud Logistics. Nevertheless, it remains a long way to go until a first successful system implementation will be achieved. The va- riety of the generically outlined challenges ahead emphasizes the manifoldness of this research field for academic research but also for successful business implementation. The methods available in related research fields show that there is no need to start from scratch when approaching this task but rather that there exists a fruitful basis from which future research can set off. This certainly ushers in another important chapter in history of logistics.

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