Developing Smart Logistics for Sustainable Transport

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Registered offices
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Address:
Tayuan Diplomatic Office Building 2-5
14 Liangmahe Nanlu, Chaoyang District
100600, Beijing, PR China
T +86-(0)10-8527 5589
F +86-(0)10-8527 5591

E transition-china@giz.de
I https://transition-china.org/mobility

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Author/Editor:
Wenwen Jiao (RIOH), Dachuan Ding (RIOH), Hongyu Chen (RIOH), Beijing
Dr. Matthias Parlings (IML), Philipp Gauß (IML), Sanja Gast (IML),
Nils Saorski (IML), Shutong Jiang (IML), Dortmund
Sebastian Ibold (GIZ), Dr. Xuan Ling (GIZ), Xin Hu (GIZ), Beijing

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Preface

Logistics is an important backbone of economic activities, trade, and globalisation. In its core, logistics includes various activities, covering transportation, warehousing, packaging, loading and unloading, and handling of goods. Due to ever-increasing globalisation, the rise of online purchases, and the demand for shorter delivery times (especially in the end-consumer business), the logistics industry and departments are facing growing negative environmental and climate impacts. Moreover, the majority of carbon dioxide emissions in the logistics sector are caused by transport, storage, and packaging.

With continuous developments and breakthroughs in digital and other new technologies, the logistics industry is increasingly becoming “smart.” Smart logistics enables the further optimisation of logistics flows and overall freight efficiency. By employing the latest communication technologies and digital solutions, real-time data about the location of transport vehicles and transport containers or the place where goods are stored and distributed can be collected. Implemented trackers or (RFID-)tags can furthermore be used for identification, registration or booking of objects. Combined with real-time analytics to, for example, avoid congestion or create resource-efficient and optimised repackaging, smart logistics has the potential to reduce energy consumption and carbon emissions or minimise waste.

Both German and Chinese companies as well as research institutions have addressed the topic of “smart logistics.” However, in addressing the climate crisis, more joint efforts are needed to fully explore the potentials of smart logistics for systematic sustainable development.

For this study, commissioned by the Deutsche Gesellschaft für internationale Zusammenarbeit (GIZ) GmbH, the Research Institute of Highway (RIOH) of the Ministry of Transport of the People’s Republic of China (MOT) and the German Fraunhofer Institute for Material Flow and Logistics (IML) have carried out joint research on the theory, policy, and application of smart logistics to provide an overview of the status quo of smart logistics in China and Germany.

Under the research framework focusing on the study of smart logistics and its influence on sustainable and low carbon development, differences as well as similarities in the understanding and application of smart logistics in China and Germany are presented. Based upon this research, a common understanding of smart logistics is proposed, and an analysis of key driving factors and future development trends of smart logistics applications in China and Germany is provided. Finally, recommendations for the further and effective development and implementation of smart logistics are put forward based on the findings of this study.

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1 History of logistics development

1.1 Logistics development

In the development of logistics, both China and Germany have been influenced by other countries, particularly the United States (US). The understanding, practical knowledge, and customised demand for logistics have been progressing with decades of business practice both in China and Germany. China's logistics development reached several milestones in line with its economic development and gradually led to the formation of an official concept of logistics via national standard. The development of logistics in Germany has been closely aligned with the automobile industry, gradually changing the understanding of logistics from a purely functional understanding to a management-oriented concept that combines various intra- and cross-organisational elements. Key milestones of both China's and Germany's logistics developments are outlined in Figure 1.

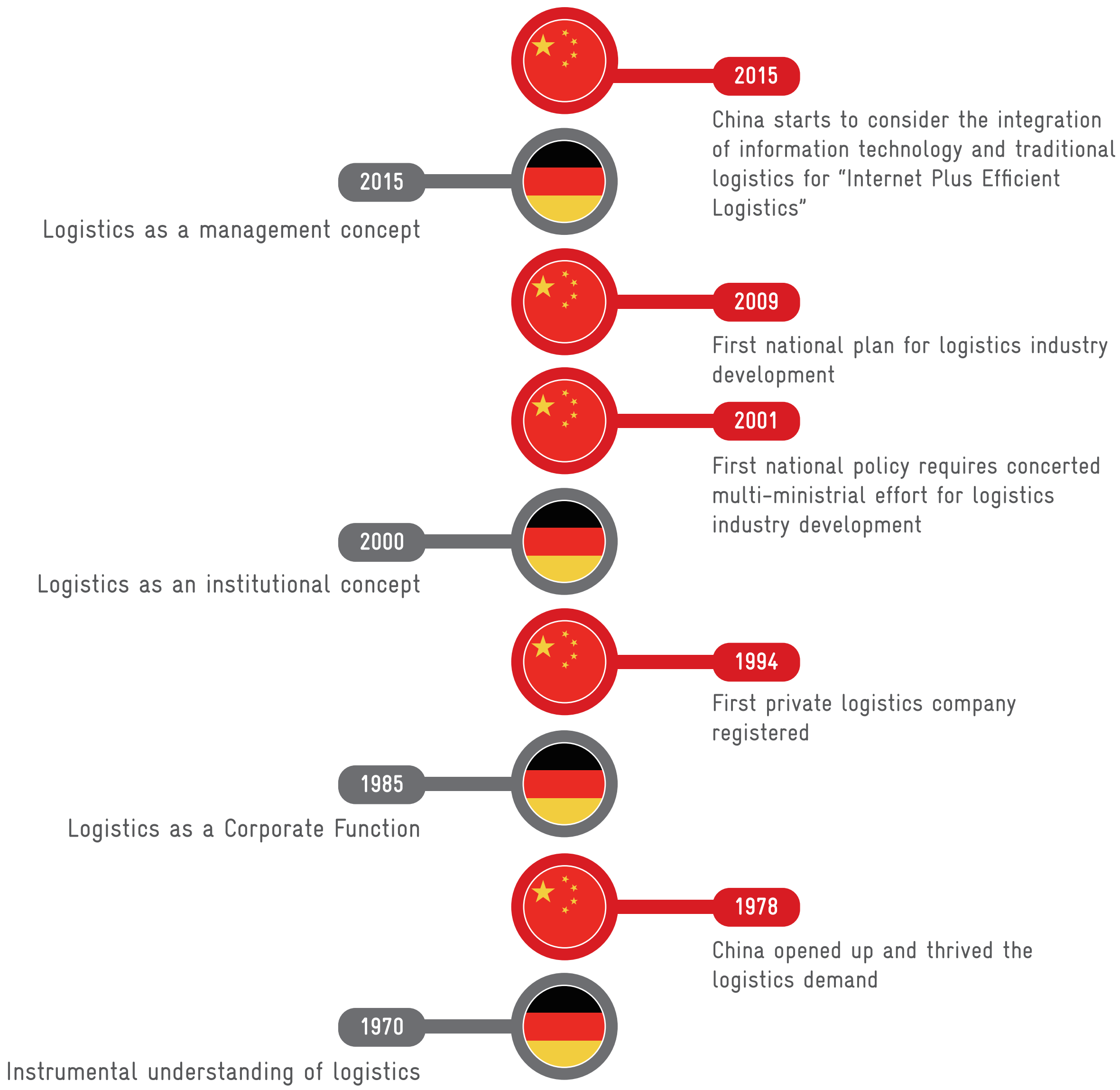


Figure 1: Important milestones of logistics development in China and Germany (author's own summary)

Adaptation and development of Logistics in China

The practice of logistics in China – in Chinese language "wu liu" (literally "movement of goods") – dates back thousands of years, even at an international scale with the ancient Silk Road. Regarding the introduction of a modern understanding of logistics, there are two different views. Some believe that China has adopted the concept from the US, another view is that China introduced the concept from Japan, which first adapted the concept of logistics as understood in the US in 1970s (Wang 2001).

The 1970s were pivotal for the development of today's understanding of logistics. The Chinese government opened-up the domestic market for international logistics enterprises along with its policy of Reform and Opening Up. By then, Chinese logistics companies started to consider the connections between global and the domestic markets.

China has been advancing with global developments and opened-up domestic market for international logistics enterprises by actively supporting the domestic logistics industry for both state-owned and private-owned companies. In addition to serving the domestic market (Huang, 2010), Chinese researchers have used different approaches to describe key developmental stages for the understanding of logistics. A prevailing consensus, however, is to consider milestones that have been instrumental in the development of logistics understanding and the logistics industry (see Figure 2; Liu, 2014).

The year 1978 saw the beginning of Reform and Opening Up, a comprehensive set of policies which led to the development of a more market-oriented economy and boosted the distribution of material resources within and beyond China.

In 1994, P. G. Logistics Group Co., Ltd was founded in Guangzhou as China's first domestic private enterprise registered under the term of "logistics" indicating the increasing role of private enterprises as players in China's logistics industry (He 2014). The enterprise is still active in China's logistics industry to the date.

In 2001, the former State Economic and Trade Commission initiated Several Opinions on Accelerating the Development of China's Modern Logistics, which was the first national policy on the logistics industry with multiple ministries involved (The former State

Logistics development in Germany

In the German industry sector, the logistics domain gained its foothold in the 1950s (Heiserich et al. 2011) and has been influenced by logistics approaches from the US (Bartels 1980; Baumgarten 2008; Heiserich et al. 2011).However, up to now, there is still no uniform and standardised definition of the term logistics in Germany, although it has been a part of business research and practice for decades. This can be explained by the fact that logistics has constantly evolved over the past decades. The evolution towards a common understanding of logistics can be described by the following development stages (see also Figure 1).

Between the early 1970s to mid-1980s, logistics was viewed as an instrumental concept that focused only on the provision of separate functions such as the planning, control, and coordination of a company's core logistics processes and the associated use of material flow, information, and communication technologies (Baumgarten 2008; Schulte 2017).

From the mid-1980s to mid-1990s, logistics was increasingly understood as a corporate cross-sectional function, at the centre of which were the operational, administrative, and dispositive coordination activities for a company's supply chain.

The understanding of logistics underwent further development between the mid-1990s and mid-2000s, when logistics was viewed institutionally and dealt with the integration of corporate functions into process chains that permeate the entire organisation.

From the mid-2000s to the present, logistics is understood as a management concept, whose task is to integrate the supply chains of several companies into competitive value chain networks (Baumgarten 2008; Schulte 2017).

Since there is no unified definition of logistics in Germany, this study is based on the following definition, which is in close agreement with the logistics concept described last above:

"Logistics is the holistic planning, management, coordination, implementation, and control of all internal and cross-company flows of information and goods. Supply chain management (SCM), the intelligent planning and control of value chains, is used synonymously." (Bundesvereinigung Logistik e.V. 2019).

Economic and Trade Commission, P.R. China 2001). This showed that the central government began to notice that the development of logistics required the concerted efforts of multiple departments.

In 2009, the State Council issued the Plan for Adjustment and Revitalisation of the Logistics Industry, which is China's first plan specifically dedicated for the logistics industry (The State Council, P.R. China 2009). With this plan, the Chinese government and enterprises had a deeper understanding of the importance of logistics development.

China's 2015 Government Work Report[1] first proposed "Internet Plus," a policy strategy aiming to integrate the internet with traditional industries. Under this overall strategy, the Chinese government proposed 11 action plans to promote the integration of the internet and various industries. One of these action plans, titled "Internet Plus Efficient Logistics," is explicitly focused on the logistics industry (China's Government Work Report 2015).

China has established an official definition of logistics by national standard after years of practice. In China, national standards are authoritative, approved by specialised agencies, and compiled by competent bodies. The current national standard definition regarding logistics is as follows:

"The physical flow of goods from the place of supply to the place of receiving, which integrates the basic functions of transportation, storage, loading and unloading, handling, packaging, distribution, and information processing according to actual needs."

(National Logistics Standardisation Technical Committee, P.R. China 2021).

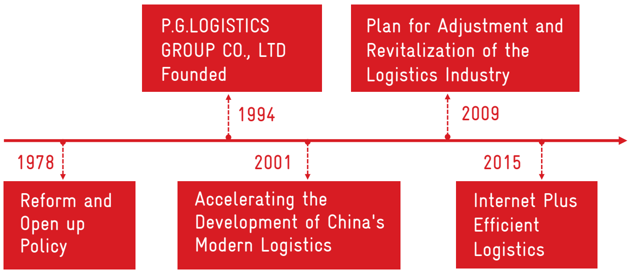


Figure 2: Development Milestones of China's Logistics Industry

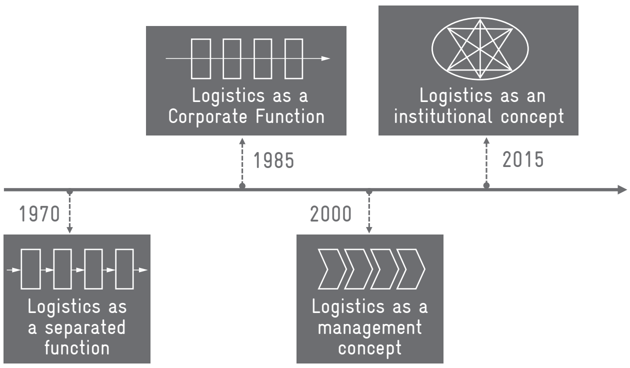


Figure 3: Understandings of Logistics over time in Germany, Author's own summary

1 China's Government Work Report is an official document that is required to be publicly reported at the People's Congress. The Report contents mainly include a review of last year's work and present year's working tasks.

1.2 Introduction of smart logistics development

In both China and Germany, smart logistics is becoming increasingly prominent, both in research and practice. In the two countries, the number of publications on this topic has risen sharply in recent years, especially since 2015 (Figure 4). An important reason for the rising interest in smart logistics is its potential as a tool for decarbonising logistics and making supply chains more sustainable and climate friendly. Both in China and Germany, researchers have found that the application of smart logistics can lead to significant reductions in carbon emissions (Pan et al. 2020; Bamberg et al. 2012). The main reason for this is the underlying information technology enabling the optimisation of resource allocation and route planning for logistics vehicles, thereby reducing energy consumption. Already in 2009, around which time some observers identify the IoT technology to have just been "born" (Evans 2011), joint research by Telekom, Huawei, SAP, Siemens, and BCG estimated that smart logistics could lead to an annual reduction in emissions of over 85 Mt of CO2e in Germany (SMART 2020; Addendum 2009).

This is not only highly relevant for policy makers seeking to advance the decarbonisation of the logistics and more broadly transport sector, but also has increasingly resonated within the private sector. Whether under the transition into digital and sustainable solutions enshrined in Industry 4.0[2] and a correlating "drive towards Logistics 4.0"[3] as has been the case in Germany, or as innovative approaches guided by China's overarching dual goals of carbon peaking by 2030 and carbon neutrality by 2060, businesses are facing a demand for sustainable practices from national policy perspectives as well as consumers (Strandhagen et al. 2017). To maintain competitiveness in increasingly environmentally conscious markets, the application of smart logistics is becoming an increasingly important element of sustainable business models and green supply chains (Koncar et al. 2020; Pang 2021).

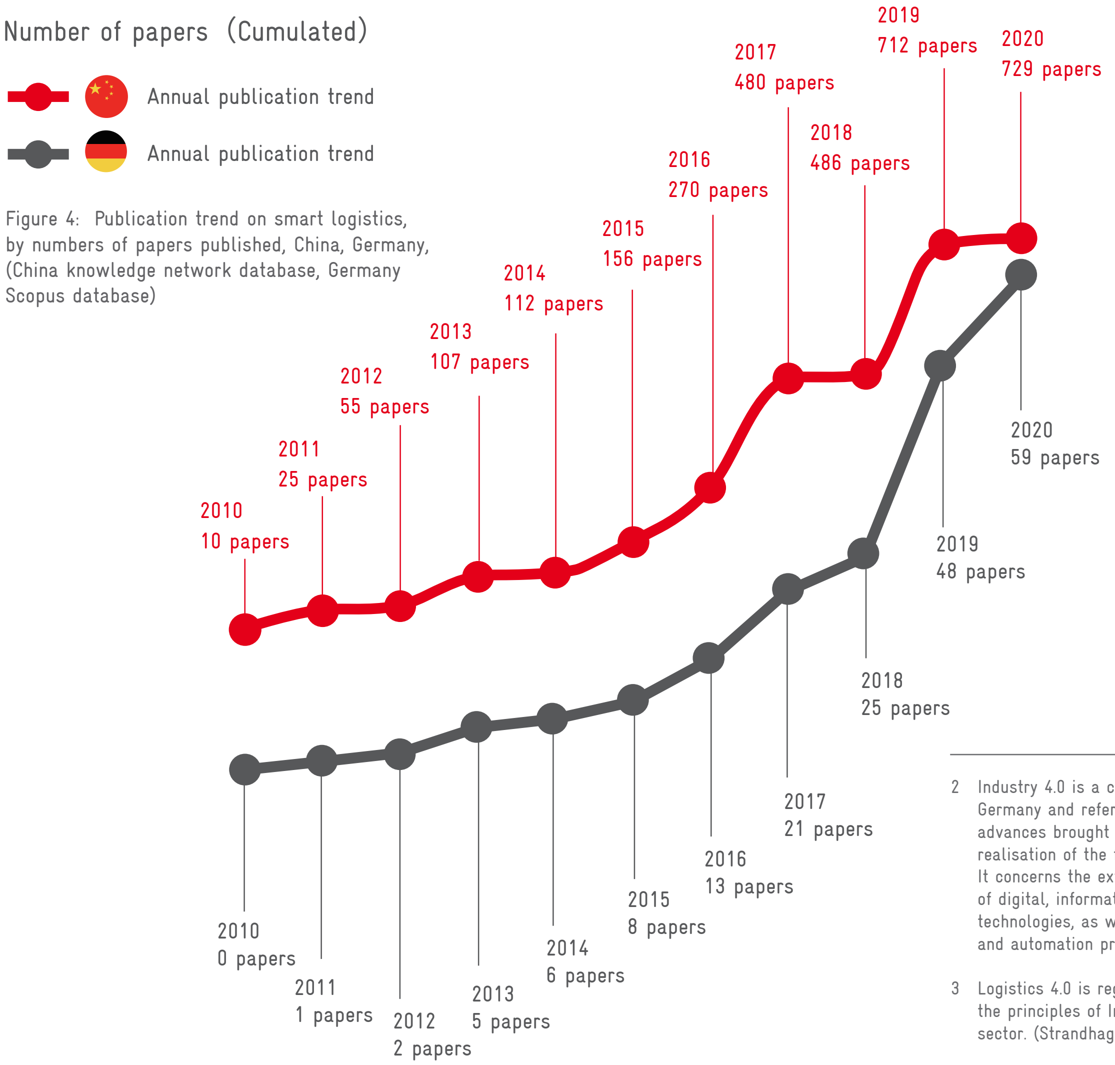


Figure 4: Publication trend on smart logistics, by numbers of papers published, China, Germany, (China knowledge network database, Germany Scopus database)

2 Industry 4.0 is a concept that originated in Germany and refers to the technological advances brought on by and necessary for the realisation of the fourth industrial revolution. It concerns the extensive and innovative use of digital, information, and communication technologies, as well as advanced production and automation processes.

3 Logistics 4.0 is regarded as an integration of the principles of Industry 4.0 into the logistics sector. (Strandhagen et al., 2017)

Introduction of smart logistics development in China

The development of China's logistics industry has undergone rapid growth particularly since the early 2000s, especially in recent ten years (Zhang 2019). Data shows that in the past decade, the total value of China's social logistics goods[4] has more than doubled, from 125.4 trillion RMB (around 16.8 trillion EUR) in 2010 to 300.1 trillion RMB (around 40.3 trillion EUR) in 2020.

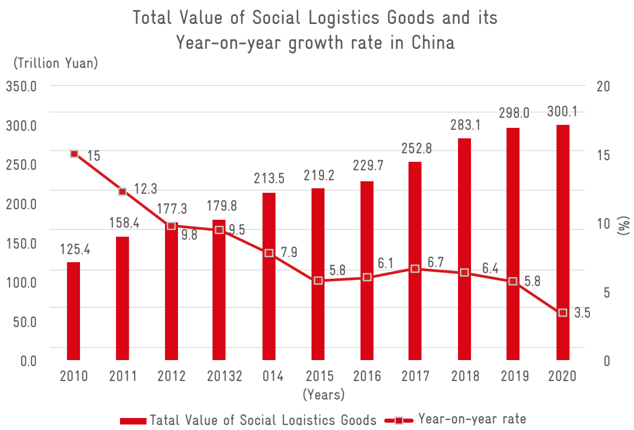


Figure 5: Total value of social logistics goods and its growth rate in China, 2010-2020, trillion RMB, (China Transportation Statistical Yearbook 2021)

Although the total value of social logistics goods in China kept increasing throughout that decade, Figure 5 reveals a decline in the growth rate, especially in 2020, when the annual growth rate dropped to 3.5%, which is 11.5% lower than the 15.0% in 2010. This can be explained by the economic downturn in China following the outbreak of the Covid-19 pandemic, which has in turn weakened the growth rate of logistics demand (Commercial Vehicles 2020).

The macroeconomic environment has led to two changes in China's logistics industry. On one hand, China's logistics industry has more actively shifted from being a single goods mover to being a comprehensive logistics service supplier, as well as an integrator of logistics information along the supply chain. This is due to the demand market requiring more professional services, such as door-to-door logistics service (Wei 2019). On the other hand, it is driven by increasing cost pressure. China's logistics industry has paid more attention to the application of digital technologies and automation technologies to cope with increasing labour and material costs (Liu et al. 2015).

4 The total value of social logistics goods is defined as the value of goods including the transportation from their supply of origin to recipients when first time entering the domestic market. It includes six aspects of social logistics goods when entering domestic market: the total value of agricultural products, industrial goods, imported goods, goods from outer provinces and cities, recycled resources, and goods for companies and residents.

Introduction of smart logistics development in Germany

After industrialisation, mass production, and automation, the German industry is currently undergoing another fundamental transformation. New, digital technologies are enabling new business models and more versatile, dynamic value chains. Due to its far-reaching implications, this disruptive change is regarded as the fourth industrial revolution, even though the process towards it will be evolutionary. In order to describe this industrial revolution, the term "Industry 4.0" has become established in Germany (Bauernhansl et al. 2014a; Kagermann et al. 2013; Reinhart 2017).

At its core, Industry 4.0 represents the intelligent networking of autonomous, situationally self-controlling resources such as production machines, robots, as well as conveyor and storage systems. The technical prerequisites for this new form of intelligent connectivity are Cyber Physical Systems (CPS)[6] and the IoT[7] (Kagermann et al. 2013). Their application enables the realisation of interconnected and inter-company value creation networks that are characterised by a high degree of flexibility, adaptability, effectiveness, and efficiency. The linking of the physical and virtual world through Industry 4.0 thus leads to a higher development level of corporate organisation as well as the management of cross-company value creation processes (Schlaepfer et al. 2015).

For gaining insights into the development of Industry 4.0 in a specific domain, such as logistics, the term "Logistics 4.0" has become popular. In order to obtain information about a growing interest in the field of Logistics 4.0, a qualitative literature research using the Scopus database was conducted. The search included the following search terms, which are often used interchangeably: "logistics 4.0," "logistic 4.0," "Logistik 4.0," "smart logistics," and "intelligent logistics." The search terms were required to appear in the title, keywords, or abstracts of the publications. In addition, the search was limited to European countries (according to the understanding of "European countries" as defined by the EU

6 CPS are embedded systems that have sensors for data acquisition and actuators for controlling physical systems. Furthermore, CPS have the possibility to store and evaluate data and can communicate them via wireless or wired interfaces (Geisberger 2012). CPS can thus connect the physical, real world with the virtual world (Reinhart 2017).

7 IoT is a communication network between individual things that can independently receive and process information (Ashton 2009). This becomes reality when several CPS are connected to form a network (Bauernhansl 2014b).

The demand for comprehensive logistics services, as well as the requirements for the promotion of digital technologies and automation technologies, have been echoed in China's academic writing on smart logistics. As part of this study, a trend analysis of research smart logistics was conducted using the China Knowledge Network[5] database. "Smart logistics" in Chinese language was defined as the key search word, to reveal the number of papers on smart logistics published annually in the database. The search results are presented in Figure 6. It shows that, although the first Chinese literature on smart logistics was published in 2010, in the subsequent four years from 2011 to 2014, related research did not develop rapidly. After those four years, a rapid expansion of academic literature on the subject began in 2015, and it has continued that growth trend until 2020. According to the trend shown in Figure 6, this study divides China's academic research on smart logistics into the following three stages:

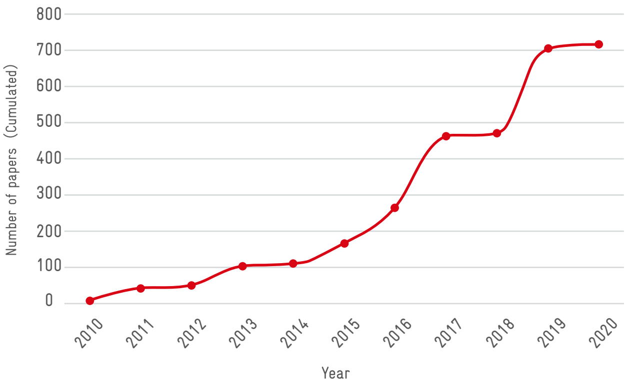


Figure 6: Publication trend on smart logistics, by numbers of papers published, China,2010-2020 (China knowledge network database)

During the first stage of this academic debate, from 2010 to 2014, Chinese researchers actively discussed the role of smart logistics and its impact on traditional logistics. Wang Ming (2011) highlighted that smart logistics would reshape the whole logistics industry, making it more intelligent, with widespread application of information technology, Internet of Things (IoT) technology, and management and service technology (Wang 2011).

Commission).[8] The results of this qualitative study are presented in Figure 7, showing the number of results published annually in the Scopus database in the field of smart logistics.

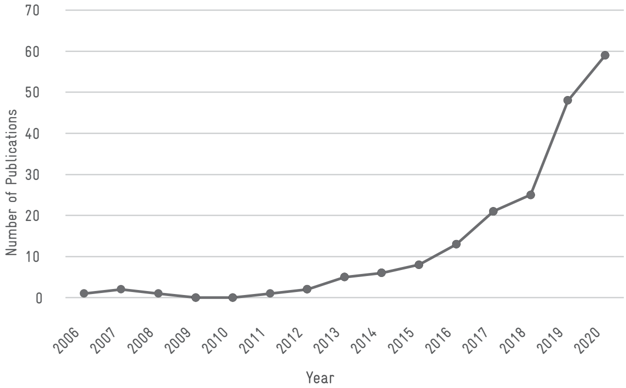


Figure 7: Number of publications on smart logistics from Europe by year

According to Figure 7, research on smart logistics started between 2006 and 2015: The number of publications per year was below ten and thus barely non-existent. However, since then the number of publications per year has already increased, reaching 74 publications in 2020. This illustrates the importance and attraction of research on smart logistics and underlines the potential beginning of a new extended development stage for the understanding of logistics.

Finally, core statements of frequently quoted authors are reproduced to reflect the understanding and potential of smart logistics (logistics 4.0) for the industrial application from a German perspective.

Smart logistics enables the mastery of the ever-increasing complexity, which is a major challenge for corporate networks. Connectivity and automation allow for intra- and inter-company transparency and real-time control of processes, thus allowing to optimise resource consumption. On the one hand, this leads to increased efficiency and reduced costs (Wurst 2020; Zsifkovits and Woschank 2019). On the other hand, smart logistics also contributes directly to increasing sustainability in the processes by saving resources (Schneider and Hanke 2020). For instance,

5 China Knowledge Network is the most comprehensive database in China, providing unified retrieval and unified navigation of Chinese academic literature, dissertations, newspapers, conferences, yearbooks, and other resources.

8 According to the definition of the EU Commission, Europe has a total of 50 countries, consisting of the EU member states, candidate countries, and other countries in Europe. Further information can be accessed here: https://www.bpb.de/kurz-knapp/zahlen-und-fakten/europa/70675/die-staaten-gebiete-europas/

In the second stage, from 2014 to 2018, the rate of publications on smart logistics grew significantly, particularly from 2015, when the "Internet Plus Efficient Logistics" action plan was introduced. With the maturing of technologies such as IoT, big data, cloud computing, artificial intelligence, and other new-generation information technologies, as well as the requirements of China's logistics industry to reduce costs and improve efficiency, Chinese researchers put more emphasis on technology innovation in logistics. Chinese researchers believed that smart logistics would help to achieve an innovative type of logistics in terms of automation, visualisation, intelligence, informatisation, and networks (Wang 2014; He 2016).

In the third stage, from 2018, the focus of smart logistics is placed on its influence on the real world, especially the ability of smart logistics to create an independent ecosystem and its broader commercial application scenarios (Wang 2018).

In conclusion, the first Chinese domestic research on smart logistics was published in 2010, and it mainly discussed the application of IoT in the logistics industry, with limited focus on smart logistics. IoT was included in the Government Work Report for the first time in 2010, which may explain why the development of smart logistics takes 2010 as the starting point (China's Government Work Report 2010). IoT has been recognised as a new global wave of the information industry – after computers, the Internet, and mobile communication networks – and as having a wide range of applications in the field of logistics (China's Government Work Report 2010).

especially in operational logistics, almost everything can be algorithmised. Therefore, logistics is the predestined domain for the application of artificial intelligence (Henke and ten Hompel 2020). The technology can process large data volumes and perform many tasks autonomously such as route planning or ordering goods (Lange 2020). The route planning aspect in particular has great efficiency potential in the future, also with regard to sustainable transport logistics. By means of complex transport optimisation, transports can be combined and empty runs on return trips can be reduced by the application of an inter-company networking. Overall, the utilisation of transports and thus the general transport volume can be reduced (Dörr et al. 2020). Moreover, by using digital capabilities, intermodal transport can also be better coordinated and the existing modes of transport can be used more efficiently (Federal Ministry of Transport and Digital Infrastructure (BMVI) 2017).

In summary, the industrial need for intelligent and smart logistics is enormous due to the great potential to increase efficiency, reduce costs, as well as to significantly increase overall sustainably.

2 Proposal for a definition of the term smart logistic

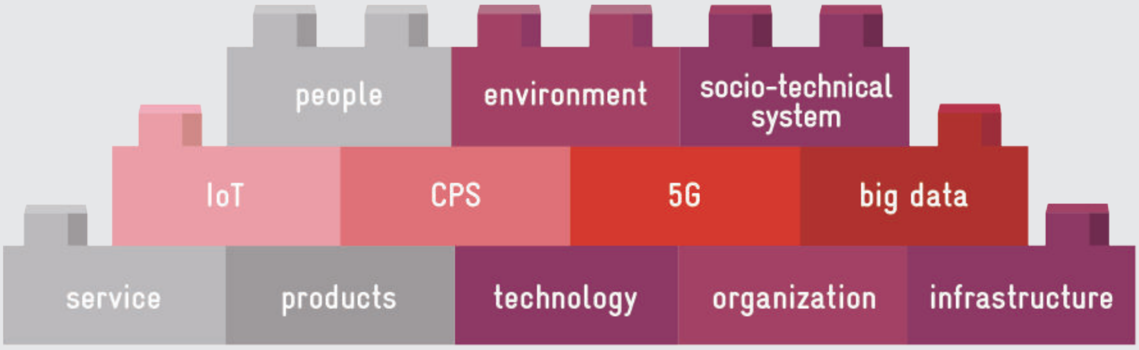


Figure 8: Key elements of the proposed definitions on smart logistics in China and Germany by the study

Logistics has always been the backbone of global trade, and it is essential to build up a universal understanding on smart logistics as a key to make transport and the logistics industry more sustainable and climate friendly. China and Germany are both key pillars of the global logistics supply chain, but currently there is no globally harmonised definition of smart logistics. Reaching a common understanding of smart logistics in China and Germany will benefit the low carbon development of the logistics industry.

In the following sub-chapters, definitions from a Chinese and German perspectives are given. By comparing the definitions in China and Germany proposed in this study, several commonalities were identified, and it is concluded that smart logistics could be employed in the key logistics processes of product manufacturing, goods shipment, and freight management services. Both China and Germany emphasise the application of innovative technologies to support creating environmental and user-friendly low-carbon transport in the future.

Based on the definitions of smart logistics elaborated in Germany and China, the consensus from both perspectives can be summarised as follows:

"Smart logistics refers to an advanced development of logistics that is aimed at optimising the use of resources and facilitating intelligent, automated management of logistics operations to achieve high efficiency, cost-effectiveness, and sustainability in logistics.

This is enabled by the integrated application of latest technologies – CPS and IoT, big data and cloud computing, and other disruptive technologies – in logistics processes, to create interconnected and intelligent networks of logistics vehicles, products, and further equipment, and facilitate real-time tracking, data exchange, and automated decision-making across logistics operations."

As mentioned at the beginning of the chapter, detailed information on the country-specific definitions of smart logistics is presented in the following subchapters.

Smart Logistics in China

Defining smart logistics in China is the interest of both academia and the industry, which already common or similar understandings on certain characteristics and core elements.

The most basic characteristic of smart logistics is that it is application scenario oriented. Basic logistics operations, such as transportation, warehousing, packaging, and handling of goods, should be embraced into smart logistics (Tang 2020). From this perspective, smart logistics is the upgrading and transformation of traditional logistics.

Another characteristic is that smart logistics is technology-driven, which clearly distinguishes it from traditional logistics. The various technologies applied in smart logistics include IoT, big data, 5G, artificial intelligence, cloud computing, blockchain, and so on (Sinotrans and CFLP 2018). The key technology is IoT, which enables interconnectivity and interaction between a range of devices, helping to realise an accurate and real-time transmission of information (Yang 2021). Big data and cloud computing technology can meet the needs of smart logistics for massive data processing in diverse formats (Li 2017). 5G technology enables the supervision of logistics operations to occur in real-time. Artificial intelligence technology has the ability to optimise data usage and eliminate the likelihood of human error, as well as to improve execution accuracy (Yuan et al. 2018).

The third characteristic of smart logistics is its pursuit of optimal decision-making. This requires the establishment of a unified, comprehensive management system that collects and computes data on logistical services, the goods being shipped, as well as the organisation and infrastructure behind logistics. This also requires massive processing capacity of data and well-designed algorithms (Wang 2018).

The last characteristic of smart logistics is its visualisation. Although smart logistics involves complex systems and algorithms, it is more user-friendly to operators. The information display and information interaction in logistics services can be achieved through multimedia technologies, such as videos, images, texts, and digital technologies (Gan et al. 2018).

Smart Logistics in Germany

One of the first German researchers who worked on a definition of smart logistics was Uckelmann. According to his findings, smart logistics is characterised by the following aspects: Smart Logistics is derived from a technology driven approach and foster the collection of data on material flow and the facilitation of state-of-the-art data processing. It integrates existing logistics technologies, such as material handling systems, and enable these to act in a correspondingly smart manner. As a result, smart products and services are developed, which are connected and operating transparently while freeing humans from controlling and monitoring activities (Uckelmann 2008).

Following the descriptions of Zsifkovits and Woschank, smart logistics will be realised through an holistic integration of the Industry 4.0 fundamentals CPS and IoT. By doing so, a logistics will be created which includes intelligent objects that can exchange information on their state and location, and are enabled to perform autonomous decisions. Accroding to the authors, the concept of smart logistics can be applied to intralogistics, but also to comprehensive transport chains or cross-company networks. Moreover, by sharing transport capacities, warehouses, hubs, and transfer points, economic (shorter transport times, lower personnel costs) as well as environmental (reduction of traffic and emissions) benefits can be achieved (Zsifkovits and Woschank 2019).

Since within smart logistics, controlling and monitoring activities that traditionally would be carried out by humans are taken over by technology, this change will not only lead to remarkable changes in logistics and supply chains in terms of processes but also in organisational structures. The role of humans in logistics will change in this new logistical development stage. Therefore, the implementation of smart logistics has always to be considered from a socio-technical point of view (Hirsch-Kreinsen and ten Hompel 2017).

Based on the findings from the literature review as well as the definitions presented above, the understanding of smart logistics could be defined as follows:

Based on these characteristics, this report proposes the following definition on smart logistics in China:

Smart logistics is an advanced stage of logistics development which coexists with traditional logistics. Through the technical upgrade of traditional logistics operations (transportation, warehousing, packaging, and handling of goods, etc.), smart logistics will achieve integrated, efficient, user-friendly, and optimal logistics services. The technical upgrade refers to the integrated application of IoT technology, big data, 5G, and artificial intelligence throughout logistics products and equipment, and having an effect on sensing, identification, tracking, calculation, and decisions on different logistics operations among key players.

Smart logistics refers to the utilisation of the latest information and communications technology to implement new types of self-controlling ecosystems - both within intralogistics and for cross-company logistics processes and networks, involving a remarkable change in the role of humans. This is enabled by CPS and the IoT that allow smart objects to interconnect, to exchange data with their cyber-physical environment, and to make automated/autonomous decisions.

If a special domain of smart logistics such as smart transportation is to be considered, it can be assumed that the characteristics mentioned above can also be applied to this domain in the meaning of a "smart transportation."

3 Current establishment of smart logistics in China and Germany

3.1 Government initiatives for smart logistics development

The governments of both China and Germany have played active roles in promoting the understanding of smart logistics and have formulated mid- and long-term development plans and strategies. The Chinese central government and German federal government form national strategies conducive to the development of smart logistics, upon which individual ministries develop (research) programmes and action plans. The development of China's smart logistics is related to the national strategy of "Internet Plus", while in Germany, the development of smart logistics is a reflection of the federal government's "High-Tech Strategy" (German Bundestag 2006) and "Sustainability Strategy" (The federal government 2018b). These policies, as well as the public products such as transport infrastructure, have played an important part in smart logistics development in China and Germany. The roles and responsibilities of Ministries in smart logistics development are summarised in Figure 9. Figure 10 gives the indicators for logistics infrastructure and freight volume in China and Germany, and their logistics performance in the world.

China	Ministries involved and roles	Germany
NDRC: Overall plan		**BMBF:** Education and research
MOT: Infrastructure construction		**BMVI:** Infrastructure and digitizing
MOFCOM: Market promotion		**BMWI:** Market promotion
MEE: Climate Protection		**BMU:** Climate Protection
MIIT: Information construction		

Figure 9: Ministries involved and roles in China and Germany, summarised by the study[9]

9 This study was conducted till December 2021. Hence, the study related information only covers the legislative period between 2017-2021.

		China	Germany	Unit
Road Mileage	Total	477. 0	83.0	10,000 km
	Average	36.82	99.76	km/10,000person
Expressway length	Total	13.6	1.318	10,000 km
	Average	1.14	1.58	km/10,000person
Inland waterway length	Total	12.7	0.73	10,000 km
	Average	0.90	0.88	km/10,000person
Railway length	Total	477.0	3.84	10,000 km
	Average	1.03	4.62	km/10,000person
Civil airport	Total	229	25	Number
	Average	585.80	332.80	Mio person
Freight volume	Total	463.4	37.14092	100 Mio ton
	Average	32.89	44.64	ton/capita

Figure 10: Infrastructure Establishment for Freight and Logistics in China and Germany, 2020, (MOT, BMVI)

Government initiatives for smart logistics development in China

The Chinese government's support for smart logistics takes a top-down approach. As mentioned, earlier in this study, IoT was first included in the Government Work Report in 2010. From then on, smart logistics has been part of either logistics and transportation, or the Internet and digitisation. The Guideline for Implementation of the Internet Plus Circulation Action Plan was issued in 2016. As the first official document of the Chinese government explicitly mentioning smart logistics, it closely followed the "Internet Plus" proposal in the 2015 Government Work Report.

The development of smart logistics is inseparable from the support and guidance of governments, and it also requires the joint efforts of various ministries at central level and governments at all levels. Through the following policies issued, this study demonstrates that the development of smart logistics starts from the central government level and is gradually carried out by various ministries and commissions, mainly including the National Development and Reform Commission (NDRC), the Ministry of Transport (MOT), and the Ministry of Commerce (MOFCOM).

The NDRC has an overall plan and strategy, while the MOT places emphasis on infrastructure construction, and the MOFCOM promotes new business models. Taking the Implementation Opinions on Further Reducing Logistics Costs in 2020 as an example, to enhance the development of smart logistics, the MOT emphasised promoting the construction of a new generation of the national traffic control network, and the digital upgrade of cargo facilities, while the NDRC focused on improving the automation and intelligence level of logistics links, including warehousing, transportation, and distribution, and on advancing the application of emerging technologies and intelligent equipment.

Government initiatives for smart logistics development in Germany

Germany is one of the ten most research-intensive economies in the world (Federal Ministry of Education and Research (BMBF) 2018). The basis for this was laid by the Federal Government in 2006, when a national High-Tech Strategy was published for the first time. The High-Tech Strategy moved innovation policy to the centre of government action (German Bundestag 2006). At the beginning of each legislative period, which means every four years, the Federal Government defines the strategic umbrella of its research and innovation funding with an update of the High-Tech Strategy (Federal Ministry of Education and Research (BMBF) 2018).

The Federal Government has a total of 14 federal ministries.[10] The two key ministries for the development of the High-Tech Strategy and for innovation funding are the Federal Ministry for Economic Affairs and Energy and the Federal Ministry of Education and Research (The federal government 2018a).

The most recent High-Tech Strategy is from 2018 – the High-Tech Strategy 2025 (Federal Ministry of Education and Research (BMBF) 2018). However, since elections took place in September 2021 in Germany, the High-Tech Strategy will be updated again soon. Since 2010, the focus has been on society's need for sustainable solutions and their achievement (Federal Ministry of Education and Research (BMBF) 2014). Accordingly, the three major thematic fields of the High-Tech Strategy relate to societal challenges, the establishment of an open culture of innovation and risk-taking, and strengthening Germany's future competencies. More precise thematic fields related to Industry 4.0 and logistics in the High-Tech Strategy are Sustainability, Climate Protection and Energy, Mobility and Economy, and Work 4.0 (Federal Ministry of Education and Research (BMBF) 2018).

Another important strategy of the Federal Government is the Sustainability Strategy,[11] which is aligned with the 17 Global Sustainable Development Goals contained in the 2030 Agenda

10 This study was conducted till December 2021. Hence, the study related information only covers the legislative period between 2017-2021.

11 The first Sustainability Strategy was published in 2002. Most recently, the Federal Government thoroughly revised the Strategy in 2016 and adopted a further update in 2018.

In addition to the central government, local governments' efforts mainly focus on the application and innovation of technology. For example, Wenzhou City has introduced a smart logistics information service platform, which provides a set of solutions for the problems of asymmetry of transaction information among logistics companies, vehicle owners, and shippers.

The motivations for the Chinese government to support smart logistics are different at different stages. Since the previous academic review of this study, the cost pressure has led China's logistics industry to use more machines instead of manpower, and spawned IoT application in the field of logistics since the year of 2015. When entering the 14th Five-Year Plan period (2021-2025), stricter requirements have been put forward for the development of the logistics industry. These serve, in particular, the achievement of overarching environmental goals, i.e., China's aim to peak carbon emissions before 2030 and reaching carbon neutrality before 2060 (State Council P.R. China 2020a).

The Outline of the 14th Five-Year Plan (2021-2025) for China`s Economic and Social Development and the Long-Range Objectives Through the Year 2035 attach great importance to logistics development and supply chain innovation, and clearly proposes building a modern logistics system (State Council P.R. China 2020a). The document mentions the word logistics 20 times, and the term supply chains 13 times. This is the first time that the terms logistics and supply chains have been mentioned this often in a five-year plan. The documents require the building of 5G-based application scenarios and a corresponding industrial environment, and the carrying out of pilot demonstrations in key areas, including smart logistics.

In addition to the promulgation of policies, the Chinese government recognises the positive supporting role of the transportation infrastructure for the development of smart logistics. China's high-speed railway operating mileage, expressway operating mileage, and coastal port berths of 10,000 tons and above, rank first in the world. The coverage of railways and expressways in cities with populations of over 200,000 in urban areas exceeds 95%, civil airports cover 92% of prefecture-level cities (China Transportation Statistical Yearbook 2021). This infrastructure has strongly supported the development of China's logistics and smart logistics.

published by the United Nations Member States in September 2015 (United Nations 2015). The Strategy should serve as a basis for policy reforms as well as for changing the behaviour of businesses and consumers (The federal government 2018b).

In addition to the Federal Government's strategies, the federal ministries also develop programmes to coordinate research needs. In 2017, in close partnership with business and science, the Federal Ministry of Transport and Digital Infrastructure (BMVI) presented the Freight Transport and Logistics Action Plan to strengthen Germany's leading position as a global logistics location. According to the Federal Government, the three core elements for the development of innovative logistics are: invest, modernise, and digitalise. The basis for future-proof logistics is the creation of a high-performance digital infrastructure in order to be able to exploit the potential of smart logistics (Federal Ministry of Transport and Digital Infrastructure (BMVI) 2017).

Two years after the programme was launched, the BMVI presented the Innovation Programme Logistics 2030 in cooperation with company representatives and relevant experts from research and science. The programme will be further developed in the future by means of an innovation commission The BMVI programme assigns implementation to itself, the federal states, municipalities, and the business community. In developing the programme, 10 fields of action were identified in which there is a need for action and innovation. The first field of action forms the basis for all others as it addresses digital infrastructures, data processing, and platform solutions. First and foremost, Germany is to become a lead market for 5G technology so that nationwide mobile communications coverage for digitalised logistics processes is made possible. Furthermore, digitalisation and smart logistics should also lead to efficiency increases and emission reductions in the future due to simplified planning regarding the choice of transport mode and the reduction of empty journeys. The need for innovation in logistics relates to all modes of transport, i.e. rail, road, waterways, sea and air, in order to strengthen a cross-modal network.

Another field of action deals intensively with innovative freight transport in the context of climate protection. The vision for 2030 includes a significant reduction in noise, pollution, and greenhouse gas emissions as an important contribution to the energy transition. The vision is to be achieved by means of expansion and a greater shift to energy-efficient rail freight transport. Additionally, commercial vehicles with alternative drive systems will continue to be subsidised in order to further reduce the emission levels of the

Table 1: Policies issued by Chinese governments on smart logistics in China

Issuing agency	Title	Year
State Council	Implementing Opinions on Further Reducing Logistics Costs	2020
	Guiding Opinions of the General Office of the State Council on Actively Promoting the Innovation and Application of the Supply Chain	2017
	Opinions of the General Office of the State Council on Deeply Implementing the Action Plan for the Internet Plus Circulation	2016
National Development and Reform Commission	Opinions on Promoting the High Quality Development of Logistics and the Formation of a Strong Domestic Market	2019
	Implementing Opinions on "Internet Plus Efficient Logistics"	2016
Ministry of Transport	Action Plan for the Construction of New Infrastructure Construction in the Transport Field (2021-2025)	2021
	Opinions on Advancing Supply-Side Structural Reform and Promoting Logistics Cost Reduction and Increased Efficiency	2016
Ministry of Commerce	13th Five-Year Plan for the Development of Commercial Logistics	2017

transport sector. The objective of reducing the emissions of the transport sector is – for example – covered by a concrete project by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) on piloting so-called "e-highways," on which catenary trucks have been tested since 2019.

In summary, the objective of the programme by the Federal Ministry of Transport and Digital Infrastructure (BMVI) concerning the research fields related to "logistics" is to develop German logistics into a digitally networked and intelligent logistics system for all modes of transport, taking climate aspects into account (Federal Ministry of Transport and Digital Infrastructure (BMVI) 2019).

Finally, the Development of Digital Technologies programme of the Federal Ministry for Economic Affairs and Energy (BMWi) should be mentioned. The programme is intended to leverage potential for efficiency and value creation through the use of new technologies, thereby enhancing the competitiveness of the German economy (Federal Ministry of Economics and Climate Protection (BMWi) 2020).

Table 2: Presentation of government initiatives in the context of smart logistics in Germany

Issuing agency	Title	Year
Federal government	High-Tech Strategy	2014
	High-Tech Strategy 2025	2018
	Sustainability Strategy	2020
Federal Ministry of Transport and Digital Infrastructure (BMVI)	Freight Transport and Logistics Action Plan	2017
	Innovation Programme Logistics 2030	2019
German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU)	Research on Catenary Truck	2019
Federal Ministry for Economic Affairs and Energy (BMWi)	Development of Digital Technologies	2019

3.2 Non-government innovation drivers and leading enterprises

Both in China and Germany, companies, universities, and scientific research institutions, as well as industry associations, play important roles in the innovation process. Even though their roles and responsibilities in both countries are different, they all contribute to advancing the development of smart logistics through their research efforts.

Non-government innovation drivers and leading enterprises in China

The development of smart logistics requires not only governmental support, but also industrial support from the whole supply chain to implement and innovate. In addition, universities, and research institutions, as well as industry associations, are important forces for the development of smart logistics.

The logistics industry is an integrated industry composed of different types of businesses, both traditional and modern types of logistics enterprises. In terms of the business practice, there are two development paths for smart logistics. One is a top-down model driven by e-commerce platforms. Alibaba and JD.com are typical examples of Internet companies that have built up e-commerce platforms in China. The platforms request the logistics data, and finally, in turn, drive the collaboration of full data and the integration of resources across the entire supply chain. This model is regarded as a reflection of the Internet Plus strategy of the Chinese government.

The other is a bottom-up model driven by logistics companies. Taking Chines company SF Express for illustration, all logistics operations produce business information, and SF Express assembles all the information and data to build up a platform, conducts big data processing, and ultimately provides customers with personalised solutions. Additionally, SF Express actively deploys emerging technologies that have great application prospects in logistics, including AGV (Automatic Guided Transport Vehicle/Robot). This bottom-up model is driven by cost control on the part of logistics companies and by their awareness of sustainable development.

E-commerce platform companies represented by Alibaba and JD.com, etc.: Focus on improving logistics efficiency through their own Internet technologies actively deployed in various fields of smart logistics. Alibaba focuses on the development of IoT, big data, and artificial intelligence, and also designs warehouse robots for extensive use.

Non-government innovation drivers and leading enterprises in Germany

In Germany, there are various types of non-government innovation drivers and development strands. On the one hand, there is scientific research and development conducted by universities, research institutions, and non-profit companies. On the other, there are the companies themselves, which drive innovations to remain competitive. Finally, there are also various industry associations providing strong knowledge transfer.

The development strand of science includes the German universities and colleges, which make a major contribution to the German research landscape. In the context of logistics and smart logistics, the Technical University of Dortmund stands out in particular, as it has been home to the first academic diploma programme in logistics in Germany since 1998 (Technical University Dortmund 1998). Closely linked to the TU Dortmund is the Fraunhofer Institute for Material Flow and Logistics (IML) in Dortmund, which is one of 75 German institutes of the Fraunhofer-Gesellschaft.[12] The three major pillars of the Fraunhofer IML are similar to those of the TU Dortmund due to the dual function of the IML institute directors as chair holders (Fraunhofer IML 2021).

Furthermore, the active testing and feasibility checks of new technologies are initiated by large companies themselves, especially in the automotive industry. BMW, for example, launched the research project on "Autonomous and Connected Logistics" to transfer innovative Industry 4.0 technologies into an overall concept and to test them under real conditions in 2019. Behind the large-scale project is the vision of fully networked production with autonomous transport systems and logistics robots (BMW

12 The Fraunhofer-Gesellschaft is a world leader in the field of application-oriented research, and the focus of its innovation policy is on key technologies and the application-oriented utilisation of results in industry and business (Fraunhofer-Gesellschaft 2021).

Leading logistics companies represented by SF Express and Sinotrans Limited, etc.: By forming R&D teams, setting up R&D institutions, or cooperating with third parties, they have clear application prospects of smart logistics technologies. For example, Sinotrans Limited aims to build a business platform with intelligent logistics services. Through widely applying IoT technologies, Sinotrans could provide the visualisation of whole-process logistics and various value-added services.

The figure below (Figure 11) describes the main operation scenarios of smart logistics and the main technologies used. Divided from the stage of logistics operations, it mainly includes warehousing, long-distance transportation, branch distribution, and express terminal. IoT, big data, and AI technologies are involved at different stages.

Not only logistics enterprises are engaged in the R&D and application of smart logistics technology. Chinese research Group 2020). Another innovation driver is the Mercedes-Benz AG with its launch of the new "Smart Factory" or "Factory56" in 2020. Under the motto "digital, flexible, green," the car manufacturer demonstrates the use of digital technologies in intralogistics (RFID, AGV and Pick-by-X) (Daimler AG 2020).

The three largest German logistics companies by revenue in 2019 are Deutsche Post DHL, Deutsche Bahn including DB Schenker and DB Cargo, and Dachser (Fraunhofer SCS 2020)[13]. To achieve more sustainable transport services, DHL is increasingly focusing on environmentally friendly solutions in delivery and transport. Relevant measures include increasing the share of e-vehicles in the delivery fleet to 60% by 2030, promoting the development and market availability of hydrogen or rather electric delivery vehicles and reducing fuel consumption through ongoing network improvements (Deutsche Post AG 2021).

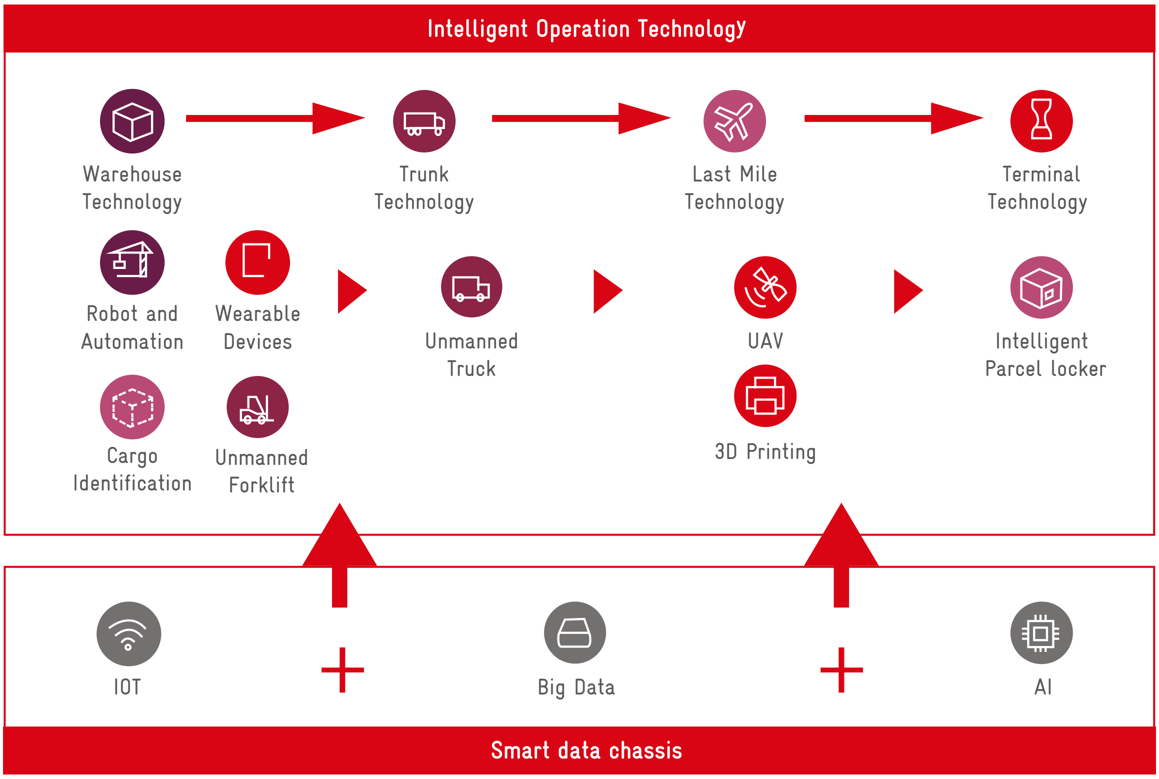


Figure 11: A general view of smart logistics technology in China, (Deloitte 2018)

13 Deutsche Post DHL is a logistics provider for parcel delivery, international express delivery, freight transport as well as postal and parcel services, supply chain management and e-commerce solutions (Deutsche Post DHL Group 2021). DB Schenker is also a leading provider of global logistics services, supporting industry and trade in the global exchange of goods – through land transport, worldwide air and sea freight, contract logistics, and supply chain management (Schenker Deutschland AG).

institutions also play a role. According to statistics on the website of the Ministry of Education of China, there are currently 128 colleges and universities in China offering logistics engineering majors. This has laid a strong educational foundation for the rapid development of smart logistics in China. The Research Institute of Highway (RIOH) of the Ministry of Transport (MOT) is a pioneering institution in this field. It was established in 1956 and is a large-scale integrated and interdisciplinary institution in the transport field directly under the Ministry of Transport, together with the other three MOT affiliated institutions, namely the Transport Planning and Research Institute (TPRI), the China Academy of Transportation Sciences (CATS), and the China Waterborne Transport Research Institute (WTRI). RIOH established a dedicated research centre specialising in logistics in 2001, achieved a leading position in policy making and technology innovation, and undertook research projects at international, national, and local levels supporting MOT, NDRC, MOFCOM, as well as through extensive partnerships with China's top logistics companies.

In terms of industry associations, the China Federation of Logistics and Purchasing (CFLP) established a Smart Logistics Branch in 2017, and the China Communications and Transportation Association (CCTA) established its Smart Logistics Branch later that year. The above two associations actively promote exchanges and cooperation in the field of smart logistics, including on standardisation, seminar discussions, and human resource training.

In parallel to DHL, DB Schenker, part of the Deutsche Bahn Group, is also committed to researching and establishing smart and sustainable logistics solutions. For example, with its product "Eco solutions," the company offers its customers a solution to mitigate CO2 emissions along the supply chain. This enabled savings of up to 20% in air freight and up to 50% in sea freight. Land transport will be more environmentally friendly through innovative engines and fuels (Schenker Deutschland AG 2021). In 2018, Dachser[14] piloted a project to deliver inner cities – such as Stuttgart – that are plagued by exhaust fumes and traffic jams with zero emissions up to the last mile. For this purpose, delivery bikes are used to deliver to shops in the pedestrian zone (Weber 2018).

The largest and almost sole drivers of intermodal transport are the seaports and inland waterway ports. One example is the inland waterway port "duisport", which plays a leading role in international rail transport, is one of the most important rail transport hubs in Europe and acts as a gateway hub for major seaports. Thirty national and international rail service providers and operators connect duisport with 25,000 trains annually, which serve more than 100 destinations throughout Europe, such as Antwerp, and also transcontinental destinations, e.g. Chongqing in China (Duisburger Hafen AG 2021).

Finally, the activities of the Federal Logistics Association (BVL)[15] should also be pointed out, whose initiatives promote the dissemination of knowledge and a general understanding of logistical terms and thus contribute to the potential realisation of smart logistics in the future. The work of the BVL is assigned to subject areas which are regularly updated. Although there are no direct subject areas on smart logistics here, it is indirectly covered by other areas (cf. the explanations in chapter). Thus, the subject areas of relevance are mainly "Digitisation of transport logistics" and "Designing sustainably" (Bundesvereinigung Logistik e.V. 2021a). The key topics of the subject area "Digitisation of transport logistics" deal with "the barriers of the digital connection between partners in transport logistics, which is still inadequate in certain cases (..)" and is discussed on a cross-company basis. Beyond that, solutions and best practices are discussed (Bundesvereinigung Logistik e.V. 2021b). Aspects of sustainability are covered by the new initiated subject area "Designing sustainably." The planned core topics will be best practices, sustainability community, and emission balancing (Bundesvereinigung Logistik e.V. 2021c).

14 Besides DHL and DB Schenker, Dachser also provides transport as well as warehouse services within the supply chain and is also active globally (DACHSER SE 2021).

15 The Federal Logistics Association (in German: Bundesvereinigung Logistik; short: BVL) was founded in 1978 with the aim of promoting the general public exclusively through the initiation and dissemination of ground-breaking logistical knowledge. It is promoted by the systematic recording of logistic problems and problem solutions based on practical and scientific findings, with an application-oriented focus on the industry (Bundesvereinigung Logistik e.V. 2021d).

3.3 Standards and norms

Standards and norms are an important basis for promoting sustainable developments in smart logistics in a targeted manner. However, both China and Germany have only made limited progress in this regard. Therefore, both China and Germany need to strengthen their standard development processes. To achieve international standards that could support the integrated development of Chinese and German technologies, it is also conceivable to strengthen transnational standard development cooperation. The coordination complexity among the numerous stakeholders is currently hindering the development of national standards and remains a significant challenge.

Standards and norms in China

In China, two national standardisation technical committees are involved in smart logistics. One is the National Logistics Standardisation Technical Committee (NLSTC), which was established in 2003, with its secretariat located at the China Federation of Logistics and Purchasing. The other is the China Logistics Information Standardisation Committee (CLISC), which was established in 2003, with its secretariat located at the China Article Numbering Centre.[16]

In December 2020, the National Standards Committee approved the establishment of the first national standard in the field of smart logistics, the Smart Logistics Service Guide. Prior to this, there were no national and industry standards for smart logistics in China, and international standards in the field of smart logistics had also not been formulated.

The standard Smart Logistics Service Guide mainly stipulates the basic requirements that enterprises need to meet when providing smart logistics services, and regulates the technology, equipment, personnel, mode, and quality requirements in the process of smart logistics services, which could be an important reference for the selection of related technologies and equipment. The standard specifically addresses the following three issues. Firstly, clarifying the scope of a smart logistics service, including requirements on

16 Specialised agency for the unified organisation, coordination and management of China's commodity barcodes, article coding, and automatic identification technology, attached to the State Administration of Market Supervision and Administration.

Standards and norms in Germany

The German Institute for Standardisation e.V. (DIN)[17] is responsible for organising the standard process for the development of nationally applicable DIN standards.[18] Since no standard has been developed for state-of-the-art technology drivers as yet and the standardisation process is often lengthy, there is currently no standard for the term “smart logistics.” DIN counters this problem by publishing so-called standardisation roadmaps.[19] The first relevant roadmap is the Logistics Standardisation Roadmap published in 2015 dealing with the following, most relevant fields of standardisation in logistics for the next few years, and serving as a clear guide for common understanding:

- Logistics system and management
- Production logistics, warehouse and material flow technology
- Packaging and order picking
- Loading and transport security
- Distribution logistics
- Identification systems
- Green Logistics
- Smart Cities

17 The association was founded in Germany in 1917 and is considered the most important national standards organisation in the Federal Republic of Germany. The European standardisation process is managed by the standardisation organisations CEN/CENELEC and the international one by the standardisation organisations ISO/IEC (DIN e. V. 2021).

18 A DIN standard is a document that specifies requirements for products, services, and processes.

19 A standardisation roadmap provides an overview of the status quo of standardisation, existing standardisation gaps, and recommendations for action for the development of further standards in a specific (usually broad) subject area and serves as a clear guide for common understanding between experts and exchange with new (international) experts.

technology, equipment, personnel, and organisation. Secondly, clarifying the service model and the related requirements of the service process. Thirdly, putting forward the indicators that smart logistics services should meet.

Standards are an important foundation for promoting the sound development of smart logistics. It is imperative that the standardisation system of smart logistics be fully established.

At the beginning, each field of standardisation is described. Reference is then made to national standards, followed by European and, subsequently, international standards. Finally, the need for further standardisation is examined. Smart Logistics is also not presented as a separate domain in this roadmap. The reason can presumably be found in the broad field of smart logistics, which covers the standardisation fields mentioned above. However, the contents of the area green logistics or identification systems, for example, will become relevant for further research and the concrete implementation of smart logistics in the future. The explanations on green logistics demonstrate that there is still a lack of research findings and clear directions. Reference to either national or international standards are absent. Solely an approximation of a definition of "green logistics" is given, which is understood as a "sustainable orientation of companies by creating a balance of ecological and also economic efficiency" and furthermore, "this results in ensuring resource replenishment and resource regeneration of the supply chain and the creation of environmentally sound and resource-efficient logistics activities" (DIN e. V. and VDI e. V. 2015, 49).

As already described above, "Industry 4.0" and "smart logistics" are closely interlinked. Therefore, relevant content regarding "smart logistics" might also be found in the fourth version of the Industry 4.0 standardisation roadmap, published by the VDE (German Electrical and Electronic Manufacturers' Association) and DIN (DIN e. V. and VDE e. V. 2020).

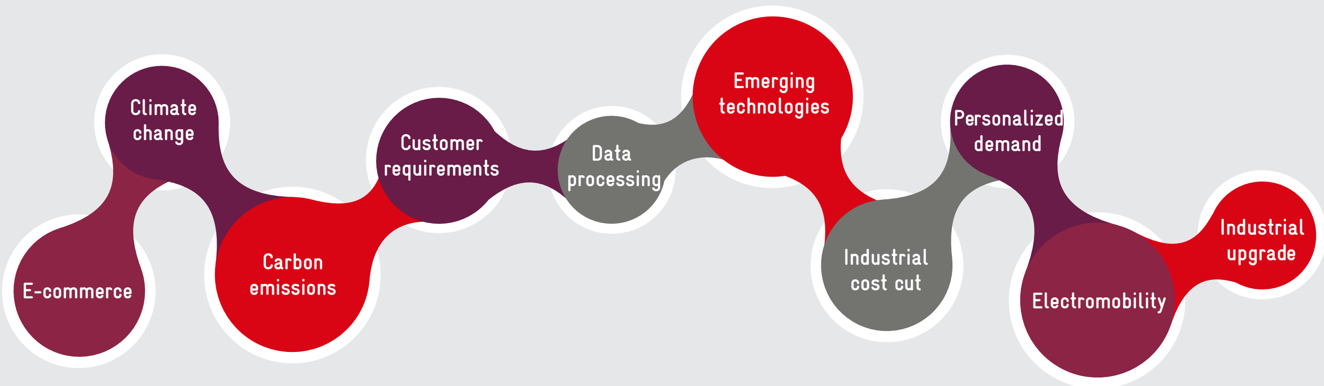
4

Future development of smart logistics in China and Germany

4.1 Key driving factors

In addition to the potentials of new technologies, several key factors will shape the future development of smart logistics. These include personalised demand and customer requirements, industrial upgrading and industrial cost reduction. In addition, both China and Germany have recognised that the development of smart logistics is also a major step toward tackling climate change as it has the potential for increasing efficiency and reducing energy consumption. Guided by national strategies, digital technologies are expected to help achieve climate protection targets.

A nascent body of research also explores the role of smart logistics in establishing sustainable supply chains even beyond its contribution to emission reduction. By integrating smart logistics into waste management and recycling operations, the establishment of circular supply chains could also be further supported. By use of the technologies underpinning smart logistics in organic waste collection, for example, researchers (Bearzotti et al. (2017) highlight the potential of a smart logistics application for facilitating linkages between urban waste generators and waste consumers, who create value from the organic waste (such as farms, compost, biofuels, etc.). Issaoui et al. (2020) also indicate a potential of smart logistics to facilitate reverse logistics[20], which seeks to make the logistics industry more sustainable with a focus on reusing packaging and managing end-of-life products, as well as streamlining recycling, remanufacturing, and safe disposal processes in the supply chain. Researchers at the Yuan Tong Research Institute suggest that elements of smart logistics, such as an integrated digital platform, could optimise the use of resources, improve the utilisation and recycling of packaging materials, and ultimately support the establishment of an effective reverse logistics as the core of a circular economy (Ma 2019).



20 In a narrow sense, reverse logistics is the behaviour of a single enterprise for resource recovery and waste treatment, such as sales return, product recall, scrap parts and so on.

Key driving factors in China

In China, customer needs, commercial needs, technical application, policy factors, and industrial costs have together become the internal driving forces for the development of smart logistics.

Increased customer requirements from the e-commerce sector

In the past 10 years, various new business models such as e-commerce, new retail, and customer to manufacturer (C2M) have developed rapidly in China. In China, the e-commerce transaction volume has reached 37.21 trillion RMB (around 4.99 trillion EUR) in 2020, a year-on-year increase of 4.5%. Among them, the commodity e-commerce transaction volume was 27.95 trillion RMB (around 3.75 trillion EUR) (MOFCOM 2020). The key factors for the development of e-commerce are payment, logistics, and data. The dilemma of high logistics costs, low efficiency, and poor service has hindered the development of e-commerce (Wen 2014). At the same time, consumer demand has also changed from singularity and standardisation to differentiation and individualisation. These changes have placed further requirements on logistics services.

Smart logistics is a viable solution. Through the technical upgrade of traditional logistics operations, smart logistics will help to reduce logistics costs, as well as to improve operation efficiency. Visualisation technologies used in smart logistics will help customers to get real-time information on their goods in the form of video or text. Smart logistics will supervise logistics operations 24 hours a day, thus guaranteeing the safety of goods.

Technological developments

It is estimated that in the ten years from 2020 to 2030, the market demand for IoT devices will grow from 75 billion RMB (around 10 billion EUR) to more than 100 billion RMB (around 13 billion EUR) (Adhyoksh 2019). The improvement from 4G to 5G is key to achieving growth of IoT. The 4G network can support 5500 to 6000 NB-IoT devices on a single cell. In a 5G network, a cell can handle up to 1 million devices. 5G technology will be more closely linked with IoT technology. Logistics personnel, equipment,

Key driving factors in Germany

With the pressure to achieve sustainability, technology is a driving force in the development of smart logistics and smart transportation to provide emission-free transport concepts and solutions – especially in urban areas. The journey towards this target is positively reinforced by a number of key driving factors, which are described below.

Technological development and data processing

For logistics or rather logistics networks to be able to fulfil its/their tasks more efficiently in the future, a strong technological basis is needed. Intelligent systems and controls in particular need large amounts of high-quality data in order to be able to learn and work in a meaningful way (ten Hompel et al. 2014). The computing power of computers has improved in recent years to such an extent that there are currently far more technological possibilities than can be utilised. In the near future, therefore, the question will no longer be about sufficient computing power, but much more about how the systems can be designed, networked, and used in a meaningful way (Henke and ten Hompel 2020).

Because of the rapid technological change, companies and research institutions should rethink both production and logistics, in order to exploit the efficiency potential and the benefits of smart logistics and smart transportation for themselves.

Increased customer requirements and prospering e-commerce sector

The former seller's market has developed into a buyer's market, in which customer-specific production in batch size 1 is moving further into focus and e-commerce or rather consumer-side online purchasing is intensifying for an increasing number of everyday items (Bogner et al. 2018). Even before the outbreak of the COVID-19 pandemic, e-commerce sales in Germany's B2C sector increased steadily, with an annual percentage growth rate of more than 20% between 2010 and 2019 (HDE 2021).

Due to the continuing rise of e-commerce in conjunction with sustainability, new concepts, and new technologies for last-mile facilities, and goods will be fully connected to the Internet, showing a trend towards wide connectivity.

The operation of these technologies in the commercial field will not only provide necessary technical support for the development of smart logistics but will also enrich and expand the operational scenarios of smart logistics. For example, during the COVID-19 pandemic, smart logistics has highlighted its own advantages. Some leading logistics companies and innovative companies are actively adopting new technologies such as big data, artificial intelligence, and 5G. Smart logistics equipment represented by drone automation has shown its advantages in improving logistics efficiency and reducing cross-infection of personnel.

Policy consideration for reducing carbon emissions

China announced its ambitious goal to peak its CO2 emissions before 2030 and achieve carbon neutrality by 2060 (The State Council, P.R. China 2020a). Reducing the carbon emissions of China's transport sector is a particularly pressing issue. In 2019, transport emissions accounted for approximately 10.4% of China's total carbon emissions (Chen 2021). Within transport emissions, the freight transport accounts for a share of about 66%, and road-transport accounts for a share of about 77% (Liang 2021). The experience from developed countries shows that carbon emissions in the transport sector will generally account for about 1/3 of total carbon emissions after industrialisation (Zhou 2021). This means that the total amount of carbon emissions in China's transport sector would continue to increase while the pressure to reduce emissions grows.

Smart logistics employs the latest technological solutions to help companies optimise their logistics supply chains in terms of where goods are stored and how they are distributed, so that the goods can be transported more efficiently. In this way, smart logistics helps to reduce unnecessary energy consumption, thereby reducing carbon emissions.

Cutting industrial costs

With the rising costs of labour and land use in big cities, smart logistics can achieve considerable cost-savings. For example, labour costs can be reduced by introducing machines to reduce personnel,

transport logistics are becoming imperative. Especially for urban areas, where delivery traffic is generally responsible for 80% of inner-city congestion at peak times (Rumscheidt 2019). To burden cities with fewer emissions in the future, electromobility is also finding its way into this area. One example of this is DHL's all-electric StreetScooter for letter and parcel delivery to private individuals in cities (Deutsche Post DHL Group 2019).

Policy initiatives to tackle climate change

Particularly regarding uninterrupted and accelerating climate change, industrial companies and logistics face a major challenge as they are two of the three largest emitters of emissions in Germany. It is particularly problematic that the transport sector, with 165 million tonnes of CO2 (in 2019), is still at the same level as in 1990 (Federal Environment Agency 2021a). Heavy-duty vehicles are responsible for about 6% of CO2 emissions in the European Union and without measures the share will continuously increase (European Union 2019).

Accordingly, the energy transition and sustainability are key trend-setting developments in logistics and smart transportation. One of the policies to be mentioned here is the Paris Agreement of 2015, which aims to limit global warming to well below 2°C, but preferably to 1.5°C, compared to pre-industrial levels (reference year 1990) (Federal Environment Agency 2021b). The need for reducing CO2 emissions and the development towards climate neutrality are ubiquitous.

Germany has taken action to fight climate change. The Climate Change Act is at the core of Germany's climate policy and sets the goal of being climate neutral by 2045. Most importantly, it fixes sector targets for the necessary emission reductions. The current version of the Climate Change Act specifies that by 2030 emissions from the transport sector must decrease to 85 million tonnes – a reduction of nearly 50% compared to 1990 (Federal Environment Agency 2022).

Societal initiatives to tackle climate change

In addition to the increasing political pressure to reduce emissions, the interest in and urge for sustainability is also growing in society. In 2021, there were federal elections in Germany and climate while centralised operations using IoT and big data can improve operating efficiency and minimise loss rates. This is also an important factor in its popularity in business enterprises.

Smart logistics has played a great role in effectively reducing business costs, facilitating people's lives, and improving overall productivity. It has become a new driving force for the transformation and upgrading of China's logistics industry.

protection and the proposed solutions for achieving the climate goals and energy transition were one of the major topics in the election campaign (BR 2021).

Increased demand and implementation of electromobility

The industry is also responding to the government's programmes (concerning the reduction of CO_2 emissions). Thus, major German automotive companies are currently planning to take up and gradually increase the production of fully electric cars to accelerate the transition to electric mobility. In the coming years, the OEMs' model range will electrify significantly and under the latest proposals in the EU Fit for 55-Package, from mid-2030 onwards, no new vehicles with internal combustion engines could be sold in the EU (Blechner 2021).

Electrification is not only a major topic in individual mobility, but also in commercial vehicles for the freight transport sector. In addition to battery-electric engines, various German truck manufacturers such as Daimler Trucks and MAN are already developing truck prototypes with hydrogen-powered engines (Daimler AG 2021; MAN 2021). According to the newest established joint venture "Cellcentric," founded by Daimler Truck AG and Volvo Group AB in 2021, series production of fuel cell systems will start in 2025. Among other use cases, these fuel cell systems are considered for use in heavy duty vehicles, which in turn will reduce CO_2 emissions on the roads (Cellcentric 2021).

Finally, in addition to research on technologies with an explicit reference to sustainability (such as battery-powered electric vehicles for reducing CO_2 emissions on the roads), the topic of sustainability should also be increasingly focused on technologies with no direct reference to sustainability. The central question is: In which ways can new technologies or the digitalisation of logistics (in the form of smart logistics) contribute to a more sustainable design of logistics?

4.2 Development trends

Regarding the development trends that will lead to continuous growth and improvement of smart logistics, as well as smart logistics making a significant contribution to climate protection, different approaches can be identified in China and Germany. In China, the focus in smart logistics development will rest on three trends in particular: a pursuit of innovation in terms of both technology and business models, an internationalisation of Chinese standards and technologies, and the promotion of sustainable approaches to logistics throughout entire supply chains. In Germany, sustainable development will continue to be a priority and is expected to provide motivation for the government to continue supporting the development of smart logistics and its underlying technologies. An emerging trend toward smart logistics in Germany is also the development of a data economy that engages a wide range of stakeholders and is expected to maintain an open-source approach, particularly to enable rapid technology development.

Development trends in China

In the 14th Five-Year Plan period (2021-2025), smart logistics will develop more extensively in China. The main development trends are as follows:

First, there will be more innovation coming from Chinese enterprises. Enterprises are the main body of market activities and the main force in the development of smart logistics. Logistics companies' development will be driven by innovation in disruptive technologies and business models. They will attach importance to the application of smart logistics in packaging, transportation, storage, and other scenarios, and encourage the development of cloud computing, big data, IoT, smart terminals, and other technological developments. It is expected that in the next 5-10 years, logistics digitisation will increase significantly, breaking industry information gaps.

Second, digital application in all aspects and fields will receive more attention, both domestically and internationally. As a result, the smart logistics technology and solutions currently employed by Chinese companies will also find international application scenarios. For key Chinese stakeholders in the logistics industry, strengthening international cooperation is the general trend for China's smart logistics industry.

Development trends in Germany

Digital technologies and their establishment play a major role for further logistics development in Germany, as smart logistics can be used to optimise the overall resource consumption and thus to exploit new efficiency potentials, as well as to make important contributions to sustainability and climate protection. It can therefore be assumed that government support for the development, piloting, and integration of key technologies, such as CPS, IoT, artificial intelligence, 5G networks and distributed ledger technology, will continue to be an ongoing trend in Germany in the future.

However, the basis for smart logistics to realise its full potential is not just the integration of such technologies within single enterprises. Rather, it requires a data economy in which large amounts of data are not only generated but shared between individual actors on digital platforms. Essential for this, in turn, is a secure data space that enables individual actors to retain sovereignty over their data and its use (Henke and ten Hompel 2020). In order to create such an open data space, leading scientists and companies from Germany, with the support of federal ministries, founded the International Data Spaces Association and are continuously developing the underlying architecture further (International Data Space Association (IDSA) 2021; Fraunhofer-Gesellschaft 2020).

Third, smart logistics will be making full use of social resources and actively reducing energy consumption, gradually materialising as an important contribution to global sustainable development. It is expected that in the next five years, green packaging, green transportation, and green storage will be promoted and applied at an accelerated pace. Most logistics companies in China will implement sustainable transportation development through adoption of smart logistics.

In addition, it has been recognised in Germany that a broad adaption of smart logistics and the resulting benefits can only be advanced jointly. With the vision of a federated platform economy – the so-called Silicon Economy – scientists, companies, and political decision-makers are promoting open-source development and provision of decisive hardware and software components. In this way, not only are efforts and risks shared, but also uniform and standardised processes in digital value chains are created. Alongside the eponymous research project "Silicon Economy" of the Fraunhofer IML, which is funded by the Federal Ministry of Transport and Digital Infrastructure (BMVI) with 25 million EUR since 2020, the so-called Open Logistics Foundation was also founded in October 2021 by the leading German logistics companies Dachser, DB Schenker, Rhenus, and duisport (Henke and ten Hompel 2020; Silicon Economy 2021; Open Logistics Foundation 2021). In the future, it can be expected that the open-source approach will be further established as an important success factor for the entire logistics industry.

The continuous technological development, the provision of secure data spaces and the rapid dissemination and application of technologies using open source will contribute significantly to establish smart and sustainable logistics in Germany.

5 Suggestions for future developments in smart logistics and sustainable transportation

Since the vision of smart logistics is not limited to individual countries, but must be considered internationally, it is important to formulate policy proposals for wider, international application.

In the context of further growing international trade and logistics volumes, exchange and cooperation in the field of smart logistics are becoming increasingly important. This is further strengthened because smart logistics not only plays an important role for economic stability and growth, but also for climate protection.

Based on the joint research, this study puts forward the following suggestions for the future development of low carbon smart logistics in China, Germany, and elsewhere around the world.

Strengthening the standardisation of smart logistics across the world

Currently, standards in the field of smart logistics are quite limited, both at international and national level. There is an urgent need to catch up on this issue. In this context, standardisation in the field of smart logistics should focus at least on the following two aspects: 1. the standardisation of logistics information or data and 2. the standardisation of the technological infrastructure. These two types of standardisation play an important role in strengthening international trade and promoting exchange of technology as well as logistical information. This is true not only at the macroeconomic level, but also at the microeconomic level, as even every single company would have its global supply chain. Against this background, China and Germany should exchange further throughout standardisation processes in the field of smart logistics to present a reference for the development of international standards.

Establishing infrastructure in support of smart logistics

Both China and Germany believe that the development of smart logistics will show an upward trend in the next five to ten years. Infrastructure, including roads, railways, as well as IoT and 5G, needs to support the application of smart logistics in more scenarios. Therefore, the necessary infrastructure upgrades and new construction should be a priority. Governments are suggested to consider the development of smart logistics when developing relevant infrastructure plans.

Ensuring appropriate legislation for smart logistics

The lack of harmonised legislation in individual countries leads to a high administrative burden. Therefore, harmonisation of legislation on various parts of the supply chain, such as customs clearance, needs to be promoted in order to simplify procedures for businesses and customers as much as possible.

Smart logistics has strong potential for increasing freight efficiency and thereby reducing energy consumption and carbon emissions. The reduced carbon emissions themselves could become beneficial to the relevant stakeholders in form of carbon credits to be used in carbon trading. China is currently working on formulating transitional regulations for carbon emissions trading and data security management (State Council of P.R. China 2021). Germany has also introduced carbon pricing for road transport in 2021 (Henke and ten Hompel 2020). It is very important to accelerate international cooperation and knowledge sharing in the field of legislation.

Educating and training professionals for smart logistics

In the era of smart logistics, multidisciplinary skills are required to ensure proper management in the industry (managers, technicians, and specialised professionals). The application of sustainability aspects and the use of new, digital technologies are radically changing logistics management. Therefore, a continuous adaptation of the skills of professionals to the new requirements of smart logistics is necessary. To ensure that the allocation of competences reflects the actual need for smart logistics skills demanded by companies, close cooperation between industry and professional colleges is recommended.

Carrying out smart logistics pilot projects

Numerous processes and technologies for smart logistics are being developed both in terms of research and application in the industry. However, these are often only available to individual stakeholders or cannot be deployed (on a large scale), for example due to a lack of legislation or regulation. In addition, it is difficult to obtain information about the current state of the art in smart logistics. Regardless of whether the results are from practice or from research in the field of smart logistics, there is a lack of transfer of best practices. Therefore, the development and establishment of pilot projects on smart logistics that integrate different approaches and actors from industry, science and politics is strongly recommended.

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Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

Registered offices
Bonn and Eschborn, Germany
Tayuan Diplomatic Office Building 2-5
14 Liangmahe South Street, Chaoyang District 100600 Beijing, P. R. China

T +86 (0)10 8527 5589
F +86 (0)10 8527 5591
E info@giz.de
I http://www.giz.de/china