The Role of Data-Driven Logistics in Arctic Shipping

Klara Paardenkooper

Abstract Modern economic conditions are characterized by a large volume of generated data. The challenge for companies is to make the most of their data, providing a competitive advantage. This is also relevant for the field of logistics, in particular logistics in the Arctic. Data analysis in determining the optimal route, reducing environmental impact, predicting shipping conditions, calculating expected arrival times, assessing risks, and determining ways to reduce their impact, and others, helps to make the most correct business decision. Data-Driven Logistics is used to carry out complex calculations to make an optimal decision. Key digital technologies are used for computing, such as Big Data, Blockchain, Robotics, sensor technology, the Internet of Things, Artificial Intelligence/Machine Learning, and 3D Printing. All of this enables Data-Driven Logistics to help add value to Arctic Shipping while keeping in mind the most gentle impact on the fragile environment of the region.

1 Introduction

Data-Driven Logistics has gained importance in recent years. The reason for this is the increasing conviction that the enormous amount of data produced by the internet and diverse sensors (Big Data) represents a major value for companies (Vicario & Coleman, 2020). Data is also called the new oil, the new fuel for the economy (Borst & Verbene, 2019). Companies that are not able to exploit their data will lose the competition (Vicario & Coleman, 2020). This is especially true for the logistics sector, which has major inefficiencies, especially in the field of capacity optimization, cooperation, and transaction costs. This traditionally conservative sector increasingly acknowledges the potential of Big Data and there have been numerous articles written on the use of data in different subdomains of logistics and supply

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K. Paardenkooper (✉)
Knowledge Center Sustainable PortCity, Rotterdam University of Applied Sciences, Rotterdam, The Netherlands
e-mail: K.M.Paardenkooper@hr.nl

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chain management (Hamister et al., 2018; Hazen et al., 2016; Song et al., 2021) However, there is no clear definition of Data-Driven Logistics to be found in the literature yet. The working definition of Data-Driven Logistics in this chapter is data-driven decision-making in the logistics domain, aiming to create value from existing data and mining additional data to create more value. Thus, Data-Driven Logistics is closely connected to data science, which is defined by Vicario and Coleman (2020) as "a science offering methodologies for processing and interpreting massive volumes of data collected by an increasing number of new devices." Data Science has a quantitative approach and belongs to the domain of mathematics and statistics. Data-Driven Logistics, as defined here, on the other hand, has a qualitative approach and focuses on the connection between the business model and data in the logistic domain. Its results are not calculations, but a system design. Which data and which technologies are necessary to create value?

The emerging possibilities of Arctic Shipping provide major opportunities to make global transport flows more efficient and sustainable. The shrinking ice gives more space for transport, especially because it is expected that the Arctic seas will be nearly ice-free during the whole year by 2050 (Marchenko et al., 2018). Consequently, the Arctic seas are becoming increasingly safe for navigation. Since 2005, Arctic shipping has been growing significantly, especially in September, when there is a minimum of ice coverage. The Arctic route has several advantages. The navigational distance between East Asia and Europe via the Arctic Northeast Passage is 30–40% shorter than the present route via the Suez Canal, 40–50% shorter than the Panama Canal route, and 50–60% shorter than the route around the Cape of Good Hope. The Arctic route especially offers a major shortcut to ships that are too large to pass the Suez Canal and as the only option, they can round the Cape of Good Hope. This way, the distance can be reduced, which leads to the reduction of fuel and operational costs. Furthermore, the Artic route does not have fees and ships do not need to pass politically unstable countries and there is no piracy at the Arctic seas (Zhang et al., 2019). As opposed to these advantages, there are disadvantages too, such as harsh weather, remoteness, and vulnerability of nature. Even though the projection is that the Arctic Seas in the long run will be ice-free, presently there is still a danger of ice movements and the route is not available during the whole year, only seasonably. Furthermore, the Arctic seas are situated between multiple countries, which also poses regulatory challenges (Marchenko et al., 2018).

This chapter focuses on exploiting the advantages and mitigating the disadvantages of the new Arctic Route using Data-Driven Logistics. The central research question is: How can Data-Driven Logistics create value for Arctic Shipping? After this introduction, Sect. 2 elaborates further on Data-Driven Logistics, exploring the following subjects: its definition and function, the classification of its parts followed by the explanation of the separate parts, Big data, Blockchain, Robotics, Sensor technology, Internet of Things, Artificial Intelligence/Machine Learning, and 3D printing. Section 3 describes the specific challenges of Arctic transport, namely, route choice, environment, navigability, calculating the expected time of arrival, and risk analysis. In the discussion in Sect. 4, the research question is answered by describing how Data Drive Logics can help add value to Arctic Maritime Shipping and what the impact is of the needed actions. Section 5, the conclusions summarize the chapter.

2 Data-Driven Logistics

This section explains Data-Driven Logistics, first its definition and function, followed by an inventory and explanation of its techniques, Big data, Blockchain, Robotics, sensor technology, Internet of Things, Artificial Intelligence/Machine Learning, and 3D printing.

2.1 *Definition and Function*

Data-Driven Logistics is a recently introduced notion, which has not been clearly defined in the literature yet. The working definition in this book of Data-Driven Logistics is data-driven decision-making in the logistics domain, aiming to create value from existing data and mining additional data to create more value. Especially the last part of the definition is important, data should be closely aligned with strategic goals and the value propositions. The introduction of Web 2.0, Industry 4.0, the Internet of Things (IoT), and other related digital technologies makes it possible to aggregate large amounts of data from different sources. A recent International Data Corporation (IDC) forecast predicted that investment in Big Data technology will grow yearly with 26.4% annual, reaching $41.5 billion through 2018. There is a close relationship between the size of the data and its usefulness, the more data, the better predictions. Big data analysis has a direct relevance for logistics, recent literature has developed different tools and techniques to make data-driven supply chain management decisions. Real-time analysis and interpretation can assist enterprises in making better and faster decisions. It will also help organizations to improve their supply chain design and management by reducing costs and mitigating risks. Recently, various research studies have indicated the benefits of using big data methods in logistics and supply chain management, for example in effective logistics planning, scheduling, and tracking technologies (Govindan et al., 2018).

There has been a growing focus on data-driven decision-making in the literature since the 2010s as due to the availability of major data sets better decision-making became possible. Data is mostly raw data, from which information needs to be derived using different analysis techniques. Interpretation of this information provides a better understanding of the facts. This leads to better interpretation and better predictions. While in the past decision-making was mostly based on experience and intuition, the availability of different data sets from different sources allows decision-makers to make better-informed choices (Yang, 2020). A US survey carried out by KPMG and based on a sample of 400 CEOs highlighted that approximately

77% of them harbored mistrust about the quality of the data upon which their decisions are based (Vicario & Coleman, 2020). This shows the importance of collecting, combining, aggregating, and analyzing data for better decision-making.

2.2 Classification

Data-Driven Logistics operate using diverse devices and technology, such as Artificial Intelligence/Machine Learning, Big Data, Internet of Things/sensor technology, Blockchain, Robotization, and 3D printing. Before explaining all of them, it is useful to understand how data is collected and analyzed for decision-making, what the function of these devices and technologies are in it. Digital supply chain networks need to collect, process, communicate and store data from different sources. For this, it is necessary that the data is digital, that there is a possibility of electronical, real-time data exchange (Manners-Bell & Lyon, 2019).

Data-driven logistics operate according to a cycle, starting from a data source. The data source can be information technology systems, such as an Enterprise Resource Planning (ERP) system, sensors, such as temperature and humidity, operational tools such as machines and robots, news from social media, financial data such as transactions data. The data sources can come from within or outside the organization (Manners-Bell & Lyon, 2019). At this point, the data quality is an important challenge. Data analysis may seem to be smart, but it cannot recognize incorrect data or human errors. It is garbage in, garbage out. That is why it is better to use data collected by (well-calibrated) scanners and sensors. Providing valuable data largely depends on the level of automation, there should not be human interaction. The next step is storing the data. This step is often forgotten; however, it is essential that the source and processed data are stored safely. Data processing technologies aggregate and analyze the data and sometimes make decisions themselves or the decision is made by human interaction. The advancement of technology is making human interaction increasingly superfluous. Finally, the decision is performed, data processing technologies that make data-driven decisions and automated physical devices, which perform the actions, according to the decisions. Some technologies perform the combination of or even all of the tasks. The performing of the tasks is a data source themselves, which can be monitored by sensors and scanners and so the cycle repeats. The overview of the technology can be seen in Fig. 1.

According to this circle, the different technologies and devices can be classified. Big data, as opposed to big data analytics, is a data source and needs to be stored. Blockchain technology, being a database, operates as a data source, is dependent on data sources and sensors for data collection, it stores data, it analyses whether it corresponds to the rules of the transaction and can perform an action if smart contracts are included in it. Robots collect information and perform actions communicated to them. Sensor technology is limited to collecting data, while the Internet of things technology collects, stores, analyzes, and sometimes performs the decisions. Artificial intelligence (AI) and Machine Learning (ML) analyze data and help or

Fig. 1 An overview of the cycle of data-driven logistics

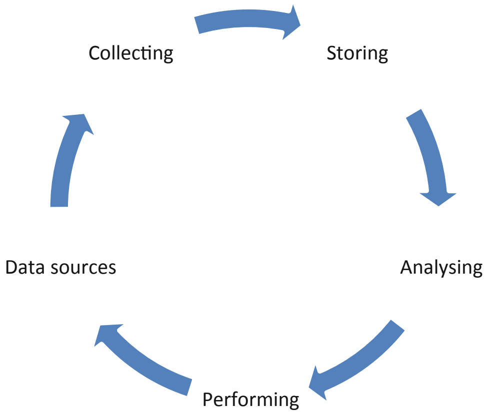

Table 1 The classification of the technologies and devices

Technology	Data source	Collecting	Storing	Analyzing	Performing
Big data	X	–	X	–	–
Blockchain	X	X	X	X	X
Robotics	–	X	–	–	X
Sensor technology	–	X	–	–	–
Internet of things	–	X	X	X	X
Artificial intelligence machine learning	–	–	–	X	–
3D printing	–	–	–	–	X

automate decision-making. 3D printing is a manufacturing process using major design data sets. Table 1 gives an overview of the classification of the technologies and devices according to their role in the cycle.

This classification is made in order to clarify the functions of different Data-Driven applications and devices; however, the division is quite artificial as there is a lot of overlap between them. Figure 2 gives an overview of the overlap.

The common denominator is Big Data. All the technologies either produce and/or consume major data sets. 3D printing is a part of robotics, as it performs an automated manufacturing action. Robots can communicate with Blockchain systems for example for the performance of an action automated by a Smart Contract. Robots heavily rely on sensor technology for example for their navigation, while blockchain only makes sense, when there is reliable data is stored in it for example collected by sensors. Sensor technology in its turn is a part of Internet of Things Technology, thus being a possible part of a Blockchain system, while Artificial Intelligence and Machine Learning are used to interpret and analyze the data from IoT systems, which in their turn can be a part of a blockchain system too.

A combination of these technologies results in cyber-psychical systems, which means that the physical assets are assigned a digital identity, which is communicated

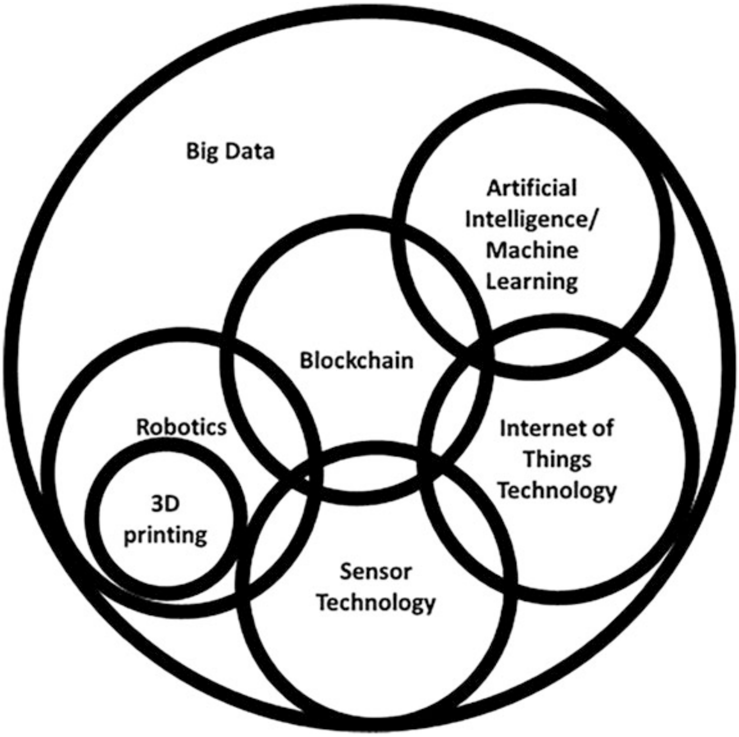

Fig. 2 Overlap between the technologies and devices

in the system. The physical and the digital identity are connected by tags, which can be read by scanners, forming an Internet of Things network, which is stored in a cloud. This way the physical and the virtual world are united in a joint system (Manners-Bell & Lyon, 2019).

2.3 Big Data

The availability of cheap sensors has made it possible to collect massive data sets. Big data can be characterized by five V's: Volume, Velocity, Variety, Veracity, and Value. Volume can vary according to industry and type of case. Velocity refers to the speed of data collection. By variety the diversity of the data is meant, it can consist of, for example, images, sensor or location data, or encrypted files. Veracity refers to the trustworthiness of data. Because of its quantity, it is impossible to evaluate the data quality manually; however, algorithms are getting increasingly better at screening data. Value is an important aspect of big data as analytics should make it possible to extract profits from the information derived from the data (Sinha et al., 2020). The value creation happens mostly by automated decision-making, which works best without human interference. The amount of data that is being aggregated is simply too much to oversee for humans. Big data analysis could be done on for example rerouting in the supply chain, planning preventive maintenance for transport units of determining the storing place for a product in a warehouse. The calculations are made by a set of algorithms without human interference (Manners-Bell & Lyon, 2019) Big data is used in maritime transport for example for maritime data management infrastructure, automatic identification systems, optimizing escape routes, e-navigation services, tracking unidentifiable ships, and to improve navigational strategies (Sanchez-Gonzales et al., 2019).

2.4 Blockchain

Blockchain is most well known as Bitcoin, which has recently grown steadily in value. However, Bitcoin is only one type of blockchain. Blockchain in general is a peer-to-peer ICT network that keeps records on digital transactions of assets using Distributed Ledger Technology (DLT) DLT means that there is no central party or intermediary, that would own the data, the exact copy of the dataset is stored at a number of computers, called nodes. At the nodes, the transaction history is kept. This, in combination with its protection by cryptographic algorithms makes it safe from tampering. Hacking is made almost impossible by the fact that the blocks of transaction history are connected to each other, which makes hacking one block useless, and that the records are verified by a consensus algorithm, which means that in order to make a change a minimum of 51% of the nodes needs to be hacked (Min, 2019). Blockchains can be categorized in different ways, they can be public or private, permissioned or permissionless. Bitcoin is the most often discussed blockchain, however, it is together with the other cryptocurrencies a particular application, a public permissionless system. Because of this, the number of its participants is almost limitless, which has consequences for its consensus algorithm, called proof-of-work. This algorithm, in order to guarantee the safety of the system, requires miners with major computational power who make the transactions possible. (Pilkington, 2015) As private blockchains are working with a limited number of nodes, they require a lot less computational power to make the transactions possible and no mining is necessary. For logistics applications the private permissioned systems are used most often; however, open systems are expected to be used in the future (Castellon et al., 2019; Paardenkooper, 2020). The most important advantages of blockchain networks are fast and cheap transactions, the becoming superfluous of intermediaries, supply chain transparency, and connectivity between supply chain partners. However, blockchain still faces some challenges too. For example, there is a lack of organizational readiness (Min, 2019). This can be explained by the fact that Blockchain technology has not reached maturity yet, it has just passed being a hype. According to Gartner (2018), it is likely to be applied widely in 5–8 years. On Gartner's curve, it is on its way to the trough of disillusionment, as it is increasingly recognized that blockchain is no magic solution to all problems (Gartner Hype Cycle, 2018). This is in accordance with Capgemini (2018). It explains that in 2018 the only a minority (23%) of Blockchain applications were developed past a proof of concept (Capgemini, 2018). Additionally, blockchain still suffers from the lack of scalability and financing (Min, 2019).

Blockchain has numerous applications, in health, education, privacy and security, business and industry, data management, finance, integrity verification, governance, and internet of things (Casino et al., 2019). In the academic literature, this innovation is often mentioned as an enabler of more efficient logistic processes. There are numerous possible applications, it can make paper documentation superfluous, combined with sensors it can be used for tracking and tracing, it has financial applications and it can help to automate processes using Smart Contracts. Kshetri (2018) identifies the benefits of the application of blockchain in the supply chain as costs, speed, dependability, risk reduction, sustainability, and flexibility.

An important aspect of blockchain within Data-Driven Logistics is its quality to store data in secured, time-stamped blocks, which makes it possible to trace transactions in a reliable way. As mentioned earlier, the quality of data is essential for the prediction accuracy of Big Data Analytics and for data sharing (Sinha et al., 2020). Blockchain gives the security that the stored data cannot be tampered with. However, blockchain has a weak point; the data can be manipulated before entering it into a blockchain. This emphasizes the importance of collecting information from reliable sources, such as scanners and sensors (Kopyto et al., 2020). A possible application of blockchain in maritime communication, which reaps the benefits of safe data communication provided by blockchain is described by Rahimi et al (2020) as a secured communication system for Unmanned Maritime Vessels (UMV) in order to make it impossible to hijack them (Rahimi et al., 2020). Other applications of blockchain for maritime shipping include an electronic Bill of lading and the earlier mentioned container tracking; however, these applications are not specifically meant for Arctic Maritime shipping.

2.5 Robotics

Robotics includes industrial automation solutions and self-driving cars, drones, and robots for different household applications. According to Merriam-Webster, a robot is "a device that automatically performs complicated, often repetitive tasks." Robotic systems are best known to be applied in warehouses (Sinha et al., 2020). Automating processes are meant to let robots perform repetitive, tiring, or dangerous tasks. This means that both humans and robots can do what they do best, robots are best in precise tasks and humans in problem-solving, creativity, and innovation (Manners-Bell & Lyon, 2019). Within logistics, robots are mostly used for handling and process operations. Robots can be autonomous, in this case, as mentioned earlier, Artificial Intelligence is included. This is still a developing area; however, there are already applications, such as autonomous surveillance robots for energy efficiency and leak monitoring. The introduction of robotics has been criticized as they will probably lead to a loss of employment, even though they will also create new jobs. At the same time, they can reduce, for example, annual maintenance costs by 10%, inspection costs by 25%, and downtime by 20%. Sinha et al. (2020) point out a few possible applications of robotics in combination with AI, of which the following are relevant for this chapter: Data-driven supply chain planning, route optimization and delivery planning using real-time data, automated risk monitoring, zero downtime by data-driven predictive and preventive maintenance and real-time tracking of cargo (Sinha et al., 2020). Application for maritime shipping includes the use of areal and marine unmanned devices to mitigate disasters, which is especially relevant in remote arctic waters with harsh weather conditions (Murphy & Arkin, 2017).

2.6 Sensor Technology

There is a large variety of sensing devices from simple thermo-sensors to advanced video systems. The main reason for the growth of IoT technology is that the sensors are becoming smaller and of affordable price. There are simple sensors with straightforward input–output systems, such as diverse temperature sensing devices, photoelectronic sensors, detecting light, warmth, distance, movement, voice, and pressure sensors. Another category of sensors is smart sensors, such as vision systems, which generate a more complex output. The data from different sources can be combined by sensor fusing, which makes information from the data. For example, it can indicate that somewhere a crowd is forming with temperature sensing. Time correlated data from multiple sensors can facilitate decision-making (Lea, 2020).

In maritime practice, sensors are used for tracking containers, checking, whether they have been opened and whether the transported goods are in good condition. Sensors can be attached to devices to perform predictive maintenance, do self-diagnostics, and if necessary order new parts themselves (Manners-Bell & Lyon, 2019). Sensor technology in Arctic Shipping can be used for diverse purposes, for example, to collect real-time data on weather conditions, the importance of which will be explained later in the chapter.

2.7 Internet of Things

The Internet of Things (IoT) is a term related to the use of sensors, technology, and networking to allow buildings, infrastructures, devices, and additional “things” to share information without requiring human-to-human or human-to-computer interaction. It can create richer data and deeper intelligence for all parties in a supply network. Sensors can be attached to appliances to perform predictive maintenance (Manners-Bell & Lyon, 2019). IoT technology is used in maritime shipping for example the tracking of containers in combination with Radio Frequency Identification (RFID) technology (Sanchez-Gonzales et al., 2019).

2.8 *Artificial Intelligence/Machine Learning*

Artificial Intelligence (AI) and Machine Learning (ML) contribute to automatization on the cognitive level thus they can be called cognitive automation, as opposed to robotics, which is physical automation. AI and ML date back to the 1950s when they were described as problem-solving without specific programming for the task. This definition is still used. Ever since they were developed further, with a dip in the 1960s to the mid-1980s. Since then, due to the emergence of neural networks, AI algorithms and applications have been growing steadily. AI and ML are often confused, the difference is that AI is a concrete application in a specific domain using ML to process data and produce insights independently from human interaction, while ML is a general adaptive, intelligent automated system. This means that ML is a part of AI based on statistics, mathematics, and visualization, using different algorithms to produce insights from big data (Manners-Bell & Lyon, 2019). AI is used in maritime shipping for example for dynamic positioning systems, navigational aids, alerts, and fleet risk management (Sanchez-Gonzales et al., 2019).

2.9 *3D Printing*

The connection of 3D printing to data-driven logistics is twofold; first, the printing process is fed by massive design data, second, 3D printing has a major impact on logistics. It is also called additive manufacturing, as opposed to derivative technologies, which remove parts of the material in order to make a product. 3D printing works by building a product layer by layer and was initially developed for making prototypes. 3D printing has numerous advantages, it can be set up fast and the manufacturing process itself is also quick, the production needs less tools, the products are lightweight, but still strong, the products are printed in one piece, and computer-aided designs can be optimized easily. Furthermore, because of its additive nature, it produces hardly any waste. 3D printing also minimizes supply chain risks as the supply chain is shortened, and the inventory can be reduced. The designs made this way can be easily adjusted to the individual needs of customers offering ample possibilities for customization. There are technologies available for a broad scale of materials, from plastic to polycarbonates. The most well-known technologies are selective Laser Melting and Direct Metal Laser Sintering. The adoption of the technology has still some limitations, for example, because it is difficult to control whether the locally produced products fit quality standards. 3D printing is a typical disruptive technology, that has the potential to revolutionize supply chains, especially that of spare parts. This means that instead of semi-finished or ready products, raw materials will be transported and the products can be manufactured close to the customers. According to a Deloitte report from 2018, 3D printing will be used most widely in the car, aerospace, and defense industry. Manners-Bell & Lyon

(2019) estimates that the market of 3D printing will grow from 13 billion USD in 2016 to 36 billion USD in 2021.

3D printing has a major potential in the shipping industry, as maritime assets are capital intensive and their downtime is costly. As ships are mostly far away from ports and they are moving, they are comparable to aircraft, aerospace, and defense units, where 3D printing has been applied before successfully. This is especially true for Arctic maritime shipping, which operates in remote areas. The fact that there is a possibility to produce spare parts on board or in close-by ports simplifies spare parts inventory management. Printing spare parts for ships has been tested extensively, a pilot project resulted in printing seven maritime parts in 2017 and the world's first-class approved 3D printed ship's propeller was manufactured at Damen Shipyard in the Netherlands in 2017. The US navy has also tested 3D printing for maintenance purposes. The technology is still improving and it is not yet used widely, however, it has major potential (Kostidi & Nikitakos, 2018). What 3D printing has to offer to Arctic shipping is on board in a close-by port printing of spare parts, which decreases repair costs, reduces risks and downtime.

3 Data-Driven Logistics and the Challenges of Arctic Shipping

This section describes five challenges of Arctic shipping and explains existing data-driven solutions for them, route choice, environmental friendliness, navigability, the prediction of the expected time of arrival, and risk assessment.

3.1 Route Choice

The Arctic Route provides a new alternative to the Suez Canal Route and rounding the Cape of Good Hope during a growing part of the year. Due to economic reasons, it is of major importance for shippers to choose the right route. The decisions are increasingly data driven as a lot of variables need to be included and there is a growing pressure on the profit marge in maritime shipping, caused by fluctuating capacity, increased shipper demands, and disruptions within the industry creating a volatile environment. Both shippers and forwarders are increasingly using information and analytics to drive their decisions. According to a survey in 2018 71% of shippers, said that real-time data analytics from third-party logistic providers help them make better choices, and 61% gave high value to the service providers' assessments of trade lanes. In the survey, nearly all logistic service providers and shippers indicated that data-driven decision-making is essential for the future of supply chains, and that big data analysis skills will be needed in the future for their supply chains (Govindan et al., 2018).

The route calculation needs to be made on more levels. The first one is, which global route to take: the Suez Canal, Cape of Good Hope, or the Arctic route. The second level is which particular Arctic Route to choose. The Arctic route has several advantages in comparison with the Suez Canal and the Cape of Good Hope route. Taking the Arctic Route can reduce the transport times between East Asia and Europe compared to the Suez Route by 10 days and the distance by approximately 5000 km (Zhang et al., 2019). Due to the reduction of ice, even the sailing times are expected to be reduced, by the mid-twenty-first century, summer season sailing times along the route via the North Pole are estimated to be only 13–17 days (Aksenov et al., 2017). The shorter transit time helps reduce fuel and operations costs. When speed is not a critical issue, a lower navigation speed can even cause more savings than the reduction of navigation time. Especially cargo bulk vessels can benefit from this as they depend less on precise schedules for loading, shipping, and unloading to keep costs down. An extra advantage of the Arctic route, as opposed to the Suez Canal route, is that there are no fees and there is no piracy on the Arctic Seas. However, there are more variables to consider to make a good analysis. The main costs for Arctic maritime transportation consist of fuel costs, ice-breaking costs, operating costs, and vessel depreciation costs. Fuel costs depend mainly on sea ice conditions and navigational distance combined with speed. The navigational speed can be calculated using the Arctic Transport Accessibility Model. As ice conditions are constantly changing, the calculation needs to be done over and over again (Zhang et al., 2019). The fuel costs can be reduced by fuel efficiency, for which there are several solutions. To reduce fuel consumption, shipping lines have taken various measures, including slow steaming, virtual (just-in-time) arrival at ports, weather routing, hull and propeller cleaning, engine maintenance, and optimization of the operating plan for each ship or fleet. Furthermore, there is an option to develop artificial neural networks that optimize fuel efficiency by advising ship captains on optimal speed. This measure can cause fuel savings of 7–8% (Du et al., 2019). The Arctic ice-breaking fee depends among others, on vessel size, ice class, and the chosen route. The main operating costs include loan costs, hull and machinery insurance, protection and indemnity insurance, repairs and maintenance, administration, and other costs. Vessel depreciation costs and operational costs can be increased by harsh weather and fog. The choice between the different Arctic Routes should be made based on data from remote sensing observations and predictions of global or regional models. The calculations are different according to ship type, and their ice classification. However, according to Zhang et al. (2019), cost-benefit analyses are still immature and need more research. He pleads for establishing a big data-driven Dynamic Optimal Trans Arctic Route system, which combines sensor and satellite data from diverse sources to determine the optimal route on the Arctic Seas (Zhang et al., 2019).

It can be concluded that decision-making for the route choice includes numerous variables and for making the choice a combination of a major amount of Big Data is needed. The cost-benefit analyses need to be developed further and there is a need for a Cyber-physical system that can combine sensor and satellite data for finding the optimal route on the Arctic seas.

3.2 Environment

Up till now the internal costs, the ones that are paid for, of Arctic Shipping have been discussed. However, the external costs, the ones that the shipping causes but does not pay for, are equally important. The most important external cost of Arctic Shipping is the cost of CO_2 emissions. In spite of the reduction of the distance, choosing the Arctic route does not necessarily make transport more sustainable, as making use of an icebreaker produces major black carbon emissions and produces local pollution, which contributes to the further warming of the Arctic seas (Zhang et al., 2019). According to Yumashev et al. (2017), even though large-scale commercial shipping on the Arctic Seas will be probably only possible from mid-2030 for bulk carriers and from 2050 for small and medium-size container ships climate feedback from Arctic shipping can cause $2.15–1400 trillion extra negative impact for global climate change until 2200, depending on the climate scenario, which is the third of the expected global economic gains projected for Arctic Transport. Reducing global emissions would slow down the melting of the sea ice, which would reduce the economic gains 3.5 times, but reduce the emissions five times (Yumashev et al., 2017). Thus, there is a tradeoff between the external costs of transportation and the commercial gains. At least improving fuel efficiency is of utmost importance, as maritime transportation is a major source of emission. According to the International Maritime Organization (IMO) in 2012 maritime ships emitted worldwide 949 million metric tons of CO_2 which is 2.7% of the total emissions (Du et al., 2019). According to Schøyen and Bråthen (2011) the choice for the Arctic Route, can more than double the fuel efficiency and deduce the CO_2 emissions by 49–78%. However, the saving in fuel will not necessarily lower the costs, because of other factors, such as higher building costs for ice-classed ships, service irregularity and slower speeds, navigation difficulties, greater safety risks, and most importantly, fees for icebreaker services (Aksenov et al., 2017; Schøyen & Bråthen, 2011).

Schroder et al. (2017) are optimistic about the relation between travel time and fuel consumption; they claim that it will cause major fuel savings which will only increase in the future. According to them, a contributing factor to fuel efficiency is the safe speed at areas with an ice coverage, which is lower than at the Suez Canal route. Slow steaming causes lower fuel consumption and exhaust gas emissions. However, outside September, the fuel consumption is higher for low ice class vessels. In order to predict future scenarios, the development of sea ice conditions needs to be explored (Schroder et al., 2017).

Concluding it can be stated that due to the reduction of distance, the choice for the Arctic Route on one hand causes a reduction of CO_2 emissions, and on the other hand causes extra emissions, as ice breaker services are necessary. Furthermore, the chosen speed has a strong influence on the emissions, which in its term depends on the ice conditions. In order to minimize the emissions, it is necessary to calculate the CO_2 emissions for the different routes well, so that a choice based on these external costs can be made.

3.3 Navigability

The route choice also depends on the navigability of the Arctic Seas. Due to global warming, sailing the Arctic Seas is becoming increasingly commercially feasible, especially in the summer season. However, harsh weather and sea ice still endanger arctic shipping, for example, ships can get trapped in ice. As the movement of sea ice depends among others on currents and winds, and other parameters, their location is continually changing. Therefore, a good prediction of the position, volume, thickness, and drift patterns of sea ice is of utmost importance (Zhang et al., 2019). Despite a general tendency toward less sea ice cover in summer, internal variability will still be large, and shipping along the Northeast Passage might still be disturbed by sea ice blocking narrow passages. This will make sea ice forecasts on shorter time and space scales and Arctic weather prediction even more important (Gascard et al., 2017). The prediction should be based on real-time datasets gathered by remote sensing devices. Large datasets of weather and climate modeling can help make a short-term forecast and long-term prediction on changes in Arctic sea ice and related weather and climate conditions. These can be included in dynamic maps, which helps the captains of vessels to avoid icebergs and sea ice, in order to reduce risks, save time and fuel and reduce operational costs (Zhang et al., 2019).

Concluding it can be stated that even though the navigability of the Arctic Seas is increasing, there are still major challenges caused by weather and ice conditions, which makes it important that these are monitored well to be able to make good predictions about navigability. For these predictions, a combination of massive amounts of historical and real-time data from different sources is needed.

3.4 Calculating the Expected Time of Arrival (ETA)

As mentioned earlier, presently, the Arctic Route is mostly used by bulk carriers. In order to make the Arctic Route attractive for break bulk and container ships, a precise calculation of the Expected Time of Arrival (ETA) is necessary. Container vessels depend heavily on as exact as possible scheduling, especially if they are a part of a Just-in-Time delivery system. Thus, for container transport, it is important to manage uncertainties. Uncertainty in maritime shipping can have five sources, the shipper, the customer, the control systems, carrier, and external environment. Delays are mostly caused by large and infrequent deliveries, delays in loading–unloading, variability of shipment time, damages, accidents, etc. (Urciouli, 2018). On the Arctic seas, ice movements and a safe traveling speed add to the delaying factors.

The calculation of the ETA consists of a predictive and a prescriptive phase. The predictive phase can start already when the order is placed and the bill of lading number is issued. Firstly, historical data about the proposed route is collected, which makes it possible to calculate the sailing time. The calculations need to be redone, when new information about the route becomes available. The adding of new data makes the results dynamic. Unlike for rail and road transport, for the calculation of maritime ETA, no topographic network information is available; consequently, it needs to be based on the dynamic scheduling and routing applied today by shipping companies. Based on this a proposed route needs to be identified. The next step is to collect historical information about the past delays of vessels on this route. Then again, real-time information needs to be collected based on a risk analysis of the historical information. Real-time information can be obtained from maritime traffic web services, which provide data gathered from satellite and terrestrial AIS that are publicly shared by vessels during the shipments. Further data that can be collected is GPS position, latitude and longitude, gross tonnage, deadweight, maximum and average speed, wind speed and direction, and temperature. Then the collected information about risks, weather conditions, and interrelationships with vessel performance are updated based on the real-time information collected. Machine learning algorithms can be used in this step in order to ensure that correlation factors with vessel performance are also updated. Delay times are estimated for both traveled routes and loading/unloading time necessary in seaports. The analyst initially computes the risk-free traveling times of vessels along the route, thereby proceeding by combining the risk-based traveling time estimations. Compute ETAs. The predictive or prescriptive algorithm will compute and return the estimated expected times of arrivals. The computed ETAs are then visualized in a dashboard to facilitate user interaction and decision-making (Urciouli, 2018).

This section has shown the importance of the correct calculation of the ETA. This complex sequence of calculations also needs massive data sets. The delay calculation can be made difficult by the lack of historical information on this route and for the Arctic route, the weather conditions also need to be taken into account, which means that the calculation needs to be combined with the calculations on navigability, mentioned in the previous section.

3.5 Risks Assessment

Due to the shrinking ice at the Arctic Seas, the maritime traffic of oil and gas, other cargo, fishing and passenger vessels is increasing, which impacts risk patterns. Risk assessment is essential to prepare a suitable level of emergency response. This involves both private and governmental involvement. The Arctic Council's Search and Rescue (SAR) Agreement divides the region into five areas that largely differ in environmental, ship traffic, and infrastructural aspects. An influential aspect is the upcoming Russian Arctic offshore oil and gas industry. Risk assessment estimates the amount of damage that can occur in a time period caused by a certain event. Risk is defined as the probability of an incident, multiplied by the damage that it causes. After determining and analyzing risks, a mitigation strategy should be developed. Risk assessment in the Arctic Region is complicated by the lack of historical data, and dynamic weather conditions. The most common risks are grounding, collision, which also includes colliding with sea ice, violence, which is rare in the region, and construction and engine failure. The cold climate can be especially harmful to humans in an emergency situation; the danger of hypothermia needs to be considered when planning emergency action, as even people in good body condition have problems surviving after 24 hours in a life raft. However, historical data on accidents does not involve occurrences, that have not happened yet, the so-called "Black swan" incidents, which are especially interesting for risk analysis. For this reason, a risk assessment can be performed best by the combination of quantitative, historical, and qualitative, derived from interviews with experts, information. For a reliable risk assessment according to Marchenko et al. (2018) the following variables are necessary: the density of maritime traffic, the capacity of fishing vessels, the size and number of cruise vessels, both for commercial and scientific purposes, the number of oil and gas exploration licenses issued, cross border government and industry regulations the efforts of international, local governmental and industrial efforts to increase safety and the availability of emergency response in the different areas. Risk assessment helps to plan the emergency response capacity, development of rescue equipment, communication, navigation, and coordination resources (Marchenko et al., 2018).

The role of Data-Driven Logistics for risk assessment and the development of an emergency response is twofold. An Artificial Intelligence system can help optimize risk assessment algorithms and robotized systems can assist in the emergency response, in tasks, which are too dangerous for humans. However, the prerequisite is again, the availability of data to perform these tasks.

4 Discussion

As explained above, Data-Driven Logistics can add value by collecting relevant real-time data by the Internet of Things technology, using sensors creating Big Data sets, analyzing the data using Machine Learning and Artificial intelligence, constantly improving the algorithms for decision-making on which is the best and most environmentally friendly route, the ETA and the risks. The potential for Blockchain can be best used in the maritime supply chain for electronic Bill of Lading, paperless solutions, circumventing middle man, generally improving the information flows. This application will reduce transaction costs and improve the maritime supply chain. However, this application is not specific to the Arctic route. In the field of robotization, the use of drones and 3D printing have special benefits for Arctic transport due to the harsh weather conditions, for dangerous tasks, collecting real-time data, delivering packages, producing spare parts on board of ships in remote areas. The operation of these assets can be partly driven by aggregated big data for example about weather conditions. For all these applications this data should be made available to all involved parties.

In order to finally answer the central research question of this chapter—How can Data-Driven Logistics create value for Arctic Shipping?—the potential of Data-Driven Logistics technologies and devices are matched with the major challenges or

Arctic Shipping. First, the question raises, what is value? Based on the section on the challenges of Arctic Shipping the value can be defined as optimization of distance, lead time, costs, fuel consumption, the minimization of CO_2 emission, and risks. In short, this means that the Arctic Route should be chosen when it is the shortest, fastest, cheapest, most environmental friendly, and safest option, as opposed to the alternative routes. This means that in order to spare the fragile environment of the Arctic Seas, this route should be only taken, when there is a strong economic and environmental case to be made for it. In order to make the decision, massive calculations need to be made, on different topics. Furthermore, the challenges are interrelated. The route choice has a major impact on the environment, navigability influences the route choice, just like the calculation of the ETA. Risk prediction also influences route choices and insurance fees, which on their term have an impact on transport costs thus also on route choice. In order to be able to make a decision on these complex issues, both historical and real-time data need to be combined from different sources. The currently available data are not sufficient for this.

However, the question is, which party is going to collect and disclose this data? To start with, setting up such a cyber-physical system requires major investments. Data collection is possible by satellites, onshore and offshore radars, and different sensors attached to maritime devices. The data should be stored and made available for multiple parties. However, as data are increasingly considered a major asset that can generate comparative advantage to parties against their competitors, why would parties make it available free of charge to their potential competitors? This is an economical consideration. The environmental consideration is that in order to decrease CO_2 emissions to the minimum, all parties should be able to optimize their processes, which is opposite to the economic argument. There should be a compromise found in this question, in a way that all stakeholders can benefit, both companies and the global environment. The goal is, as Urciouli (2018) proposes: "The ultimate goal is to develop digital ecosystems combined with sensor data to allow companies, including suppliers, logistics service providers, transport carriers, freight forwarders, manufactures to jointly and openly share data, improve visibility, and optimize operations" (Urciouli, 2018). In this case, it includes a lot more parties, for example, oil companies, shipping lines, local and international organizations and authorities. Further research is needed on how to operationalize this, including an underlying business model.

5 Conclusion

In this chapter, Data-Driven Logistics is defined, its function is explained and seven of its parts are elaborated on, Big Data, Blockchain, Robotics, sensor technology, Internet of Things, Artificial Intelligence/Machine Learning and 3D Printing, followed by a description of five major logistic challenges of Arctic Shipping, Route choice, environment, navigability, calculating the expected time of arrival and risks and their possible solutions. As shown, in the case of all of the five challenges, complex calculations need to be carried out for an optimal decision-making. These calculations are based on economic considerations and concentrate on the internal costs of transportation. To calculate the external costs, especially the CO_2 emissions, require more, even more complicated calculations. These calculations are based on the combination of different data sources, both historical and real-time; however, the insufficient availability of the data obstructs the optimization of the processes. The chapter concludes that in order to optimize the shipping process, a cyber-physical system is needed in which both historical and real-time data is made available to parties, to be able to make decisions on shipping routes, which will both serve their economic considerations and spare the environment as much as possible. Further research needs to be done on the operationalization of the cyber-physical system. Notwithstanding, a case could be made that the whole process of global supply chains could be changed by reshoring production, and place it close to the consumer, by for example customized 3D printing, which would change global production and consumption patterns in a way that a lot less emission creating transport is necessary. That way, the vulnerable Arctic environment does not need to be compromised at all.

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