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Hans-Dietrich Haasis, Hapsatou

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Editor:
Prof. Dr. Lars Hornuf
Phone: +49(0)421 218 66820
E-mail: hornuf@uni-bremen.de

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Digital Transformation of Maritime Supply Chains Focusing on Ocean Shipping, Port Management and Hinterland Connection

Hans-Dietrich Haasis[1] and Hapsatou[2]

Abstract For many years, shipping companies, terminal operators, port industry actors and logistics service providers have been successfully engaged in innovating their assets, processes and business activities. The best-known key innovation is the introduction of the standardized container. This innovation has been the basis for other innovations such as supply chain management, just-in-time delivery, port integration, ship size development and linked hinterland connections. The business world is abuzz with talk about automation, self-control, cloud logistics, electrification, green processes and dematerialization. However, the most important key innovation now and for the foreseeable future is related to digitalization and digital transformation of business activities. Digital transformation is widely understood as the process of implementing digital technologies and supporting capabilities to create digital business models. In this context, a rethinking of previous approaches to communication, coordination and cooperation between stakeholders along the supply chain is appropriate and necessary. The purpose of the present chapter is to reflect the opportunities and challenges related to this digital transformation, focusing on ocean shipping, port management and hinterland connectivity. This chapter aims to identify and characterize expectations, opportunities and peculiarities of this transformation, and to sketch a picture of the future. Particular attention is given to the influence of digital gaps, cultural differences and the power of data.

9.1 Innovation in Maritime Business and Transportation

The maritime economy and the transport industry have always been an innovative economic sector. For over half a century, shipping companies, terminal operators, port industry actors and logistics service providers have been successfully engaged in innovating their assets, processes and business activities. The industry has thus shown its innovative potential for change and adaptation and its ability to react to new market and technological conditions (Buer et al., 2019; Heilig et al., 2020).

Here, innovations are understood, as usual, to be innovations and changes in the company through the application of new ideas and techniques. In business

[1] Hans-Dietrich Haasis, Universität Bremen, Chair in Maritime Business and Logistics, Bremen, Germany, e-mail: haasis@uni-bremen.de
[2] Hapsatou, Universität Bremen, Chair in Maritime Business and Logistics, Bremen, Germany, and Université de Ngaoundéré, Cameroon, e-mail: hapsatou@uni-bremen.de

consulting, innovations are generally understood to mean the introduction of new or significantly improved techniques, products, services, processes, or organizational principles.

Well-known innovations in logistics and transport include the pull principle and just-in-time delivery (both introduced by Taiichi Ohno as core aspects of the Toyota Production System), and the concept of anticipatory shipping (developed by Amazon) which uses data to predict the shopping behavior of customers and to automatically send them the corresponding products. The best-known and probably the most visible innovation has been the introduction of the standardized container by Malcolm McLean, considered the "father of containerization." It is thanks to his personal commitment and capital that the container established itself worldwide as a standardized transport container in the middle of the twentieth century. The container is becoming the engine of globalization and revolutionizing the world economy (Tran et al., 2017; Tran & Haasis, 2015). In 2004, McLean was inducted into the Logistics Hall of Fame. This innovation can be credited for further innovations such as supply chain management, just-in-time delivery, port integration, ship size development and linked hinterland connections.

There has been increasing discussion about automation, self-control, cloud logistics, electrification, decarbonization, zero-emission processes and dematerialization. Despite the importance of all these innovations, digitalization and digital transformation of business activities and processes are considered the most significant since the introduction of the container. This has consequences for all business activities and business developments, presenting a wealth of challenges and opportunities for strategic and operational change management (Board of Academic Advisers to the Federal Minister of Transport and Digital Infrastructure, 2018; DHL Trend Research, 2018; Dujak & Sajiter 2019; Federal Ministry of Transport and Digital Infrastructure, 2019; Lind et al., 2021).

Austrian economist Joseph Schumpeter, the author of "Theory of Economic Development", published in 1912, spoke of "creative destruction" and the replacement of an existing one by something better. This characterization can and should even be transferred to the current activities in companies in connection with digitalization and digital transformation.

As known, digital transformation is the process of implementing digital technologies and supporting capabilities to create digital business models. While digitization can be defined as the action to convert analog information into digital information, digitalization concerns the changing of tasks and processes in an organization with the objective of reconfiguration assets to develop new business models. Digital transformation goes one step further, and can be understood as a process of adoption and implementation of emerging technologies in all aspects of operations, with far-reaching implications for systems, from companies to entire supply chains (Haasis et al., 2015; Heilig et al., 2020; Heilig & Voß, 2017; Jahn & Saxe, 2017; Lind 2021). Changes through digital transformation include digital connectivity, cross-company collaboration, changes to business ecosystems, digital service innovations and the use of platforms as enablers. In this context, a

rethinking of previous approaches to communication, coordination and cooperation is appropriate and necessary.

With regard to process control management and information management between partners in maritime supply chains, there is substantial potential for improving efficiencies. Such improvements can be obtained through better coordination along the maritime driven supply chain, by region-comprehensive cluster-orientated cooperation between seaports and port industry actors, and by an innovative shifting of control mechanisms into the cloud. To date, the options of modern information and communication technologies have been considerably underutilized. The reasons are related to high transaction costs and the necessary change management, as well as to unforeseeable consequences of the transfer of business data (Board of Academic Advisers to the Federal Minister of Transport and Digital Infrastructure, 2018; Haasis et al., 2021).

This shows that considering the design and operation of supply chains along international or intercontinental freight transport routes will be essential not only for spatial planning and construction industries. More than ever, it is important to invest in the provision and use of information, and in the development and assessment of innovative and trustworthy cooperation and business models (Haasis et al., 2021; Lind et al., 2021).

9.2 Present Developments and Trends

A visionary description of the future of the logistics and transport industry is provided by the Logistics 2030 Innovation Programme of the German Federal Ministry of Transport and Digital Infrastructure (2019). Today the industry and its actors are on a visible path there.

Economic, reliable and secure maritime supply chains are essential for a functioning national and global economy. Those involved in ocean shipping, port management and hinterland connection therefore have an essential role in the sustainable development of the economy and society, highlighting the importance for them to seize the opportunities of digitalization and digital transformation of processes and business models.

Efficient and well-developed maritime supply chains are also important for the international networking of essential production sites with procurement and sales markets. Their design and expansion aim to ensure economic accessibility for supply chains, to increase the attractiveness and visibility of the regions along transport corridors, to increase the reliability, cost-effectiveness and safety of freight transportation, and to ensure a future-oriented sustainable development of economic regions (Jahn et al., 2020; Jahn & Saxe, 2017; Kersten et al., 2020).

To support, test and develop innovative solutions for the digitalization of the maritime supply chain, digital test fields have been established for the German seaports in the German Bight for some time by the Federal Ministry of Transport and Digital Infrastructure. Within Europe, such developments can also be found in

the port of Antwerp and the port of Rotterdam, and outside Europe in the port of Singapore and in the port of Dubai. Capabilities of test fields should be developed to demonstrate, for example, how port processes can be carried out partially or fully automatically, how their control can be shifted to the cloud, how traffic and handling processes can be self-controlled, and how waiting times and congestion can be avoided.

Platform solutions are also currently being developed and even made available to make the transfer of data along the maritime supply chains as easy as possible in the sense of a sharing economy. Examples include the collaboration between Maersk Line and IBM (see: www.tradelens.com) as well as between CMA CGM and Alibaba (see: www.lloydsloadinglist.com) for the development of platform-oriented digital supply chain management. For several years now, the funding programs IHATEC (see: www.innovativehafentechnologien.de) of the German Federal Ministry of Transport and Digital Infrastructure have made a significant contribution to this development.

Various information and communication systems have been in use in German seaports for several years. These include systems for the automatic identification of ships, controlling traffic processes and port telematics; port community systems; access control systems for security-relevant areas of the port in accordance with the International Ship and Port Facility Security Code; and systems for shipment tracking using tracking and tracing for containers (Buer et al., 2019; Heilig et al., 2020; Heilig & Voß, 2017; Wan, 2021).

However, it is now time to undertake the process of implementing digital technologies and supporting capabilities to create digital business models. Thus, digitalization should focus both on digital infrastructure and on digital services. This entails more than the introduction of paperless procedures and extends to port community systems, terminal operating systems and automated procedures, for example implemented in combination with automated guided vehicles. The time is ripe for the implementation of "smart" procedures enabled by the Internet of Things, big data, business analytics, cloud computing and cyber-physical systems. These smart procedures allow object-to-object communication and decentralized control of processes.

By the way, this topic is also a high priority goal in China in connection with the Belt and Road Initiative. The prioritization of digital connectivity through the integration of the Internet of Things and e-commerce was already put forward in a white paper prepared by the National Development and Reform Commission in 2015. This policy of Digital Silk Roads was outlined by Lu Wei, the director of the Cyberspace Administration, at the China–EU Roundtable for Digital Cooperation in 2015, where he announced, "We can build a digital silk road, a silk road in cyberspace" (Brown, 2017).

In realizing smart procedures and object-to-object communication, it is interesting to note that many of the associated decision-making processes involve assignment problems. For these problems, existing operations research solutions can be applied, for example for the allocation of containers to ports according to

conditions, for the assignment and shifting of services to selected ports, for the assignment of terminal operations to vessels, for the assignment of hinterland connections to containers, and for a multi-port and multi-terminal profit allocation based on transfer payments.

Smart procedures and new digital service innovations relevant to a smart service port include the re-direction and re-assignment of vessels to terminals and/or seaports, berth allocation and quay crane scheduling, container storage and handling in the yard, truck appointment and ramp management, interterminal transportation and empty container management, ship announcement and terminal preparation, and gate drive-through management (Buer et al., 2019; Fibrianto et al., 2020; Jahn & Saxe, 2017; Kersten et al., 2020; Lind et al., 2021; Philipp, 2021).

In view of bottleneck situations caused by port operations and hinterland transports and the associated focus on investments in port development and infrastructure provision, cooperation between seaports from time to time may already be an option today, but it will certainly be an option in the future. This may lead to such advantages as shorter wait times in front of gates and terminals, better usage of straddle carriers and container yard capacities, and more time-efficient transshipment processes. Such competitive cooperation (or "coopetition") can be supported by the installation of a web-based digital service and data platform covering the data exchange between all cooperating seaports (Haasis & Elbert, 2018; Hoshino, 2010; Lind et al., 2021; Notteboom et al., 2009; Philipp, 2021; Stamatovic et al., 2018). In general, the ports are competitors; however, for providing efficient and economic digital solutions, the ports could cooperate on a digital level. Areas with potential for digital service innovations based on collaborative decision-making include yard and container lot management, ship announcement after re-direction and terminal preparation, gate drive-through management, and flexible and conditional supply chain management. It should be kept in mind, however, that problems could arise in combination with dedicated terminals, loading plans, customs processes, container fumigation, or the assignment of trucks (Board of Academic Advisers to the Federal Minister of Transport and Digital Infrastructure, 2018).

Artificial intelligence will also play an important role in transforming processes related to ocean shipping and port management. The development of a "smart ship" (a fully digitized, autonomous ship without a crew) is one of the major goals, with a prominent example being the container ship Yara Birkeland, with a capacity of 120 TEU, launched in 2020 (see: www.yara.com).

9.3 Future Studies and Vision on Digital Maritime Supply Chains

One vision for digital maritime supply chains, ports and hinterland connections is the Silicon Economy Logistics Ecosystem proposed and headed by the Fraunhofer Institute IML in Dortmund (see: www.iml.fraunhofer.de). According to the managing director of the IML, Michael ten Hompel, the philosophy behind this eco-

system and the related logistics and industrial value creation is characterized by the following issues: orchestrate instead of producing; together instead of alone: collaboration und coopetition; share instead of controlling: sharing-economy; agile instead of pipeline: platform economy; ecosystems instead of hierarchy: crowds und communities; and open instead of proprietary: open source, open innovation.

However, the question remains how the individual parts of the ecosystem might fit together. Examples of parts or services of this ecosystem include: automated ETA forecast with artificial intelligence, digitized pallet exchange, electronic bill of lading, e-navigation and emulation control, digital customs clearance using blockchain, and smart contracting for import and export processes (Chaising & Haasis, 2021; Heilig et al., 2020; Jahn et al., 2020; Jahn & Saxe, 2017; Kreeb & Haasis, 2017; Lind et al., 2021).

Potential solutions might include a container ship deciding autonomously the best terminal and berth for container transshipment, or a vessel moored at a quay independently controlling the terminal operations for its containers. Or a retailer might control the transshipment of requested containers through hinterland transportation to the demanding shop based on the specified demand of customer products. The container itself might even self-controls some of its operations on the container yard.

Future cloud-based applications may be operated on a digital web-based service platform across locations, upgraded on the basis of port community systems and terminal operating systems. The platform could have the characteristics of an essential facility. The related process model could be developed further towards a port-as-a-service model and the port than can be called a smart service port (Board of Academic Advisers to the Federal Minister of Transport and Digital Infrastructure, 2018; General Assembly of Terminal Industry Committee 4.0, 2021). For example, GAIA-X can be seen as a platform for the use case of supply chain collaboration, mainly for the automobile industry and for mobility (see: www.data-infrastructure.eu). It represents the next generation of data infrastructure for Europe.

Automation is already a current development, for example in selected terminals in the seaports of Hamburg, Busan, and Dubai. Visions of a future “seaport 4.0” can be seen in the Next Generation Port 2030 in Singapore or the well-known TradeLens initiative of Maersk and IBM based on a blockchain-enabled digital shipping platform. Based on the familiar principle of the landlord model, the digital platform could be provided as standardized public infrastructure, and the service applications could reflect that of customer-orientated private suprastructures. Then, algorithms and new data-driven applications for berth allocation, container yard operations, storage management and crane scheduling policies can be shifted towards cloud solutions. Of course, similar considerations can be made for freight villages and, in general, for logistics hubs. In the future, services could be offered by new internet enterprises powered by data sources (Haasis et al., 2015; Haasis et al., 2021; Jahn & Saxe, 2017; Lind et al., 2021).

To understand what is likely to continue and what could plausibly change is topic of the scientific research field of future studies. In this context, considerations can be made as to how digital service innovations, new business models and cooperation arrangements can be identified and deliberated.

Such considerations have been made for the aforementioned seaport of Singapore, which will feature a maritime single window, automated terminal, automated quay and yard cranes, automated guided vehicles, automated truck pilots, autonomous ships, e-navigation, a vessel traffic management system, unmanned aerial vehicle, and just-in-time planning and coordination systems. The port, located in Tuas in Singapore and operated by PSA International, is expected to be completed by 2040, with a total capacity of 65 million TEU. Construction commenced in 2019.

Blockchain technology is emerging from its first applications in cryptocurrency and is now likely to have significant impact across almost all industries (DHL Trend Research, 2018; Dujak & Sajter, 2019; Lind et al., 2021; Wan, 2021). In the context of logistics and ocean shipping, many projects are in progress applying blockchain technology to supply chain efficiency, security and transparency, as well as the handling of administrative processes. For data transfer along the maritime supply chain, as well, scientists and business experts are increasingly focusing on developing blockchain solutions.

For example, in 2020 Alibaba joined the International Port Community Systems Association's blockchain bill of lading initiative (see: www.ipcsa.int). This project aims to standardize blockchain applications in logistics and e-commerce. Alibaba, LOGINK and IPCSA have created a working group to elaborate innovative digital logistics solutions. LOGINK is China's information network for sharing logistics data. COSCO shipping has signed a deal with Ant Group and Alibaba Group to examine applications of the Ant blockchain technology within the global shipping industry.

Of course, these developments will have consequences for the employment situation in maritime business, in seaports and terminal operators as well as logistics companies. Frey and Osborne (2013) have found that most workers in transportation and logistics occupations, together with quite a number of office and administrative support workers, are likely to be displaced by automation and digital solutions. In line with technological developments, more and more transportation and logistics processes are becoming automated and self-controlled. Algorithms for big data analytics are also rapidly entering domains reliant upon storing or accessing information (Frey & Osborne, 2013). However, this can also be a great opportunity to counteract the shortage of skilled workers in certain areas of activity.

Whatever the future may hold, there is no doubt that there will be an impact on both employment prospects and employment requirements – and impact for which not just companies in the shipping and logistics sector but also chambers of commerce should be prepared.

9.4 Digital Divide and Decision Culture

The development in the economy towards more digitalization and more digital transformation is encountering at least two issues worldwide: the digital divide and decision culture. Whether these factors are taken into account will determine the extent to which the gap between industrialized and developing countries continues to grow or can be closed. The ICT Development Index of the International Telecommunication Union clearly shows the differences between countries in terms of the availability, utilization and further development of modern information and communication technologies (see: www.itu.int). The question remains how to handle the digital divide between companies and between regions. Therefore, related market consequences for international maritime supply chains and logistics hubs such as seaports and freight villages must be observed, analyzed, and challenged (Haasis et al., 2021). We must also decide about the extent of external web-based control. This is a thrilling and challenging topic that should be addressed in the context of the ethics of logistics.

The decision-making behavior of the actors involved in supply chains is largely shaped by their social, political and cultural dispositions (Baumann et al., 2013; Hofstede et al., 2010). This has an impact on the willingness and scope of a digital transformation of processes, as well as the success of digitalization measures. Different cultural practices can have an impact on the design and control of logistics chains and their impacts on trade and social coexistence. The implementation and operation of maritime supply chains must therefore consider decision-makers and logistics service people with different cultural backgrounds. By the way, the indicators used for determining the Logistics Performance Index, a benchmarking tool published by the World Bank (Arvis et al., 2018), are largely dependent on people's decisions. This is exemplified in the widely recognized and accepted consideration of public holidays. But it should also be noted that in some regions, contracts are just a general commitment to do business together and are less meaningful than personal relationships between individuals. Or if you think there is a standard service contract with a warehouse service provider, which however contains a "change in circumstances" clause, this essentially means that the contract is not legally binding (Fawcett et al., 2004; Smyrlis, 2004).

To barriers to ensuring time-efficient and reliable processes are not limited to different languages, time zones, and measurement units, but also include behavior patterns and contextual interpretations. In the implementation of logistics information systems and decision support tools, it is not uncommon, mainly in developing countries, to hear something like: "We were used to work without pressure and postponing some tasks for later because the system was not synchronized. Everyone was working for themselves without pressure. However, with this synchronized system, work must be always done instantaneously so that operations can take place on time. As a result, we feel that we are under pressure from the system and that we are no longer acting according to our own free will, but that we are subject to the system." This statement highlights that cultural aspects must

be considered as part of maritime supply chain decisions to avoid misunderstanding and miscommunication, which is known to increase uncertainty and risk and therefore costs, and can lead to miscalculation in supply chain decisions (Baumann et al., 2013; Haasis et al., 2021).

Heterogeneity in cultural backgrounds may thus influence the efficient and reliable execution of logistics processes, as well as decisions on how these processes may be digitalized. On the other hand, these backgrounds may result in the transfer of ideas, experiences and knowledge between the regions and people along the international maritime supply chains, as has happened in the past. Thus, in addition to focusing on the supply chains of freight and goods and the corresponding digitalization and digital transformation, it is also enhancing and worthwhile to consider the cultural chain of ideas and knowledge to increase the understanding and appreciation among decision makers and others who are communicating, cooperating and working together (Haasis et al., 2021).

9.5 Power of Data and Consequences for Business Models

As discussed above, in future, maritime and logistics services could be offered by new internet enterprises powered by data sources and by digital control of processes. Data and process owners of today may be substituted by tomorrow's unknown owners. Thus, it is not only a question for example a member of the maritime blockchain community of whether to be or not to be. The questions are who will provide the digital business models on demand in the future, who has the data and process power, and how to handle the unevenly distributed access to data and thus the unevenly distributed power in competition between companies and between regions. From a conventional point of view, this could be the communications provider, the data provider, the automobile industry, the energy supply company, the city administration, the logistics infrastructure provider, the ocean shipping company, or the logistics service provider (Brinker & Haasis, 2020; Jahn et al., 2020). However, it could also be that logistics service providers and terminal operators will be downgraded to puppet figures in the future. Therefore, in terms of an early warning system, digitalization-related market consequences for seaports and the other actors in the maritime supply chains must be analyzed and challenged in good time.

As early as 1976 Joseph Weizenbaum, who has been awarded an honorary doctorate from the University of Bremen in 1998 in recognition of his services to computer science and the social responsibility of computer scientists, published his famous book “Computer Power and Human Reason: From Judgement to Calculation”, in which he criticized the power of computers and the “impotence of reason” (Weizenbaum, 1976). Weizenbaum warned against the wrong use of information and communication technology. It may be prudent to extend this wisdom to the power of digital processes and the power of data.

The consequences for business models are clear. Due to the power of digital processes and data, the conventional differentiation – 1PL for cargo owners focusing on manufacturing or retailing, 2PL for carriers and forwarders providing transportation as a service, 3PL for logistics service providers providing logistics (mainly contract logistics) as a service, and 4PL for lead logistics providers and consultants focusing on supply chain management – must be extended to 5PL for big data driven logistics providers focusing on demand chain management, and 6PL for digital internet logistics providers realized by cloud logistics. Ultimately, the control and decision-making power can and will be shifted towards software on the internet that is available 24 hours a day, every day, regardless of weekends and holidays.

As discussed above, this is an essential development because many decisions in ocean shipping, port management and hinterland transportation are assignment problems for which easy-to-use and powerful algorithms have been available for years. Used with the right data, these algorithms can be used within software systems provided on demand on the internet. This also highlights the need for and importance of digital data sharing. Such transformation will create opportunities for data analytics, digital innovations to support transport processes, and learning systems that enable better decision-making. This will give rise to new startups within the market of shared logistics, as seen in the case of Cargonexx or Sennder.

On a global scale, interoperability between the software and decision systems is necessary. It is therefore important to develop, test and shape frameworks, for example the Silicon Economy Logistics Ecosystem designed by Fraunhofer IML. Platform technologies characterized by sharing principles, interoperability, data protection and innovative digital services will play an important role in such ecosystems. For example, the platform DataPorts may provide a trusted and secure environment for all actors operating in the diverse maritime supply chains involved in European seaports (see: dataports-project.eu). Using this data platform across connected digital ports would support the transition to cognitive ports, which will open the way to new capabilities: real-time control of operations, streamlined decision-making, accurate prediction of events and situations, and prescriptive analytics. Examples include the aforementioned blockchain-enabled digital shipping platform TradeLens, jointly developed by A. P. Moller–Maersk and IBM, and a similar development realized by COSCO Shipping, Alibaba, and the Ant Group.

Of course, this implies increased shifting of power in maritime driven supply chains. Needless to say, monopolistic platforms put competing market players and business models at risk, with such consequences as loss of data sovereignty and loss of direct customer relationships, as well as unequal distribution of process and market power. For this reason, the European Commission is currently discussing adoption of the Digital Markets Act, a legislative proposal aimed at ensuring competition in digital markets.

9.6 Synopsis and Conclusions

The maritime industry and the logistics community have shown their innovative potential for change and adaptation and an ability to react to new market and technological conditions. Now and in the near future, digitalization and digital transformation of maritime supply chains will be the most powerful and challenging forces of innovation. The purpose of this chapter has been to reflect the opportunities and challenges related to this digital transformation, with a focus on ocean shipping, port management and hinterland connectivity.

Knowing that world trade flows are interconnected and changeable, the logistics industry must ensure distributed production and supply in a dynamic environment. The aim here has been to identify and characterize expectations, opportunities and peculiarities, as well as to sketch a picture of the future. Particular attention has been given to the influence of digital gaps, cultural differences and the power of data.

Access to digital processes, innovations and communication platforms is essential to increase the efficiency and reliability of logistics processes and supply chains worldwide, so now is the time to act with foresight. It is necessary to make innovation and development visible and transparent, to learn from each other, and to take people and employees with them on this journey. In this context, major changes are to be considered and established norms to be questioned. It will also be important to maintain vigilance toward monopolistic tendencies.

As this chapter points out, access to digital processes varies from company to company and from country to country, and it remains to be seen who will provide the digital business models and who possesses the data power. A stronger focus on the people and their cultural differences is thus essential to supporting the improvement of the logistics performance of companies and regions and their corresponding successful digitalization and digital transformation.

In the context of maritime supply chains, a robust discussion of digitalization and digital transformation may motivate not only investment in infrastructure and technology but also investment in knowledge, education, training, communication and understanding. As Hajo Schumacher implores in the column *Netzentdecker*, it is essential that we expand the social market economy to include the ecological and the digital, and that we interlink modern technology and educational ideals. The focus could be on the Bhutan strategy. From now on, every political decision should be appraised by asking: Is the well-being of the individual and the community being promoted? (Schumacher, 2020). Perhaps now is the time to think more deeply about an ethics of logistics.

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