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The greening of hinterland corridors: towards a research agenda

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Introduction

According to Rodrigue and Notteboom (2020), the definition of the hinterland is 'a land area over which a port (or a transport terminal) sells its services and interacts with its users. Depending on its nature, the port (terminal) serves as a place of convergence for the traffic coming by roads, railways, inland waterways or by sea/fluvial feeders'. Due to congestion and lack of space in port areas, inland hubs have been constructed along waterways and railways, providing reliable connections with the seaports. Around these inland terminals, logistic zones have emerged, offering additional services such as customs clearance, empty depots for containers, value-added logistics, and attracting regional or global distribution centers (Caris et al., 2014). The added value of the associated flows of goods and logistics has been demonstrated for the economic added value of the Netherlands (Ministery of Infrastructure, 2017). The importance of hinterland connections is shown in Parola et al. (2016) where, besides the port costs, the key drivers for port competitiveness are 'hinterland proximity' and 'hinterland connectivity. Hinterland proximity refers to the geographical proximity of the main hinterland markets served by a seaport and hinterland connectivity refers to the efficiency of inland transport networks.

An important concept within the hinterland connections is the so-called 'corridor' (see e.g., Witte et al. 2012 and Witte et al. 2013). The main components of a corridor are usually a seaport, waterways, road and rail networks in the hinterland, inland ports or bulk ports, and border controls. In a corridor, all modes of transport follow the same spatial orientation and serve the most important agglomerations and economic centres within their route. A distinction can be made between corridors according to their scale, from corridors within and between regions to corridors that stretch and connect entire continents to Europe. In addition, the approach to the corridors varies from coordination and development of the infrastructure to the coordination of spatial trade and economic developments (ITF, 2022). As Wiegmans & Janic (2019) expected, the corridors serve (new) supply chains by attracting more voluminous freight transport demand primarily from road at the continental (European) and from deep-sea shipping at the intercontinental (Asia-Europe) scale. The Silk Road initiative is clearly a proof of this.

The Trans-European Networks in the fields of Transport, energy, and telecommunications (TEN-T) are represented by nine Core Network Corridors, which are identified to streamline and facilitate the coordinated development of the Core Network. The policy of developing TEN-Ts has been an integral part of the European Union's policy since the last decade of the 20th century. In addition, the Trans-European Transport Networks (TEN-T) are related to the European Union's policy toward the development of road and rail infrastructure, inland waterways, maritime routes, airports, and road-rail terminals across Europe. Union guidelines for the development of the trans-European transport network define that the TEN-T includes a comprehensive network covering all European regions, and a core network that relates to routes that connect the most important points of the comprehensive network (EU, 2013). In addition to building the necessary infrastructure and improving the existing one, the objective of the TEN-T policy is to remove bottlenecks and eliminate technical barriers that exist between the transport networks of EU member states, as well as to strengthen the EU's social, economic and territorial cohesion and to contribute to a single European transport area. According to ADB (2008) a corridor is a holistic strategy that improves and enhances investments in transport, energy, and telecommunications in the corridor. A highly efficient transport system means goods and people movement without excessive cost or delay. These corridor improvements promote further economic growth and regional development, thus contributing to poverty reduction.

The TEN-T policy also includes the promotion and adoption of innovative digital technologies and the use of alternative energy sources in transport. According to Panagakos (2016), an extension to the corridor concept is the green corridor which has gained popularity as a policy tool that enhances the overall environmental sustainability of transport by improving the competitiveness of the railway and waterborne modes that exhibit better environmental characteristics than road haulage (Panagakos, 2016).

On a Dutch national scale (Ministery of Infrastructure, 2017), one can observe that the focus of the policy must be on better use, sustainability, and optimization of all modalities, by removing remaining infrastructural bottlenecks on the corridor itself, improving multimodal connections in nodes, digitization, and data management and the application of innovative measures.

To support the development of green corridors a research group Greening Corridors is subsidized by Taskforce for Applied Research SIA to develop a knowledge infrastructure of 5 Applied research Universities together with practice partners, universities, and knowledge institutes. The main objective is to develop and promote sustainable logistics corridors and in the meantime radically reduce the emissions of CO_2 and other harmful substances from the logistics sector with new technologies focused on the hinterland connections of North Sea Port, Rotterdam, Amsterdam, and Antwerp. The research will focus it centrally on 3 themes: (1) better usage of capacity; (2) clean, safe, and autonomous modalities; (3) Digitalization in the supply chain.

Figure 1 Research themes with Greening Corridors

Theme 1
Better usage capacity
- Synchromodality
- Sharing capacity planning
- Smart maintenance

Theme 3
Digitalisation in the supply clain
- Data sharing
- Data learning
- Physical Internet

Theme 2
Clean, safe, autonomous modalities
- Alternative energy-carriers
- Autonomous modalities
- Risc-analysis

The goal is of this paper is to develop a research agenda for the 3 themes mentioned in the Greening Corridors consortium. Within each team the methodology applied is based an expert-meeting with the consortium members of Greening Corridors supported with main findings in the literature review.

Theme 1 - Better capacity usage

Better utilization of available capacity requires to further develop and apply (synchromodal) planning methods to organize the capacity of different operators in the corridors more effectively and efficiently. Current industry business and governance models are a barrier to information and capacity sharing with other stakeholders. Concepts from the sharing economy and the emergence of online platforms offer opportunities to gain more transparency in the available capacity and efficiency of the transport market. Smart planning of maintenance is also possible leading to a higher availability of capacity. The scope of the research focuses on the planning and business models and the way in which the sector that implements these can organize and realize change.

The capacity of road infrastructure is still sufficient. According to Rodrique (2020) the capacity can be defined as the dynamic capacity that relates to superstructure, labor, and technology, which can be improved upon. The intensity and density of utilization are improved with a more efficient superstructure and management. For example, the dynamic capacity of a road system can also be improved with a better synchronization of traffic lights or the introduction of road pricing to avoid peaks in infrastructure usage (Verhoef, 1996). Another issue in road transport is the driver shortage. To tackle both issues it could be interesting to look for synchromodal opportunities with the usage of rail or barge transport. As a research action, it is good to continue work with the Off-Road Runners program where companies are supported in their choices to make use of other modalities (Joint Corridors Off Road, 2022).

Rail freight transport suffers from the fact that some tracks are not well aligned causing (un) foreseen delays. The causes can be different track widths, different voltages at the overhead lines, or different infrastructure costs per country. As an example, it takes 5 days to travel from the Netherlands (Tilburg) to Poland, however, it takes just 10 days to travel from Poland to China. The usage of rail freight still remains low compared to the other modalities (about 9%). A more detailed analysis of the railway planning process is needed to understand the full complexity of the railway issues. The railway capacity during daytime is restricted due to the priority of railway passenger transport. During nighttime capacity seems to be available, however, maintenance and noise restrictions do not allow operational usage of the tracks. In the literature, the most appropriate monitoring technologies are available for each of the main railway track failure modes. Sensor technologies, such as strain gauges, piezoelectric sensors, fiber-optics, geophones, and accelerometers have proven to offer appropriate characteristics and accuracy for the continuous monitoring of a railway track's structural state (Castillo-Mingorance et al., 2020).

The *inland waterway transport sector* has sufficient infrastructure capacity. At the same time, one can observe that waterways are more and more disruptive and disturbed by low and high water levels causing congestion or sometimes a navigation ban for inland vessels. In recent years, also problems have arisen due to outdated waterworks. The main bottlenecks are at the (sea)terminals where there are high waiting times for inland shipping as the terminals do not have the capacity (cranes and quay capacity). Although sophisticated simulation models/games are developed to gain more insight in the barge planning process (Kourounioti, et al., 2018), the current practice still shows extreme long waiting times for the inland vessels. A more detailed analysis of the planning process is needed to understand the full complexity of the barge planning issues. The complexity of port operations severely challenges the mitigation of port delays. Deepsea vessel arrival times to the ports are typically uncertain. Even though vessels must submit their estimated time of arrival (ETA) and estimated time of departure (ETD) in advance, these estimates are usually inaccurate (Nikghadam, et al., 2021). The ETAs are often too optimistic and they are adjusted many times (Veenstra & Harmelink 2021).

The *inland terminals* can play a buffer in the network (dry port/extended gates) for the seaport terminal with transport with fixed connections to the ports or the hinterland via inland shipping and rail. Extended gates can play a role in reducing delays in the port by postponing the receipt of goods until the inland terminal. The extended gate concept aims to reduce this pressure on ports by shifting processes from seaport terminals to inland terminals, also called dryports (Veenstra et al., 2012). In essence, a dry port is able to offer the same service as a seaport. Research has shown that demurrage costs are reduced as a result of using dryports (Fazi & Roodbergen, 2018). Studies addressing the most commonly represented thematic areas, i.e., a network perspective on dry ports or performance impacts, are based on quantitative approaches. Gammelgaard (2004) adds that the actor-approach is highly contextual and argues that it is impossible to make predictions based on external cause-effect relationships of social reality because of people's intentions. Therefore, an understanding of reality requires an investigation of intentions, mainly through qualitative studies' (Gammelgaard 2004, p. 4). Both approaches are needed to arrive at the right advice.

The *shipping company* wants to concentrate empty containers in one place (often in the port), so that many empty containers are shipped back and forth between the port and the hinterland. Another issue is that a terminal often does not know where to put containers in the stack, because they do not know the destination for the hinterland. Quite often there exists a mismatch between ICT systems as a result of which information cannot be shared with each other in the chain.

Shippers often don't realize the influence they could have on the transport chain and the choices they can make as they simply pay for the transport service. Shippers must make good agreements with the shipping company so that hinterland transport can be better arranged and the various links in the chain are better connected. In line with this are the findings of Khakdaman et al. (2020) who identified four market segments among the shippers. The first and largest segment is called high service-level seekers, who have a high willingness to use synchromodal services and delegate modal control, provided LSPs are able to secure high-quality transportation in terms of service time, flexibility and reliability. The cost-sensitive risk-taking shippers make up the second largest segment. They are mainly willing to relinquish modal control in exchange for cheaper transportation services. The third shipper segment is called ancillary service seekers who are to a large extent willing to delegate modal control by shifting towards synchromodal services that provide the value-added services they are looking for in transportation service. The fourth segment contains the risk-averse shippers who are not willing to relinquish modal control and prefer using the transportation services they are currently using. The segments indicate that there are opportunities for a variety of transportation service improvements (Khakdaman, 2020).

The *locations of distribution centers* (logistics service providers) can play a role in the spread of capacity in waterborne, railway, and road transport. It should be noted here that most distribution centers do not have a railway connection. The government could facilitate this process. At the same time the provinces, companies, and the national government could develop a freight flow map of the current and future freight flows. This is important to know where to position new energy hubs as they influence transport flows and vice versa. At this moment 14 terminals in the hinterland are evaluated on their performance in a region. In some regions, there are too many terminals. A future terminal plan (with the identification of high and low volume areas) and/or real-time corridor management are interesting to develop. Less emphasis has been placed on the opportunities lying within *port-hinterland corridor management initiatives* that have been formally or informally developed, addressing not only the strategic but also the tactical and operational levels. These initiatives could bring together corridor members to discuss existing challenges, persistent bottlenecks and major inefficiencies, and jointly plan the implementation of appropriate actions that can successfully address them and improve, in turn, business competitiveness and trade attractiveness (Sdoukopoulos & Boile, 2021).

By 2030, equipment and infrastructure need to use fewer resources, i.e., have a lower footprint, while having lower costs and higher availability (EU, 2022). For companies within service industry, it is difficult to achieve these long-term goals, as they deal with the complexity of equipment/infrastructure and high uptime requirements of its users. They need to achieve low costs and high equipment/infrastructure availability, but also a low footprint in terms of usage of raw materials, energy and (highly skilled) personnel. This requires performing maintenance just-in-time, and organizing the after-sales service delivery such that parts and service engineers are at the equipment/infrastructure before it fails, without using unsustainable and expensive transportation. The (after-sales) service should be organized such that it has a lower footprint, lower costs, and a higher availability than currently. Innovation such as smart sensors linked to the internet of things (IoT) that signal when a part of the infrastructure needs to be replaced and drones that conduct inspections are feasible solutions for the future. With advanced AI, it also becomes much easier to predict maintenance, reducing the number of disruptions.

Summarizing the following research agenda topics are formulated for better usage of capacity:
- Study night-time operations for all combined transport modes;
- Active studies on searching multimodal transport options for specific companies;
- Possibilities of dry port concepts for inland terminals;
- Detailed analysis of the planning processes in the corridors;
- Improvement of the ICT systems to follow the position of the container;
- Shippers' behavior analysis on key drivers for synchromodal transportation based on the Khakdaman's customer segments;
- Policy issues related to location of (new) warehouses;
- Development of Corridor management/performance monitor;
- Improve footprint, costs, and availability of equipment/infrastructure through the development of smart Operations Control Centers.

Theme 2 - Clean, safe, and autonomous modalities

The assignment from the Climate agreement to achieve a 30% CO_2 reduction through better utilization of capacity is significant. The technical solutions for zero-emission long-distance transport are still under development and very limited available. The more technical research is developing quite extensive. However, the choices for alternative energy carriers, such as hydrogen and batteries, to made by the entrepreneurs and their scaling up to system level are hardly studied. At the same time, the supply chains of the new energy carriers (including maintenance and preconditions for physical safety) have not yet been developed. A second change with a high impact on the transport system is the development of autonomous modalities. This introduction leads to change and shifting of tasks and responsibilities in the chain, but can also lead to the development of a network of intelligent and autonomous hubs that operate 24/7.

Connected and Automated Transport (CAT) is expected to revolutionize transportation and logistics by providing major improvements in the field of road safety, traffic flow, logistical efficiency, comfort, and reduction of emissions. Connected and Automated Transport includes all technologies and applications aimed at the control, routing, and communication of a vehicle with the environment in order to (Madadi & Verduijn, 2022):

- move the vehicle safely, efficiently, and sustainably through traffic move;
- make optimal use of the infrastructure;
- the logistics chain (by streamlining the digital sharing of information).

With respect to the last issue the interface with logistics entities such as distribution centers, terminals and logistics parcs is an important issue to implement CAT. Current operational *Automated Guided Truck* applications are bound to fixed infrastructure and do not offer opportunities to operate in the public domain. The challenge is to connect the automated transport operations to DC areas, terminals and logistics parks and meanwhile bridge the gap with autonomous driving in the public domain (Kusumaker, et al., 2021; Van Duin et al., 2022).

Interest in the concept of *autonomous ships* is rapidly growing in the past few years. Inspired by the recent adaptation of autonomous and automated systems in other transportation methods and the accelerated evolution of technology, one could wonder how and if these technologies can be implemented in the shipping industry. Different to the 5 levels of autonomy in road transport, the International Maritime Organization (IMO) distinguishes four degrees of Autonomy (IMO, 2017):

Degree 1: Ship with automated processes and decision support: Seafarers are on board to operate and control shipboard systems and functions. Some operations may be automated and at times be unsupervised but with seafarers on board ready to take control.

Degree 2: Remotely controlled ship with seafarers on board: The ship is controlled and operated from another location. Seafarers are available on board to take control and operate the shipboard systems and functions.

Degree 3: Remotely controlled ship without seafarers on board: The ship is controlled and operated from another location. There are no seafarers on board.

Degree 4: Fully autonomous ship: The operating system of the ship is able to make decisions and determine actions by itself. (IMO - Autonomous shipping, 2017.

From a study by Kooij (2022) it is found that the factor that has the largest influence on the economic feasibility of unmanned ships, is the nationality of the crew and the flag state. For that reason, it is expected that ships registered in high-wage countries are more likely to transition to unmanned than ships registered in low-wage countries. When looking at the operation of the ship, the number of port calls is the most influential. Making more stops in port costs money, as extra personnel is required to perform services to the ship. This could also have an influence on inland shipping as most vessels arrive at several terminals. Also, the traffic is more intense on the inland waterways than at the open sea. More in-depth research is needed for inland shipping.

Moving freight by rail hasn't changed much over the last several decades. Trains can move freight four times as efficiently as trucks can, and they can move a huge amount of it at once with minimal human supervision. *Autonomous trains* can ride more closely together. Combined with smart rail traffic management, this enables you to increase capacity. The disadvantage of trains is that they are best at long-distance hub-to-hub freight transfers, and usually a truck is needed to get it to its final destination. In addition, autonomous trains are very expensive due to all required information and systems.

From a technical perspective, it is obvious that these autonomous electric-rail vehicles really seem likely to be used in practice. Due to its today railway safety systems for infrastructure usage ((European Rail Traffic Management System (ERTMS)), it is a substantial simplification of an autonomous-driving problem. With some halfway decent sensors to detect obstacles on the track, the road to autonomous trains is open. Like in road and barge they identify four levels of automation:

- **Level 1:** the train operator is in full control. He/she oversees the tracks and decides when to speed up or slow down;
- **Level 2:** the locomotive is controlled remotely but the operator is still in the driver's seat, overseeing the tracks and deciding whether to intervene;
- **Level 3:** the train is controlled remotely;
- **Level 4:** the train's control is fully automated, and its operation is being monitored remotely.

Considering the current conditions of the European railways, only degrees of automation 1 - 2 are used. Fully autonomous trains in the world are used only in urban railways (metro) and airports (inter-terminal traffic), where there is no risk of collision with an obstacle on the line between stations. In most cases, it is also possible in an emergency to take over remote train control from a remote-control room. On conventional national railways, autonomous trains are only in the development phase (e.g., Amtrak in the United States of America), with the exception of Australia, where the autonomous train successfully passed a 100 km track during the tests. However, even in this case, the presence of a driver is still necessary in case an emergency needs to be dealt with (Hranický, et al., 2021). Due to employee shortages, it raises urgency to investigate and experiment with autonomous railway vehicles.

The other important issue theme in this research topic is *sustainable development toward emission-free vehicles, trains, and vessels*. For all modalities, there are many uncertainties about which energy carriers or combination of energy carriers will be used. At the same time, it is important to think about smart and safe locations for bunkering energy. The following sustainable alternative fuels are considered also proved the technology-readiness level (TRL) (Schmidt et al., 2022):

LNG (liquefied natural gas)

The TRL is mature and there is an increasing trend of vessels in service and on order with LNG as a main engine fuel type. There is no need for further RD&I but rather stricter regulations regarding methane slip. For the trucking industry it is a dead end as the European environmental organization Transport & Environment (T&E) studied trucks that run LNG are no better for the climate than diesel trucks.

(e-)Hydrogen

The general TRL still need to further mature. There are several projects ongoing that investigate the use of compressed and liquid hydrogen in both internal combustion engines (ICE) and fuel cells (FC), all applied in trucks, smaller vessels and even trains. Further RD&I in the form of demonstrators is needed to investigate the best fit regarding truck/vessel type and operational profile for this technology. Fuel cell electric vehicles (FCEVs) commonly use hydrogen gas as a power source. FCEVs are more suitable for replacing heavy-duty internal combustion vehicles because this energy vector has a high specific energy density, and fuel cells have good energy efficiency. FCEVs have fast charging times and great autonomy (Pagliaro & Meneguzzo, 2018). The way how hydrogen can be obtained varies a lot. Most promising looks sodium borohydride ($NaBH_4$). For the future it is necessary to experiment and make use of more demonstrators in the coming years which fits best for which type vehicles/vessels/trains. Demonstrators for inland shipping can be seen such as the AbInitio, Antonie and the Neo Orbis. In the railway sector similar demonstrators can be found. This year ProRail successfully tested a hydrogen train. On the route between Groningen and Leeuwarden, a sprinter and express train service run several times, demonstrating that this innovative train can be accommodated within the service. Hydrogen trains can serve as alternatives for the diesel trains that run on 1,000 km of the 7,000 km of track without overhead wires. With green hydrogen, that kind of train is not only more sustainable than diesel, it's also significantly more quiet (Slump. 2022).

(e-)Methanol

Methanol is considered one of the most promising sustainable alternative fuels in the short term. Compared to fossil fuels, renewable methanol as a fuel for elan 'electrofuel' reduces carbon emissions by 65 to 95% depending on the feedstock and conversion process. That's one of the highest potential reductions of any fuel currently being developed to displace gasoline, diesel, coal and methane. Renewable methanol can be made from many plentiful sources. The necessary carbon molecules to make synthesis gas for methanol production can be obtained from CO_2 from industrial process streams, or even captured from the air. Other sources include municipal solid waste (MSW), agricultural waste, forestry residues and renewable hydrogen (Klein, 2020). The general TRL of onboard storage and propulsion is maturing and there is an increasing trend of a wide range of vessel types in service and on order with methanol (Schmidt et al., 2022).

(e-)Ammonia

The TRL of ammonia is still quite low and is the least advanced sustainable alternative fuel. There are no vessels active yet. There are vessels are designed in such way that once the fuel is available, the vessels can be retrofitted relatively easy.

Electrification/batteries

Electric powertrain systems include the main components that generate and deliver power to the road surface for fully electric, hybrid electric and plug-in hybrid electric vehicle applications. Battery Electric Vehicles (BEVs) that contain an electric powertrain has higher energy efficiency than internal combustion engines since they have less heat loss (Lee et al., 2018). They also have power reversibility associated with a charge-discharge efficiency of the Li-Ion batteries, which reduce the overall energy consumption by recovering braking energy. However, intensive use and long distances require high energy storage, which increases battery mass, reduces available cargo volume in the vehicle, and boosts costs and energy consumption. It is already proven that for short distances.

In road transport heavy trucks like the Euro-trailer do operate in (large) retail transport operations with range of 150 kilometers without charging. At same time the smaller transporting companies, almost 40 per cent of these companies are not even planning to switch to electric vehicles. The main reason is that companies are worried about the high purchase costs and the limited radius (SCM, 2022).

Same developments can be found in the shipping industry where the smaller ferries opt for fully electric due to the possibility to recharge partially. Illustrative example to mention is the 'Alphenaar' who travels with a 2-container battery swap from Alphen a/d Rijn (Heineken) to port of Moerdijk (distance 65 km). Each container battery consists of 45 battery modules that generate a total of 2 MWh. One battery is used during the journey towards Moerdijk, a journey that takes about six hours. The second container is used for the return trip. Recently, a large investment has been announced to increase the number of battery packs and ZES vessels. Like the road sector the barge sector with a 6,000 vessels mainly operated by private captains is struggling with the questions how to invest in which sustainable engine as the future is uncertain about what the best energy carrier will be, how is the supply of the energy carrier guaranteed, what are the logistical consequences and safety procedures of the new technology, and how can I make such a high investment. This implies that for both modalities further research is needed how to upscale and integrate the technologies from policy making perspective as well as from an entrepreneur perspective.

Summarizing the following research agenda topics are formulated for clean, safe, and autonomous modalities:

- The challenge is to connect/integrate the automated transport operations to logistics environment and meanwhile bridging the gap with autonomous driving in the public domain.
- Demonstrators and pilot testing seem to be the best way to obtain insights. To scale-up from a research perspective digital twins could be the solution to use the individual vehicle behavior/consumption to integrate these in large multi-agent simulation models.
- At policy level the government needs to develop robust roadmaps to provide clarity what the potential futures could look like in terms financing, locations, safety procedures, and integration in the public domain.

Theme 3 - Digitilization in the supply chain

New technology, such as 5G, Blockchain, and Physical Internet (PI), makes it easier to share data in chains. With advanced data processing, such as data science and machine learning, complex issues can be solved. The investigation of the SPRONG group, focuses on the effective use of new technology in practice. A precondition for achieving sustainable corridors is that all companies (including SMEs) that form part of the corridor can apply the new solutions. The research focuses on the success factors for the adoption of digitization by SMEs, such as insight into application possibilities, business cases and human capital needs.

As Behdani et al. (2020) stated efficiency improvements are often attributed to the increasing use of information in freight transport chains (e.g., Blockchain). According to them research should focus into the role, effects and impacts of the increasing use of information and the related business cases.

The introduction of Industry 4.0, the Internet of Things (IoT), and other related digital innovations makes it possible to collect and aggregate large amounts of data from different sources. Data science and advanced analytics have a direct relevance for logistics; in recent literature different tools and techniques to make data driven supply chain management decisions have been proposed (Govindan et al., 2018). Heilig et al. (2017) define digitalization as a sociotechnical process, in which digital tools in a broader social and institutional context are implemented. Digital transformation is described as a broader process of transformation of, among others, strategy, governance and leadership and possibly the business model of the company. The same holds for digitalization on the hinterland connections where Behdani et al. (2020) also state that efficiency improvements are often attributed to the increasing use of information in freight transport chains (e.g., Blockchain). According to them research should focus into the role, effects and impacts of the increasing use of information and the related business cases.

From the 100 top logistics companies 20% is seriously involved in digitalization and only 5% uses it to its full potential. Numerous SMEs in the logistic sector are lagging behind in the field of digitalization and data driven logistics. Mostly they are not well informed about how it can improve their business model (Moonen, 2021). Furthermore, relevant knowledge is often conceptual and risky, and it uses a lot of companies' resources to implement. For this reason, companies can better be offered plug and play solutions, which are less risky and costly to implement (Dahlander, et al., 2016).

In the market of synchromodal transport new initiatives become available to provide standard digitalization solutions (see for example NextLogic and Ishare are good examples in the Netherlands). In Germany a new type of solution is provided by the utilization of a data hub, which for the first time connects all players in combined transport in terms of data technology. The shareholders are the combined transport operators Hupac and Kombiverkehr, the transport companies Hoyer and Paneuropa, the railway undertaking Lokomotion as well as Kombiterminal Ludwigshafen. The company DXI emerged from the research project "Digitalization of intermodal supply chains - KV4.0", which created a cross-system data platform for combined transport. In the long run data in these systems can be analyzed with data analytics techniques to provide more artificial intelligence.

Summarizing the research topics:

- Integration of information systems to make the corridor operations more efficient by the use of preferable standardized solutions from managerial, organizational, juridical, and logistical perspectives.
- Application of data analytics (selection of some nice pilot projects).

This chapter has proposed a future research agenda for the sustainable development of the freight corridors for the next five years. As the corridors can be seen as the connecting lifelines of our ports and our cities (respectively distribution centres), the research topics in the agenda are quite important for the development and wellbeing of our future generation.

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