Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 00 (2022) 000–000

Transportation Research Procedia

www.elsevier.com/locate/procedia

Transport Research Arena (TRA) Conference

A Federative Approach to Digital Transport Ecosystem Innovation

Mikael Lind[a*], Jan Bergstrand[b], Sandra Haraldson[a], Kenneth Lind[a], Annica Roos[b]

[a]*Research Institutes of Sweden, Lindholmspiren 3a, S-417 56 Gothenburg and 417 56, Sweden*
[b]*Swedish Transport Administration, S-781 89 Borlänge, Sweden*

Abstract

Transport is a global phenomenon with regional and local impacts. It involves a multitude of actors, and today there is increasing pressure for transport chains to be environmentally sustainable, predictable, seamless, and cost-efficient. An end-to-end transport most often actually engages multiple transport modes involving visits to various transport nodes. There is a need to better synchronise transport practices, why big hopes are being placed on digitalisation as an enabler and means for integrated and sustainable performance along multi-modal supply chains. To do this requires informed decisions on what changes are needed and how they should be made. Before implementing changes, one need to reflect on and experiment with the available options to ensure that desired effects are both feasible and effective. This paper provides some observations on how digital innovation in such transport ecosystems can be pursued.

Peer-review under responsibility of the scientific committee of the Transport Research Arena (TRA) Conference
Keywords: Information sharing communities; Living Labs; Ecosystem innovation; Decarbonisation; Green transports; Seamless logistics

1. Introduction

Transport is a global phenomenon with regional and local impacts. It involves a multitude of actors, and today there is increasing pressure for transport chains to be environmentally sustainable, predictable, seamless, and cost-efficient. An end-to-end transport most often actually engages multiple transport modes involving visits to various

* Corresponding author. Tel.: +46 705 66 40 97
E-mail address: Mikael.Lind@ri.se

2352-1465
Peer-review under responsibility of the scientific committee of the Transport Research Arena (TRA) Conference

transport nodes. This then requires a high degree of collaboration between the involved actors both within and often across national borders. Today, there is a call for better synchronisation within and between transport practices. Big hopes are being placed on digitalisation as an enabler and means for integrated and sustainable performance along the multi-modal supply chain (Lind et al., 2021a).

To do this requires informed decisions on what changes are needed and how they should be made. Before implementing changes, there is a need to reflect on and experiment with the available options to ensure that the desired effects are both feasible and effective, both for the individual organisations and entities involved and for the ecosystem as a whole. Engagement of the multitude of stakeholders is particularly important. Drawing from experiences derived from the ecosystem innovation arenas (Living Labs), initiated under the European financed FEDeRATED project (Lind et al., 2021b), combined with a use case capturing a global approach to Virtual Watch Towers for Supply Chain Visibility (Lind et al., 2022a), this paper provides some observations on how to pursue digital innovation in transport ecosystems.

2. Digital innovation in transport ecosystem settings

The transport industry is a self-organized ecosystem (SEO) of many independent entities that cooperate as needed to achieve a common goal, such as bringing goods from a point of origin to a point of destination (Watson et al., 2021). Achieving a higher level of continual collaboration for innovation and change is a challenge, as an SEO has no keystone organization that can command action by other organizations. Decision rights are distributed among the various players in the ecosystem. Thus, adaption is not centrally directed but organic in response to each party's pressures.

Digital innovation in ecosystem settings is a challenging task. It is crucial to define a common object of interest as well as each of the participants' needs so that they see the value of taking part in the innovation effort (Lind et al., 2022b). There is a need for reaching agreement on how each participant needs to act, and which standards to utilise in emerging interaction patterns, before making appropriate implementations and changes at each end.

The initial step is to establish co-ownership of the problem by identifying and describing a common object of interest for the parties engaged. A common object of interest that unifies and fosters engagement across the ecosystem's members is urgently needed to redress today's increasingly fragmented world. This requires incentives to engage the major stakeholders, a high degree of transparency to ensure fair engagement, and a self-regulating mechanism to reduce self-interested actions detrimental to others or the community. The credibility and trustworthiness of coalition participants are critical to achieving a multi-year goal.

Orchestrator(s) who represent and can act on behalf of the collaborative innovation alliance or even the ecosystem can drive the formation of partnerships and an orchestrator should ensure that knowledge is shared between the parties across the ecosystem. Knowledge is the currency for rewarding participation.

Collaborative innovation also needs a shared measurement system to report milestone achievements. Real-time feedback and data analytics must be available to inform the community and grease collaboration and innovation.

3. Illustrative use case: A global approach to Virtual Watch Towers for Supply Chain Visibility

Cargo owners and transport buyers wish enhanced visibility and forecasts on the times of goods and (returnable) assets arrival at various locations in the global end-to-end multi-tiered supply chain network. Logistics service providers also do need to stay informed on progress and disruptions on the activities related to their cargo. Carriers can benefit from visibility before and after their activity. Given the vast amount of data that now are becoming released through diverse data streams there lies great opportunity to achieve enhanced situational awareness for the involved parties and the clients of multi-modal transport chains. This can be achieved by Virtual watch towers (Lind et al., 2022a), which pull data together for analysis to create business value, like the location of assets and goods or higher on-time arrival compliance.

During the last decades as digital technologies like cloud, blockchain etc. have become more advanced and widely deployed, more virtual approaches to tower capabilities have been established with the development accelerating recently. Within road, rail, and sea transport we have been seeing both public and private initiatives to establish situational awareness of operations within a particular geographical area, for a transport hub, and/or a particular corridor or fleet. There are also initiatives taken of which maritime cargo is possible to track and trace through platforms like Tradelens. Other insight providers with varying focus and approaches are Blume, FourKites, Project44, Roambee and Tive. They all are building upon enhanced digital connectivity and big data.

Different types of supply chain control towers have emerged over the years. A first generation of such towers were brought to use in the 1990’s which were limited to logistics operations, and were more reactive than proactive, only working on normalizing operations when there was a disruption that someone spotted. Those however suffered from lacking verifiability and connectivity across the supply chain. The second generation were aimed at more operational control and provided near real-time data on fleet locations, inventory levels, as well as custom alerts when exceptions or anything that affects overall supply chain performance occur. This generation of supply chain control towers however suffered from manual processes, lack of end-to-end and multi-tiered perspective, uniformity, and information overload. The third generation took the end-to-end logistics and supply chain control into the scope. That generation however suffered from lack of adequate or uniform infrastructure (technology, connectivity), manual intervention required for exception handling, and shortcomings in prescriptive analytics along the entire value chain of a company. The fourth generation puts more emphasis on automation and better analytic capabilities.

For transport operators it is important to distinguish between the different types of control towers, like logistics/transportation control towers, fulfilment control towers, inventory control towers, supply chain assurance control towers and end-to-end (E2E) value chain control towers. Some are custom-built by large enterprises, others are provided by vendors, for example forwarders to act on behalf of their customers based on standard operating procedure (SOPs). This contribution reflects on logistics/transportation control towers.

Fig 1. Virtual Watch Towers for Supply Chain Visibility (Lind et al., 2022a) (Illustration: Sandra Haraldson)

As supply chains are global, there is a need for a framework that is holistic in nature and that guides the developments of watch towers throughout the world. We use the concept of “watch” tower, rather than “control” tower, to stress the importance of the need for building smart decisions on rich sets of data constituting situational awareness (figure 1).

The underlying model for the virtual watch tower builds upon a digital agent that detects actual or future supply chain disruptions. In its processing, the agent takes numerous data streams into consideration cleanses the data to detect the transports/transport or upstream and downstream value chains that have been negatively impacted and/or are likely to be disrupted in relation to planned transports and transports being conducted. On the flipside, the watch tower will not surface those activities that are expected to be pursued as planned with a high degree of probability. Fundamentally, the watch tower is therefore to build upon data covering planned times, estimated times, and actual times, i.e. plan vs. progress and plan vs. anticipated progress. As digitalization allows us to detect multiple instances and calculate multiple outcomes, emerging choke points can be identified in advance, as e.g. congestions occurring at particular transport nodes, like ports and terminals can be detected hours, days or even weeks in advance given that it would be possible to achieve situational awareness through analysing vessel data or run simulations of how many transports are expected to be served at the same time at a particular node. Of course, this may need some time to reach a high level of accuracy. Once the digital agent has detected a potential variance to plan, the engine can calculate alternative options which the agent can prioritize to prescribe the one with the most promising outcome based on pre-set parameters or rules, e.g. on-time and in-full (OTIF) delivery at minimal costs. The agent triggers action, either through an automated process or by guiding people through the distribution of deviation and risk alerts and identified best possible alternatives.

The model that guides the composition of the watch tower is divided into four activity components; aggregate, alert, analyse, and act (figure 2). Within these components, the digital agent would pursue most of the tasks, while humans would rather monitor and execute on the recommended options. The human influence on the process should be limited to validating conformity with the rules, ensuring proper system performance, and to factor in last-minute information.

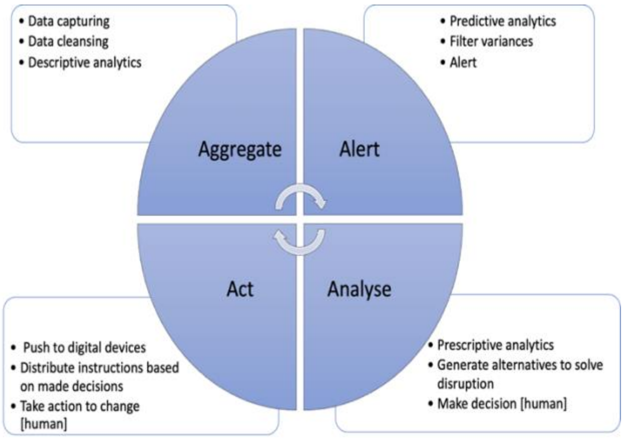

Fig 2. Fundamental model for the watch tower (Lind et al, 2022a)

The different action components of the model can be unpacked in the following aspects (Lind et al., 2022a);

- The aggregate component takes the maximum number of data feeds into consideration that may be of relevance for the transports depicted in the transport plan and supplier network. This component also entails the cleansing of the data through artificial intelligence/machine learning (AI/ML) features.
- The alert component continuously scans the cleansed "watch" data and produces signals that point to potential disruptions or deviations with potential impact on the transport plan. This component uses thresholds, such as temperature ranges or an expected arrival time at an intermediary transport node.
- The analyse component produces for each signal with the help of AI/ML a list of alternative options (if available) that could be adopted according to known parameter, e.g. shifting to a truck instead of using the planned train to ensure compliance with the transport plan.
- The act component, which is an operational function that provides machines or humans with the agent's findings to take effective measures, such as re-routing a truck or selecting an alternative parts supplier.

Empowering supply and value chain visibility with logistics/transportation and other types of watch towers is made possible due to an ever-increasing computing power and distribution of data across the globe. People become more connected which also allows for people using mobile devices to feed systems with data about what they see and achieve, but they can also receive on the same devices recommendations from virtual watch towers to act upon. In this paper we propose a network of logistics/transportation watch towers to meet the demands of 1) cargo owners and transport buyers to get more insights in the progress and how disruptions are managed that may affect the arrival of their goods, and 2) enhanced situational awareness for logistics service providers allowing to manage cargo flows more efficiently. While carriers themselves also benefit from enhanced E2E visibility they may face questions from their customers about some routing made visible through the higher level of transparency.

Watch towers empower just-in-time operations across the supply chain optimizing on time, space, and resources as well as optimizing for sustainable operations with as little CO_2 emissions as possible. Shipping is global and digitalization enables seamless interaction across the globe, and as more and more data streams are made available and more sophisticated filtering and analytic tools are being developed, proactive management of supply chain is increasingly possible. Connecting watch towers for supply chain visibility in a network of smart centers around the world will lift the concept of control towers to a totally different level. The authors invite practitioners and academics to provide their views on the topic and ideas how this promising concept can be brought to life.

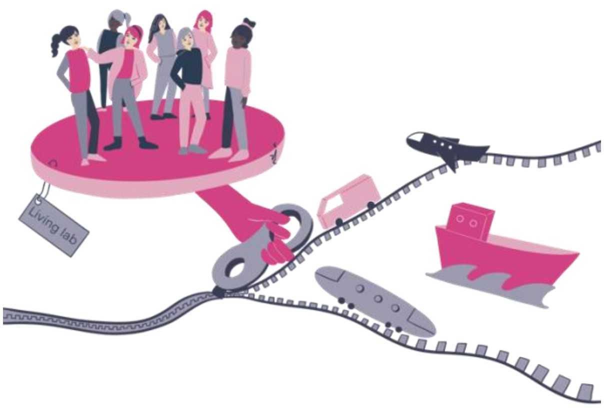

Fig 3. Innovating the transport ecosystem enabling seamless transports and logistics (Lind et al., 2021b) (illustration: Sandra Haraldson)

4. The role of democratic platforms in transport ecosystem innovation

Innovating the transport domain requires that involved actors meet and join forces to seek each other's contribution to an overall common object of interest (figure 3). Such an approach ensures ecosystem innovation by focusing on the value creation process in which involved actors are value contributors. Related to transport operations, such common objects of interest might concern such things as a port call pursued at a (sea)port, a passenger's journey through multiple transport nodes, or the processes pursued at a railway yard and stations. The objective for the actors participating in a Living Lab as an arena for reflection and co-creation, are to achieve better overall collective performance and thereby improve their individual efficiency, reputation and profitability by contributing to ecosystem improvement and societal change.

Following the Living Lab methodology (Pallot, 2009; Haraldson et al., 2015), the key actors involved in the common object of interest are engaged in a collaboration arena. The actors co-create a common understanding on how the actors currently collaborate, define objectives for the common object of interest, identify information sharing needs to realise desired effects, understand actors' incentives to data sharing and conceptualise collaboration principles. A Living Lab approach is preferred as it shortens the time between idea and implementation and paves the way, through stakeholder buy-in, for a successful implementation.

Fig 4. Demonstration arena exploring different innovations (Lind et al., 2021b)

Getting the key actors involved is important to establish relationships of trust and identify incentives for the participating actors to share information. The Living Lab approach is aimed at encouraging the different stakeholders involved in the common object of interest to participate in the use, refinement and evaluation of more efficient procedures and collaboration, principally through improved data sharing. The purpose of the Living Lab approach is to integrate and engage the participating actors in the development process as prospective users and co-creators of transport ecosystem innovations. It allows them to explore, test and evaluate digital collaboration through the approach and principles of the guiding concept, utilising data sharing technologies (figure 4).

Revisiting the use case of a virtual watch tower, it becomes critical to engage the different providers of services along the supply chain corridor in digital collaboration endeavors. This means agreements to be made of when data should be shared and what data to share. As the common object of interest for supply chain visibility and supply chain predictability, the common object of interest should be the transport assignment from the cargo owner or the transport buyer. The realization of the transport assignment identifies from which transport operators (carriers and transport nodes) that data needs to be retrieved from and channeled back to the cargo owner / transport buyer. Such data would be channeled through a data sharing technology (see section 5 below).

To fully support ecosystem innovation, experience shows that the Living Lab approach can successfully be combined with data-sharing technologies into so-called democratic platforms (Lind et al., 2022a), that will be further elaborated on in the next section.

5. Putting the FEDeRATED principles into play

Digitalisation is an enabler for innovating the transport ecosystem. However, digital interaction in multi-modal transport requires infrastructure support, such as the coordination of information in interoperable systems. Currently, operational data sharing systems exist for more-or-less limited purposes, often around transport nodes of different types. Operational system vendors offer the means of integrating to other operational systems, but this is a slow process that does not easily support new ecosystem actors and the exploration of new business models or use cases. Furthermore, the operational systems are typically not suited towards adding different types of sensors required for digitalising the operations around multi-modal transport nodes. The introduction of data feeds emerging from connected (physical) devices through sensors is expected to grow exponentially (EU, 2020) and may be a source to enhance the quality of the data managed by different system environments and thereby also the quality of the data being shared across environments (Lind & Renz, 2020).

5.1. The need for demonstration platforms supporting transport ecosystem innovation

As the illustrative use case about virtual watch tower has shown, there is a need for different types of data sharing technologies, as part of the democratic platform, to support ecosystem innovation in multi-modal transport. Operational systems need to be complemented with demonstration platforms tailored to collect information from different data sources and to test new solutions in a fast and flexible way (figure 5). Besides data from operational systems like Port Management Systems (PMS), Port Community Systems (PCS) and Terminal Operating Systems (TOS), there is a multitude of different sensors providing data for digitalising key parts of operations, such as RFID readers, cameras with image processing algorithms, GPS, IoT sensors for temperature, humidity (such as the ones installed in Smart Containers (Becha et al., 2020)), etc., sourced from different physical entities and owned by different actors. Based on data from different sources, prototype solutions can be built for different use cases, like the automation of recurring events at a transport node, end-to-end supply chain visibility, etc. Learnings from the prototype solutions can then be used for maturing the requirements for developing operational applications supporting the use cases in later phases (Lind et al., 2021b).

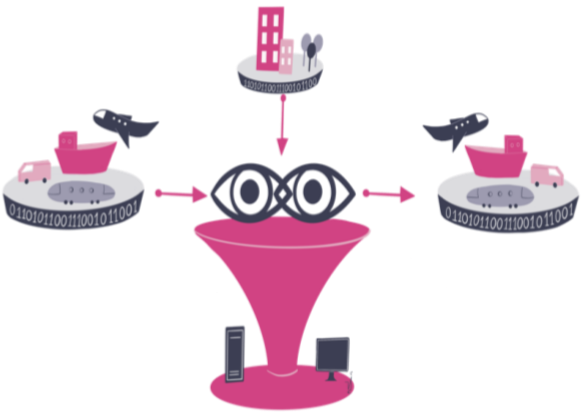

Fig 5. A demonstration platform facilitating digital interaction in multi-modal transport (Lind et al., 2021b) (Illustration: Sandra Haraldson)

Besides facilitating the test and demonstration of data sources and use cases in a neutral setting, business models and other incentives for sharing data are crucial in digital interaction and can be explored in this type of demonstration platform (figure 5). Common ecosystem needs and capabilities can be identified, such as new standards, processes, etc. Security threats can be explored and system mechanisms taking care of identified threats can be verified. Finally, learnings and experiences from test and demonstration activities to elicit requirements for forthcoming implementations are valuable input when sourcing operational platform solutions.

Data sharing technologies in the form of demonstration platforms as described in this sub-section are tailored to support collaboration arenas such as Living Labs described in section 4. Together – data sharing technologies in the form of demonstration platforms and collaboration arenas in the form of Living Labs –constitute the central building blocks in a democratic platform supporting transport ecosystem innovation.

5.2. Properties of demonstration platforms and their use

Besides facilitating the test and demonstration of data sources and use cases in a neutral setting, business models and other incentives for sharing data are crucial in digital interaction and can be explored in context in a demonstration platform (figure 6). Important properties of such a demonstration platform are (at least):

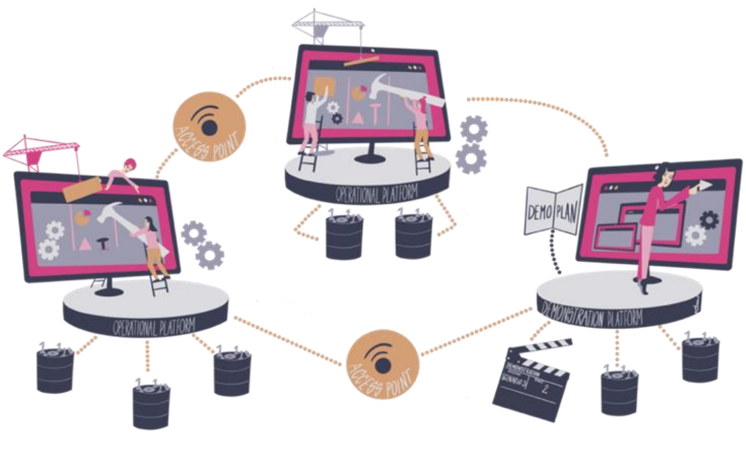

Fig 6. Emerging IT-infrastructural solutions for a Federated Network of Platforms (FEDeRATED, 2022) (Illustration: Sandra Haraldson)

- Flexible collection and transformation of data from different data sources such as different sensors and operational platforms providing data for digitalising key parts of operations.
- Flexible access to collected data from different front-ends and applications exploring prototype solutions for important use cases addressing the needs of the participating actors.
- Efficient coordination, search, and manipulation of data flows captured in real-time from different data sources - so-called event streaming.
- Durable storage of collected data for later retrieval.
- Flexible connection to analytics and

visualisation frameworks in real-time as well as retrospectively.

- A focus on short turn-around time for changes in the platform and development of connectors to integrate with existing systems.

5.3. Deplide as example of a demonstration platform

One example of a demonstration platform supporting ecosystem innovation in multi-modal transport chains is Deplide, being developed by RISE and used within different concept validation and requirement elicitation projects. Deplide is based on solid experience from similar platforms in several large-scale projects within the maritime sector adapted to more generic multi-modal transport needs. It has been developed primarily to support data sharing around a transport node, where main events along the supply chain occur. It integrates technology and solutions that are available as open-source and will itself be published as open-source.

Different types of data providers can be connected to Deplide, including temperature sensors, RFID readers, Port Management Systems, Terminal Operating Systems, etc. In a similar way, different types of data consumers can be connected, including front-end applications and services. These connection capabilities make Deplide ideal as a democratic platform for collecting different types of data, aggregating, and analysing streaming data. Front-end applications and services can be built on top of the platform to explore different use cases around multi-modal transport.

The data that needs to be shared are typically concentrated around events during the transport process; it could be a ship arriving at a port, an airplane arriving at an airport, or cargo that is transhipped at a logistic centre. A flow of events with associated data makes up a so-called event stream. Deplide is developed to manage event streams using Apache Kafka[*], an open-source distributed event streaming platform used by thousands of companies for high-performance data pipelines, streaming analytics, data integration, and mission-critical applications. The use of Kafka and the layered structure of Deplide provides the important properties for a demonstration platform (Lind et al., 2022b).

6. Concluding remarks

Nowadays, transport ecosystem innovation can be significantly enabled by technologies. However, due to the collaborative nature of transport, such innovation processes cannot exclude the human and organisational aspects. The business practice cannot be detached from the technologies to be used. In this paper, we have highlighted the use of generic and guiding concepts, such as concepts for collaborative decision making and concepts for a federated network of platforms, as a foundation to direct attention to the relevant themes within the specific practice and possible technological use. Those concepts both guide what to put at focus when bringing people together to reflect on current business practices and develop and evaluate new practices as well as being a foundation for eliciting requirements for emerging interoperable system environments.

In this paper we have described some experiences gained from adopting a democratic platform to:

1) gather people from different organisations within the ecosystem;
2) pursue focused discussions on the collaborations and associated data sharing technologies needed to innovate the part of the transport ecosystem in focus (= the common object of interest); and
3) gather experiences from digital solutions, information sharing platforms and user interfaces, as becoming a support for establishing up-to-date common situational awareness.

We argue that democratic platforms are the foundations for transport ecosystem innovation by reducing time to implementation, saving costs, allowing actors to co-create for societal change, develop well-anchored solutions that become reliable and efficient when implemented in operational environments, and by that, achieve a sustainable change within the transport ecosystem.

---

[*] https://kafka.apache.org

References

Becha H., T. Frazier, M. Lind, M. Schröder, J. Voorspuij (2020). Smart Containers and Situational Awareness, Smart Maritime Network, 2020-08-12 (https://smartmaritimenetwork.com/2020/08/12/the-cargo- owners-case-for-smart-containers/)

EU (2020) A European Strategy on data, Communication from the commission to the European Parliament, The Council, The European Economic and Social Committee and the Committee of the regions, Brussel 19.2.2020

FEDeRATED (2022) Intermediary progress report Pilots/LivingLabs, forthcoming at http://federatedplatforms.eu

Haraldson S., Karlsson M., Lind M. (2015) The PortCDM LivingLab Handbook, STM Validation Project

Lind M., Alvarado J.L., Haraldson S., Mulder H., Nykänen L. and Piccoli G. (2021a) Digital data sharing for green transport - a FEDeRATED approach, 3/6-2021, The LoadStar (https://theloadstar.com/digital-data-sharing-for-green-transport-a-federated-approach/)

Lind M., Bergstrand J., Haraldson S., Lind K.,Olsson E., Roos A., Renz M., Strokirk C., Bull Sletholt K., Björkman A., Carling K., Ivansson G., Karlsson M., Rudolfsson P. (2021b) Digital ecosystem innovation in action – a federative approach to sustainable and seamless multi-modal transport chains, 2021-09-06, Smart Maritime Network (https://smartmaritimenetwork.com/2021/09/06/a-federative-approach-to-multi-modal-transport-integration/)

Lind M., Haraldson S., Lind K., Bergstrand J., Roos A., Lundgren M. (2022b) The Role of Democratic Platforms in Transport System Innovation, 14th ITS European Congress, Toulouse, France, 30 May-1 June 2022

Lind M., Lehmacher W., Haraldson S., Simha A., Larsson T., Hagerstrand-Avall B., Lyrberg M., Zuesongdham P., Hurley S., Fu X. (2022a) Virtual Watch Towers for Supply Chain Visibility, 29/3-2022, Smart Maritime Network (https://smartmaritimenetwork.com/2022/03/29/virtual-watch-towers-for-supply-chain-visibility/)

Lind M., M. Renz. (2020) Do maritime authorities have a role in digitalization of shipping? – the "Digital (port)Approach" in a sea transport context, Smart Maritime Network, 2020-07-02 (https://smartmaritimenetwork.com/2020/07/02/do-maritime-authorities-have-a-role-in-shipping- digitalisation/)

Pallot M. (2009). Engaging Users into Research and Innovation: The LivingLab Approach as a User Centred Open Innovation Ecosystem, http://www.cwe-projects.eu/pub/bscw.cgi/1760838?id=715404_1760838

Watson R. T., Lind M., Delmeire N., Liesa F. (2021) Shipping: A Self-Organising Ecosystem, in M. Lind, M. Michaelides, R. Ward, R. T. Watson (Ed.), Maritime informatics. Heidelberg: Springer.