Roadmap towards a smart logistics ecosystem

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Abstract

Currently, the fundamentals of a technical infrastructure for a logistics 'systems-of-systems' are laid, facilitating improved, more effective and efficient logistics services based on higher levels of self-organization. Through situation awareness with enhanced methods for sharing (real-time) data, logistic stakeholders can improve decision-making, which allows for coordinated actions to overcome transport bottlenecks, optimize capacity utilization, and support synchromodality based on real-time chain composition. The required information infrastructures for such system-of-systems supporting self-organization are technically realized by means of distributed, interrelated and interoperable functions for data manipulation, process support, end-user interaction, semantic interoperability and controlled (data) security. Incorporating functionality for compliance with (inter)national laws and regulations further evolves the system-of-systems into what is referred to as a 'smart logistics system'.

As components of the technology to realize a system-of-systems are becoming mature, their successful introduction and application critically depends on innovation diffusion. This paper proposes a Living Labs approach in which the relevant challenges identified for innovation diffusion are addressed. Whilst (besides logistics organizations) also authorities are involved in creating such smart logistic ecosystems, these authorities also need to collaborate in the Living Labs to realize its long-term vision and goals.

The first steps towards the roadmap that is described are already being taken in EU funded projects, but the approach needs to be validated further in practice.

Keywords: logistics, system-of-systems, smart system, regulation, data governance, roadmap, living labs

1. Introduction

Today's logistics sector can be characterized as a strongly networked environment, with a multitude of stakeholders functioning in different roles. The majority of stakeholders are SMEs (Small and Medium sized Enterprises), collaborating and competing in a highly complex and fragmented logistics market, referred to as the 'logistics ecosystem'.

The logistics ecosystem has a low Information Technology (IT) maturity level [1]. Nevertheless, for achieving competitive advantage through an improved portfolio of effective and sustainable logistics services with a high level of operational efficiency, innovative IT for data sharing is key. It enables stakeholders to apply the two basic priniples of *self-organization* [2] in the ecosystem: situation awareness and real-time chain composition.

- A higher level of *situation awareness* [3] can be reached as the concepts of open and big data are adopted, which leads to improved decision-making [4], not only for an individual,

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an organization or society, but also in the collaboration with participants of a network. As such, the value of data is considered high.

- As outcome of this improved decision-making, *real-time chain (or service) composition* can both reduce bottlenecks in the physical infrastructure optimize capacity utilization through synchromodality. It allows for dynamic business relationships, multi-sided markets [5] based on data sharing [6] as means of competitive effectiveness.

Various EU funded projects – like EU FP7 SEC CASSANDRA and EU FP7 INFSO iCargo – elaborate the technical implementation and validation of such logistics ecosystems. As the complex and fragmented logistics environment makes it Utopian to strive for strongly centralized IT solutions, they adopt a peer-to-peer – or federated – approach as a more viable option, in which individual stakeholders are enabled for optimizing their logistics service chains through the capabilities for improved self-organization. This results in a distributed, interrelated and interoperable implementation of functions for data manipulation, process support, end-user interaction, semantic interoperability and controlled (data) security: a logistics *'system-of-systems'*. Similarly, smart cities and smart ports are examples of such system-of-systems [7].

Where a distributed 'system-of-systems' enables a self-organizing logistics ecosystem [2], compliance with (inter)national laws and regulations is an additional fundamental requirement for their implementation. Incorporating functionality for regulatory compliance further evolves the ecosystem into what is referred to as a 'smart logistics system'.

The basic infrastructural concepts and components for smart systems are becoming technical mature. However, their introduction is yet to become implemented. Therefore, this paper complements the technical implementation with concepts from data and service science to facilitate a successful introduction roadmap into real-life logistics commercial environments and trade lanes. The paper elaborates on regulatory compliance, innovation diffusion theory and data governance. It describes how a Living Labs approach can help to gain the critical mass for the effective introduction of the smart logistic systems, as depicted in Figure 1.

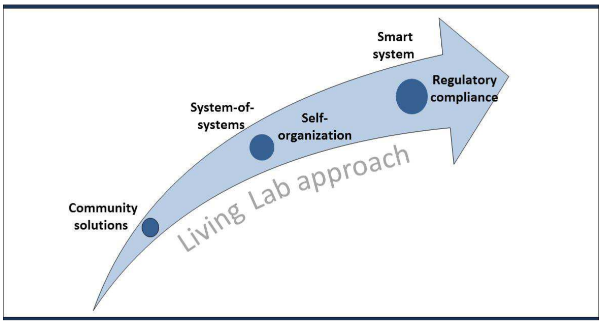

Figure 1: The Living Labs approach towards a logistics system-of-systems.

2. Self-organization: an example in logistics

The case of a barge operator in this section, illustrates the two basic principles for self-organization: 'situation awareness' and 'real-time chain composition'.

2.1 Situation awareness for coordinating behavior

Barge operators operating in a port environment (like the port of Rotterdam) can better coordinate the combination of their container (un)loading schedules at a terminal and their berth location by sharing their intentions with others. Currently, barge operators don't have sufficient knowledge of turnaround times and times at which they are able to pick up and deliver containers at a terminal. There are specific berth locations, where they can wait before a next action can be taken. These locations are most often crowded with barges. The closer to terminals, the more barges wait at these locations to be in time at a terminal.

Thus, barge operators require to know (1) when they are expected at a terminal and (2) if there is sufficient waiting space at a location from which they can reach a terminal in time. Given that a barge operator knows its expected call time at one or more terminals, he can decide where to wait. To know whether there is sufficient waiting space at a location from which they can reach a terminal in time, a barge operator needs to be aware of intentions and actions of his colleagues. Each of his colleagues shares its intentions to all others in a peer-to-peer environment (P2P). Of course, there are many of these barges, not all need to be consulted on their intentions. A general rule could be to share intentions within a certain distance from the port area (geo-fencing).

To meet this requirement, in this example each barge operator is equipped with an app for situation awareness for berth locations. The app gathers intentions of other operators, publishes his intentions and informs a barge operator of changes in intentions of others. Gathering intentions, a barge operator is able to construct some sort of 'expected' agenda for available dwell time at a berth location and uses this as input for his internal planning and decision-making processes.

In addition to improving the barge operator's planning process, situation awareness can be applied for compliance to safety rules in the port area. As example, the barge can have chemicals as cargo. Hence, for reserving a timeslot at a berth location, a minimum distance applies between its berth location and others (e.g. of 10 meters). This rule is validated automatically when the barge operator makes its intention clear by accessing data of other barges at the same location and querying them for dangerous cargo. The port authority responsible for safety can also access intentions of barge operators and evaluate them against the same rules. Whenever he detects a safety breach, the relevant barge operator(s) are warned.

2.2 Real-time chain composition for increasing capacity utilization

A barge operator is able to publish its available capacity in combination with a route. For instance, at a particular berth location, the barge operator makes the next calls available, together with the available capacity on the stretches between these calls. The capacity is expressed as temporary transport services that are only available if there is sufficient capacity on these stretches. The capacity is expressed in the type of cargo and potentially the amount that can be carried on these stretches, e.g. 5 twenty feet equivalent units (TEU) from Rotterdam to Venlo and 10 TEU from Venlo to Basel.

A forwarder that is responsible for on-carriage of containers from the Rotterdam port to the hinterland, can discover these temporary transport services. Based on service requirements of individual containers, e.g. their final destination and expected delivery time, the forwarder

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can select one of the transport services. If for instance, three containers need to be transported to Frankfurt, two of these containers might be carried directly by the barge and one other additional transport service needs to be arranged. The forwarder has two options: select another operator directly from Rotterdam to Frankfurt (e.g. by rail, road or another barge operator), or to transport the container from Rotterdam to Venlo and utilize the available transport service of the barge operator from Venlo to Frankfurt. The latter requires additional handling, so costs need to be evaluated.

Fortunately for the forwarder, at a late stage one TEU is cancelled on the barges trip from Rotterdam to Venlo: the temporary transport service is published, and the forwarder is able to book all three containers on the same barge. The barge operator needs to re-plan its route in the port with a potential delay. The costs of delay and extra handling are evaluated against the extra profit for carrying the three containers.

In a more advanced scenario, he can even decide to further outsource the transport if the planning process indicates that this is more lucrative. This may occur if availability of either the terminal or the berth location provides time constraints for him, or when the sharing of load yields a more cost-effective option. With real-time chain composition he can identify and negotiate with other logistic operators the transport the containers on his behalf against an agreed upon price, timing and quality level. This is known as 'synchromodality': the operator has no obligation towards his customers on the transport modality (road, rail, water, air, …), which gives him the freedom to flexibly use and change various transport modalities on the basis of situation awareness on capacity availability, traffic information, etc..

3. Self-organization, system-of-systems and smart systems

As the barge operator's example illustrates, *self-organization* is a dynamical and adaptive process where systems structure themselves, without external control [2]. It means that all participants take actions obeying particular rules, comparable to a flock of birds. For this, situation awareness has to be implemented. *System-of-systems* behave according concepts of situation awareness.

Situation awareness has three levels [3]:

- *Level 1 'Perception':* A participant assesses its physical environment, e.g. by accessing data shared by other participants.
- *Level 2 'Comprehension':* A participant comprehends its situation, e.g. availability of berth locations or temporary transport services are discovered and matched with goals.
- *Level 3 'Projection of future state':* A participant evaluates potential decisions and uses decision support functionality to produce an (intended) action. Predictions as to behavior of the total system (e.g. in the port area) are evaluated or hinterland transport alternatives are evaluated.

Level 1 requires data sharing. The type of shared data depends on the level 3 action. An (intended) action as output of the level 3 function can be of a physical nature, e.g. slow steaming to a terminal to decrease fuel costs, or an administrative nature, e.g. a business transaction to induce some (physical) action like transport by another actor. Slow steaming requires availability information of terminal locations. The business transaction requires information on the availability of (temporary) transport services. In the latter case, level 2 ('comprehension') requires a matching algorithm to determine which discovered (temporary) transport services meet a particular goal. Additionally, level 3 requires a coordination mechanism for business transactions to synchronize all physical activities.

Apps for smart devices supporting level 1 functionality already exist, based on (layers on) maps. Interpretation by a human of data presented by those apps provides level 2 functionality, e.g. to find a berth location or a (temporary) transport service. Level 3 functionality and decision support is not very common in apps on smart devices; it requires infrastructure functionality like predictive analytics.

Assessment of the environment implies data access, whereas evaluation of decisions considers analysis of (potentially large amounts of) data (big data). Actions will affect the environment; these actions can be assessed and analyzed by other systems. An action might not always take place immediately; there may also be an intention for an action ('future state') that can be communicated with the environment. Sharing intentions allows synchronization of actions based on more and better quality data.

In a *system-of-systems*, stakeholders are able to share their (intended) action(s). However, to really become a *smart system*, these actions need to comply with *laws and regulations* that are governed by for instance a port - customs - and food and drugs authority. These governing authorities need a complete picture of the environment for their governance tasks, e.g. all goods imported, exported or in transit via a particular country governed by a customs authority. This complete picture is analyzed to detect any risks, potentially using a combination of historic data, past behavior of all participants and prediction of future behavior. Compliance rules should be made explicit to allow individual participants in a system-of-systems to behave accordingly.

4. Technology for the system-of-systems

A system-of-systems is distributed by nature. Its complex organizational structure forces to expose both data, processes and the processing of data of different sources as utility [8]. Hence, interoperability on a large scale and at various functional layers needs to be realized, as described in this section.

4.1. Distributed implementation

Scientific literature provides various definitions of system-of-systems, with as common features:

- *Heterogeneous and autonomous*: A multitude of various systems under the responsibility of different organizations that operate on their own. This reflects the aspect of self-organization [2].
- *Large-scale*: A large number of systems, reflecting the vast amount of organizations participating in global logistics.
- *Interoperable for a common goal*: The individual systems share information to reach a common goal, e.g. to reduce turnaround times, optimize capacity utilization, reduce carbon emission or avoid traffic bottlenecks.

These system-of-systems are constructed along the lines of traditional three-tier models for computation that consist of data virtualization, business logic and processes, and user interfaces. With today's IT technology, different actors can provide functionality of a

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particular tier. A Logistic Service Provider or a Port Community System can for instance provide data storage and processing services, whereas Web Entrepreneurs provide user interface functionality as apps on smart devices. In some cases, apps providers also offer a platform containing business logic (e.g. publish/subscribe) and simple business processes for mashing data such as offered by Yahoo pipes.

Additionally, these system-of-systems keep data at its source. As unnecessary data duplication to other stakeholders (potentially leading to data changes and thus inconsistencies) is avoided, data quality is expected to be optimal.

4.2. Perspectives on a system-of-systems

Basic functionality is already available to compose an IT infrastructure supporting a system-of-system, e.g. the functionality provided by Yahoo pipes. In a similar manner, stakeholders can install basic functionality, exposing their services and/or data via Application Programming Interfaces (APIs). Registries for API management can be implemented [9] and there are frameworks for visualizing data retrieved by APIs on maps [10], thus allowing users to construct level 1 and 2 types of applications [3].

However, a more structured approach is needed that combines the three-tier model with configuration information on how and where other organizations provide functions for the various tiers. The structured approach combines various perspectives of the infrastructure:

- *Data perspective*. To handle all types of data manipulation functions in a secure and authorized way. Data might be from multiple sources and linked [11]. These data manipulation operations can be serialized or parallel. The data infrastructure must integrate legacy systems into the system-of-systems. A data custodian provides data storage and processing functionality; a data steward is responsible for data quality. Individuals already use data custodian services for sharing and collaborating, e.g. Dropbox, iCloud, or Google Drive. From a technical perspective, the data perspective can be constructed by integrating Application Programming Interfaces (APIs) supported by API management platforms with (limited) data governance and – security functionality [9].
- *Process perspective*. Providing functionality to participants for publish/subsribe to information events on state changes in the system to evaluated state changes to trigger a next action, resulting in for instance a physical inspection. Protocols for collaboration and value exchange are also part of the process infrastructure. These protocols govern events for sharing data amongst collaborating stakeholders. The behavior of individual components in a system-of-systems needs to be compliant to laws and regulations. The process infrastructure thus also considers compliance rules specified by authorities. Yahoo, Amazon, and Salesforce are examples of a service provider offering the process perspective with Yahoo Pipes, Amazon Simple Workflow Service, and Salesforce Visual Workflow respectively.
- *End-user perspective.* A set of APIs exposing various functions represented by a semantic model. End-users will be able to access the functionality, based on their access policies, in various ways, e.g. as apps developed by web entrepreneurs running on smart devices or via a browser interface. End-users are also able to receive notifications based on publish/subscribe functionality offered by the process perspective.

- *Semantic perspective.* Specifying concepts, associations, and rules common to all actors in a particular domain, allowing actors to make agreements on collaboration. Semantics not only contributes to reducing technical complexity by creating awareness of dependencies, but also contributes to a rapid uptake of new applications and to their ability to share data. Research issues have been to link semantic models of different resources thus constructing networked ontologies [12] to interrelate data of different sources, thus creating Linked Data [11] in accordance with the model proposed by Tim Berners-Lee [13]. These linked models express different viewpoints, e.g. linking a cargo with a vessel maintenance viewpoint via the 'vessel' concept.
- *Data governance - and security perspective*. Constructing a distributed chain of trust based on available trust communities for identification, authentication and access control policies [14]. It provides controlled data sharing based on governance mechanisms addressing privacy, liability, and commercial sensitivity [15]. One can distinguish between policies agreed in communities that collaborate, e.g. to share capacity or combine orders, open data with no security, and discretionary access by a particular actor, e.g. access to one's patient record or transaction data.

These perspectives are interrelated. For instance, the data perspective behaves according configuration by the semantic and process perspective. Data access policies are specified by the governance and security perspective. Yet, the data infrastructure has to integrate with legacy systems that are not yet able to behave according to the principles of the semantic web. They have to be supported by data transformation functionality for resolving differences in semantics and syntax between semantic web and database standards. This can be offered as a service as part of the infrastructure and be called upon by the process perspective. In a similar way, the process perspective can integrate other types of services, for instance those of predictive analytics.

4.3. Seamless participation and interoperability in smart logistics systems

All ingredients seem to be available to (technically) construct a distributed system-of-systems. Separating the infrastructural perspectives and specifying their interfaces, a system-of-systems can be created that is flexible, extendable, and scalable. However, their implementation is still time consuming, costly and may lead to closed subsystems in for instance a port area.

In this respect the concept of *seamless participation* is introduced: the ability to connect once to a system-of-systems and participate. Each participant should register itself to be able to be found and utilize the ecosystem's APIs. Its own functions are exposed in the ecosystem as a Logistics Profile expressing the participants functions as:

- Data access profiles, where data access restrictions are specified through policies. This functionality supports level 1 and 3 of situation awareness, with level 3 an intention for a particular action.
- Logistic services that can be provided to support business transactions as level 3 output.

The Logistics Profile prescribes the technology it applies for actually sharing data: syntax, protocols, Uniform Resource Identifier(s) (URIs), etc..

Additionally, the inherent distributed nature of the system-of-systems makes that *seamless interoperability* is key for their further successful introduction [16]. Interoperability should

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address the mutual dependent aspects of the individual infrastructures for the various stakeholders, at the same time with lower Total Cost of Ownership (TCO) in large scale distributed and open systems.

In scientific research, various frameworks have been presented that focus on the different levels of interoperability. An approach that is often recognized and seems to be well accepted distinguishes three interoperability levels that should be implemented: technology, semantics and organization [17]. The basic concepts and systems for realizing interoperability at the technology and semantics level are currently maturing (although technology for seamless interoperability is still scarce). The successful introduction of a smart logistics system therefore strongly depends on the more 'non-technical' level of organization, for which some critical concepts are still lacking or insufficient. The following section elaborates these organizational concepts and proposes a Living Labs approach in which concepts from data and service science are applied.

5. Creating a smart logistics ecosystem

There are numerous challenges for creating and implementing innovative systems [18]. Two types of innovation-decisions often drive innovation diffusion by organizations: collective and authority innovation decisions. Whereas consensus building is central to collective innovation decisions, a few individuals with high positions of power in organizations drive authority innovation decisions [19].

A Living Labs approach is a means to resolve the innovation challenges in practical settings. Their objective should be clear to all participants: to construct a smart system in which all participants are able to make their decisions based on the principles of self-organization (system-of-systems), while complying with laws and regulations (smart system).

This section discusses the role of authorities, the challenges on innovation diffusion in the Living Labs approach and touches upon governance of these smart systems.

5.1 Smart systems – why authorities should participate

In a smart logistic system, authorities not only assess the state of a system, but are also able to intervene based on rules and predictions of the behavior of the system. They currently implement data sharing with declarations: traders have to push data to those authorities by electronic messages, although not all regulations are yet paperless in all countries. Data is aggregated and analyzed to provide for instance permits, perform inspections, or collect duties. In a smart logistic system, this declaration-based approach would increase the administrative burden for traders. Furthermore, it does not always produce high volatile data, which has impact on physical inspections and introduces unnecessary delays leading to potential high logistics costs. Moreover, data replication reduces data consistency and -completeness, affecting risk analysis results.

There are potentially two options to improve compliance. The first option is to implement compliance rules specified by authorities in the system-of-systems and audit these systems. This improves compliance of the behavior of the system. The second option is to have traders provide data access to authorities, which provides the actual - and predicted future state of the system. This improves improves risk analysis and coordinated border management by authorities. Laws have to support these types of approaches leading to implementations like ‘Horizontal Supervision’ as part of the Modernized Customs Code.

It can be expected that data access and analysis by authorities, potentially leading to inspections or other corrective actions, largely simplifies IT systems of authorities with a decreased Total Costs of Ownership (TCO). Business cases to support this assumption are yet to be established, which is also considered to be part of diffusion of innovation [19]. These aspects need to be addressed in Living Labs to allow the implementation of a smart logistic system.

5.2 Innovation diffusion: aspects of the Living Labs approach

Diffusion of systems-of-systems comprises various aspects. One way of addressing innovation diffusion, is to create so-called Living Labs [20] based on a convenant of participants, not only addressing their collaboration rules and the objective of the Living Lab, but also financing until the solutions for self-organization (the system-of-systems) are adopted by the majority of followers and the subsequent steps toward regulatory compliance (smart system) can be taken. The commitment should also involve authorities as they need to take these final steps towards such a smart system, as explained in the previous paragraph. As the solutions evolve, they can be implemented on a large scale, adopted by the majority of followers [19] and spread via various communication channels, including viral marketing via social media, as is illustrated for instance for the uptake of Layar Technology.

Within Living Labs, the solutions for various aspects can be developed and validated:

- The *type of innovation-decision* that needs to be taken is a critical success factor for a smart logistic system. With respect to the innovation diffusion lifecycle [19], one would like to involve early adopters and commit them to the use of the system. However, systems-of-systems involve a large number of stakeholders, giving issues to find sufficient critical mass to implement a logistics system-of-systems and/or opinion leaders with sufficient authority. As logistics consists of a large number of SMEs with low IT maturity [1], it will be difficult to involve early adopters, obtain critical mass and get opinion leaders and early adopters on board. To select early adopters, assessing their IT maturity using a capability maturity framework can be used.
- *Culture* and *trust* are important aspects of innovation diffusion. Whereas early adopters will see the benefits and will be enthusiastic, the majority of stakeholders will be skeptic. They trust the way they currently operate and develop (IT) solutions and focus on new ways of collaboration instead of sharing data according to protocols and rules. These rules and protocols need to be established to cater for trust and provide a cultural change. The behavior of individual stakeholders can be monitored to create trust with similar mechanisms as used for instance by AirBenB (a peer-to-peer marketplace for bed and breakfast) and Zoover.
- *Value creation* for each of the stakeholders, cost-benefits for each of them, and gain sharing mechanisms [18] are aspects of a commercial - and business nature. Many authors propose a life cycle in which these issues are addressed for instance with an IT service innovation lifecycle. Especially for start-ups, innovation lifecycles are too ling for today’s evolving technological environment with an ever-growing app economy. IT services should be developed in short development lifecycles [21], which are also considered for developing business value propositions. Stepwise, with relative low

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investments, innovative IT services and their corresponding value propositions are developed and validated in practical settings. *Open innovation* based on data sharing provided by the process infrastructure can contribute to a functionality increase, mobilize available skills and expertise and create sustainable business models in an app economy.

- *Privacy, liability, and commercial sensitivity* need specific attention in a system-of-systems [15]. Privacy of individuals has to be guaranteed according to existing privacy laws. Privacy in logistics applies for instance to the movement of barges (see the example) that are also used as a home by the operator and his family and truck drivers. Liability of a participant considers data provision that leads to for instance loss of goods or to accidents of transport means that are operated by others. Providing access to for instance goods data increases ones liability. Commercial sensitivity relates to competition. It involves both pricing structures and value exchange patterns between stakeholders. Sensitive data can only be shared in a restricted manner within a system-of-systems, but analysis of large amounts of data may yield emerging patterns that can lead to individuals or enterprises [22].

5.3. Governance of a system-of-systems

A distributed, peer-to-peer (or federative) approach is the guiding principle for developing a system-of-systems. Each participant governs its own particular components of the system. However, to be operational at a large scale, a minimal rule set needs to be defined and governed, on top of the business rules for sharing costs and profits and gain sharing mechanisms. This is comparable to the governance of the Internet, see for instance http://www.internetsociety.org/what-we-do/internet-issues/internet-governance.

The minimal rule set comprises for instance rules on good behavior, protocols and technology for data sharing, data semantics, and reachability of all participants. All IT components of in-house developed systems or systems and services provided by commercial – or web entrepreneurs including apps running on smart devices providing situation awareness, have to behave according these rules. Governance considering functional – and non-functional aspects has to be installed. Non-functional objects are for instance Service Level Agreements specifying availability and performance of individual components of the system. Functional objects are protocols, semantics, and open standards applied in the system-of-systems, but also gain sharing models and privacy rules.

Existing models for governance of open standards [23] could be extended to cover all governance aspects for a system-of-systems.

6. Conclusions

There are many initiatives to create (parts of) a smart system. Many of these initiatives are aimed at what one could call ‘vertical applications’. They focus on one particular transport mode or address a single bottleneck like turnaround time at hubs. Hence, they consider how different parts of the infrastructure should be evolving. But there is not an unified approach yet.

This paper proposes a phased Living Labs introduction approach for a more structural, unified, infrastructure for a smart logistics ecosystem. It allows the further development alignment of its IT components and addresses all relevant aspects of innovation diffusion in a controlled way. Further elaboration and evaluation of the approach need to be performed by practical applications and study of existing initiatives.

Implementing a smart system of this nature in logistics requires on the one hand validation of behavior of components when registering as participant and on the other hand simulation to evaluate stability and robustness of a system-of-systems.

References

[1] Consultrans, "ICT and e-Business Impact in the Transport & Logistics Industry - a sectoral e-Business watch study," European Commission, DG Enterprise & Industry, Brussels, 2008.

[2] T. d. Wolf and T. Holvoet, "Emergence versus Self Organization: Different concepts but promising wehn combined," in *Engineering Self-Organising Systems*, 2005, pp. 1-15.

[3] M. R. Endsley, "Toward a theory of situation awareness in dynamic systems," *Human Factors, 37(1),* pp. 32-64, 1995.

[4] N. Stanton, P. Chambers and J. Piggott, "Situational Awareness and safety," *Safety Science*, vol. 39, pp. 189-204, 2001.

[5] E. G. Weyl, "A price theory of multi-sided platforms," *The American Economic Review,* 2010.

[6] W. Banzhaf, "Self-organizing Systems," 2009. [Online]. Available: http://www.cs.mun.ca/~banzhaf/papers/sos.pdf. [Accessed 2 12 2013].

[7] M. Jamshidi, System of Systems Engineering, John Wiley & Sons, 2009.

[8] M. Armbrust, A. Fox, R. Griffith, A. D. K. R. Joseph, A. Konwinski, G. Lee, D. Patterson, A. Rabkin, I. Stoica and M. Zaharia, "Above the clouds: a Berkeley view of Cloud Computing," Electrical Engineering and Computer Sciences University of California at Berkeley, Berkeley, 2009.

[9] W. Hofman and M. Rajagopal, "A technical framework for data sharing," *Journal of Theoreticla and Applied Electronic Commerce,* vol. 9, no. 3, pp. 44-57, 2014.

[10] C. Shahabi, F. Banaeir Kashani, A. Khoshgozaran and S. Xing, "GeoDec: a framework to effectively visualize and query geospatial data for decision-making," *Multimedia, IEEE,* 2010.

[11] T. Heath and C. Bizer, Linked Data - evolving the Web into a Global Data Space, Synthesis lectures on the Semantic Web: Theory and Technology, Morgan & Claypool Publishers, 2011.

[12] A. Ferraram, A. Nikolov and F. Scharffe, "Data linking for the Semantic Web," in *Semantic web; ontology and knowledge base enabled tools, services, and* , Hershey, Information Science Reference, 2013, pp. 169-200.

[13] T. Berners-Lee, "Linked Data - four rules," 18 June 2009. [Online]. Available: www.w3.org.DesignIssues/LinkedData.

[14] P. Pruksasri, J. v. d. Berg, W. Hofman and S. Deskapan, "Multi-level access control in the data pipeline of the international supply chain system," in *iCETS*, Macau, 2013.

[15] S. Eckartz, W. Hofman and A. F. v. Veenstra, "A decision model for data sharing," in *eGOV2014*, Dublin, 2014.

[16] W. H. J. Manthrope, "The emerging joint system of systems: a systems engineering challenge and opportunity for APL," *John Hopkins APL Technical Digest, volume 17, number 3,* pp. 305-313, 1996.

[17] European Commission, "European Interoperability Framework for European public services," European Commission, Brussels, 2010.

[18] J. K. S. Spohrer, "Service Science, Management, Engineering, and Design (SSMED) - An emerging discipline - Outline and References," *International Journal on Information Systems*

*Corresponding Author. Email: wout.hofman@tno.nl

in the Service Sector, May 2009.

[19] E. Rogers, Diffustion of innovation (fifth edition), New York: Free Press, 2003.

[20] A. Følstad, "Living labs for innovation development of Information and Communication Technology: a Literature Overview," *The electronic Journal for Virtual Organizations & Networks*, pp. 99-131, 2008.

[21] K. Schwaber, Agile project management with SCRUM, Redmond, Washington: Microsoft Press, 2004.

[22] V. Mayer-Schonberger and K. Cukler, Big data: a revolution that will transform how we live, work, and think, Eamon Dolan/Houghton Mifflin Harcourt, 2013.

[23] E. Folmer and M. Punter, Management and development model for open standards - version 2, Enschede: NOiV, 2009.