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The anatomy of digital trade infrastructures

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Abstract: In global supply chains information about transactions resides in fragmented pockets within business and government systems. The introduction of digital trade infrastructures (DTI) that transcend organizational and systems domains is driven by the prospect of reducing this information fragmentation, thereby enabling improved security and efficiency in trade process. To understand the problem at hand and build cumulative knowledge about its resolution a way to conceptualize the different digital trade infrastructure initiatives is needed. This paper develops the Digital Trade Infrastructure Framework that identifies its structural components.

Keywords: International trade, Digital infrastructure, eGovernment

1 Introduction

The global demand for perishable products such as fruits and vegetables [1] and flowers [2] has made the international trade highly dependent on efficient infrastructures. Efficient port administration [3], reliable vessels carrying the goods, and robust mechanisms for coordination of hinterland transport chains [4], as well as digital trade infrastructures (DTI) for handling of data related to the goods are prudent to support a seamless flow of goods. A recent literature review of Information Systems for port administration [3] concludes that integrated systems are crucial for the enhancement of the performance of ports. The review points at the technological advances i.e. cloud computing, sensors and RFID, supporting improvement of the information flow which they observe is confronted with challenges in compliance with regulatory requirements. The complexity of port administration is only one component in the puzzle of moving fruits, vegetables and flowers from producers to the consumers. One fundamental issue in these global supply chains is that information about transactions resides in different business and government systems, which lead to fragmented pockets of information. From an IT perspective this fragmentation can be due to legacy systems [3], different standards and little or none interoperability within and across systems and sectors [5]. Furthermore, non-technical barriers related to strategy and legislation play a central role, parties are often reluctant, or even legally not allowed to share data [2; 6]. As a result, the flow of goods is accompanied with data and information streams of poor quality and end-to-end supply chain visibility is extremely challenging to achieve [2; 6]. The lack of reliable, accurate and complete data makes it hard to detect risks (such as safety,

security, and compliance), which challenges the timeliness of commercial transactions and at the same time makes international trade inefficient.

Governments and interest organizations involved in international trade are increasingly recognizing this information fragmentation across nations and business units as one of the key challenges for improving the conditions for international trade. Information infrastructures for the international trade domain (referred to as Digital Trade Infrastructures/ DTI) are considered a key component for the solution. DTI concepts such as Single Window, National Community Hubs, and Data pipelines [7; 8; 9; 10] have emerged and recently data pipelines have been conceptualized as Thick or Thin depending on whether documents are exchanged in the data pipeline or only limited event data is exchanged [11]. These initiatives reduce the data fragmentation. They do however not eliminate the need for robust digital infrastructures. A digital infrastructure (DI) has been conceptualized as a Systems-of-Systems [12; 13] that transcends organizational and systems domains. In the trade area specifically, it has been suggested that DTIs that transcends the current information silos can enable more efficient risk assessment, supply chain optimization and cost savings [14; 15; 16; 10]. However, accounts from the field suggest that conflicts related to data sharing, standards, financing and benefits distribution make infrastructural initiatives come to a halt [9]. Some of the reported issues correspond to issues of technological complexity and actor enlistment that are known challenges within the digital infrastructure literature. Other issues seem to be specific to the trade domain with its intricate interplay of governments at national and international level to control the flow of goods and in influencing decisions related to infrastructural initiatives [17; 6].

While in the research community there is a growing body of knowledge related to DIs, there is still little understanding about the of DTIs. The highly-regulated domain of international trade, where goods transcend national borders and regulatory regimes set DTI apart from other DIs, such as infrastructures for healthcare at national level [5]. This far, little cumulative knowledge development has been made about the specific challenges of developing DTIs. One important aspect of building an understanding relates to how the many attributes of a DTI are configured. The objective of this paper is to build understanding and provide grounds for cumulative learning regarding DTI. The goal is to conceptualize components of DTIs and map the challenges faced by DTI initiatives. The aim is to address how such initiatives move from initiation to implementation and adoption, thus supporting efficient international trade activities. The specific research question addressed is: What are characteristics related to architecture, process and governance across different types of DTIs? To this end, through an empirically grounded analysis based on four cases of DTIs and using the conceptual lens of DI this paper develops the DTI Framework. This DTI Framework is built around three dimensions identified in the DI literature, i.e. architecture [17; 18], process [19; 13; 5; 20] and governance [21; 22].

The remainder of the paper is organized as follows. The next section briefly presents the three dimensions architecture, process and governance which guide the empirical study. The following section outlines the specific context, the research method, the empirical cases and an analysis of the cases. Section 4 provides a presentation of the elements constituting the anatomy of DTIs. The final section elaborates on a discussion of the possible implications of the framework presented in section 4 and offers some concluding remarks.

2 Digital Infrastructure and Digital Trade Infrastructure Design

The research on the building of infrastructures points to a broad range of challenges. Challenges include the inadequacies of traditional systems development methods [23; 24; 25; 26], the inertia of the installed base [27], coordination among stakeholders [21] and political struggles for influence and control [28]. It is widely recognized that infrastructures are built upon existing work practices, human resources, standards, technological artefacts and organizational commitment [21; 13]. This installed base results in, that infrastructures are rarely built from scratch [27], they are rather nurtured and grown involving relevant stakeholder groups [17]. Metaphorically they are cultivated [13]. Consequently, the general conclusion is that effective development of DI requires approaches that are different from the traditional system development methods [13; 29]. Generally, suggestions on how to cultivate a digital infrastructure focus on three design domains: architecture, governance and process.

Architecture refers to the components of the DI and how they are connected. Because DIs are socio-technical, any DI will contain both social and technical components. The social components include stakeholders and practices for using the DI [17]. Drawing on Edwards [17] Gal [18], p. 18 states: ‘‘Technically, the construction of an infrastructural system requires the establishment of protocols and standards that enable the system to be used and seamlessly connect with other systems. Socially, its construction necessitates the elaboration of a system of classifications that symbolically represent and organize things in society: people, classes, geographical areas, religions, civil status, and so on.’’

Regarding governance of DIs there is an extensive body of research demonstrating the shortcomings of traditional IT management strategies, including hierarchical organizational structures and distribution of decision rights, careful planning and execution of plans for the management of DIs [21]. But research on what kind of governance regimes that actually works is largely lacking, with just a few exceptions. One exception is Constantinides’[22] research in which he draws extensively upon Elinor Ostrom’s [30] research on “Governing the Commons”. It describes three kinds of property or decision rights related to an DI: constitutional, collective choice, and operational. Operational rights refer to rights related to access and contribution and extraction of resources – i.e. rights to access a DI. Collective choice rights refer to rights of removal, management and exclusion of users, while constitutional rights refer to who may or may not participate in making collective choices.

The process design refers to how the DI is being built or how they change into a more complex form [20]. A review of DI cases reported in IS journals identified forty-one different cases were found which focused on the processes in the building of infrastructures [20]. It was assessed that out of the 41 cases 17 were unsuccessful and 24 were successful. A central contribution in this context is the observation that all successful infrastructures started small and evolved into large ones.

The architecture, process and governance design components identified in the DI literature are the starting point for our empirical analysis. In the next section we describe how building on four cases from the trade domain and by using analytical induction [31] we arrived at an anatomy of DTIs.

3 Methodology

We attend to our research objective by an approach similar to analytic induction [31]. An analytic induction approach starts deductively with the formulation of a guiding framework, which is empirically validated and extended by analysis of case data. We use the three design domains of DI (i.e. architecture, governance and process) as general theoretical framework for analyzing cases within international trade to establish the sub-dimensions of each design domain.

3.1 Case background

During our involvement in different large scale trade projects some general insights have been accumulated which motivate this search for mechanisms which can contribute to effective sea traffic management including onwards processes ensuring more efficient and secure trade. Fundamentally, the observed scenario relate to the increased security requirements carriers are now obliged to follow. They have to send Entry Summary Declaration before the goods are loaded on the vessel at the port of departure, so that Customs at port of entry in EU can make risk analysis. However, in order to do that the carriers have to rely on information earlier in the supply chain. Often the information available in the declaration is not sufficient for Customs at the port of entry to do the proper risk analysis. For example, the Customs may not be able to see based on the declaration who the real seller of the goods is. Sometimes the name of the freight forwarder may appear on the declaration rather than the name of the actual seller.

If Customs is not able to do the risk assessment based on the available information they will request additional information, causing delay in the flow of goods. Any delay has business consequences in terms of costs, i.e. waiting time for the driver at the port, re-planning, calling and e-mailing, which further down the chain can influence the delivery to the customer and cause possible costs of violation of contracts. A delay may also require a change in the on-ward mode of transport, where missing a slot on a cheap on-ward transport via barge may require doing a last minute booking of trucks for road transport at premium prices leading to extra costs. With perishable goods delays can influence the quality of goods and in extreme cases the complete cargo may be damaged. These are just a few examples to sketch the broader context, where the carriers are not only responsible for shipping the goods from port to port but have a large responsibility in terms of information provisioning related to the goods and parties involved in the exchange of goods. The different stakeholders involved in activities related to sea transport such as carriers, terminals, customs administrations, play a key role as users and providers of information and have to deal with inefficiencies of the information fragmentation.

In line with our analytic inductive approach, we searched for cases that would allow us to reveal contextual elements influencing the work with digital infrastructures in international trade. As a basis for our analysis we took four international trade infrastructure initiatives. Each of cases is briefly introduced below:

The Felixstowe Case: focuses on linking a National Hub for information exchange between businesses and the authorities to international, private Thick Data Pipelines. The context of the Felixstowe Case is the Port of Felixstowe which is Britain's

biggest and busiest container port, and one of the largest in Europe. The port handles more than 4 million TEUs (Twenty-foot Equivalent Units) and welcomes approximately 3,000 ships each year, including the largest container vessels afloat today (www.portoffelixstowe.co.uk)

The FloraHolland case: focuses on a specific trade lane for importing flowers from Kenya to the Netherlands via Sea and Air by using a Thick Data Pipeline. This trade lane further zooms in the complexities related to coordinated border management involving two different authorities (i.e. Customs and Phyto-sanitary), as well as on mutual recognition of ePhyto certificates. The sea freight trade lane, FloraHolland offers full services to growers from container loading until delivery at the flower auction. Services such as shipment and customs clearance are outsourced to various other parties. This requires high level of control over the supply chain and it is therefore crucial to know where a shipment is, who holds responsibility for the goods and how to anticipate to irregularities such as delays or faulty documentation [2; 6].

The Shipping Information Pipeline (SIP) initiative: SIP is an attempt of one of the largest Global shipping companies MAERSK and the technology provider IBM to develop a global Thin Data Pipeline for international trade. The SIP is like an Internet for shipping. It provides a digital infrastructure in which supply chain partners and authorities can share and access information about events (such as container loading, discharge etc.), as well as links to relevant documents. The shipping information pipeline aims to create end-to-end supply chain transparency and a flow of information that facilitates the flow of goods (www.maersk.com).

The Alpha-initiative (real name is removed due to anonymity): The Alpha-initiative is an attempt to set-up a national digital infrastructure. The aim of the Alpha-initiative is to optimize logistic information-sharing in order to make the sector more efficient and sustainable and to reduce administrative load. The Alpha-initiative focuses on the entire logistics chain, from the public sector to logistic providers and from shippers to main ports, knowledge institutions and system suppliers.

The four cases represent different national contexts (UK and Netherlands) and international relations (FloraHolland). The cases involve interaction between different means of transportation – sea, air and land which all have different requirements (FloreHolland). The cases furthermore involve public sector (Customs, Phyto-Sanitary authorities), private sector (the MAERSK and IBM SIP), and public-private partnerships (the Alpha-initiative). For each of the cases we collected data within the broadly defined streams of digital infrastructure research. The data collection relied on interviews, participation in face-to-face meetings, and used documentation (emails, project reporting and evaluations) for triangulation purposes. The data collection is part of a longitudinal study of a FP7 funded EU project. The direct involvement of the stakeholders from the four cases in the project provides an in-depth insight to the empirical domain and provides an ideal platform for longitudinal involvement and exchange of insights. The data collection took place during the period 2014-2016. An exception is the Alpha-initiative case where data was collected over a longer period from 2012-2016.

3.2 Data analysis

Data analysis focused on the three dimensions identified in theory (i.e. architecture, process and governance) and we used the "constant comparative analysis" to identify sub-categories, and attempted to link this evolving set of concepts to the higher-level categories [32]. Eventually, the higher-level categories and the sub-categories identified from the cases were consolidated into the emergent DTI characterization framework. During the data analysis we used our own observations accumulated through our continuous engagement in the project, we reviewed project documentation such as deliverables, reports and meeting notes available from the cases. Two of the authors engaged in a number of sessions to discuss the findings from contrasting and comparing the cases. The two other authors played the role of critical reviewers of the findings.

When looking at the architectural component, we compared and contrasted the cases and tried to identify common dimensions that can be used to characterize the DTI initiatives. While the initiatives were quite different they all aimed to facilitate international trade processes, which involved interactions among business and government actors. By comparing and contrasting the cases we also identified actors such as Port Community Systems which played a role in facilitating these interactions. We therefore included the concept of intermediary actors. Next to that when comparing and contrasting the initiatives it was observed that in some cases the actors who were directly involved in supply chain initiatives (such as shippers, freight forwarders, carriers) were driving the DTI development while in other cases trade and business associations were in the lead. We therefore made an explicit distinction among direct and indirect actors.

The analysis of the four cases suggests that some initiatives aimed to introduce National Hubs, while others aimed at Thin or Thick Data Pipelines. To capture that diversity we introduced the concept of DTI type, where we distinguished among Data Pipelines (Thick/ Thin) and National Hubs. By doing the continuous comparison and contrasting there appeared to be differences in the scope of the initiatives: while some were focusing on a national level, others had international scope (2 or more countries) and other global ambitions. As such we introduced also the concept of levels under the Architecture dimension in our framework.

Regarding the process dimension, cases were compared and contrasted. There were clear differences, i.e. whereas some initiatives were in the early initiation phases, others were already in operational phase. Next we distinguished new services as a separate phase, as in two of the cases there were prominent discussions about the development of apps as new services that can be offered on top of the infrastructure once the infrastructure is operational. The issues related to these phases were quite different. Therefore we decided to introduce phases and sub-categories of the process dimension. When looking at infrastructure governance it was observed that while in all the cases it was considered as an important dimension, in 3 out of the four cases the governance was informal, and only in one case there as a formal board. We therefore introduced formal/ informal as sub-dimensions to indicate a maturity level of the development of governance structures for the DTI initiatives. As governance was considered important but the governance structures in the cases were not well developed further categorization was needed. To give further structure to the

governance dimension we introduced the analytical categories of three types of decision rights [22], namely constitutional, collective choice and operational. Lending inspiration from earlier research [9] and empirical observations from the four cases suggest that in all cases cost-benefit sharing, standards and data access are key decision areas. We included these as sub-categories of collective choice rights, as these pointed to specific decision areas related to DTI initiatives.

The brief outline of the components of the DTI framework illustrate that the process of development of the framework utilized empirical insights in a grounded manner by comparing and contrasting the cases and furthermore that we also iteratively went back and forth from the case findings to literature and vice-versa. As a result, we also further sharpened our thoughts and we linked our findings to concepts and findings from literature.

4 Results: Digital trade infrastructure (DTI) framework

Table 1 illustrates the empirically derived DTI Framework. The framework is structured around the three components identified in the DI literature (architecture, process and governance) as overarching dimensions and it further specifies sub-categories of these dimensions based on the four cases and insights from literature.

Table 1. The DTI Framework

Dimension	Category	Values
Architecture	Levels	National, International, Global
	Actors	Business/ Government/ Intermediary; Direct/ Indirect
	Interactions	Business-to-Business (B2B); Business-to-Government (B2G); Government-to-Government (G2G)
	DTI type	Data pipeline (thick/ thin); National hub
Process	DTI development phases	Initiation; Operation and maintenance; New services
Governance	Infrastructure governance	Formal/ Informal
	Decision rights	Constitutional rights Collective choice rights • Standards • Cost- benefit sharing • Data access Operational rights

Under architecture, we distinguish among (a) Levels: National, International, Global; (b) Actors: Business, Government, Intermediary; as well as Direct, Indirect; (c) Interactions: Business-to-Business (B2B); Business-to-Government (B2G); Government-to-Government (G2G); (d) DTI types: National Hub, Data Pipeline (Thick/ Thin). The Thin and Thick data pipelines represented in Figure 1 suggest one possible positioning (e.g. Thick Data Pipeline limited to the Business-to-Business

actors), however other configurations are also possible. The figure also includes three National Hubs connecting business and government actors but depending on the scope and ambition of the infrastructure initiative the role and number of National Hubs can also vary. National Hubs are used here as an organizational configuration that enables exchanges among business and government actors on a national level and does not address a technical architecture (i.e. the technical architecture can vary)

Under process we make a distinction among three phases: Initiation, Operation and Maintenance, and New Services. Under governance we distinguish among Infrastructure Governance (Formal/ Informal) and Decision Rights (Constitutional, Collective choice, Operational). We further identify Standards, Data Access, and Cost-Benefit Sharing as sub-categories of collective choice rights.

4.1 DTI Architecture

The architectural dimension of the DTI Framework enabled us represent the four different initiatives using the same concepts and visualize them in a similar way.

The analysis of the four cases suggests that the initiatives range from national to international to further to global levels. The cases also differ in terms of the DTI type that they aim at establishing. The Alpha-initiative and the National Hub components of the Felixstowe case (the private Hub Destin 8 and the public attempt the OneGov to establish such a Hub) are all examples of initiatives that try to establish a National Hub to optimize the information exchanges among businesses involved in international trade in a given country along with its relevant government authorities. It is beyond the scope of this particular analysis, but it would be useful to compare these initiatives in order to gain further insights in what are the core drivers behind the setting-up of National Hub infrastructures. In this context it is recognized that these national hubs are important to ensure efficient flow of the goods from the port to the further in-land destination. Better information can facilitate both the processes involving the authorities such as Customs and allow for faster clearance, as well as providing the business parties further in the supply-chain better options for planning of onward transport, supporting reduced waiting times and increase cost savings.

Looking at the Felixstowe, the FloraHolland, and the SIP cases, it is observed that all of them focus on Data Pipeline DTI. We see different choices with respect to the infrastructure type. The Felixstowe case focuses on Thick Data Pipeline, where physical trading documents are exchanged along with the goods which aim at international coverage. The FloraHolland case similarly focusses on a Thick Data Pipeline but is limited to a specific trade lane between Kenya and The Netherlands. The SIP case on the other hand focuses on a Thin Data Pipeline where only event information is exchanged providing links to documents rather than the documents themselves, thus implementing a digital exchange of documents. The SIP case furthermore aims at global reach of the soft documents.

The architectural component of the framework helps us to see how different initiatives fit together. A global Data Pipeline initiative like the SIP aims for global coverage. It relies on existence of and interoperability with other parts of the infrastructure necessary to bring the goods from producers to its final destination. The global coverage requires availability of National Hubs to connect to national

governments in the different countries, as well as Thick Data pipelines which can facilitate a physical document exchange among parties if needed.

Thus, the architectural component can be useful for both looking for meaningful comparison cases (e.g. comparison of National Hub DTI initiatives and comparison of Thick Data Pipeline initiatives), as well as for identifying complementarities among different DTI initiatives and how they can be combined as part of a larger DTI.

4.2 DTI Process

The second component of the DTI Framework focuses on the process. As discussed in Section Three, by comparing and contrasting the initiatives we saw the need to conceptually differentiate among three phases, namely: (a) Initiation, (b) Operation and maintenance, and (c) Development of new services. Especially in the SIP demo and the Alpha-initiative we see that a lot of complications arise when it comes to the initial investment and investors willing to invest in the infrastructure. Specifically in the initiation phase, issues related to cost-benefit and infrastructure governance are related to how to get stakeholders on board and make them invest and commit to adopt the DTI.

Once such an infrastructure is up and running (operation phase) the governance issues and the cost benefit issues become quite different, as they relate to development of business models for the operation and maintenance. In the Felixstowe case for example, the initial investments were already done in the past by commercial parties and in the Operation phase the Pipelines are now commercially run with a viable business model behind them. The business model is based on fees for services offered by the infrastructure providers.

In the cases analysed, most of the initiatives are still in Initiation phase, however discussions about the Development of New Services are vividly present. The motivation for new services available on mobile artefacts is driven by a general shift towards apps in society. In the SIP case, a new service App was developed before the infrastructure was in place to gain users' interest and experience. In the Alpha-initiative the parties are eager to develop new planning Apps. However, they are waiting for the infrastructure (the APIs) to be in place so that they can offer their new services. At the same time the initiatives that we analysed are still trying to gain financing for the Initiation phase or are in search for business models for the Operation and Maintenance phase. Such business models are not directly obvious due to the characteristics of the different parties involved and the public and private interests.

The issue of fair cost-benefit sharing (part of the Governance component of DTI Framework) comes repeatedly as a discussion point, especially in the Alpha-initiative. The DTI is expected to bring savings and efficiency gains to the parties in the chain but it is not obvious how these gains will be redistributed in the chain due to its international dimension. In the cases analysed, substantial efforts are put now in addressing this issue. As we can see, discussing the DTI process immediately links to issues related to DTI governance and this illustrates that the issues are very much inter-linked.

4.3 DTI Governance

Governance is the third dimension of our framework. In the complex multi-actor network of stakeholders governance is very important but remains a challenging issue to address. Data suggests that in only one out of the four cases (the Alpha-initiative) there was a formal governance structure in the form of a governance board. In all the other three cases the governance appeared to be informal. In the Felixstowe case the private providers of Data Pipelines and the private Hub had their governance internally organized and the collaboration among the Pipelines and National Hubs (Destin 8 and OneGov) were managed informally. The FloraHolland case is still in early demonstrator phases but there is a Steering Group of decision-makers from the key partner organizations which oversees the process at the moment. Interview data and interaction with central stakeholders suggest that their role is informally defined. The SIP case is driven mainly by the two established business partners MAERSK and IBM and its formal governance structures still need to evolve. One observation that we can derive regarding the governance dimension is that although theory suggests that it is very important to address the governance is still a complex area that needs to be further understood.

As discussed earlier the allocation of the three categories of rights (i.e. constitutional, collective choice and operational) is central to the governance of DIs [22]. To recall, operational rights refer to rights related to access and contribution and extraction of resources – i.e. rights to access a DI. Collective choice rights refer to rights of removal, management and exclusion of users, while constitutional rights refer to who may or may not participate in making collective choices. These categories can help us to further reflect on the four cases and derive insights for further research.

Reflecting on the four cases and looking at these decision rights in relation to the phases that we identified we can say that the decision rights as defined by Constantinides [22] mostly apply to the Operation and Maintenance phase, as they seem to assume the existence of the DI. It is interesting however to explore the possible links of the conceptual categories of decision rights in relation to the case findings, as well as the other phases we defined.

The constitutional rights refer to who may or may not participate in making the collective choices. If we look at the SIP case, the technology supplier IBM and the shipping company MAERSK are now driving the initiative. Key challenges related to how to mobilize a collective action to secure further funding and ensure wider adoption for this initiative still remain unsolved. To add complexity it is observed that it is likely that the parties who participate in making decisions in the initiation phase are different from those making choices about the Operation and Maintenance phase and when it comes to New Services. It is too early to identify trends on if APIs for New Services are made available and furthermore if external parties take the opportunity to utilize the potential of APIs. If external parties are included into the New Services phase it may be possible that new parties enter and gain decision rights and thus become players in the decision-making process. Thus, it would be meaningful to extend the notion of constitutional rights also to the Initiation and the New Service phase and see what learnings can be derived from that.

The Collective choice rights as discussed earlier refer to rights of removal, management and exclusion of users. This definition is very much centered around the subject of users. If we broaden the view that the parties who have constitutional rights will need to make collective choices related to a number of areas (where users could be one of them for example), then we can further explore and identify which are the specific areas related to the DTI for which collective choices need to be made (i.e. the collective choice rights could be exercised). Our case findings reconfirmed findings from prior research that important choices concerning DTI relate to (a) standards; (b) data access; (c) cost-benefit sharing. The Operational rights as discussed earlier refer to rights related to access and contribution and extraction of resources – i.e. rights to access a DI. Again, this presumes the existence of the DI and the question is what would be the meaning if expanded to the other two phases. For the Initiation Phase it may be linked to investments needed in the set-up of the infrastructure and possible return on investment (in our cases we see that initial investment is crucial and that securing such an initial investment is a difficult process). In the New Services phase it may relate to rights of App providers to the infrastructure and value exchanges related to the use of the infrastructure and the offering of new services.

Another observation that we need to make is that the rights outlined above seem to assume that such rights are easily defined. In our case findings we saw however that most of the initiatives (except one) had informal governance. The rules were not yet explicitly defined. Furthermore, although these categories can help to bring further structure into key decision-making processes, the process dimension of how the actors come together and how constitutional rights are obtained along with the question of who drives and shapes this process is still unclear. Furthermore, the analysis highlights that changes of the actor configuration and evolvement through the different phases of the infrastructure development needs to be further conceptualized and explored. An analysis of collective action processes appears to be a suitable conceptual lens to further examine such processes [33].

5 Discussion and Conclusions

Two big challenges that our society faces today is on the one hand how to increase the safety and security, and at the same time reduce inefficiencies and facilitate trade. Increasing the quality and availability of data is seen as key to achieving that. Governments and businesses are increasingly recognizing it and struggle with establishing the necessary digital infrastructures. Still, as discussed in this paper achieving this digital infrastructure is a difficult task. Over the years we observed different initiatives trying to solve parts of the puzzle but it has so far been difficult to see how the pieces fit together and where the similarities and overlaps are. And while on a demonstrator setting the benefits of initiatives such as the data pipelines have been tested in series of EU projects the scaling-up of these initiatives have turned out to be challenging. Given the importance of these initiatives the need for a framework that will allow comparing and contrasting the initiatives is of utmost importance in order to assess similarities and complementarities. By building on four cases which have different scope and coverage we arrived at a conceptual framework. This framework captured a rich variety of cases, ranging from the Alpha-initiative which

aims to optimize a national hub, to the Felixstowe demo which aims to set the link between a national hub and international thick data pipelines for information sharing about goods imported via sea to the UK; to the trade-lane specific data pipeline of FloraHolland and the global Shipping Information Pipeline driven by MAERSK and IBM.

Reflecting on the experience so far the DTI Framework has been useful as a conceptual lens to reason about the architecture, process and governance components of DTI initiatives and their interrelationships. Our analysis illustrates that the architectural, process and governance component are strongly intertwined, and exploring these dependencies is necessary to gain better understanding of the complexities and problems at hand. The DTI framework allows us to characterize a range of components and to look for meaningful comparisons of similar cases, and further to look for complementarities. Understanding better the complex interplay among architectural configurations, processes and governance of DTI will enable us to better understand the complex processes that drive DTI from initiation to operation and further to growth through new services. From all the components, the governance component (and its relations to the other two components) seems to be most complex to address, as it is the complex interplay of actors and decision-making processes that brings DTIs to a halt or drive them to success.

Looking at the process component a possible area of research would be to zoom into the initiation phase and identify factors that block these initiatives and put them on a halt and what are mechanisms that unlock these processes and allow the DTI initiatives to move towards implementation. Regarding the governance, one possible question is to explore the processes of how constitutional rights are obtained and whether and how they change when the infrastructure develops from initiation to operation towards new services. Cost-benefit sharing is another very central area, where further research can focus on identifying cost-benefit sharing models which are useful for supporting the business case in the initiation phase; cost-benefit models for supporting the business model for the operational phase or cost-benefit models for allowing app providers to the infrastructure. Regarding the architecture component possible areas for research is to carry out comparative studies and gain cumulative knowledge on what are complexities related to setting-up a specific DTI type (e.g. National Hub, Thick Data Pipeline or Thin Data Pipeline) and what are lessons learned.

With regards to a general understanding of DI design, three important findings emerge. First, there is a tendency towards archetypical architectural DTI set-ups. That is, in theory, choices in decision points of the infrastructure can be combined freely. In reality, however, it seems like some architectural design choices go more naturally together. These "natural fits" of architectural design choices indicate that there might be possible archetypical infrastructure set-ups of design attributes that align with each other. The implication of this finding is that anyone interested in the shaping of digital infrastructures cannot make independent choices regarding the architectural design but has to recognize the systemic dependencies between the choices. That is, one specific choice will influence the possibility for choices in the other design areas. Second, the different archetypical digital infrastructure set-ups seem to address different problems. Contrasting different set-ups is not about declaring one being better than the other. They are simply different tools, used in different scenarios. The

scenario is defined by of the infrastructure set-up. Depending on the set-up (level, actors, scope, etc.) a different archetypical set-up is suitable. For example, for the Felixstowe DTI with a more limited actor and geographical scope it was decided that the best set-up would be to exchange documents within the pipeline (and hence adherence to data standards was of key importance) and offer this as a commercial service. In contrast, the inclusive (geographically and actor) design of the SIP aiming for global scope led to a decision to a minimalist standardization (not standardizing data elements) and a common-good philosophy. Critically, the choice regarding decision points in the Felixstowe case would not be suited for the SIP case, and vice versa. So, the question to answer in a specific case then is: What is the problem to be solved and how to map the connectivity infrastructure set-ups according to that problem. To the extent that an infrastructure set-up design might be flawed, it is because the combination of attribute is not coherent, that the elements for the DTI Framework are misaligned. For example, combining an international ambition with standardization of data elements is likely to be a futile exercise, as no global agreement can be made down to that level. Third, each of the archetypes seems to have their distinct "must win battles", depending on the process (i.e. the phase in which the DTI is in), as well as the governance choices. For the SIP which is currently in its initiation phase, the critical "must win battle" is to mobilize the mass of supply chain actors to join the initiative. Such a design is subject to network effects: the more actors that join the initiative the greater the benefits for all. However, initially, there are no benefits of joining, in the same way that there would be no benefits of being the first (only) one with a telephone or a Facebook account. This is in the infrastructure literature referred to as the "bootstrapping problem" and should be addressed through pre-emptive strategies. This relates to the complexity of governance of DTI in the initiation phase of the initiative. Research on mobilizing collective action can be used as inspiration for further research to address this problem [33].

For future work, it is critical to advance the understanding of DTI architecture set-up archetypes, building knowledge about which choice, and governance decision points, and processes go well together into coherent archetypes, which problems the archetypes can be used to solve, and the particular challenges of each archetype. To this end, what does this research mean for practice? It is important to realize that parties like sea carriers, terminals, port community systems and authorities are well positioned to play a key role in setting up digital trade infrastructures. Some will grasp the opportunities and will try to be the first-movers, others will be forced to reposition their activities to stay in business. Our mapping of the anatomy of DTIs as well as future research in the directions that we identified in this paper can be instrumental for these parties to understand the complexity of the playing field when defining their strategies for action.

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