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Cluster Perspective on Inter-Organizational Information Systems

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1. Introduction

The inter-organizational information systems have been attracting researchers' attention since 1980s. Their potential to decrease costs and improve service quality and consequently boost a firm's competitive position is significant (Clemons and Row, 1993; Reekers and Smithson, 1996). Inter-organizational information systems are information systems that span the boundaries of a single organization (Chatterjee and Ravichandran, 2004). Accordingly such systems are able to enhance not only the competitiveness of a given firm but also the competitive position of the network of organizations connected via the system. However, the majority of inter-organizational information systems studies are carried out at the single firm level or dyadic level (Robey et al., 2008).

The researchers that argued for the necessity to study the systems at the higher level suggested the industry as the unit of analysis (Damsgaard and Lyytinen, 2001; Rodon, 2007). But I believe that the nature of modern competition and structure of organizations' connections suggest another, more appropriate unit of high level analysis – the cluster. Market competition exists both at the firm level and at the higher global level – cluster level (Carrie, 2000; Haezendonck and Notteboom, 2002; Porter, 2000; Schmitz, 1999).

"Clusters are geographic concentrations of interconnected companies and institutions in a particular field" (Porter, 1998, p.78). Clusters consist of organizations producing a certain product or service and of their supply chain partners; clusters encompass value chains that produce complementary products; they also include governmental and other institutions that provide specific services like authorization, training, technical support. Hence clusters have both vertically linked organizations within them (i.e. supply chain partners) and horizontally linked organizations (i.e. competitors, alliance partners, public institutions etc.). Industry, on the other hand, is a group of companies which produce a particular product and their supply chain partners. Thus, the notion of the cluster subsumes the notion of the industry if the latter is limited by the geographic dimension. The industry is the part of the cluster but clusters also include other organizations like certifying agencies of the government, knowledge producing institutions etc. Therefore, it is beneficial to take a cluster as the unit of analysis rather than industry as this allows accounting for a wider variance of inter-organizational relationships.

Being part of a cluster brings a number of advantages for a firm. Clusters can provide better access to employees and suppliers, access to specialized information, complementary services, access to institutions and public goods, better motivation and measurement (Porter, 1998). The major factors that influence the competitive position of a cluster on the global scale are factor conditions, context for firm strategy and rivalry, demand conditions, and related and supporting industries (Porter, 2000). Information infrastructure is a constitutive part of factor conditions. Quality of information exchange within the cluster can influence the overall cluster's competitive position (Van Baalen et al., 2008; Wrigley et al., 1994).

Implementation of inter-organizational information systems is a way of improving information exchange quality within the cluster. Researchers suggested different dimensions of information quality. The most common ones are accuracy, reliability, completeness, timeliness, accessibility, interpretability (Goodhue, 1995; Jarke and Vassiliou, 1997; Wand and Wang, 1996; Wang and Strong, 1996; Zmud, 1978). Inter-organizational information systems have the potential to improve all of the named dimensions of the information exchange (Patnayakuni et al., 2006; Van Baalen et al., 2008; Wang and Wei, 2007).

When considering competitive position of a cluster as a dependent variable the focus on a single independent inter-organizational information system operating within the cluster is not sufficient. The development of inter-organizational systems is contingent on the social structure of the cluster (Rodon and Sese, 2010). As a consequence, one inter-organizational system in a given cluster can provide the services that are covered by two inter-organizational systems in another cluster. For instance, Portbase system in port of Rotterdam facilitates both communication of business community with port authority and with customs. Meanwhile in Hong Kong Oneport system enables communication between business community and port authority while Tradelink system assists the link between business and customs. Different inter-organizational information systems can cover different parts of the cluster information exchange network. Thus, when describing information exchange quality within the cluster it is necessary to consider all the inter-organizational information systems operating there. Therefore cluster information exchange arrangement via inter-organizational information systems is the construct that is considered in the current thesis. Cluster information exchange arrangement via inter-organizational information systems is the set of all inter-organizational information systems functioning within the cluster at the given point in time. An inter-organizational information system is considered to belong to this set if it connects two or more organizations belonging to the specified cluster. The term arrangement does not imply that the development of these inter-organizational information systems has been intentionally planned at the cluster level to support cluster's competitiveness. It can be the case. However, it can also be the case that the relevant systems have been developed by independent companies or groups of companies within the cluster in their own private interests.

The companies that have the choice to join one cluster or another require a tool that allows comparing the information infrastructures of different clusters. The framework enabling the comparison of cluster information exchange arrangements via inter-organizational information systems is suggested in the current thesis. There can be different ways of evaluating the quality of information exchange supported by inter-organizational information systems. Firstly, the existing exchange can be evaluated against the best theoretically derived solution. Alternatively, it is possible to compare information exchange arrangements across different clusters. The second approach is chosen in this work and the relative advantages of different cluster information exchange arrangements of inter-organizational information systems are discussed.

Furthermore, for the organizations responsible or interested in the prosperity of a specific cluster it is important to understand what causes differences in the information infrastructure between clusters. Is it more or less effective policies or other factors that are out of their control? On the basis of exploratory comparative case study of six port clusters this thesis demonstrates that network structure and governance power division among cluster organizations influence the character of cluster information exchange arrangements via inter-organizational information systems. Moreover a pattern in the inter-organizational information systems development is spotted showing that the probability of creation of vertical links is much higher than the probability of creation of horizontal links within the cluster. These insights contribute to the theory of information systems design. Explicit consideration of the importance of information infrastructure for the cluster development adds to the discussion on the clusters' competition.

The construction of the research framework of the thesis was guided by the following general research question: *How the differences in the cluster level arrangements of information exchange via* *inter-organizational information systems can be explained?* The remainder of the thesis starts with the review of the relevant academic publications. A discussion is then presented that directed the development of the research framework. The cluster information exchange arrangements via inter-organizational information systems of six ports are described in detail preceded by the introduction to the research methodology and data collection principles. The paper closes with the comparison of the information infrastructures of the ports and the derivation of propositions suggesting the cause of the observed differences and similarities.

2. Literature review

2.1. Inter-organizational information systems

The investigation of inter-organizational information systems (IOISs) started in 1982 with a seminal research paper by Barrett & Konsynski (Robey et al., 2008). During the last thirty years inter-organizational systems became more wide-spread in practice and the interest of the research community to the topic rose accordingly. The most recent reviews of the research on the inter-organizational information systems appeared in the papers of Chatterjee and Ravichandran (2004) and Robey, Im and Wareham (2008).

The review by Chatterjee and Ravichandran (2004) covered the articles published in the period from 1982 to 2002. The review by Robey et al. (2008) covered the studies published in approximately the same period: from 1990 to 2003. Both reviews agree that the field of inter-organizational information systems research could be divided into three main areas of investigation: 1) antecedents of organizational adoption of IOIS, 2) impact of IOIS on the transactions governance structure and 3) organizational consequences of IOIS adoption. The firm has been a unit of the analysis in the majority of the studies.

The large number of studies in the research stream on IOIS adoption looked specifically at EDI adoption and EDI infusion as dependent variables through the theoretical lens of Rogers' innovation diffusion theory. The other prominent theoretical perspectives implemented in IOIS research on adoption were network externalities theory and institutional theory, although they were much less popular in comparison with innovation diffusion theory. The factors that were demonstrated to influence the adoption could be grouped into eight clusters: external environment, organizational readiness, innovation characteristics, perceived benefits, transaction characteristics, resource dependence (on the initiator), network externalities, and culture/institutional forces (Robey et al., 2008).

The second large IOIS research stream considers the influence of IOIS implementation on the governance of economic transactions: market-based vs hierarchical. The scholars adopted transaction costs perspective, game theory, network externalities perspective, the property right perspective, and industrial organization theory to study the phenomenon. The findings so far have been contradictory. The majority of studies support the hypothesis that introduction of IOIS favors the use of market mechanisms over hierarchies (Robey et al., 2008). However, there have been studies that disprove the hypothesis (Hess and Kemerer, 1994; Holland, 1995; Klein, 1996).

2.2. Consequences of inter-organizational information systems implementation

Organizational consequences of IOIS use can be divided into three broad groups: operational, strategic, and social (Robey et al., 2008). Operational benefits include improvement in operations such as ordering, delivery, productivity, and control. Strategic impacts refer to the effects of the systems on the mission and scope of organizations. They include among others opening of new markets, development of new products and services. Social impacts incorporate changes in the adopting organization and in the inter-organizational relationship between partners.

At the operational level inter-organizational information systems have been demonstrated to increase the efficiency of transactions (Reekers and Smithson, 1996; Vijayasarathy and Robey, 1997) and decrease transaction costs (Clemons and Row, 1993; Martinsons, 1992). IOIS increase the amount of vertical interactions between the companies (Nidumolu, 1995) and increase the amount of information available in the distribution channel, facilitating through this the development of more efficient coordination structures such as quick-response and vendor-managed inventory (Clemons and Row, 1993). A number of studies showed in greater detail the positive impact of EDI on order lead-time, service levels, and inventory levels (Clemons and Row, 1993; Vijayasarathy and Robey, 1997). Integrated IT infrastructures enable firms to develop the higher-order capability of supply chain process integration. This allows firms to unbundle information flows from physical flows, and to share information with their supply chain partners to create information-based approaches for superior demand planning, for the staging and movement of physical products, and for streamlining voluminous and complex financial work processes (Patnayakuni et al., 2006). Enhanced information visibility and supply chain flexibility in general were shown to be the results of IOIS implementation (Wang and Wei, 2007).

At the strategic level implementation of inter-organizational information systems accompanied by the standardization in business practices and transactions might result in the reduction of the number of competitors and in increase in market-level performance (Ramamurthy and Premkumar, 1995). In the retail sector IOISs were shown to improve company image because of improved service quality (Fearon and Philip, 1999; Iskandar et al., 2001). A global electronic banking system was able to create a business presence in Asia without brick-and-mortar investment (Martinsons, 1992). Implementation of IOISs can reduce the prices throughout the whole industry (Choudhury et al., 1998).

The social impacts of IOIS implementation are numerous and much more controversial than operational and strategic ones. On the positive side inter-organizational systems can foster organizational learning (Christiaanse and Venkatraman, 2002); they facilitate trust and collaboration between partners providing information transparency and a platform for intensive collaboration (Bensaou, 1997; Nakayama, 2000; Scott, 2000). On the negative side IOISs might reinforce existing power inequalities among the partners rather than produce mutual benefits (Webster, 1995). For instance, Reekers and Smithson (1996) found that EDI allowed both auto manufacturers and their suppliers to achieve efficiency gains, yet manufacturers achieved their gains at the expense of their suppliers. However, depending on the design, IOISs can also lead to the change in the bargaining power among the parties (Clemons and Row, 1993).

2.3. Typologies of inter-organizational information systems

To compare the information exchange arrangements via inter-organizational information systems it is necessary to develop the dimensions along which the arrangements can differ. Various studies suggested different dimensions for the classification of IOISs. The table summarizes the overview of nine academic works with classifications and sixteen proposed dimensions. The dimensions were clustered into two groups – technical and relational. Relational group consists of the dimensions that describe not the system itself but rather the relationships between the organizations participating in it. The division can be considered as a rather superficial one as in many cases the dimensions are closely interconnected. However such clustering helps to deal with the large number of identified dimensions.

Table 1. Typologies of inter-organizational information systems

Group	Paper	Dimension	Types
Technical	(Choudhury, 1997)	1. Architecture	- Electronic monopolies - Electronic dyads - Multilateral
	(Van Baalen et al., 2008)	2. Data capture	- From other information systems - Directly from supply chains
	(Van Baalen et al., 2008)	3. Data storage and transfer	- Bilateral - Private storage hub - Central orchestration hub - Modular distributed plug and play architecture
	(Van Baalen et al., 2008)	4. Data processing	- enabling intra-enterprise planning - inter-enterprise planning - chain planning - chain synchronization and inter-enterprise planning
	(Van Baalen et al., 2008)	5. Data transfer technology	- ASCII formatted messages - EDI messages - XML - Standardized XML messages - Messages written in Web services orchestration languages like BPEL and BPML
	(Saeed et al., 2011)	6. Purpose/functionality with respect to inter-firm relationship	- Evaluating - Monitoring - Streamlining links - Data compatibility support - Planning - Forecasting
	(Choudhury et al., 1998)	7. Market-making functionality (for e-markets)	- Identification - Selection - Execution
	(Ravichandran et al., 2007)	8. Service orientation (B2B hubs)	- Transactional hubs - Systems support services
	(Tang, 2011)	9. System capabilities (B2B hubs)	- Bonding - Bridging
	(Bakos, 1991)	10. Economic functionality (vertical	- Information link - Electronic marketplace

		markets)	
Relational	(Kumar and Dissel, 1996)	1. Nature of inter-organizational interdependence	- Pooled information resource - Value/supply-chain - Networked
	(Choudhury, 1997)	2. Development approach	- Cooperative - Competitive
	(Hong, 2002)	3. Key development drivers	- Strategic - Operational
	(Hong, 2002)	4. Type of link between participants	- Vertical - Horizontal
	(Boonstra and de Vries, 2005)	5. Combination of partners' interest in the system development and the power balance in the relationship	- Unlikely - Unbalanced - Balanced
	(Ravichandran et al., 2007)	6. System ownership (B2B hubs)	- Industry participants - Outside providers

Some of the suggested dimensions are very general, for instance, the division of system capabilities into bonding and bridging (Tang, 2011) or of system service orientation into transactional hubs and system support services (Ravichandran et al., 2007). Therefore they won't be considered further. More specific proposed technical dimensions are system's architecture, data capture, data processing, data transfer technology, and functionality.

The dimensions of architecture and data storage and transfer were proposed in two different papers (Choudhury, 1997; Van Baalen et al., 2008). However they describe the same construct. As the classification of Van Baalen et al., 2008 was suggested later, it gives more up-to-date types of the IOIS. According to it, *data storage and transfer* within an inter-organizational system can be organized in four ways: bilateral, private hub, central orchestration hub, and modular distributed plug and play architecture. Bilateral systems support point-to-point connectivity between separate systems of two partners. Private hub architecture is used when one strong company wants to communicate with its external partners. For instance, a company can develop a special system for communication with its customers where they could place order, trace its status etc. Central orchestration hub represents a situation when the system is run by an independent operator and can be used by different even competing companies within the relevant industry. Finally, modular distributed plug and play architecture supposes that there are no permanent linkages among the parties using the inter-organizational system. The companies can interact via the system if needed, exchange information and later easily disconnect and connect to other organizations.

In terms of *data capture* it can be distinguished between data retrieved from other information systems, possibly owned by other organizations, and data captured directly from the supply chain (Van Baalen et al., 2008). The first way of data retrieval is self-explanatory from its name. Implementation of RFID technologies can serve as an example for the second type. RFID tags are able to provide information on the whereabouts of containers or products in the store in a real-time fashion. Another example is GPS technologies that can supply information on the positioning of vessels and vehicles.

The third relevant dimension is the *data exchange technology* that is being implemented with the inter-organizational information systems. The most famous technologies from the simplest to the most advanced are ASCII formatted messages, EDI messages, XML, Standardized XML messages, and messages written in Web services orchestration languages like BPEL and BPML. The technologies can significantly differ in terms of investment required from the participating companies in order to connect to the system. Another difference is the accessibility of IOIS services – depending on the technology it can be more or less difficult for the users to access the system. Some systems can be accessed from any PC with internet connection while others would require the use of a specific PC depending on the data transfer technology that is being implemented.

Inter-organizational information systems can serve not only the purpose of business processes optimization within organizations but also improve inter-organizational processes. Therefore in terms of *data processing* four types of inter-organizational systems can be defined: enabling intra-enterprise planning, inter-enterprise planning, chain planning, and chain synchronization and inter-enterprise planning (Van Baalen et al., 2008). Systems enabling chain planning ensure that planning takes place at a higher level and its results are communicated back to individual organizations. The fourth type of systems is the merger between inter-enterprise planning and chain planning. This type of data processing facilitates higher level of synchronization among enterprises while leaving autonomy for local planning.

The *functionalities* of the system can be described in different ways depending on the researcher's goal. Bakos (1991) suggested classification of vertical market systems based on their economic functionality. Vertical market systems are the inter-organizational information systems that connect participants in a linear value-added chain (suppliers and customers; sellers and buyers). The two types of such systems were identified – information link and electronic market. Information link serves a bilateral integration where a relationship between a supplier and a customer has already been established. Electronic marketplace allows participating buyers and sellers to exchange information about market prices and product offerings (multilateral information sharing). The main difference between these two system types is that the goal of electronic marketplace is to establish bilaterally buyer-seller relationships while information link serves already established relationships.

Saeed, Malhotra and Grover (2011) also focused on the functionality but they distinguished between IOIS characteristics that help evaluating, monitoring, streamlining links with business partners, supporting data compatibility, planning and forecasting. Choudhury et al. (1998) studied electronic markets that are inter-organizational information systems which link multiple buyers and sellers. He categorized electronic markets in accordance with three market-making functions that electronic markets can provide: identification, selection and execution. Identification is the function that helps identify potential trading partners for a transaction. All electronic markets provide this service. Selection is the function that provides access to price information and allows buyers to compare prices without contacting each seller individually. It helps buyers to take an inform decision on which seller to select. Finally, electronic markets can also provide execution capabilities that facilitate exchange of the necessary information between buyer and seller in order for the transaction to take place. Thus, the functionality of the IOIS is an important dimension. However, there is no agreed typology of functions that would be universal for all the systems. Therefore, researchers have freedom in choosing the relevant types.

The group of relational dimensions of IOISs includes the nature of inter-organizational interdependence, development approach, key development drivers, type of link between participants, system ownership and combination of partners' interest in the system and power balance.

Based on the *nature of inter-organizational interdependence* three types of IOISs can be distinquished: pooled information resource IOISs, value/supply-chain IOISs, networked IOISs (Kumar and Dissel, 1996). Pooled information resource system is an inter-organizational sharing of common IS/IT resources (e.g common databases, communication networks, applications). The main benefits that organizations seek in such arrangements are economies of scale, costs and risk sharing. The partners can be either competitors or non-competitors. Value/supply-chain systems support customer-supplier relationships. The examples of such systems are electronic orders, order tracking, database look-up of adjacent partners. The main benefits that these systems bring are the reduction of uncertainties in the supply chain and resulting decrease in costs and cycle time and increase in service quality. Networked systems support reciprocal relationships among organizations when each partner contributes with unique capability. The typical example of such system can be the use discussion databases and data interchange for coordination of the operations of joint ventures or partnerships. As organizations might participate in different kinds of inter-organizational relationships, a specific IOIS can posses the features of two or even all of the suggested types.

As for the *development approach*, a firm could choose to develop the system competitively or cooperatively (Choudhury, 1997). In the cooperative approach firm can decide to attract a partner/partners for the system development. Furthermore, in the cooperative approach firms can decide whether the product of their cooperation should become a public good or be restricted to the use of alliance members only.

Drivers of the IOIS development can be divided into strategic and operational ones (Hong, 2002). Systems providing strategic support are used by partnerships and strategic alliances. These systems might enable firms either to pool or share resources, to reduce investment in the hardware/software risks. The second type of IOISs serve the primary purpose of supporting day-to-day operations. Such systems cause the operational processes of the partners to be integrated and create exit barriers for them.

Links between organizations participating in the IOISs can be classified as either vertical or horizontal (Hong, 2002). Vertical links connect organizations with different roles in the value or supply chains. Meanwhile horizontal links are formed via interconnection of firms performing common value activities; they contribute identical inputs toward the augmented output.

Based on the *interest and power dimensions of the participating firms* IOISs can divided into unlikely, balanced and unbalanced (Boonstra and de Vries, 2005). Participating firms can range along two characteristics: low or high interest in the IOIS and low or high power over its IOIS partners. Combinations of participants with various characteristics theoretically will result in three general IOIS types: unlikely, unbalanced and balanced. Unlikely IOIS is the one in which both parties have low interest in it. It can be technically feasible but not socially or economically. In balanced IOIS, on the contrary, both parties are interested in IOIS development. Unbalanced IOIS exist when one party has a high interest in it while another party has a low interest. Depending on the power balance between the parties different actions might be required from the high interest party in order to bring IOIS into existence.

Finally, inter-organizational information systems can differ in their *ownership structure*. The relevant ownership types can be determined based on the more specific system type and the research goal. For instance, business-to-business virtual marketplaces (B2B hubs) can be divided into owned by industry participants and owned by out-side organizations (Ravichandran et al., 2007). Ravichandran et al. (2007) showed that industries with higher concentration rates and more complex products are more probable to have B2B hubs that are owned by industry participants.

2.4. Design of inter-organizational information systems

The concluding sub-chapter of the literature review deals with the design of inter-organizational information systems because the goal of the thesis is not only to compare but also explain the differences and similarities in the information exchange arrangements. The following papers were identified that concentrated on the questions of strategic choices in IOIS development process: Choudhury (1997); Malhotra, Gosain and El Sawy (2005); Saeed, Malhotra and Grover (2011); Ravichandran, Pant and Chatterjee (2007); Tang, Rai and Wareham (2011).

Choudhury (1997) addressed two important strategic choices that a firm has to make in the development of an inter-organizational information system – choices on the type of IOIS and development approach. Based on the case study of the development of IOISs in the aircraft parts industry, Choudhury concluded that technological uncertainty of the product, demand uncertainty and market variability determine the type of IOIS choice. Meanwhile, strategic significance of the IOIS for the firm, size and bargaining power of the firm influence the firm's decision to develop a system cooperatively or competitively.

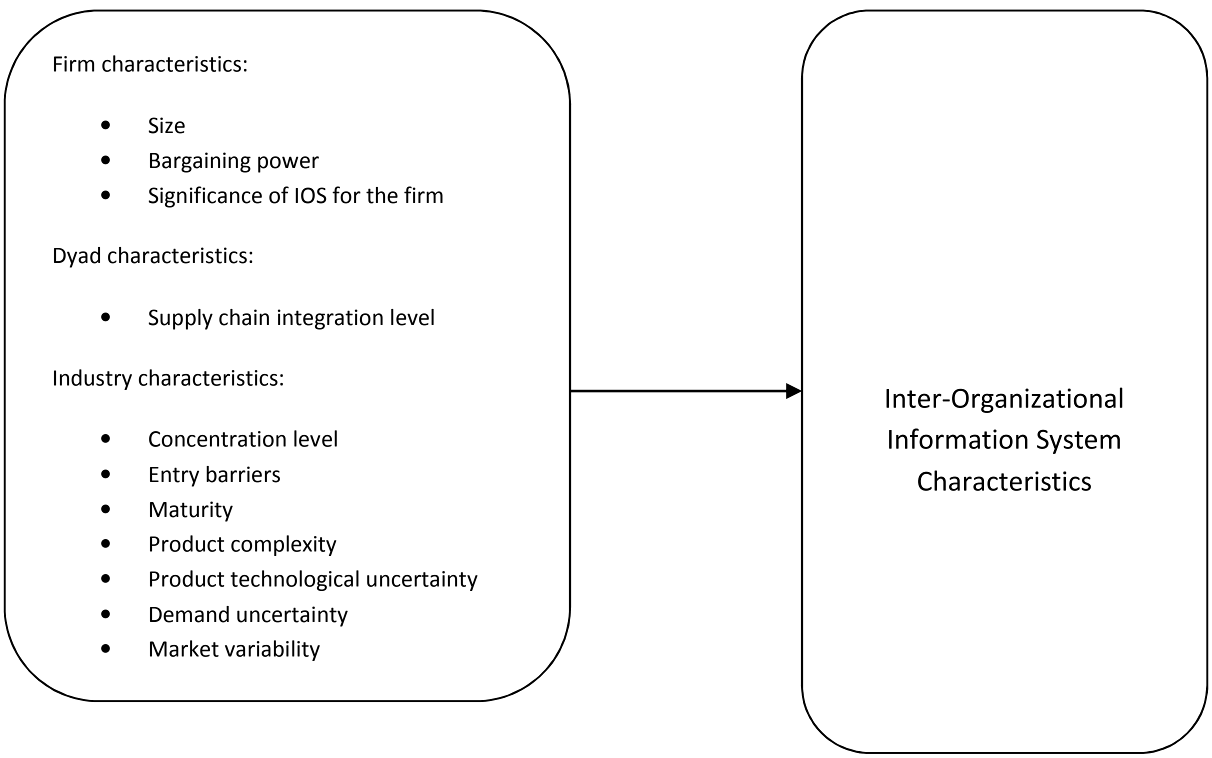
Malhotra, Gosain, and El Sawy (2005) depicted that organizations with different collaboration capabilities demonstrate variation in the configuration of IT systems in terms of storage, retrieval, manipulation, and interpretation of information related to the relationship with supply chain partners. Later Saeed, Malhotra and Grover (2011) switched the level of research from a single firm to a dyadic relationship. They showed that strength of supply chain integration between two partners was connected to the characteristics of IOIS that they used. The integration level was judged based on the existence of joint knowledge sharing routines, coordination level of routine inter-organizational processes and joint investments level in the projects of mutual interest. The authors concluded that when supply chain level integration between two firms is low they invest primarily in IOIS characteristics that will help in evaluating, monitoring, and streamlining links with business partners. As firms move towards higher supply chain integration level in their relationships, they put more emphasis on IOIS characteristics that support data compatibility and planning and forecasting capabilities.

Ravichandran et al. (2007) studied how industry structure and product characteristics influenced the shape of successful B2B virtual marketplaces using industrial organization perspective. They showed that industries with higher concentration rates are more probable to have B2B hubs that are owned by industry participants. Industries with high entry barriers were more likely to have a biased (towards buyers or sellers) B2B hub with systems support services. Mature industries also tended to favor systems with support services well integrated with internal systems of the companies over simple transactional hubs. Finally, the researchers showed that hubs where more complex products were traded were more likely to be owned by industry participants.

Tang et al. (2011) also moved from a firm or a dyad level to a higher, network level. They researched how network structure influenced the roles that can be effectively assumed by independent digital intermediaries in B2B electronic markets. The authors took structural embeddedness perspective to understand how required from the intermediaries capabilities are shaped by the networks in which they are embedded assuming that network structure influences the available strategic choices and value-creation opportunities for digital intermediaries. Based on the comparative case study of two systems, Tang et al. (2011) derived among others the following proposition: exchange networks with information gaps present digital intermediaries with greater opportunities for bridging while exchange networks requiring the coordination of multilateral relationships present them with greater opportunity for bonding. Bridging capabilities are the ones that focus on enabling information exchange. Bonding capabilities rather focus on increasing the richness of exchanged information and streamlining the operations among partners.

The following scheme summarizes all suggested factors that influence the shape of different inter-organizational systems:

Figure 1. Factors influencing IOIS characteristics.



3. Research Framework

3.1 Inter-organizational information systems and cluster's competitiveness

Global cluster competition arises because total business infrastructure remains different from country to country or region to region. Prosperous multinational companies can establish their presence in any part of the world. However, the agility of individual manufacturers depends not only on their own operations but also on those of the interrelated organizations. The success of such clusters of organizations can be judged by how fruitfully they attract new companies and don't lose the existing members in favor of the other clusters.

The crucial difference of clusters from supply chains and industries is that clusters allow taking into account the presence of common interests even among competing organizations. For example, several small companies together can bid for large contracts that they could not on their own. In the insurance sector insurance providers can share their client databases in order to make better decisions with respect to the policy issues. In the port clusters trucking companies can share the information on their excess capacity to organize the traffic from and to port territory in a more efficient way.

Information infrastructure plays an important role in the functioning of a cluster. The result of the implementation of inter-organizational information systems for communication among cluster companies differs depending on the type of systems implemented. The effect of the implementation of IOISs on the competitiveness of the cluster can be judged based on how this infrastructure is evaluated by potential and existing cluster members. Potential and existing cluster organizations are analogous to regular retail shoppers in this case who choose which supermarket they should by from. The retail shoppers make their decision based on the assortment size, quality of the products and their prices. In the similar manner individual companies can judge cluster IOISs based on at least three criteria: 1)variety of services, 2)quality of services, 3)costs of services. Further the different types of inter-organizational information systems are compared in accordance with their influence on these three characteristics of cluster information infrastructure. This shows which systems are more beneficial for the development to increase cluster's competitiveness.

Architecture

As discussed earlier inter-organizational information systems can have four basic architecture types: bilateral, private hub, central orchestration hub, and modular distributed plug and play architecture (Van Baalen et al., 2008). IOISs with bilateral architecture are the least attractive option for the cluster companies because they have the worst potential in balancing the variety of services and their quality with costs. Firstly, these systems are expensive because a company should have a separate connection to each of its partners. Secondly once a new service has been developed every connection should be remodeled again one by one. These systems can't benefit from the economy of scale in the service development.

Private hub architecture, on the contrary, allows the company owning the system to benefit from the economy of scale in the development of new services. The new solutions can be rolled out to all of the partnering companies at the same time. However, from the cluster's point such systems aren't the optimal solution. Only big companies can afford to develop such systems. If there is only one company in the cluster which can roll out a private hub IOIS then this company can gain substantial competitive advantage in the market over its competitors which may bring about the adverse effects of having a monopolist within the cluster. Alternatively if there are two or more big companies that will each roll out their own private hub IOISs their buyers in the cluster may suffer. They will have to use two or more systems performing the same services only connected to different suppliers what results in additional costs for an individual company. Otherwise they will have to stick to one of those big suppliers which will result in their loss of negotiating power.

Central orchestration hub represents a situation when the system is run by an independent operator and can be used by different even competing companies within the relevant industry. Such system can benefit from the economy of scale in the introduction of new services and doesn't distort the competitive positions of the cluster organizations. Furthermore, if such a system is organized as digital platform where service development is also carried out on the competitive base then the variety of services available to the community becomes even larger. The competitive development of services for bilateral links and private hub systems is socially infeasible. Therefore, central orchestration hub inter-organizational information systems are the most favorable ones for providing information infrastructure from the cluster point of view. The more types of different cluster actors are connected via one system the better. This would eliminate the need for the companies to connect to one system for communication with its buyers, to another for communication with sellers and to the third one for communication with competitors which is costly. If the system allows competition in the development of services then there will be no danger that such system will monopolize the market.

Modular distributed plug and play architecture is still in conceptual phase therefore it is impossible to evaluate its potential in balancing the costs of services with their variety and quality.

Functionality

With respect to the functionality of the inter-organizational information systems operating within the cluster, the more is the better. The variety of functions is equal to the variety of services available to the companies. Therefore the wider the number of different functions that are available via inter-organizational information systems within the cluster the higher cluster's competitive position. Although it is important that company had the opportunity to choose which services to use and pay for and which not.

The typology of Bakos (1991) of the vertical IOISs based on their economic functionality is the most appropriate for the cluster level analysis of the information infrastructure. Its generality fits the high level of analysis. Moreover, it can be extended to account for the presence of horizontal links within the cluster. Bakos (1991) distinguished between information links and electronic markets serving vertical relationships between the companies. However, IOISs can facilitate the communication not only between vertically linked partners but also between the competitors. Insurance companies share their client databases to make a more informed decision on the price of the insurance for a customer. Using the system they can base their decision on the full insurance history of a customer, not only its part related to the home company. IOISs can be used not only to share information but also to coordinate competitors' operations when they use common physical infrastructure like port territory. The virtual integration can extend even further when the private assets of companies are used on the cooperative base. For instance, in the ports of Los Angeles and Long Beach truckers can exchange information on empty containers available and fleet availability eliminating "bobtails" when the truck moves without cargo.

Horizontal links are the links connecting the organizations performing the same role within the cluster, in other words direct competitors. For instance, horizontal links can connect two or more insurance companies offering the same services with each other. Vertical links, on the other hand, connect the organizations performing different roles within the cluster, like buyers and sellers or private companies and government certifying agencies.

The common goal of all inter-organizational information systems linking the companies horizontally is collaboration. The companies are always informed what other organizations are participating in the system. The presence of horizontal inter-organizational information links shows that organizations within the cluster collaborate on the regular basis. Therefore, they fully exploit the benefits of being part of the cluster. Thus, the classification of Bakos (1991) can be extended and the variety of inter-organizational information systems with respect to their economic functions can be represented by three distinct system types: vertical information links, vertical electronic markets and horizontal information links.

From the cluster point of view the more there are different types of functional links between different types of companies the better. The cluster companies will have different options to decrease their operational costs using the inter-organizational information systems. It is also important to note that technically it can be one link to a single inter-organizational information system facilitating different functions.

Data transfer methods and standards

Van Baalen et al. (2008) suggested classifying inter-organizational information systems in accordance with data transfer standards that were implemented in them. Such classification is valid. However it puts too much stress on technical qualities rather than on economic qualities of IOIS. As the focus of this thesis is on the cluster competitiveness and organizational decision making, it is more fruitful to classify IOISs with respect to communication methods. Such typology indicates not only what kind of data transfer standards can be used but also the relative costs of accessing different types of systems.

The data transfer methods used in inter-organizational information systems can be divided into three general groups – private networks, Internet connections and mobile technologies (Free Encyclopedia of Ecommerce, 2011). There are two ways to establish a private network: point-to-point communication and value-added network provider (EDI Basics, 2011a,b). Point-to-point communication was the first invented way of electronic message exchanging. Generally for point-to-point communication telephone lines were used to send messages via standard communication protocols. Nowadays the dial-up approach allows using regular telephone lines for irregular exchange of low amount of data. However, for frequent exchange of high amount of data expensive leased lines are required. Point-to-point private networks are most expensive in development and operation in comparison with other communication methods. Therefore usually only big companies can afford to establish them. Today such systems are being used in most cases for legacy reasons only. This communication method can support bilateral links and private hub architecture systems. The benefit of such communication can be seen in that the system is completely in control of the company/companies that established it; such power can be valuable for a company but not for a cluster as a whole. The presence of such system in a cluster can be considered as advantageous only if there are no other ways of electronic communication between the companies what is highly unlikely taking into account the widespread use of the Internet these days.

Value-added networks (VANs) are networks dedicated exclusively to exchange of electronic messages between the companies (Free Encyclopedia of Ecommerce, 2011). Usually such networks are provided by third-party companies. Unlike point-to-point networks they not only transfer information but also contain storage areas where data sent from one party can be held until it is scheduled to be delivered to the receiver. VANs can provide translation services, data backup, report generation, issuance of warning in case of disruptions in data transmission. VAN providers offer technical support and training to the participating organizations. VANs are attractive for small organizations for which it is too expensive to do translation with their own software services. Furthermore, they offer much more opportunities for the service development as their technical functionality is wider in comparison with simple data transfer available via point-to-point systems. Point-to-point connections do not provide the transaction visibility, reporting or traceability that a VAN provider can offer. VANs providers have different business models. Some charge high setup fees followed by low monthly usage fees. The others do vice versa. In many cases charges are based on the number of documents or characters involved in a given transmission. VANs can support the systems of all architecture types. The use of VANs is good for cluster’s competitiveness as they are able to support large variety of high quality services.

Internet connection can be used in two ways in inter-organizational information systems: via virtual private networks and via web browsers (EDI Basics, 2011c,e). A Virtual Private Network (VPN) exploits public telecommunication networks (in most cases the Internet) to conduct private data communications. VPN allows using a single internet connection to connect all of the PCs from the internal network to its trading partners. VPN servers can also connect directly to other VPN servers forming joint network between organizations. VPN is a more advanced alternative of private point-to-point connections which is much cheaper than its traditional alternatives that use telephone lines. However, this communication method can only support bilateral links or private hub architectures for inter-organizational communication.

Internet web browser is the cheapest way of exchanging standardized messages among organizations nowadays. The browsers are installed on nearly every PC and the majority of companies have internet access. Companies are not required to install any special software on their PCs. The users fill in the fields on the web page with the relevant information which is further converted into an EDI message and is then sent securely via protocols like File Transfer Protocol Secure (FTPS) or Hyper Text Tranpsort Protocol Secure (HTTPS). Web browser connections can serve both private hub and central hub architectures. VANs and Web browser connections are the main competing modes of communication for the modern companies. The advantage of VANs is in higher security levels and higher service reliability. The main benefit of web browser connection is its low cost of access to the inter-organizational system which allows attracting smaller companies to use the system. For the cluster's competitiveness the presence of both communication ways is treated as the best option. In such cases the companies can choose the connection method that meets their requirements whether it is low cost or high quality.

Finally, the growing popularity and technological advancement of mobile devices in recent years led to the attempts to use them to connect to inter-organizational information systems (EDI Basics, 2011d). So far the number of different applications is limited but their number is growing. Potentially it is possible to use a mobile device for completing a purchase order or an invoice, checking status of the delivery, reviewing performance reports and many other options. Naturally, implementation of mobile technologies increases the variety of services that are available to cluster companies via inter-organizational information systems. Therefore the use of mobile technologies besides others is treated as favorable for cluster.

3.2. Cluster governance and infrastructure development strategies

The sources of local competitive advantage for a cluster are factor conditions, demand conditions, context for firm strategy and rivalry, and presence of related and supporting industries (Porter, 2000). Organizations within cluster can exercise control over these sources of competitive advantage to a certain extent. The effectiveness of their actions directed on enhancing cluster's competitiveness depends on the cluster governance arrangements. Cluster governance is "the mix of, and relations between, various mechanisms of coordination used in a cluster" (de Langen, 2004, p. 143).

Cluster companies have to coordinate their actions in order to influence the cluster factor conditions like infrastructure, human resources, capital resources and other. It is a rare occasion when a single company is powerful and big enough to establish its own educational programs, build roads etc. The quality of cluster governance depends on the level of coordination costs and the scope of coordination beyond price (de Langen, 2004). The high level of trust in a cluster, presence of intermediaries and leader firms enhance the quality of cluster governance as they lower coordination costs and increase the scope of coordination beyond price (de Langen, 2004).

Furthermore, the success of cluster largely depends on its ability to solve collective action problems, one of which is the development of information infrastructure. Collective action regime is "a relatively stable collaborative agreement that provides actors with the capacity to overcome collective action problems" (de Langen, 2004; Eisenhardt, 1989). Each cluster has its own collective action regime with its own coordination modes. There are three modes of coordination useful for solving collective action problems: associations, public-private bodies and public bodies. Each of these mechanisms can have their role in the development of common infrastructure. In the very least they can act as the initiators of the infrastructure development. Additionally such institutions can finance the creation of the common projects, participate in the governance and manage the operations at the later stages. However, when it comes to the development of inter-organizational information infrastructure, the level of awareness among the modern companies in the necessity to develop such systems collectively is still quite low. Information technology for decades has been considered as the source of competitive advantage for the individual firm or for a firm and its partners. Large cluster companies usually can afford to roll out private hub inter-organizational information systems for communication with their buyers and suppliers. Therefore, when it comes to the development of inter-organizational information systems within the cluster it is necessary to pay attention to the actions not only of associations, public-private or public bodies that are oriented at solving collective action problems but also to the private firms that are sufficiently strong and interested to create inter-organizational information systems.

Damsgaard and Lyytinen (2001) compared eight distinctive attempts of developing electronic trading infrastructure in three different countries (Hong Kong, Finland and Denmark). The cases turned out to differ significantly in the types of initiator and the intent of the initiative. In Hong Kong alliances of private companies ignited the development of three complementary inter-organizational information systems. Two of these systems were created with the ambition to enhance not only the competitive position of the initiating companies but the competitiveness of the respective clusters as a whole. Meanwhile in Denmark and Finland the initiative to develop information infrastructure in rail and port clusters stemmed from public bodies. The authors showed that the development of such infrastructure is historically contingent and path dependent. Therefore it might be not fruitful to compare whether public or private initiatives are more effective or efficient. However, it is evident that there is a need in certain coordination arrangements in a cluster to solve the problems of information infrastructure development.

The cluster governance arrangements influence what organization or group of organizations initiates the development of information infrastructure. This influences in its turn how the information infrastructure is governed and organized. There can be one monopolistic inter-organizational system supported by all the organizations within the cluster. Otherwise there can be more systems, either complementing or competing with each other with respect to services that they provide to the cluster. All of these alternatives have their costs and benefits. The monopolistic system allows fully benefit from the network effects if all the cluster organizations are connected to it. The companies will have to gain access to one system only. However, there are always dangers that the monopoly won't have enough incentives for further improvement of its services and will charge unfairly high fees for its services. The presence of complementary systems will force some companies to invest in the access to two or more systems which is costly. But it would also allow the developers to focus more closely on the respective target user groups of different systems. Finally, the presence of competing systems offering similar services will lead to the split of customers into several groups. The buyers won't be able to access all the suppliers via one system and will have to deal with limited number of options or gain access to multiple systems with similar functionalities. The benefit of competition between the systems is that their operators and developers will always have incentives to improve their services and keep prices for their services at the reasonable level.

Organizations that initiate the development of information infrastructure also play role in determining the ownership and governance structures of the infrastructure. The ownership structure influences the neutrality in the infrastructure development. Inter-organizational information systems can cement the existing power inequalities among cluster organizations but they can also shift power statuses of the companies. The more representatives of the different organizations or associations there are in the management boards of the infrastructure developing companies the better the interests of the cluster as a whole are represented. If the designers of the inter-organizational information systems are leaning in favor of certain cluster organizations, the danger exists that certain companies will benefit at expense of other cluster companies which won't be compensated.

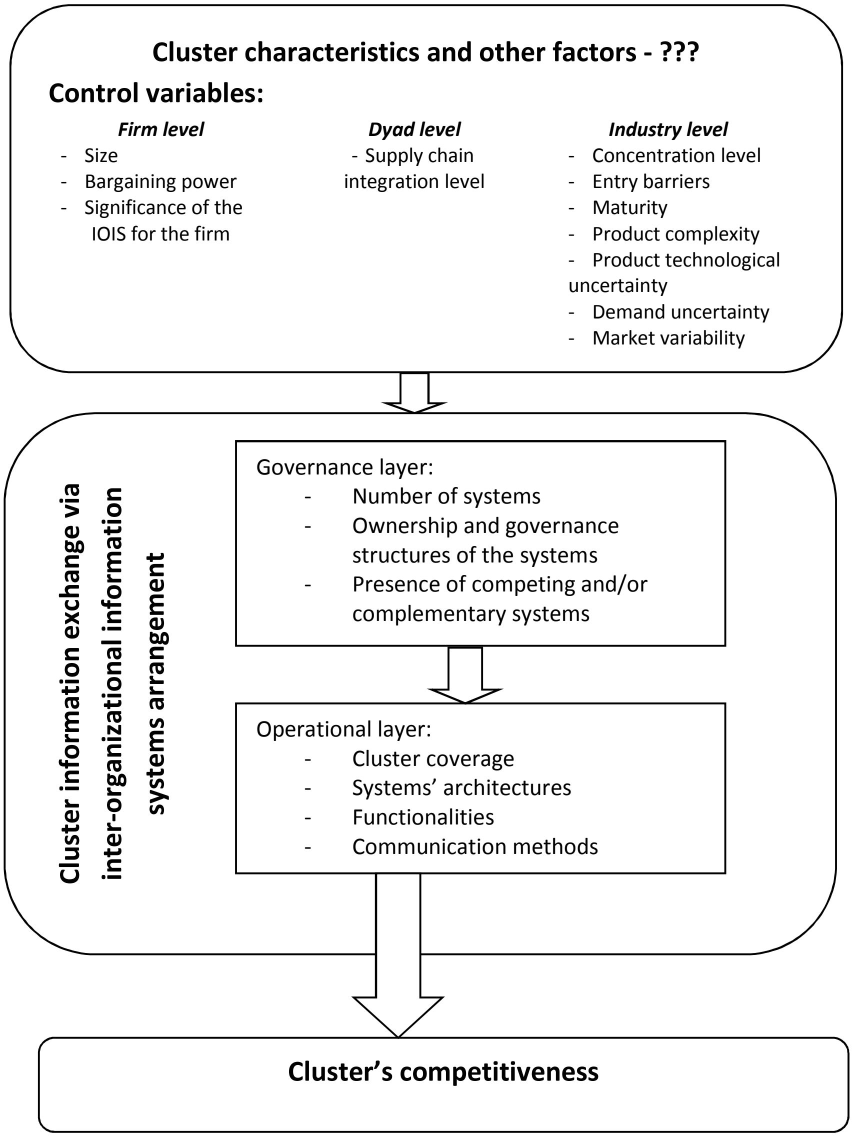
3.3. Framework for comparison of cluster IOISs infrastructure

The characteristics of cluster level information exchange arrangement via inter-organizational information systems can be divided into two groups – governance and operational. Operational characteristics are the ones to which potential or existing cluster companies pay attention when making decision to operate within the cluster or not. These characteristics influence the companies' decisions to join the cluster or leave it. Cluster coverage, architecture of the systems, functionality of the systems and communication methods form this group. Clusters consist of the organizations with various needs and roles. Cluster coverage measures what share of different types of users within the cluster is covered by inter-organizational information systems. Architecture, functionality and communication methods implemented in the inter-organizational information systems influence the costs, variety and quality of services available to the cluster companies as discussed earlier. All together operational level characteristics allow to compare the relative attractiveness of information exchange arrangements in different clusters.

It is difficult to influence the operational level properties of the information exchange arrangements for organizations interested or responsible for cluster development. These decisions are not in their direct control but in control of the companies developing the systems. However, public bodies or leader firms are in position to initiate the development of infrastructure and through this influence the companies developing the systems. Accordingly every cluster information exchange arrangement via inter-organizational information systems has the following governance layer characteristics – number of inter-organizational systems, their ownership and governance structures, and their market strategies (whether they offer complementary to different user types or similar services to the same user types). The comparative analysis of information exchange arrangements along these dimensions allows seeing what options exist for developing cluster-wide information infrastructure and analyzing the influence the organizations within the cluster can have on the development of the information infrastructure.

Analogously to individual inter-organizational information systems, the characteristics of cluster level arrangements of information exchange via inter-organizational information systems depend on the external factors. It is reasonable to suggest that the factors that have been shown to influence the design of inter-organizational information systems also influence the characteristics of cluster level arrangements. Although this research targets to unveil cluster level characteristics that influence the shape of cluster information exchange via inter-organizational information systems, the factors that have been discovered earlier in the research on individual inter-organizational information systems can serve as control variables. Especial attention should be paid to the industry level characteristics as the industry level is the closest to the cluster level of analysis.

Figure 2. Research framework



Thus, the more specific research questions of this thesis can be formulated as follows:

1. What factors influence the information exchange arrangement via inter-organizational information systems?
2. Do governance layer characteristics of the cluster information exchange arrangement via inter-organizational information systems influence the operational layer characteristics?

4. Methodology and Data Collection

Comparative case study is the most suitable method for answering these research questions. It allows both testing the assumption about the connection between governance and operational layer characteristics of the information exchange arrangements, and theory building with relationship to what factors influence the shape of information infrastructure. For theory building this method is useful when there are no existing theories describing the phenomenon properly (Eisenhardt, 1989); and the cluster level analysis of the information infrastructure has never been conducted before. The last part of the theoretical framework that suggests the influence of the information infrastructure on the competitiveness of the cluster is not theoretically tested in the current thesis due to research resources limitation. However, this part of the framework is already quite thoroughly grounded in the previous research.

Seaport clusters were chosen as the empirical setting for the current research because the development of inter-organizational information systems has been traced there in the academic literature since 1990s (King and Konsynski, 1990; King and Konsynski, 1995; Wrigley et al., 1994). Seaports are concentrations of economic activity related to the arrival and service of ships and cargoes at port. Seaport clusters are constructs as they have no natural boundaries. De Langen (2004) suggested the following steps to delimit clusters: select an economic specialization and a roughly defined region for which the cluster analysis will be made; identify economic activities and non-business organizations included in the cluster; define the relevant region for the cluster; identify the cluster population, consisting of business units, associations and public(-private) organizations that are both relatively strongly linked to the cluster core and located in the relevant cluster region. Seaports are not only centers for logistics activities but also for production and trade activities. However, in this thesis the focus is only on the companies serving the containerized cargo movement through the port. This limitation is necessary to manage the large scope of the analysis. Furthermore, the majority of port inter-organizational information systems are focused on the containerized cargo flows.

The relevant cluster organizations were identified based on the information exchange map developed in the monograph by Van Baalen et al. (2008) (see Appendix 1). This map reveals the information flows that accompany the movement of containerized cargo. According to it the following cluster stakeholder types can be distinguished:

Table 2. Port cluster stakeholder types.

Stakeholder	Function in the supply chain
1. Shipper (consigner)	An organization that originally sends the goods.
2. Consignee	An organization that receive the goods in the end.
3. Inland carrier	An organization that executes the shipment of goods in the hinterland (by truck, rail or barge).
4. Forwarder	An organization that manages the shipment by booking or otherwise arranging space for the shipment at carrier, applying for necessary permissions from authorities etc.
5. Depot (stuffing/unstuffing centers)	Centers where the empty containers are stored, where cargo gets packed/unpacked for loading/unloading respectively
6. Sea terminal operator	An organization that is responsible for loading/unloading goods from a specific type of transport or warehouse to another type of transport or warehouse
7. Shipping agent	An organization responsible for customs clearance of the cargo
8. Shipping line	An organization that executes the shipment of the goods over deep sea
9. Port authorities	An organization that operates and manages the port and its operations
10. Customs & Inspection authorities	Government's agencies that collect the taxes and duties and inspect the legal status of the goods
11. River police	An organization that inspects vessel crew list
12. Port services	Organizations providing services like pilotage, towage, mooring services
13. Bank	Banks are responsible for the money transfer and payments between the other stakeholders
14. Insurance	Organizations that insure the cargo

Sampling of the relevant cases is an important step of the comparative case study analysis. For theory building purposes theoretical sampling is suitable as it allows studying the greater variance in the variables of interest. In our case the main constructs under the consideration are the port cluster information exchange arrangement via inter-organizational information systems and general port characteristics. To describe the variance in these variables six representative port cluster were chosen:

Rotterdam, Felixstowe, Hong Kong, Singapore, Los Angeles and New York. These port clusters significantly differ in the inter-organizational information systems that are used there and in the port governance structures. The ports represent three major economic regions: North America, Europe and Asia. These clusters differ in terms of the competitive and institutional environment that they function within.

As this is exploratory case study it is also important that the cases do not differ significantly along the control dimensions (concentration level, entry barriers, maturity etc.) to make sure that other factors that have not been studied earlier contribute to the differences in the outcomes. The focus on the containerized cargo movement ensures that product complexity and technological uncertainty are the same in all six clusters. The global standing of the ports suggests that they face approximately the same level of the demand uncertainty and market variability. The only control dimensions along which the six port clusters can differ are concentration level and entry barriers what is accounted for in the analysis.

Data collection was carried out with the help of internet sources and published case studies. The web-sites of relevant port authorities and customs offices were investigated in order to identify the information systems for the communication with the government. The web-sites of shipping lines, terminal operators and freight forwarders were studied with the intent to spot relevant business-to-business inter-organizational information systems as these types of stakeholders are in the middle of the information exchange network. Accordingly there was no need to investigate the web-sites of shippers, consignees or inland carriers as these systems would be mentioned already at the web-sites of shipping lines, terminal operators or freight forwarders. Finally, the web-sites of software providers that focus on the freight industry were studied to identify the relevant applications or systems available to the port companies.

5. Inter-organizational information systems of six port clusters

5.1 Common systems of the port clusters

The global character of shipping line operations brought about the development of global shipping portals. These portals are available to port communities all over the world. The functionality of these systems allows freight forwarders and shippers access sailing schedules of multiple carriers connected to the platforms, book cargo, submit shipping instructions, access Bill of Lading drafts, track and trace cargo, get user-defined alarm notifications (in case of cargo movement disruption). There are three shipping portals – INTTRA, GT Nexus and CargoSmart (IT Wiki, 2007). They differ in terms of shipping lines connected via them. INTTRA is the largest portal in terms of the ocean traffic that it covers. Nowadays it connects more than 30 carriers (among them Maersk Sealand, P&O Nedlloyd, Hapag-Lloyd, Hamburg-Süd, MSC Mediterranen Shipping Co, and CMA CGM) with more than 65,000 customers in 105 countries (INTTRA, 2011; Hapag Lloyd, 2001). GT Nexus takes the second place – it connects 19 ocean carriers, among them APL, CP Ships, ANZDL, Canada Maritime, Cast, Contship Containerlines, Lykes Lines, TMM Lines, Hanjin, Hyundai, K Line, Mitsui OSK Lines, Senator Lines, Yang Ming, and Zim Israel Navigation Company (GT Nexus, 2005; GT Nexus, 2011; Crowley, 2003). Finally CargoSmart provides access to over 30 carriers, including China Shipping, COSCON, Hanjin, "K" Line, Matson, MISC, MOL, NYK, OOCL, and Yang Ming (Cargo Smart, 2011).

All the shipping portals have central hub orchestration architectures. They provide electronic market capabilities with the help of which freight forwarders and shippers can choose the best shipping line option. The portals also support vertical links between freight forwarders/shippers. Once the shipping line is chosen the customer can submit the order and instructions via the system and track the shipment status. Carriers get connected to portals via value-added networks connection. Shippers and freight forwarders have a number of different solutions available. They can not only use value-added network connection, but also a web-based tool or a PC-based software with which shipping documents and bookings can be created offline and then sent via e-mail or web services. Additionally there are independent software providers, ports, and major ERP providers, that enable connection to the platforms.

These shipping portals constitute the information infrastructure of all six port considered in this thesis. However, the focus of this work is on the differences in the infrastructure arrangements. Therefore later shipping portals won't be included in the analysis as they offer the same services in all six clusters.

The other systems that are common for all port clusters are order management systems offered to freight forwarders by independent software providers all over the world. Usually these are web-based solutions via which the customers can request quotes, make bookings and trace their orders. There are many software providers who develop such systems. The examples are Cargo Manager Systems and IES Ltd in the port cluster of New York, Four Soft and Kewill in the port cluster of Rotterdam, CargoWise, Forward Office, and Freightdata 2000 in the port cluster of Felixstowe (IES, 2011; Kewill, 2011; CargoWise, 2010; Forward Computers Limited, 2011; Freightdata 2000, 2011). These systems also will be exempted from further consideration as they are available in all six clusters without discrimination.

5.2. Inter-organizational information systems of Singapore port cluster

Singapore port cluster is the only one in the sample that has a digital platform functioning within it. Its name is TradeXchange (Government of Singapore, 2008). It is sufficient for companies to get connection to TradeXchange in order to be able to use the majority of the functions available via different inter-organizational information systems of the cluster, even connect to the global shipping portals like INTTRA and GT Nexus. The inter-organizational systems to which the users can gain access via the platform are Portnet, JP online and Marinet.

TradeXchange of Singapore was initiated by Singapore Customs, Economic Development Board and Infocomm Development Authority of Singapore (Government of Singapore, 2008). The platform is developed as a public private partnership. CrimsonLogic Pte Ltd has been appointed by the Singapore Government as an independent contractor to develop, operate, maintain, and drive the adoption of the project. The Singapore Government is involved in the development of services for communication with Customs (formerly TradeNet system); the other services are developed by owners of the respective inter-organizational systems or by value-added service providers who get approved by CrimsonLogic.

The Singapore Government has the monopoly in development of services for communication with Customs and Maritime and Port Authority of Singapore via systems TradeNet and Marinet (Maritime & Port Authority of Singapore, 2007). Subsidiaries of two Singapore terminal operators Port of Singapore Authority and Jurong Port Authority enjoy the monopoly of developing services for communication with the terminals via systems Portnet and JP-online respectively (Portnet.com, 2010;

PSA Singapore, 2010; Jurong Port, 2011). The rest of business to business services are provided on the competitive basis by various providers such as E-Trek Solutions and Y3 Technologies in trade insurance area (Government of Singapore, 2008; Ebix, 2010; E-Trek Soultions, 2003; Y3 Technnologies, 2011).

The inter-organizational information systems of Singapore are able to connect all the identified port cluster stakeholder types. All stakeholders are connected via vertical links. Portnet and JP-online provide communication linkages between shipping lines, terminal operators, freight forwarders, inland carriers, port authorities, and shippers. TradeNet facilitates communication between business community and customs. Marinet allows electronic ordering of port services and application for necessary inspections and licenses. Horizontal information links connect terminal operators and shipping lines through Portnet system. Terminal operators coordinate their actions with respect to dangerous goods handling via integration of Portnet with JP-online. Shipping lines coordinate with respect to transshipment processes and capacity management within alliances via Portnet application. Insurance companies and banks also get connection to the digital platform through the value added service providers that have special applications for their operations. Ebix Exchange serves as a portal for shippers and freight forwarders to e-connect with their insurers for the submission of marine cargo insurance (Ebix, 2010). For banks TradeXchange offers title registry service through which banks can electronically receive and endorse title and Bills of Lading.

The digital platform of Singapore is the central hub architecture system and sole connection to it is sufficient for organizations to gain access to all the possible services. Singapore users can access the platform via Web-browser or via Value Added Network of one of the value-added services providers. Mobile technologies are also actively used within the community. The number of services like container status, berthing enquiry, berthing update can be conducted via mobile devices.

5.3. Inter-organizational information systems of Hong Kong port cluster

In the port of Hong Kong there exist two government backed inter-organizational information systems - OnePort and Tradelink that are not integrated with each other - and three privately managed inter-organizational systems belonging to terminal operators (OnePort Limited, 2009; Tradelink Electronic Commerce Limited, 2011).

Tradelink system was created in 1988 as a joint venture between two of the largest Hong Kong banks, two container terminal operators, an air cargo terminal operator and a couple of trade associations. However, in 1992 the Hong Kong Government became the largest single shareholder of the system. As of 2005 Tradelink is a publicly listed company with the Government still as the largest single shareholder; another key shareholder is the Hongkong and Shanghai Banking Corporation Limited. Tradelink facilitates communication between business community and customs. It also provides electronic links between shipping lines, shippers, freight forwarders and insurance agents. They can exchange electronic orders, apply for insurance and process payments electronically. Tradelink services can be accessed via a web-browser and via special software packages LogiNet Deluxe and ValuNet Deluxe that also use Internet to send information. Tradelink has central hub architecture.

The OnePort system was initiated in 2003 by three sea terminal operators of Hong Kong (Hongkong International Terminals Limited (HIT), Modern Terminals Limited (MTL) and COSCO-HIT Terminals (Hong Kong) Limited (CHT)). Later Tradelink Electronic Commerce Limited also became one of its shareholders. OnePort provides services for shipping lines, terminals, freight forwarders, inland carriers, shippers and mainland customs. Inland carriers can arrange appointments with terminals, shippers and freight forwarders can track status of containers, pay terminal fees. Terminals and shipping lines exchange information on vessel bookings, gate transactions, vessel schedules. Inter-terminal Trucking Solution provides a unified platform which administers inter-terminal trucking and fleet management which optimizes trip arrangements and minimizes wasted trips.

The competition level in the service development between two Hong Kong government backed systems is very low as one of the systems is the shareholder of another one. So far there has been enough room for expansion for both systems without competing for provision of certain service types. The only area of competition can be the payment processing. However, OnePort system is more custom-built for terminal operations while Tradelink offers general solutions. OnePort can be accessed via web-browser or via value added network depending on the service type.

The privately developed system of Hongkong International Terminals Limited facilitates the information exchange between terminals, shipping lines and freight forwarders (Hong Kong International Terminals, 2007). These services mirror the services provided by OnePort. The special feature of this system is Mobile Terminal Message that sends the data needed to identify container in the yard to the mobile phones of truck drivers. This is a private hub architecture system that can be accessed via private network.

ModernPorts is the privately developed system of Modern Terminals Limited (Modern Terminals Limited, 2005). Through the system shipping lines can access sailing schedules, declare/change status and container details, revise demurrage of containers, give container handling instructions. Inland carriers can schedule appointments with the terminals. All the interested parties can track container status, on spot traffic updates from the web-cameras around the terminal facility. The system has private hub architecture and can be accessed via web-browser.

The private system of Asia Container Terminals facilitates information exchange between the terminal and shipping lines via private network (Asia Container Terminals, 2001). It also provides web-based access to real time data on container status to truckers, shippers and freight forwarders.

5.4. Inter-organizational information systems of New York/New Jersey port cluster

The following inter-organizational information systems were identified in Port of New York/New Jersey cluster: FIRST, AMS, private systems of American Stevedoring Inc, Port Newark Container Terminal.

FIRST system was developed by Port Autority of NY/NJ together with Federal Highway Administration Office of Freight Management, the I-95 Corridor Coalition, local port community and regional transportation agencies (FIRST, 2011). This system was created with an aim to improve the overall traffic in and around the port, specifically to reduce the lengthy truck queues at terminal gates. The FIRST system is a centralized on-line application that consolidates existing sources of information on cargo and transfer and carrier information in the port. FIRST stores all of its information on a central database populated by port community participants (steamship lines, terminals, freight forwarders, brokers, truckers, maritime authorities, etc.) via FTP, as well as direct data input. FIRST doesn’t support documents exchange between community members except for truckers’ nominations from freight forwarders and brokers to port authorities. This system isn’t evolving any further for the last five years as it lacks support from terminal operators (Waterfront Coalition, 2009).

Communication with the US Customs and Border Protection (CBP) takes place via Sea Automated Manifest System (Department of Homeland Security, 2011). The participants can transmit manifest data electronically prior to vessel arrival. According to CBP list of companies offering Sea AMS data processing services to the trade community there are at least nine vendors and service centers in New York/New Jersey area who can provide access to the system. The system has private hub architecture with CBP at the center of the system. Depending on the vendor AMS can be accessed via Web-browser or VAN.

The private system of the terminal operator American Stevedoring Inc. facilitates communication between terminal, truckers and brokers (American Stevedoring Inc., 2011). Brokers can assign a container to a trucking company by submitting electronic order form via the system. The system sends automatic notification once the container is available for the pick-up to the trucker. The system is web-based and allows tracking the container and booking status.

The private system of the terminal operator Ports America supports EDI exchange with shipping lines to streamline cargo loading/unloading processes (Ports America, 2009). The terminal is in favor of direct connections with its partners through internet or other means of communication. Its system supports electronic invoicing and payments. At the web-site the customers can track container availability, booking status, vessel schedules, and validity of interchange agreements. The web-site also runs the live stream from the in-gate camera to give an update on the traffic situation.

The web-sites of other three terminal operators (Global Marine Terminal, APM Terminal, NY Container Terminal) all provide access to the status of container, booking inquiry, vessel schedules, and gate cameras' streaming (Global Terminal and Container Services LLC, 2005; A.P. Moeller – Maersk Group, 2011; New York Container Terminal, 2005). Maher Terminal stands out among other terminals as it doesn't provide any electronic services at all. The container status can be requested via a phone call 24/7 (Maher Terminals, 2008).

5.5. Inter-organizational information systems of Los Angeles port cluster

The following inter-organizational systems are functioning in the port of Los Angeles: eModal, private system of Ports America "VoyagerTrack", and private system of California United Terminals. There is no neutral platform functioning in the port.

Four terminal operators (Trans Pacific, Yusen, APM and Eagle Marine) use the system provided by independent software provider e-Modal (eModal, LLC., 2010; TraPac, Inc., 2011; Yusen Terminals, Inc., 2009; A.P. Moeller – Maersk Group, 2011; Eagle Marine Services, 2011). This system provides the following services: cargo status at the terminal for freight forwarders, online fee payment, input of the truck driver information for verification at the terminal, appointment system for truckers, exchange of delivery orders along the chain from shipping lines to freight forwarders (eModal, LLC., 2010). The system supports not only vertical links between shipping lines, terminal, truckers and freight forwarders but also the horizontal coordination inside the truckers' and shipping lines' communities. Virtual Container Yard application allows posting and searching for available empty containers. The system finds container matches in the desired area and sends the match to the shipping line for approval. Thereby it reduces unnecessary truck trips. The system also allows trucking companies to post fleet availability, make those postings available to importers, exporters, brokers, forwarders and other trucking companies. This helps eliminating 'bobtail' drives for trucking companies. E-Modal has central hub architecture. The system is web-based but it also provides mobile applications for tracking container availability.

Two other terminal operators of port of Los Angeles use their own systems. The system of Ports America is called VoyagerTrack (Ports America, 2011; West Basin Container Terminal, 2011). This system allows to track and request information about containers, container status, and related activities; get up-to-the-minute event notification, delivered via fax or email, and review outstanding notifications; obtain and filter vessel schedules; inquire on statuses of import and export containers; receive demurrage warning notifications and make demurrage payments on-line.

The system of California United Terminals provides customer shipping lines and agents with up-to-the-minute data on the status of their vessels and cargo availability (California United Terminals, 2011). In contrast to other terminal systems it also has a direct link with the U.S. Customs Service

Automated Manifest System (AMS) what allows customs brokers and consignees to use it for clearance of their cargo. However, unlike the other systems it doesn't facilitate on-line payments.

Communication with US Customs and Border Protection agency takes place in the similar way as in port of New York. There are at least four vendors and service centers providing the access to Sea Automated Manifest System of CBP in California (Department of Homeland Security, 2011; Port of Los Angeles, 2011).

5.6. Inter-organizational information systems of Rotterdam port cluster

In the port of Rotterdam the following inter-organizational information systems are functional: Portbase, SAGITTA, NCTS, private systems of ECT, APM and Uniport terminal operators.

Portbase is the system fully financed by the port authorities of Rotterdam and Amsterdam as the system is also functional at port of Amsterdam. Its aim is to make the logistics chains of the ports of Rotterdam and Amsterdam as attractive as possible by offering a one-stop-shop for logistic information exchange (Portbase, 2011; Port of Rotterdam, 2011). Future plans include the expansion of the system to all Dutch ports. The system facilitates communication between customs, port authorities, veterinary inspection, shipping lines, terminal operators, inland carriers, freight forwarders, and shippers. Through the system port companies can make all the necessary notifications for the port authorities and process veterinary inspection documents. Portbase partially automates the communication process with customs. However, freight forwarders and shippers still have to use separate application for submission of declarations to the information system of the customs. The system enables track and trace of the container status through the logistics chain. It also contains applications for terminal appointment management of the inland carriers. For the business community the system offers vertical links between shipping lines and terminals, between terminals and inland carriers, and between freight forwarders and terminals. There are no electronic market functionalities or horizontal links in the system. Portbase has central orchestration hub architecture. The system can be accessed in two ways: via web-browser or through VAN. Portbase doesn't offer mobile applications.

Dutch customs use the systems Sagitta and NCTS (for transit declarations) to electronically accept declarations from the trading community (NETUBA, 2007). External providers can develop applications that comply with the standards required by the Dutch customs (Intris NV, 2011). Therefore the users have a choice which application they would choose. Accordingly, the system can be accessed via web-browser or VAN depending on the choice of the provider. The system has private hub architecture with the customs in the center of the network.

Terminal operators ECT, APM and Uniport also have their own web-sites that offer the functionality to track the status of containers and bookings (Europe Container Terminals, 2011; A.P. Moelle – Maersk Group, 2011a,b; Uniport, 2011a,b). The system of ECT additionally facilitates information exchange between its terminals, shipping lines and inland carriers. The system has private hub architecture. It can be accessed via private network of ECT in the point-to-point mode or via the web-site depending on the service type.

5.7. Inter-organizational information systems of Felixstowe port cluster

The main inter-organizational information system in the port of Felixstowe cluster is Destin8 (Port of Felixstowe, 2011a; MCP Plc, 2011). The system is provided by Maritime Cargo Processing plc which is a private company the shares of which belong to the port authority of Felixstowe which in its turn is a subsidiary of Hutchinson Port Holdings (Maritime Cargo Processing Plc, 2011). Port authority of Felixstowe performs also functions of a terminal operator and a stevedore. The system provides services for the following user types: shipping lines, importers, exporters, clearing/forwarding agents, terminal operators, port authorities, inland carriers and customs. All the users can track container movements. Shipping lines and terminals can exchange information accompanying the cargo loading/unloading processes. Freight forwarders can use Destin8 for customs declarations as it provides interface to the main system CHIEF of Her Majesty Revenue and Customs. It is important to note that Destin8 is the only system in the port of Felixstowe which can provide access to the customs system (Her Majesty Revenue and Customs, 2011). Freight forwarders can use other applications but these applications also go through Destin8. The system also handles nominations of inland carriers. Destin8 has central hub orchestration architecture and can be accessed via web-site for tracking purposes and also via value-added network provided by MPC plc.

The second inter-organizational information system that is functional in the port of Felixstowe is Vehicle Booking System (Port of Felixstowe, 2011b). The system allows drivers pre-book their containers for delivery/collection within certain allocated time slots. The system has private hub architecture as it is provided by the port authority and can be accessed via web-browser.

6. Comparison of port cluster information infrastructures

Closer examination of cluster level information exchange arrangements via inter-organizational information systems of six port clusters showed that their share a number of similarities and differences. At the governance layer port clusters of Singapore and Felixstowe stand out among others. The port of Singapore is the only one that introduced digital platform via the public private partnership. This platform will be the operator of the whole cluster infrastructure. The connection to it gives access to all the services provided by inter-organizational information systems of the cluster. The port of Felixstowe has only two inter-organizational information systems that offer complementary service. The other clusters have four or five inter-organizational systems and some of those systems offer similar services. In terms of the ownership structure only the port cluster of Los Angeles stands out as there is no system belonging to the port authorities.

The pronounced similarities of the governance layer characteristics are that in all six ports there are systems belonging to terminal operators and these systems in five out of six cases offer similar services. Only port of Felixstowe cluster stands out in this respect because it has only one terminal operator and it is practically impossible for such competing systems to be developed there. The summary of governance layer characteristics of each port is presented in Table 3.

The comparison of port clusters information exchange arrangements brings about the following questions: 1) Why Singapore port cluster is the only one that developed a digital platform?; 2) Why Felixstowe port cluster has only two systems which is lower than four or five systems of the other clusters?; 3) Why in port of Los Angeles port authorities don’t participate in infrastructure development?; 4) Why government agencies and terminal operators are the ones developing infrastructure in all six cases and not other players? The potential answers to these questions are discussed in further chapters.

Table 3. Governance layer characteristics of port clusters.

Governance layer characteristics	Singapore	Hong Kong	Rotterdam	Felixstowe	New York/New Jersey	Los Angeles
Number of systems and their ownership	1 digital platform (public-private partnership) with access to 5 other systems of which 2 government owned, 2 owned by terminal operators, 1 by external provider	5 systems: 1 system government owned, 1 system jointly owned by 3 terminal operators and government, 3 private systems of terminal operators	5 systems: 1 port authority owned system, 3 privately owned terminal systems, multiple providers of e-customs access software to 1 government system	2 port authority owned systems, 1 of which integrated with customs	4 systems: 1 port authority owned system, 2 privately owned systems of terminal operators, multiple providers of e-customs access software to 1 government system	4 systems: 2 privately owned terminal systems, 1 system provided by external provider, multiple providers of e-customs access software to 1 government system
Presence of competing and/or complementary systems	The systems provide complementary services except for two systems of terminal operators that offer a number of similar services	The government system offers complementary services while private terminal systems and a jointly owned system offer both similar services and complementary services	The private systems of terminals offer similar services to the services of port authority owned system. The port authority owned system offers complementary services.	The two systems offer complementary services	Port authority owned system and privately owned systems offer similar services. Port authority system offers a limited number of complimentary services.	The terminal systems and externally provided system offer similar services. The system of external provider offers complementary services as well.

At the operational level information exchange arrangements via inter-organizational information systems demonstrate larger characteristics variety although not along all dimensions. The summary of operational layer characteristics of each port is presented in Table 4. For instance, all information systems use either web-browsers or value-added networks to connect users and different connectivity types are present within each cluster. Furthermore, each cluster has a number of mobile applications available within it.

There is a pronounced difference in terms of cluster coverage. Only Singapore infrastructure covers all user types with services available via inter-organizational information systems. Meanwhile the other clusters miss three, four or five user types. However, it is striking that the user types not covered by the systems are the same in the clusters: depots, port services, banks, insurance agencies (except for Hong Kong) and port authorities (in cases of NY/NJ and Los Angeles). Thus, there seem to be a certain pattern in terms of users getting the priority in the coverage by inter-organizational information systems within the cluster.

Port clusters of Singapore, Hong Kong and Los Angeles stand out because they offer horizontal links functionalities. Port of Singapore has two such links – among terminal operators and shipping lines; port of Hong Kong – among terminal operators; port of Los Angeles – among truckers. The clusters of Rotterdam, Felixstowe and New York/New Jersey offer only vertical links. There are no electronic markets developed within the compared port clusters.

All the port clusters have both central hub orchestration architecture systems and private hub architecture systems. The private hub architecture systems belong to terminal operators. However, there are also central hub orchestration systems developed by terminal operators through their subsidiaries.

The comparison of port clusters information exchange arrangements at the operational level brings about the following questions: 1) Why Singapore port cluster is the only one that developed services for all user types?; 2) Why the users left out by the other cluster arrangements are the same along the clusters?; 3) Why horizontal links were developed in ports of Singapore, Hong Kong and Los Angeles and not other clusters? The potential answers to these questions are discussed in further chapters.

Table 4. Operational layer characteristics of port clusters.

Operational layer characteristics	Singapore	Hong Kong	Rotterdam	Felixstowe	New York/New Jersey	Los Angeles
Cluster coverage	Included all user types	3 types missing: Depots, banks and port services are not covered	4 types missing: Depots, banks, insurance agencies, and port services are not covered	4 types missing: Depots, banks, insurance agencies, and port services are not covered	5 types missing: Port authorities, depots, banks, insurance agencies, and port services are not covered	5 types missing: Port authorities, depots, banks, insurance agencies, and port services are not covered
Functionality	Vertical links, horizontal links among terminal operators and among shipping lines	Vertical links, horizontal links among terminal operators	Vertical links only	Vertical links only	Vertical links only	Vertical links, horizontal links among truckers
Architecture	Digital platform connected to four central hub architecture systems and one private hub architecture system	2 central orchestration hub systems, 3 private hub systems, not integrated with each other	2 central orchestration hub systems, 3 private hub systems, not integrated with each other	1 central orchestration hub system, 1 private hub system, not integrated	2 central orchestration hub systems, 2 private hub systems	2 central orchestration hub systems, 2 private hub systems
Communication methods	VAN, Web-browser, mobile applications	VAN, Web-browser, mobile applications	VAN, Web-browser, mobile applications	VAN, Web-browser, mobile applications	VAN, Web-browser, mobile applications	VAN, Web-browser, mobile applications

The hypothesized connection between the government layer and operational layer characteristics turned out not to be straightforward. The reason is that only port of Singapore significantly differs in terms of both from the other clusters. This is the only cluster with the functioning neutral digital platform which could allow it to cover all user types. The other cluster arrangements sufficient variance in governance and operational layer cluster characteristics. Thus, they don't provide significant evidence to support the hypothesis that governance layer characteristics of information exchange arrangement via inter-organizational information systems influence its operational layer characteristics.

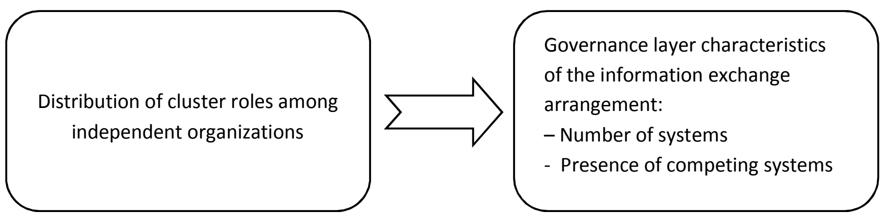
7. Propositions on the factors that influenced infrastructure design

On the basis of the demonstrated data the four propositions regarding the factors influencing the shape of cluster information exchange via inter-organizational information systems have been derived. The first two propositions fall within the scope of the initially suggested research framework and put forward the answers to the stated research questions. The last two propositions offer insights into the nature of the development of the inter-organizational information systems within the cluster. They present more general rules rather than connections between cluster characteristics and cluster information infrastructure.

Research question 1: What factors influence the information exchange arrangement via inter-organizational information systems?

Proposition 1. Distribution of cluster roles among the independent organizations within the cluster influences the governance layer characteristics of the cluster information exchange arrangement via inter-organizational information systems: the spread of cluster roles among higher number of organizations and increase in the number of organizations performing the same cluster role lead to the development of higher number of competing systems that might offer similar services.

Figure 3. The link between cluster characteristic and information exchange arrangement.



Port of Felixstowe is the only private port among the six port clusters in the sample while the other five ports are landlord ports. In the private port the land and infrastructure are privately owned; port operations are under the control of the private owner or a private operator to which the operations of the port are leased. Port of Felixstowe is operated by the Felixstowe Dock and Railway Company, which is wholly owned by Hutchison Port Holdings Ltd. In the landlord port the land and infrastructure are owned by government and managed by a port authority; port operations are controlled by private terminal operators that lease the public infrastructure. The landlords and terminal operators of Singapore, Hong Kong, Rotterdam, Los Angeles and New York/New Jersey are presented in the Table 5.

Table 5. Landlords and terminal operators of five landlord ports.

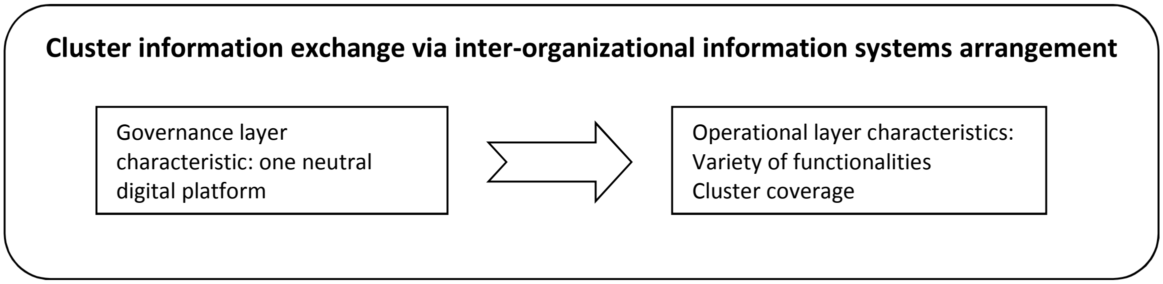
	Singapore	Hong Kong	Rotterdam	Los Angeles	New York/New Jersey
Landlord	Singapore Maritime Board	Marine Department of the Hong Kong Special Administrative Region	Port of Rotterdam Authority	Los Angeles Harbor Comission	Port Authority of New York and New Jersey
Terminal operators	1. PSA 2. Jurong	1. Modern Terminals Ltd 2. Hongkong International Terminals Ltd 3. COSCO Information & Technology (H.K.) Ltd 4. Dubai Port International Terminals Ltd 5. Asia Container Terminals Ltd	1. ECT 2. APM 3. Uniport	1. Ports America 2. TraPac, Inc 3. Yusen Terminals, Inc 4. Eagle Marine Services 5. APM 6. California United Terminals	1. American Stevedoring Inc 2. Global Terminal and Container Services 3. Ports America 4. Maher Terminals 5. APM 6. New York Container Terminal

In the landlord ports the cluster governance power is spread among landlords and multiple terminal operators. Terminal operators have enough resources to develop their own private hub inter-organizational information systems which results in the existence of different systems with similar functionalities within one cluster. This phenomenon has been observed in all five landlord port clusters. However, in the port of Felixstowe which is a private port there is only one operating company that also performs landlord functions. Thus, the landlord and terminal operator roles are merged together and performed by one organization. Furthermore this organization doesn't have competitors within the cluster in any of its roles. As a consequence, the number of inter-organizational information systems in the port of Felixstowe is much lower than in other ports (two against four/five in other port clusters). Existence of monopolies inside a cluster impedes the development of many systems with similar services which is happening in competitive situation.

Research question 2: *Do governance layer characteristics of the cluster information exchange arrangement via inter-organizational information systems influence the operational layer characteristics?*

Proposition 2. The introduction of neutral digital platform as the base of cluster information infrastructure leads to the development of larger number of inter-organizational information system services for the cluster.

Figure 4. The link between governance and functional layers of the information exchange arrangement.



Singapore port cluster is the only one in the sample where the digital platform has been introduced as the base for the provision of information infrastructure. This is also the only cluster where all stakeholder types are covered by the inter-organizational information systems services. The introduction of digital platforms makes the development of services much easier for the external providers. There is no need to create physical infrastructure anymore and get organizations engaged to connect. The customer base connected via the single network is ready. Thus, much more software developers can participate in the development of services. The user types at the periphery of information exchange network also become attractive as they usually have the lowest number of services available to them. The neutrality of the platform is very important as only the neutral platform can gain access to the variety of existing inter-organizational information systems already existing within the cluster. Furthermore neutral governance of the platform will ensure that the system doesn't discriminate certain organizations over the other which will provide it the credibility that is necessary for acquiring a large customer base.

The next two propositions are not derived in congruence with the initial research framework. The peculiarity of the exploratory case study as the research method is that it allows for the unexpected results based on the novelty of the collected qualitative data. The propositions three and four offer the insights regarding the regularities in the development of inter-organizational information systems within the cluster.

Proposition 3. The higher the number of connections the cluster role has in the cluster information exchange map is the higher is the probability that this user type will be covered by the inter-organizational information systems functioning within the cluster.

In the port cluster according to the information exchange map of Van Baalen et al. (2008) (see Appendix 1) the following number of connections to other user types can be assigned to the stakeholder types: freight forwarders – 8, shipping agents – 3, terminal operators – 3, inland carriers – 3, shippers – 3, shipping lines – 2, banks – 2, customs – 1, port authorities – 1, port services – 1, insurance agencies – 1, depots – 1. The stakeholders that were not covered in certain port clusters by the inter-organizational information systems are port authorities, depots, banks, insurance agencies, and port services. All of these stakeholders have the only one connection for banks which have two different connections. This observation supports the proposition.

The organizations that have the highest number of different connections in the cluster information exchange map are the core of the cluster while the organizations at the periphery, like banks and insurance agencies, can serve the needs of different clusters. Once the cluster organizations are developing the inter-organizational information systems they are focusing on the links through which they transfer the larger amount of information on a more frequent base. These are the organizations with high number of different connections. Furthermore, the organizations with higher number of connections are more interested in the automation of their inter-organizational communication as these activities take much more resources from them in comparison with the organizations with low degrees of centrality.

Proposition 4. At the early stages of cluster inter-organizational information systems development the probability of establishment of vertical links is much higher than the probability of the creation of horizontal links and electronic market places.

In all six port clusters if the stakeholder type was involved in the inter-organizational information exchange it had a vertical link connection. Horizontal links were developed only in three clusters and for very limited number of stakeholder types. Electronic marketplaces function only in form of three global shipping portals. The little use of horizontal links and electronic marketplaces can be explained by the fact that they offer reengineering of business processes. They offer the possibilities to do operations that could not have taken place before the inter-organizational information systems were in place. Meanwhile the development of vertical links is only changing the way the information is being transmitted. The very same information has been transmitted before the inter-organizational systems were in place but it was transmitted by means of telephone or fax.

The practices of an organization get transformed in any case with the introduction of an inter-organizational information system. However, the magnitude of the business practices transformation differs. In case of the development of horizontal links companies are especially reluctant to share information with their competitors despite the fact that such a sharing can bring operational and strategic benefits for all participants. The coordination facilitated by horizontal links was not possible before the inter-organizational information systems were created. Therefore the companies cannot proper evaluate their risks of sharing additional information.

Electronic marketplaces can be successfully set up only when the large number of sellers is participating in them. The buyers are not interested in searching among two or three options. Thus, the development of electronic marketplaces requires the engagement of many companies before the systems can be introduced. Furthermore, many companies are using the existence of high costs of search in their pricing strategies and they are not interested in the buyers having the possibility to compare their prices with those of competitors with a click of a mouse. Therefore the development of electronic marketplaces and horizontal links is much more difficult than the creation of vertical links among the cluster organizations.

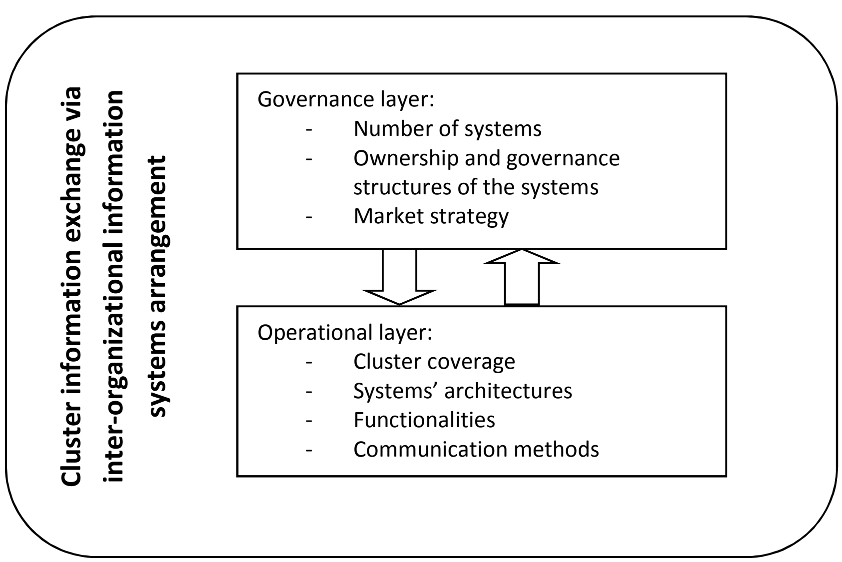
8. Discussion

The initial research framework suggested that cluster characteristics influence the shape of cluster information exchange arrangements via inter-organizational information systems. The first proposition formulated based on the collected data supported this insight. One cluster specific factor – distribution of cluster roles among independent organizations – was shown to influence the character of the information exchange arrangement via inter-organizational information systems. The second proposition supported the second link that was put forward in the framework – the connection between governance and operational layer characteristics of the cluster information exchange arrangement via inter-organizational information systems.

It is necessary to acknowledge that six cases that were analyzed in the current study turned out to demonstrate relatively low variance in the dependent construct – characteristics of cluster information exchange arrangement via inter-organizational information systems – than initially expected. Due to this fact only two propositions have been derived in accordance with the initial research framework despite the general nature of the framework links. Nevertheless the similarity of the cases was used to suggest two propositions of another kind. These propositions explained the regularities that all cluster information exchange arrangements go through regardless of the specific cluster characteristics. The development of inter-organizational information systems within the cluster tends to start with the user types that have more connections to other user types, i.e. the user types that lie in the center of the cluster information exchange map. Secondly, the creation of vertical information exchange links within the cluster is more probable than the creation of horizontal information exchange links at the early stage of the cluster inter-organizational information systems development.

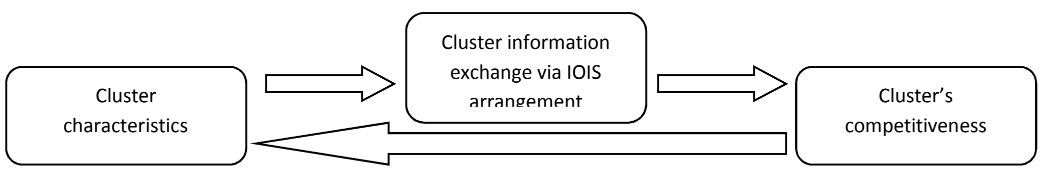
The indication of the certain path that cluster information exchange arrangements via inter-organizational information systems goes through led to reconsideration of the initial research framework. In the current analysis both differences and similarities in the cluster inter-organizational information systems have been shown. Empirical observations and analysis of the different cluster arrangements suggest that governance layer decisions are dependent not only on cluster characteristics but also on the previous decisions at both governance and functional layer characteristics of cluster information exchange arrangements via inter-organizational information systems. Future research on the topic can investigate the presence of the backward link from the functional to governance layer characteristics.

Figure 5. Modified research framework with reverse influence from operational to governance layer characteristics



Furthermore the question remains why Singapore port cluster is the only one that has come to the development of the digital platform as the basis of the inter-organizational information exchange. Singapore has been a pioneer in the development of business to business communications since early 1990s. Moreover, the state government pays specifically generous attention to turning the country into an “intelligent island” (Government of Singapore, 2008). The lack of natural resources forced Singapore to focus on the investment into knowledge-oriented development. As a result, nowadays Singapore has not only advanced port industry but also serves as an important financial and educational hub of the Asian region. For decades Singapore port ranks high among the world’s busiest ports which justifies the chosen development strategy. This suggests that the links between the constructs in the research framework are even more complicated than initially supposed. There might be a dynamic reverse connection between the cluster’s competitiveness and cluster’s characteristics which influence the development of the cluster information exchange via inter-organizational information systems arrangement.

Figure 6. Modified research framework with reverse influence from cluster’s competitiveness on cluster characteristics



Finally, the empirical investigation gave additional supporting evidence to the initial hypothesis that a digital platform is advantageous over other types of inter-organizational information systems in forming the backbone of cluster’s information infrastructure. Therefore the next chapter is devoted to a more detailed analysis of the digital platform concept, its potential of serving as the backbone of cluster’s information infrastructure and to speculation regarding the future research on the topic.

9. Platform as the backbone of cluster's information infrastructure

9.1. General definition of the platform

The term platform is being used in academic discussions on different topics in various disciplines. For instance, it can be found in engineering papers on electronic systems design or in economic research on two-sided markets. It is also widely used in general conversations. Therefore the term itself has not got a specific common definition. The insight into the discussions on modular and platform-based designs and on two-sided markets can provide the necessary basis for defining the platform that could serve as the backbone of cluster's inter-organizational information infrastructure.

The products can be treated as complex systems that interact and are interdependent to some degree. Therefore, the products can be decomposed into a structured ordering of successive sets of subsystems. Product designs differ significantly in the degree to which a design has been decomposed into loosely coupled or tightly coupled components, i.e. to which extent a change in the design of one component requires compensating design changes in other components. Modular design is a distinct design approach which intentionally creates a high degree of independence between component designs by standardizing component interfaces (Sanchez and Mahoney, 1996).

The consequences of modular product design implementation are two-fold. Modularity reduces the cost of managing the cognitive burden of complexity (Simon, 1962); it allows "mixing and matching" of modular components creating a large number of product variations with distinctive functionalities, features or performance levels (Sanderson and Uzumeri, 1990). Modular product design brings about strategic flexibility for a firm because it can more rapidly respond to changing markets and technologies by creating new product variation based on new combinations of new or existing modular components (Sanchez and Mahoney, 1996). Finally, modularity in the product design allows designing and production tasks to be partitioned and worked on in parallel. These tasks can be divided among several firms. The latter feature of the modular design also brings about the danger for the company developing the product because the architect of a modular system risks losing the big share of value created to complementary innovators (Henkel and Baldwin, 2009).

The review of the academic literature in three research streams, namely product development, technology strategy and industrial economics, let Baldwin and Woodard (2009) suggest that the fundamental architecture behind all platforms is essentially the same: the system can be divided into a set of 'core' components with low variety which make up the platform and a complementary set of 'peripheral' components with high variety which constitute additional modules.

Modularity in product design has blurred the distinction between complementary products and components of modular design architecture product. For instance, consider a game console and a cartridge. One is useless without each other. The question is: are they two complementary products or two components of a complex modular product produced by different firms? The answer to this question is not as important as the fact that the question exists. Katz and Shapiro (1994) studied the economics of such forming systems which they defined as collections of two or more components together with an interface that allows the components to work together. The examples of such component pairs besides already introduced game consoles and cartridges are cameras and films, search engines and on-line advertisement, cars and fuel, nuts and bolts. In the market competition between such forming systems the issues of expectations, coordination and compatibility play a completely different role in comparison with market competition between individual products (Katz and Shapiro, 1994).

Platforms have another definition in the industrial economics literature. In this line of research platforms are "products and services that bring together groups of users in two-sided networks" (Eisenmann et al., 2006, p.2). This perspective is related to the discussed above modular design view but it broadens the platforms to include not only products but also services. When two complementary products or components or services construct a forming system, they have different status relative to each other. The very same game console can be used with various cartridges. Each time the cartridge is changed the customer gets a new product, new experience. The cartridge on the other hand can be used only with one type of game console. Therefore it has a position dependent on the game console.

As a consequence the platform products or services create two markets: traditional end-consumer market and the market for producers of complementary product or service (the market for complementors). The management of such platform products requires adjustment of regular practices because these products face specific challenges. Platform producers can exploit pricing strategies based on the difference in price-sensitivity of two markets; they should consider the intellectual property issues – whether it is more beneficial to develop an open or proprietary platform and others (Eisenmann et al., 2006).

9.2. Overview of the research on platforms

The academic literature studying the platforms has been focusing mostly on three closely interconnected topics – platform governance, platform strategies and platform design. According to Gawer and Cusumano (2002) the governance of platforms is based on four distinct levers. They are the firm scope, technology design and intellectual property, external relationships with complementors and internal organization. The first choice that the platform leader has to make is to decide on what activities to perform in house versus what to leave to other firms. The second lever is based on the platform's leader ability to decide what functionality or features to include in the platform and to what degree the platform interfaces should be open to outside complementors and at what price. The third governance issue is organizing the process by which the platform leader manages complementors and encourages their participation. Finally, the internal organization of the platform leader should provide assurance to external complementors that they are working for the overall good of the ecosystem surrounding the platform.

Boudreau and Hagiu (2009) stress the importance of platform governance not only at the earlier stages of the platform development but also after the platform has been rolled out and is fully functional. They argue that externalities, complexity, uncertainty, asymmetric information and coordination problems are always present within a platform's ecosystem due to its multi-sided nature. The platform owner has a suitable position and an array of legal, technological, informational and other instruments to deal with these problems and maximize both value created for the entire ecosystem and value extracted from platform ownership.

Platform strategies should differ for new firms depending on their design capability, whether they are an assembler/integrator/system maker or a specialist/component maker, and depending on their market situation, i.e. presence of another dominant platform (Gawer, 2009). Firms can choose between two general strategies 'coring' and 'tipping' (Gawer and Cusumano, 2008). Coring encompasses the set of strategic moves aimed at creating a platform when none existed before. Tipping is the set of activities that shape market dynamics and win platform wars when platform candidates compete.

All platforms have to deal with the problem of attracting the critical mass of both users and complementors for successful organic growth. Evans (2009) suggests at least two strategies to achieve this goal – the zig-zag and the two-step. In the two-step strategy platform owner gets enough members of one side on board first and then gets members of the other side on board. The successful example of the implementation of this strategy is the advertising through the search engines which first gained their user base and only later entered advertising business. The zig-zag strategy suggests that platform owners can jump-start their platforms by providing complementing services themselves at the initial stage.

The studies on the platform design mainly address the issues of the intellectual property and the decisions on what part of the complex system should be produced in house. Baldwin and Woodard, (2009) suggest that systems are harder to contain in house if they have a modular structure with clean and easily duplicated interfaces. Furthermore they consider the interfaces to be the main parts of the system over which the developer should retain the control as they are the most stable parts of the forming system.

Eisenmann, Parker and Van Alstyne, (2009) theorize that platform openness occurs at multiple levels depending on whether participation is unrestricted at the 1) demand-side user (end user), 2) supply-side user (application developer), 3) platform provider, or 4) platform sponsor levels. They hypothesize that forces tend to push both completely proprietary and completely open platforms over time toward hybrid governance models typified by central control over platform technology and shared responsibility for serving users. Schilling (2009) partially supports this conclusion by suggesting that one key determinant of a technology's success, platform integrity (i.e. a platform that does not become fragmented through uncoordinated development), may be achievable only through a strategy that incorporates some degree of control. Accordingly, it is possible that a wholly open strategy is never optimal for technologies that require standardization and compatibility, irrespective of the firm's resources or industry conditions.

In the next two sub-chapters I consider how the inter-organizational digital platform can be defined in accordance with current literature on the topic. Furthermore, I reflect on what issues might arise when establishing such a platform as the backbone of the cluster's information exchange infrastructure.

9.3. Inter-organizational digital platform

An information system can be treated as a collection of hardware, software, data, and people, that work together to gather, process, store and disseminate information for a person or an organization. People, data, software and hardware are four basic components of an information system. Human resources consist of end users and IT specialists; hardware consists from machines and media; software consists from programs and procedures; data component includes data, model and knowledge base (O'Brien, 1993). An inter-organizational information system is an information system shared by two or more organizations.

Based on the earlier discussion on the notion of platform and an empirical example of the inter-organizational digital platform TradeXchange, an inter-organizational digital platform can be defined as a central orchestration hub inter-organizational information system with the extensible codebase that provides core functionality shared by the modules that interoperate with it and the interfaces through which they interoperate. A module can be defined in accordance with Tiwana et al. (2010) as an add-on software subsystem that connects to the platform to add functionality to it. The hardware of an inter-organizational digital platform can include personal and mainframe computers, web and database servers, remote communication lines and other elements. Hardware components, human resources and data can belong to or be provided by different organizations participating in the inter-organizational digital platform.

This definition falls in line with the discussion on platform products in industrial economics. The two groups of users of an inter-organizational digital platform are value-added service providers that develop distinct modules for it and end-user organizations that utilize the functionality of the platform to automate their inter-organizational daily operations. In the example of Singapore TradeXchange the company providing an inter-organizational digital platform is CrimsonLogic. Its main responsibility besides the development of the extensible codebase is the governance of the platform.

CrimsonLogic should decide on who can be allowed to join as an end-user or as a software provider; on how can the platform be accessed; on which kind of hardware should be used; on how the data shared via the system should be stored and disseminated, and on many other issues. For successful acceptance of TradeXchange among Singapore trade community it is probably necessary to organize a discussion with the cluster companies before making these decisions as the development of the platform is path-dependent and will be largely determined by its initial configuration.

The main advantage of the introduction of an inter-organizational digital platform as the backbone of the cluster information exchange infrastructure is that it allows gaining benefits from the network effects of the majority of cluster companies joining one system while eliminating the problem of monopolistic service development that is present in the traditional central hub inter-organizational information systems. It is convenient for cluster companies when connection to one platform can enable communication with all their partners within the clusters and maybe even outside it. Furthermore it is also important that cluster companies will be able to choose from various modules provided by different value added service providers on the competitive basis. The software developers tend to focus on specific user group, study its business processes and create information services for this group. The presence of different user types within the cluster makes it extremely difficult for one software developer to cover needs of all user groups. Therefore the introduction of an inter-organizational digital platform that allows participation of different software providers increases the probability that all cluster user types will be offered services for inter-organizational information exchange.

9.4. Future research on inter-organizational digital platforms

As of today there has been no research on inter-organizational digital platforms as these specific types of platforms did not exist until recently. I was able to identify only one active inter-organizational digital platform – TradeXchange of Singapore that was launched in 2007. This can be explained by the focus of the current research on port clusters. Therefore further investigation of other than port clusters might reveal the existence of other inter-organizational digital platforms.

The introduction of inter-organizational digital platform has the potential to significantly increase a given cluster's competitiveness as discussed earlier. However the successful launch and further functioning of the platform is dependent on its governance model. Therefore the future research is necessary to describe how initial choices in the platform design influence its adoption. Furthermore, in line with previous research on inter-organizational systems I concluded that in the interest of cluster's competitiveness the platform should be developed by a neutral organization which doesn't favor distinct groups of users. However, it might be the case that the platform mitigates by its very design this problem of favoring certain groups of users over others. Platform users have access to different software solutions that they can choose from. Therefore in case they see that their interests are poorly met by one value added service provider they can switch to another one. A more detailed investigation of the technology behind the inter-organizational digital platforms is required to answer this question. The data that were available via open sources were not sufficient to provide adequate insight into this issue.

In the case of TradeXchange the development of the inter-organizational digital platform was organized as public private partnership. CrimsonLogic has been appointed by the Singapore Government as an independent contractor to develop, operate, maintain and drive the adoption of this project. Theoretically at least two other development options are possible – purely public and purely private. This consideration falls in line with the long lasting economic discussion on the infrastructure development alternatives. All of the named options have their benefits and costs in general. The specific consideration of this issue with respect to inter-organizational digital platform creation might give a less controversial answer to the question because the market competition between forming systems is different from the market competition between individual products (Katz and Shapiro, 1994).

When investigating the clusters researchers always have to deal with the problem of defining cluster's borders. The very same problem can be faced by the developers of the inter-organizational digital platform when defining their target users. In Singapore the target user group was named broadly as trade and logistics community. However, to market the platform successfully they had to name their potential users more precisely: carriers, forwarders, exporters, importers and financial service providers. Thus, the question arises how to set the optimal borders for the customers' base of the digital platform.

Modern business has a truly global character. Therefore it is important for the clusters that their inter-organizational information systems were able to facilitate such information exchange. Digital platform should be able to provide access to other systems important for its customers. Moreover certain companies like banks can simultaneously belong to a number of different clusters with distinct information exchange infrastructures. They will have to face the choice of connecting and dealing with many different systems or specializing and serving a specific cluster unless other solution can be offered.

More specific questions should be investigated with respect to the governance or business model of the inter-organizational digital platform. Platform leader has to decide on the pricing model. Eisenmann et al. (2006) advice subsidizing quality and price-sensitive users of the platform. In the case of inter-organizational digital platform value-added service providers should be more willing to pay for the access to the larger base of the general cluster organizations. However it can be dependent on the cluster type and other factors. For that reason a more detailed analysis is required for determining the pricing model that would ensure the successful implementation of an inter-organizational digital platform. Data sharing model is another important aspect of the platform governance. Modern companies are still reluctant to provide data to common databases because of the fears that competitors will gain access to it. Furthermore, they always tend to retain their ownership over information. Current technologies like agent-based systems allow using the information from competing companies for common benefits while revealing only the necessary minimum of it. However such arrangements require extremely cautious design which would be approved by all interested parties. The mechanism of creating such services and data sharing arrangements should be organized by platform developers so that the cluster coordination with the help of the platform could be conducted on the regular basis.

These are the examples of the research questions that require further investigation with respect to the introduction of inter-organizational digital platforms as backbones of clusters' information exchange infrastructure. Naturally, as the topic has not been investigated before, many more can and will be asked and answered in the future.

10. Conclusion

Competition exists not only between individual companies but also at the higher level – between clusters. One of the factors that can influence the competitive position of a cluster is the quality of information infrastructure. Inter-organizational information systems are nowadays the most advanced way of facilitating information exchange between organizations. Thus, it is in the interest of the organizations responsible for cluster development to facilitate the creation of inter-organizational information systems to serve the cluster's needs in the information infrastructure.

There are different strategies which leading organizations of the cluster can choose with respect to the development of inter-organizational information systems. They can develop the systems by themselves. Alternatively they can leave this function to the market. Then either independent providers, seeing the free niche, will fill it in, or industry leaders will develop the systems, or consortium of cluster companies can do this. These decisions depend on the governance structure of the cluster and the power balance within it. As a result of the implementation of a certain strategy or not having any, the governance structure of the information exchange via inter-organizational information systems within the cluster is being formed. The main governance layer characteristics of the cluster information exchange arrangement via inter-organizational information systems are 1)the number of the systems; 2)their ownership structure; 3)competition level between the systems in the service development.

The goal of the cluster competition is to attract more companies to the cluster. For the companies, operating or deciding whether to join the cluster, the governance layer of the information infrastructure is not important; what matters for them are the services that are available via this information infrastructure and the costs of using them. These characteristics belong to the operational level. The main operational layer characteristics of the cluster information exchange arrangement via inter-organizational information systems are 1)cluster coverage; 2)systems' architecture; 3)functionality; 4)data transfer technologies. These parameters influence both the quality of the information infrastructure services and their costs, which influence in their turn the price and quality of the products or services that cluster organizations can offer to their customers.

The comparative analysis of six port clusters showed that the governance layer characteristics of the cluster information exchange arrangement influence cluster coverage by the information infrastructure and have little effect on types of services and communication methods used by the systems. Moreover the analysis allowed formulation of a number of propositions regarding the development of cluster information exchange arrangement via inter-organizational information systems. The cluster stakeholder type has a higher possibility to be covered by the inter-organizational information systems with the cluster if it has a higher number of information exchange connections to other user types. The governance structure of the cluster influences the governance layer characteristics of the cluster information exchange arrangement via inter-organizational information systems. At the early stages of cluster inter-organizational information systems development the probability of establishment of vertical links is much higher than the probability of the creation of horizontal links and electronic market places. Finally, the introduction of neutral digital platform as the base of cluster information infrastructure leads to the development of larger number of inter-organizational information system services for the cluster.

This thesis offers a number of theoretical contributions to the cluster theory as it explicitly considers how the information infrastructure in form of inter-organizational information systems can influence the cluster's competitive position and compares the effect of different information infrastructure development strategies. For the research in inter-organizational information systems this thesis offers the framework along which the cluster level arrangements of information exchange can be compared. Moreover, the propositions on the character of information infrastructure development are being developed.

The practitioners can use the framework suggested in the thesis for the evaluation of different clusters' infrastructure when taking the decision to join one of the clusters as the relative advantages of various inter-organizational information systems types have been discussed in the chapter three.

The main limitation of this research is that the data was collected mostly from the internet sources. The cross-check with industry practitioners would have ensured that none of the systems functioning with the cluster has been missed out. However, this would have taken the resources that were not available at the time of development of this thesis. This was a theory building case study and theoretical sampling has been used as its basis. Therefore, all the conclusions regarding the testing of proposition on the connection between governance layer characteristics and operational layer characteristics should be treated with cautious as testing requires random sampling. The focus of this thesis was on the development of new theory which can be later subject to test.

Appendix 1

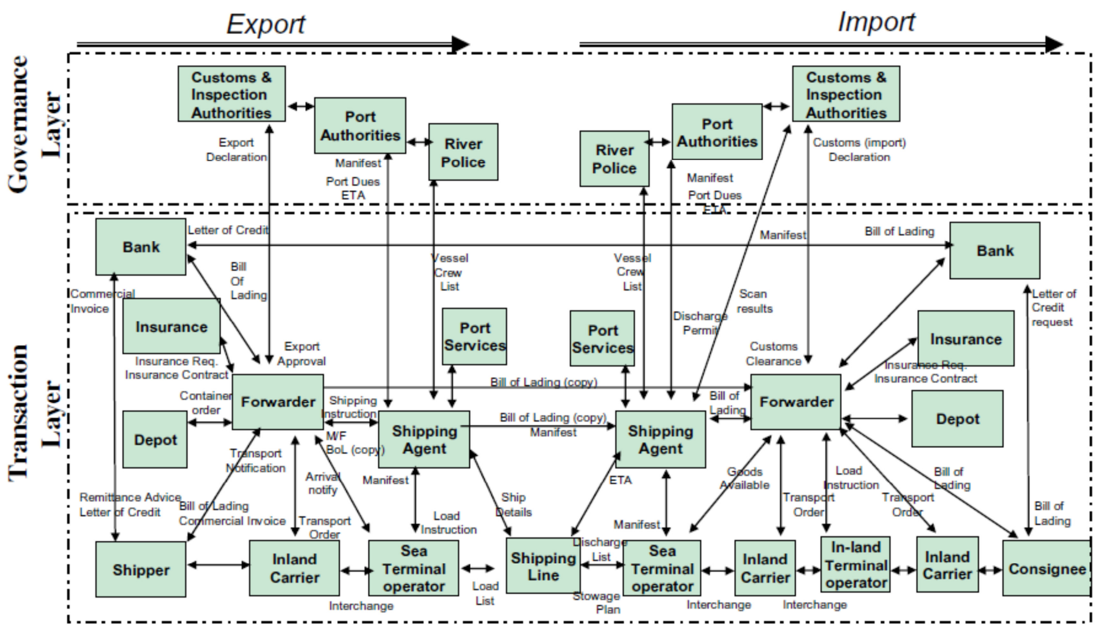


Fig. A.3 Information flows in the transaction and governance layers.

Adopted from Van Baalen et al. 2008, p. 183

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