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Dynamic Governance of Industrial and Infrastructure Investments – Quantifying the Benefits

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DYNAMIC GOVERNANCE OF INDUSTRIAL AND INFRASTRUCTURE INVESTMENTS – QUANTIFYING THE BENEFITS

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ABSTRACT

This paper presents how performance measurement can enable dynamic governance and thereby increase the value obtained from industrial and infrastructure investments over their lifecycle. The basis for the performance measurement is a combination of sensing both the physical and strategic functions that in combination improve the actions in governing the investments. We summarize this as dynamic governance. The governance has its basis in the dynamic lifecycle and the environment of the investment. In this paper, we present a case study where we quantify the benefits of dynamic governance, using a deep sea containership as the case investment. The method is based on outlining a lifecycle value model for the containership as part of the container logistics industry. Through this model, we define the actors that affect the lifecycle value creation, and analyze how the lifecycle financial value is increased through the implementation of dynamic governance structures. The findings indicate that the implementation of dynamic governance structures improves the investment utilization rate, and therefore increases the lifecycle cash flow potential.

KEYWORDS: Business ecosystems, project governance, performance measurement

INTRODUCTION

In this paper we have applied a case study to deep sea container logistics in quantifying the benefits of dynamic governance structures. The overall interest of the research lies in analyzing and developing industrial business ecosystems. It is also concerned with examining how recent developments in performance measurement systems enable and support the governance and organization towards combined efforts of several different actors in sustainable value creation. This value is created through industrial and infrastructure investments. Performance measurement systems provide information vertically concerning the physical and strategic requirements of the investment, the eco-system, or the industry. The information supports the decision makers when predicting and organizing upcoming activities. Such activities can be long-term strategic decisions, day-to-day operational procedures, maintenance, new investments, or reconfiguration of existing investments (*i.e.* upgrades, modernizations or even change of functions). This is the overall phenomena that we summarize as dynamic governance, in which the organizing is based on predicting and planning activities according to the dynamic lifecycle of large industrial and infrastructure investments. Dynamic governance also takes into consideration the dynamic industry, economy, and society that surrounds the activities.

In earlier research (Sundholm et al. 2015), we outlined a framework (Figure 1) for understanding dynamic governance structures through the features of a performance measurement

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system. The framework is based on six development trends which act in a supportive and enabling role in the formation of dynamic governance structures. The first five identified trends relate to global digitalization. Ubiquitous sensing and broader performance measures represent the data and information that can currently be gathered from micro (nano) level to the industrial level. This data can be converted into highly accurate future predictions for the material-, part- and investment physical state and requirements through multi-physical and multi-scale modeling. Collection, storage, and analysis of data and information has increased in speed and reduced in cost, and online knowledge management tools communicate real time actionable knowledge. The sixth trend is the new governance models, which refers to that industry governance models have become increasingly collaborative. The actionable knowledge that is generated through these sophisticated performance measurement systems supports fast and accurate decisions being made between the multiple actors responsible for investment lifecycle value creation.

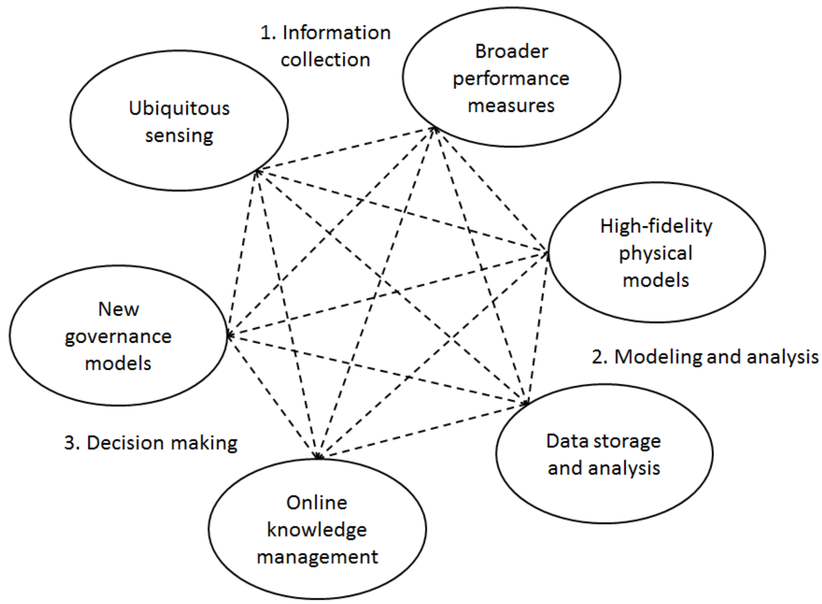

Figure 1 The framework for research on dynamic governance, based on an understanding of the six enabling and supporting trends, and their interrelation. Acquired from Sundholm et al. (2015)

This paper presents research in the form of a case study on how the implementation of dynamic governance improves investment lifecycle value creation. The method in quantifying the value benefits of dynamic governance is based on providing estimations of how the financial values are impacted by the system in which the investment functions. We argue for alternative opportunities for creating improved lifecycle value and which governance structures could be applied in order to achieve this. The argument is grounded though estimating the increased lifecycle financial value. The research question is therefore formulated as follows:

RQ: *How does the implementation of dynamic governance structures affect the lifecycle value of large industrial- and infrastructure investments?*

We begin the paper by reviewing the key perspectives of the theory of industrial ecosystems and project governance theory, in order to understand how to analyze investment lifecycle value creation. This is followed by the case study chapter where we present how we apply perspectives from governance theory to the method in quantifying the benefits from the implementation of dynamic governance structures. The case study description identifies opportunities from the implementation of dynamic governance structures in the container logistics industry. In the empirical chapter, we define the container logistics industry as a system and model the lifecycle financial value creation for a deep sea containership. This serves as the basis of how we estimate the quantified benefits from implementing dynamic governance structures in the container logistics industry. Based on this we reflect and discuss the case study findings, together with the implications for other industries and investments.

LITERATURE REVIEW ON GOVERNANCE

Governance research, especially within industrial and large infrastructure governance, has seen the development of bodies of literature focused on the governance of business ecosystems and project governance. A common definition summarized of business ecosystems is a system of interconnected workflow. Workflows are connected across multiple actors, forming networks of interdependence that span beyond the boundaries of firms (Zott and Amit 2010). The key perspectives in the development of frameworks is the simultaneous systems and workflow perspective that remains neutral to the value creation of individual firms (Tsvetkova et al. 2015), and the perspective of a sustainable outcome from the system (Tsvetkova 2014). Projects can be viewed as temporary activities that are undertaken in order to implement the aims of a business ecosystem. Project governance research provides frameworks and analysis on how multiple actors involved in a project can achieve a mutually defined goal (Ahola et al. 2014), and how value is created through multiple projects (Biesenthal and Wilden 2014).

Both business ecosystem and project governance research argue for an understanding of the external environment of investments and projects, and how the external environment affects an investment's or a project's success. Ruuska et al. (2011) characterize projects as open systems that are affected by business and non-business actors. In earlier project management research, Youker (1992) classified actors and factors in the construction project environment according to the following elements; the physical, infrastructural, technological, commercial/financial/economic, psychological/sociocultural, and political/legal. We utilize this framework for identifying and categorizing different actors that affect the lifecycle value of a large investment.

The literature on project governance and its foundations in project management has extended towards lifecycle perspectives for projects. In project business theory, Artto et al. (2008) view the lifecycle of an investment as the pre project, project, and post project phase. Governance literature on Public Private Partnerships (PPP's) views the lifecycle of the PPP project itself, with defined boundaries according to when the public organization is involved (Fischer et al. 2006). We divide the lifecycle of an investment according to its operational phase and a set of projects (investment-, construction-, maintenance-, and reconfiguration projects).

CASE STUDY

Dynamic governance in the container logistics industry

We have selected as a case study deep sea containerships which are a part of the container logistics industry. Deep sea containerships form an important part of the industry's process flow (transported containers), and are directly connected to other investments in the industry.

Information and data for the case study has been gathered mainly through industrial reports (UNCTAD 2015, Sanders et al. 2012) concerning industry values and actor definitions, literature on the maritime industry (Stopford 2009) for information on investment technology-, calculations-, and actor definitions, and clinical research (Schein 2008; Tsvetkova 2014) within the container logistics industry. A central role of the research group in the clinical research projects has been to perform feasibility studies for projects in implementing dynamic governance structures (Figure 3). In these feasibility studies we have used actual data and figures. However, the calculations used in the model presented in this paper are based on a hypothetical case and values. Different projects have been performed with different actors, and therefore the feasibility studies have been conducted from several perspectives and according to a varying amount of data availability. The estimations used in the case study are, in a sense, a summary of different estimations that have been used in actual projects.

Figure 3 presents a mapping of the central activities as regards to how the container logistics industry can function as an ecosystem. The research group uses this mapping as an overall framework for a set of clinical research projects, where we strive to work with collaboration partners in academia and industry to implement different parts of the mapping.

Presently, container shipping is experiencing overcapacity in the industry as a result of excessive investment, especially in ever larger containerships. The effects of this can be seen in rate cuttings (see Chinese shipping 2016, for Shanghai Containerized Freight Index). It has been estimated that rate cuts during 2011 cost the industry $11 billion (Sanders et al. 2012), as a result of overcapacity and increasingly larger containerships. Another negative effect of larger containerships is that port terminal capacity does not correspond with the larger ships. Terminal productivity is reduced due to the limitations of berth lengths, thus, terminals can only handle one large ship instead of two smaller ones. This can be seen as a system level mismatch, where the performance of terminals is reduced by these larger ships. There is considerable data and information available in the container logistics industry, among others, the cargo flows, capacity on route, containership new build projects, and terminal characteristics. This makes it possible to gain a full understanding and predictions as regards to capacity and demand (1 in Figure 3), and therefore to plan both ship and terminal new build investments that have an optimal and matching capacity (2 and 3 in Figure 3).

We have observed in various research projects that part of the technology providers to the container logistics industry are developing their strategy from product- to solutions business. These technology providers are moving part of their business from providing their products according to request, towards striving to achieve active involvement in the lifecycle value creation of container ships and terminals (2 and 3 in Figure 3). Previously, shipyards have had the main technological and design responsibility for containership new build investments. In some cases, the technology procurement for the investment has been based on minimizing the price through an active bidding process with multiple different suppliers. This has, in some cases, led to disparity in the technology on containerships, resulting in poor technological performance. Container securing systems that are non-optimal can result in the containership not carrying containers to its full capacity, and a non-optimal propulsion system can result in poor fuel efficiency. Active involvement from technology providers can reduce this problem through correct expertise in the early phases of the investment project. This involvement should focus on the investment lifecycle value creation. Despite the fact that expert technology can increase the new build investment costs, it can also lead to a higher cash flow potential. Similarly, port equipment providers have changed from only providing individual equipment to planning the entire port flow, and acquiring the responsibility for maintaining the equipment. Existing containerships, ports, and terminals are also seeing upgrades with the aim of improving existing technology or increasing the capacity.

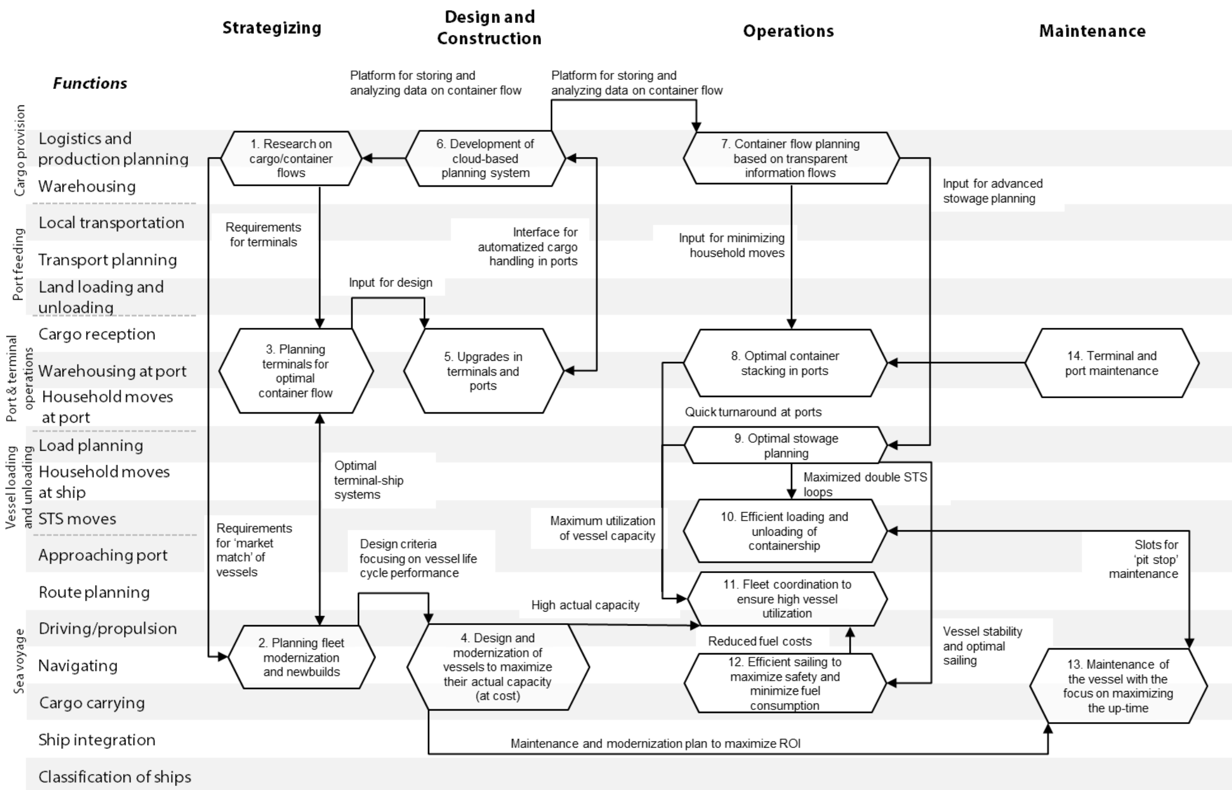

Figure 3 Ecosystem mapping of the container logistics industry

The global container logistics industry is currently experiencing several operational inefficiencies. Experts estimate (Pernia 2015) that there is currently a $17 billion waste in port and containership operations that could be reduced through operational collaboration throughout the entire logistics chain. One part of this involves combined container flow optimization and planning between liners, terminal-, and port operators (8-11 in Figure 3). Such a solution is now possible through the latest development of cloud based planning software (Xvela 2016) based on transparent information flow between all the relevant parties (6 and 7 in Figure 3). Using this type of software, liners and terminal (port) operators can plan the port and terminal container stacks in alignment with the container stacks on the containership. Through this, the number of double- and twin lift moves could increase. Double loop lifts involve lifting one container off and one container on to the ship, and twin lifts involve two containers being lifted at the same time. Four containers can be moved in one lift through double loop twin lifts. Combined planning can also result in the reduction of household moves (movement within the container stacks at ports) or re-stowage on ships. Ideally, there should be as few household moves and re-stows as possible.

The fuel efficiency of containerships is not only based on technology, but also on the ship's speed and the weather conditions. Route and speed optimization is possible through the development of route optimization software (Napa 2016; ABB Marine 2016). This type of software is based on simulating the ships fuel consumption according to the weather conditions prevailing on alternative routes, and selecting the most efficient option (12 in Figure 3). By knowing about any alterations in the terminal schedules, it is also possible to reduce or increase the ship's speed in order to harmonize the ship's arrival with the terminal's changes in schedule. This can also be viewed as a fuel efficiency factor in relation to the container flow.

Expert maintenance of containerships and terminals is mainly the result of the increased involvement of the technology providers and remote monitoring (13 and 14 in Figure 3). Containerships and port equipment are robust structures, yet there are complex parts such as the engines, propulsion systems, hydraulics, and electrical systems. Through inspections and remote monitoring, part breakdown can be predicted and spare parts can be changed proactively. Expert involvement during dry dock maintenance can also speed up the process, thus reducing the containership's downtime for maintenance.

Method for quantifying the benefits

The case study is based on modeling the lifecycle value of a deep sea containership. We define a base scenario according to various inefficiencies that we have identified in the container logistics industry, which we then compare to scenarios based on the implementation of dynamic governance structures.

Figure 2 presents a framework that we have created in order to outline and discuss the lifecycle value of a large investment. The base logic is that the investment provides a function for its given system, *i.e.* industry, infrastructure network, or business ecosystem. The investment as a function contributes to forming the system flow. The first part of the case study describes the system, the key actors, and the system environment. This serves as the basis for the second part of the case study, which moves on to structuring and describing the lifecycle value modeling of a case investment. The investment lifecycle is divided according to the investment operations, *i.e.* its function, and a set of projects that are categorized according to investment-, construction-, maintenance-, and reconfiguration projects (*i.e.* upgrades or modernizations). Investments form a functional output; system-, financial-, environmental-, and societal value. These values can be scaled when applied to several investments, according to the function, global positioning and business actors. The third part of the case study is based on simulating different scenarios according to the model.

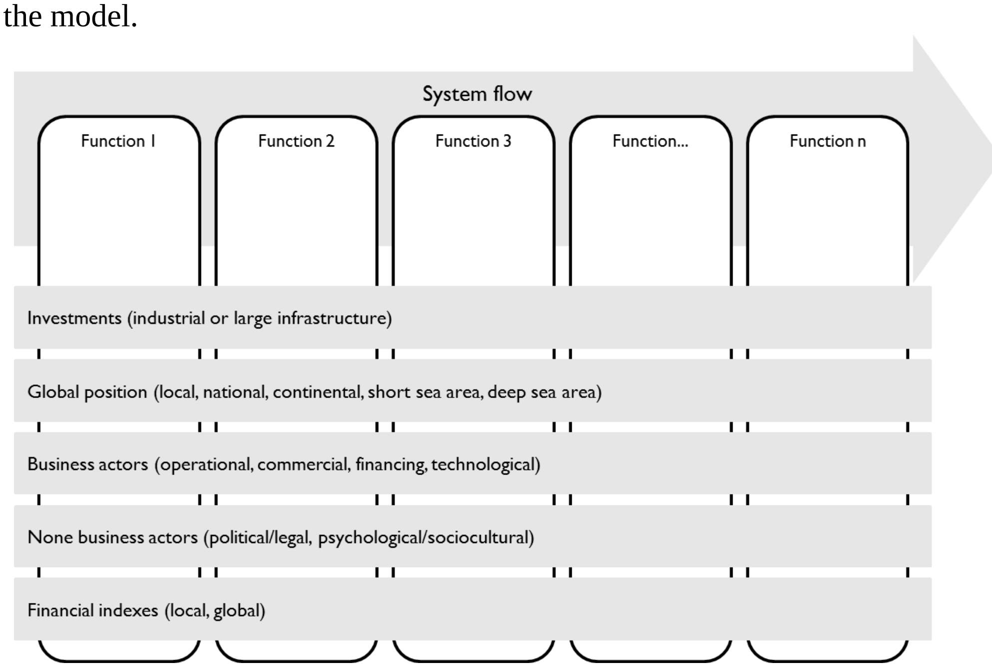

Figure 2 Framework for defining the lifecycle value of large industrial and infrastructure investments as part of a system

The system and environment is categorized according to the framework provided by Youker (1992). The investment lifecycle value is created by business actors, and influenced by its environment, the system flow, global position, non-business actors, and financial indexes. Business actors involve operational- (organizations that operate the investments), commercial- (organizations that purchase the functions), financing- (organizations that finance the investments), and technological actors (organizations that provide the investment). Non-business actors are political/legal actors that affect the lifecycle value through legislative rules and psychological/sociocultural actors through norms.

QUANTIFIED BENEFITS FROM DYNAMIC GOVERNANCE

System definition of the container logistics industry

The system definition of the container logistics industry is summarized in Table 1 in the Appendix. The system flow that is formed through the container logistics industry is the global container flow, which is measured according to twenty equivalent foot containers, TEU. The journey of a container from door to door varies, and can include anything from local truck transportation to international transport involving multiple different land transport means, passage through several ports, and seaborne transport on several different containerships. Most of the global container flow includes shipping. Since 2011-2014 the number of shipped TEU per year has been estimated to have grown by 5% per year and to have reached 171 million TEUs in 2014 (UNCTAD 2015, p.19). In 2014, 43% of this flow was on the East-West routes (Asia-North America, Asia-Europe, and Europe-North America), 40% on Intraregional and South-South routes (mainly intra-Asia), and 17% on North-South routes (UNCTAD 2015, p. 20). The direct tie to global trade can be seen in the correlation between the world merchandized trade, the world seaborne trade, and the world GDP and OECD industrial production index (UNCTAD 2015, p. 5). Intercontinental import and export volumes are directly reflected in containerized cargo transport volumes. On the East-West routes (UNCTAD 2015, p. 21), it is estimated that containerized cargo flows from Asia to North America and Asia to Europe are nearly twice the number of returning payload containers on the same routes.

The global container flow is formed through three main functions; land transport, port operations, and shipping. Port operations and shipping are divided according to short sea and deep sea. A short sea involves more localized seaborne transport in a certain short sea area, and deep sea involves inter-continental transport on deep sea routes. Land transport, short sea, and inland shipping form feeder traffic for the deep sea shipping. This is an important distinction in container logistics, as feeder traffic is based on coordinating cargo flows to deep sea ports, from which containers are shipped across transcontinental routes.

The main operators of this industry are liners, terminal operators and port authorities, truck- or railway transport companies, and freight forwarders. Liners are companies in the business of container shipping. Port authorities are governmental or quasi-governmental bodies that are responsible for the overall port investment and operations. A port can consist of several terminal operators, who lease a terminal area (berth) from the port authority. Land transport responsibility varies between land logistics companies, freight forwarders, and liners. Liners may have their own land logistics network, and can also transport containers within land areas via rivers.

The need of a containerized logistics can be based on business to business-, internal business-, or private consumer transports. Dealing with container transport varies, and can be executed by a freight forwarding agent or directly by the liner booking services or sales department. Apart from individual container transport sales, liners also sell container shipping quotas on contractual basis, commonly to freight forwarders or directly to businesses that have large shipping quotas per year. Liners purchase the port services mainly on contractual basis from the terminal operator. This transaction is either based on the number of lifts or containers moved, the terminal handling charge.

The container transport industry is globally regulated by the International Maritime Organization (IMO), which is the United Nations body responsible for the overall maritime industry. Recently, the IMO has set an enforcement of mandatory container weights, which can directly be seen as having an impact on the system value creation. This is not due to the cost of weighing the containers, but due to the potential in reduced inefficiency from lacking information regarding container weights. Other political and legal bodies that affect the industry are classification societies and local governments. Classification societies provide the necessary registration required for containership insurance, through setting standards on new builds and maintenance. Local governments affect the industry mainly by the fact that port authorities are usually a governmental body. In various countries, the national governments have set limits so that only containerships sailing under the country's flag can transport containers within the country's boundaries. According to UNCTAD (2015, p.23), transportation customers are increasingly demanding sustainable container logistics, which in turn is placing pressure on liners to reduce their impact on the environment. This has an indirect impact on the environmental lifecycle value creation of containerships.

Deep sea containership lifecycle value

Financially, the liner business is the main business directly affected by container ship productivity, and the business of liners affects the containership lifecycle value creation through their operational activities. Therefore, the lifecycle value creation of a containership is mainly viewed from a liner perspective. Liners position themselves through a set of route services, and consign their containership fleet to formation of scheduled capacity on the route services. The containership utilization rate, *i.e.* transported containers in relation to its capacity, can be limited due to the non-optimal technical specifications of the containership, competition or overcapacity on route, and the liner operational activities.

A liner's fleet consists of a combination of ships that are owned or chartered. Containerships can be financed by ship management companies, banks, financial institutions, and the private sector, who gain their return on investment through time charter agreements with liners. The freight market can therefore be divided according to freight forwarding-, voyage charters- and time charter agreements (Stopford 2009, p. 182). Freight forwarding agreements form the spot market, and voyage charters are contractually sold container freight according to a certain quota per year. Time charter agreements are based on non-operating ownership of containerships, where ship management companies broker time charter agreements of containerships to liners for a certain time period and time charter day rate. In this sense, a containership can generate revenue from its operational activities to the liner, and as an investment for its financers. The time charter revenue for financers and cost for liners can be neglected in the containership lifecycle value modeling.

Stopford (2009, p. 220) structures the shipping cash flow model according to revenue, operating costs, voyage costs, cargo handling, capital, interest, and maintenance. Operating costs covers the crew costs, stores, lubricants, minor repairs and maintenance, insurance and administration costs. The voyage costs include fuel costs and port charges (berthing, wharfage, mooring/unmooring, pilotage, tugging, and other services). The cargo handling cost is the cost of moving containers between ship and shore, priced according to the terminal handling charge, which is based on the number of moved containers, both with a payload and empty. We model the lifecycle cash flow over a set of given years, R_t of a containership according to:

$$R_t\ (N) = \sum_{t=0}^{N} Rev_t - OpEx_t - CapEx_t$$

Where N defines the number of yearly periods in time, t, of the yearly generated revenue, Rev_t, yearly operational expenditure, $OpEx_t$, and yearly capital expenditure, $CapEx_t$. The operating-, voyage- and cargo handling costs are included in the $OpEx_t$ and $CapEx_t$ is the ship investment and dry-dock maintenance costs.

Rev_t is based on a calculation of the income that is generated through transporting payload containers, *i.e.* containers containing goods. Estimating the yearly revenue generated in container transport is based on multiplying the estimated number of transported payload TEU per year, $C_{TEU,t}$ with the estimated yearly freight rate α_t. The total count of transported containers is a different figure than $C_{TEU,t}$ due the existence of both 20 foot and 40 foot containers. Each transported 40 foot container has the value of $C_{TEU,t} = 2$ TEU.

Estimation of Rev_t is divided in to the revenue generated from the main- and return leg due to different prices and demand. The main leg refers to the leg on the service route with higher demand. Typically, containerships sailing between Asia and Europe, or Asia and America, can carry a full ship of payload containers on the main leg, $C_{TEU,ml}$ while carrying half the number of payload containers on the return leg, $C_{TEU,rl}$. The remaining capacity is filled with empty containers needed to transport new cargo on the main leg. Rev_t is therefore calculated as:

$$Rev_t = (C_{TEU,ml} *\ \alpha_{ml,t}) + (C_{TEU,rl} *\ \alpha_{rl,t})$$

Estimation of the number of payload containers carried per year, $C_{TEU,t}$ is based on the nominal (or registered) capacity, q_{nom} of a containership, multiplied with the number of roundtrips that the containerships performs on the route service. We define q_{nom} as the theoretical maximum number of containers that a containership can carry. For some containerships, q_{nom} is never reached in payload containers due to structural- and lashing force limitations. If the container securing systems are optimal then it is possible to reach q_{nom}. In order to account for this in lifecycle value modeling, a utilization rate limitation from technology, U_{tech}, can be estimated for the containership. The maximum capacity of a containership, q_{max} is calculated through multiplying q_{nom} with U_{tech}, representing the technical number of payload containers that can be carried on a containership.

The number of transported payload containers is limited due to the fluctuating demand and competition. Containerships commonly only attain 1-2 full roundtrips per year, and sail with limited cargoes during the rest of the year. Therefore, the number of roundtrips are divided into commercially limited roundtrips, RT_{clim} and full roundtrips, RT_{full}. A utilization rate limitation from commercial factors, U_{com}, is set on the commercially limited roundtrip. The utilization rate limitation from operations, U_{op} accounts for containers left off ship from various activities in containership operations. Containership cargo- and stowage planning is highly complex in both optimizing the container stack on the ship, and minimizing the number of lifts at ports. The number of transported containers per roundtrip and time spent at ports for a containership is dependent on the cargo planner's capabilities. Other reasons for U_{op} can be the use stricter structural- and lashing force limitation rules than allowed, and deviations from the stowage plan.

In summary, the estimation of transported payload containers per year is divided into the yearly number of payload containers per main- ($C_{TEU,ml,t}$) and return leg ($C_{TEU,rl,t}$), and divided according to full- ($RT_{full,t}$) and commercially limited roundtrips ($RT_{clim,t}$). The maximum number of transported containers per leg is set as q_{max}, *i.e.* the estimated maximum number that the containership can technically carry. This number is reduced from q_{nom} according to U_{tech}, which represents limitations from non-optimal container securing systems. Market limitations are accounted for according to estimating the number of $RT_{full,t}$ and $RT_{clim,t}$, and to what extent the containership is utilized (U_{com}) on commercially limited roundtrips. A reduction in the containership utilization rate from operational activities is also set through U_{op}.

The estimated yearly number of transported payload containers on the main leg is calculated as:

$$C_{TEU,ml,t} = \left(RT_{full,t} * q_{max} * U_{op}\right) + (RT_{clim,t} * \ q_{max} * \ U_{com} * U_{op})$$

The estimated yearly number of transported payload containers on the return leg is calculated as:

$$C_{TEU,rl,t} = \left(RT_{full,t} * q_{max} * \ 0,5 * U_{op}\right) + \left(RT_{clim,t} * q_{max} * \ U_{com} * 0,5 * U_{op}\right)$$

The majority of the operating costs of a containership are from the fuel costs, $OpEx_F$, and cargo handling costs, $OpEx_{CH}$, typically forming a total of 80-90% of $OpEx_t$. Estimating $OpEx_t$ is therefore based on estimating the fuel- and cargo handling costs, to which a factor of 1,15 is multiplied in order to account for the rest of the operational expenditure, as:

$$OpEx_t = 1{,}15 * (OpEx_{F,t} + OpEx_{CH,t})$$

Pricing logics of container terminals vary globally. In some cases they are strictly based on the number of containers, but can also vary according to 20 and 40 foot containers, and import- and export traffic. Prices at a container terminal can also vary between different liners. We based our estimation of $OpEx_{CH,t}$ on the number of containers per year, $C_{cont,t}$, and an estimate of the terminal handling charge, β:

$$OpEx_{CH,t} = \beta * C_{cont,t}$$

Estimating the number of containers includes both the payload and empty containers, and therefore excluding the utilization rate. Empty containers are not limited according to the structural- and lashing forces, market-, or operational factors. Therefore, estimating C_{cont} is based on q_{nom} and the total number of roundtrips per year, RT_t. As q_{nom} is based on TEU, the quota of 20 foot containers (μ_{20}) and 40 foot containers (μ_{40}) is estimated to convert the TEU into the number of containers for $C_{cont,t}$. The number of transported empty and payload containers per year is calculated as:

$$C_{cont,t} = q_{nom} * RT_t * 2 * (\mu_{20} + \frac{\mu_{40}}{2})$$

The count of lifts during port operations is affected by the cargo profile-, stowage- and port operations planning. Ideally, containers are placed in the stacks at the port yard and on the containership, so that containers can be lifted on and off the ship in the same lift (double loop lifts) compared to one container on or off the ship in one lift (single loop lifts), and so that two containers can be lifted at once (twin lifts). Double loop and twin lifts are a mutual benefit for the liner and terminal operator, as they reduce the turnaround time of a ship. Estimating the number of lifts includes setting a quota of the number of double loop lifts (μ_{dl}), twin lifts (μ_{tl}), double loop twinlifts ($\mu_{dl,tl}$), and single loop lifts ($\mu_{dl,tl}$), and accounting for how many containers are lifted according to the different lift types. The number of lifts per year is calculated as:

$$L_t = C_{cont,t} * (\frac{\mu_{dl}}{2} + \frac{\mu_{tl}}{2} + \frac{\mu_{dl,tl}}{4} + \mu_{sl})$$

An estimation of the daily fuel consumption, F_d is acquired from Noteboom and Cariou (2009), who have estimated the daily fuel consumption of different sized containerships according to different speeds. When multiplied by the number of sailing days per year, SD_t, it forms the yearly fuel consumption, which when multiplied with the bunker fuel price, γ, provides an estimate of $OpEx_{F,t}$. Fuel consumption is affected by several factors; the overall propulsion system efficiency and its alignment to the hull configuration, the sailing speed, and prevailing weather conditions. We therefore include a technical fuel efficiency percentage, FC_{tech}, in order to simulate the difference between containerships with optimal and non-optimal propulsion systems, and the operational fuel efficiency, FC_{op}, accounting for the crew competence in sailing the ship with optimal speed:

$$OpEx_{F,t} = \gamma * SD_t * F_d * (1 - FE_{tech}) * (1 - FE_{op})$$

The investment costs are an output from the investment and construction project. Maintenance of a containership is based on a yearly minor maintenance that can be performed at ports or during sailing, and dry docking every five years. Dry docking maintenance is regulated by the classification society, and involves mainly hull cleaning and painting, maintenance of underwater parts, and a hull inspection by the classification society. It is also possible to extend the dry docking interval through underwater cleaning and photography.

Quantified benefits from dynamic governance structures of deep sea containerships

We quantify the benefits from dynamic governance structures of a hypothetical deep sea containership through the lifecycle financial value creation according to the net present value (NPV):

$$\text{NPV}(i, N) = \sum_{t=0}^{N} \frac{R_t}{(1+i)^t}$$

Where R_t is the net cash flow at time *t*, on yearly intervals in a 25 year lifecycle. Therefore the periods, *N*, are set to a total of 25, where we include year 0 as the decision year of the investment. The discount rate *i* is 10%.

The containership has a nominal capacity of $q_{nom} = 10000$ TEU, and sales six roundtrips per year at a speed of 18 knots. The containership gains two full roundtrips per year ($RT_{full,t} = 2\ \mathrm{roundtrips/year}$) and four commercially limited ones ($RT_{clim,t} = 4\ \mathrm{roundtrips/year}$). We have estimated that the number of sailing days required as $SD_t = 270\ \mathrm{days/year}$, with a baseline value for the daily fuel consumption as $F_{d,18knots} = 100\ \mathrm{ton/day}$ according to estimations from Noteboom and Cariou (2009). The freight price on the main leg is estimated based on the Shanghai freight index indices to Europe, Mediterranean and US West Coast to $\alpha_{ml,t} = 830\ \$/\mathrm{TEU}$ and freight rate on return leg as $\alpha_{rl,t} = 600\ \$/\mathrm{TEU}$. The terminal handling charge is estimated to $\beta = 180\ \$/\mathrm{container}$ and the fuel price is according to the current bunker world index (Bunkerworld, 2016) as $\gamma = 600\ \$/\mathrm{ton}$. The quota of 20 foot containers on the route is $\mu_{20} = 20\%$ and the quota of 40 foot containers on route is $\mu_{40} = 80\%$. We have estimated the costs for dry-docking every fifth year as $CapEx_t = 1\,000\,000\ \$$. We compare five different scenarios (A-E) of the containership's lifecycle NPV (see Table 3 in the Appendix)

Scenario A is the worst case scenario. The containership has a non-optimal container securing system, resulting in that the containership is technically limited in carrying containers to its full nominal capacity, and therefore the utilization rate limitation from technology is set at $U_{tech} = 85\%$. The technical fuel efficiency is set as $FE_{tech} = 0\%$ due to a non-optimal propulsion system. Investment costs for the ship are estimated as $CapEx_{t=0} = 90\,000\,000\ \$$. On commercially limited roundtrips, the utilization rate limitation from commercial factors is set as $U_{com} = 85\%$. We estimate that in a worst case situation, the liner's overall operational competence in cargo planning and port operations can further reduce the number of transported payload containers through the utilization rate limitation from operations as $U_{op} = 90\%$. The containership sails according to the average speed without alternating the route whereas there is no reduction in the fuel consumption due to operational efficiency, whereas the operational fuel efficiency is set at $FE_{op} = 0\%$.

Scenario B represents expert involvement from the technical supply chain in design and construction of the investment. With optimal container securing systems, that the containership can carry up to 95% of its nominal capacity ($U_{tech} = 95\%$) and the fuel consumption is reduced through an optimal propulsion system for the hull form ($FE_{tech} = 5\%$). The investment cost is higher than in Scenario A ($CapEx_{t=0} = 100\,000\,000\ \$$) in order to account for more expensive technology and services. Scenario C simulates market conditions without overcapacity on route, allowing for the ship to sail with a higher utilization rate ($U_{com} = 95\%$). Scenario D represents operational efficiency from dynamic governance, through the combined planning between the liner, port- and terminal operation, which increases the utilization rate limitation from operations to $U_{op} = 95\%$. The containership sails according to best possible weather conditions, resulting in reduced fuel consumption than Scenario A. The operational fuel efficiency is set as $FE_{op} = 5\%$. Scenario E is the best case scenario, where Scenarios B-D are combined. Results are presented in Figure 4.

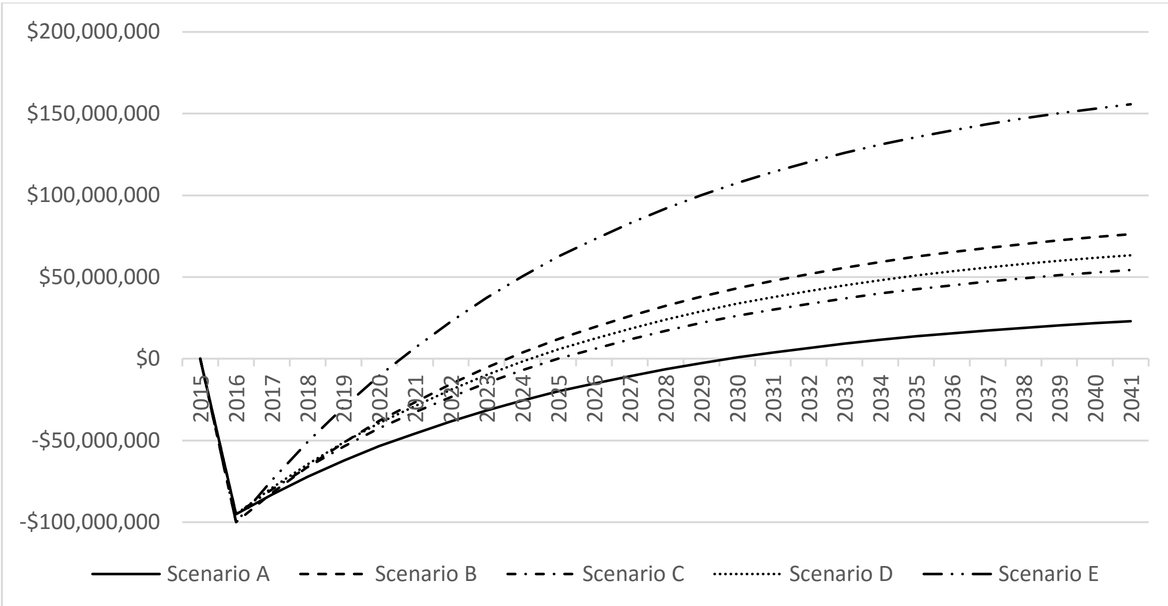

Figure 4 Simulated lifecycle NPV for the containership

DISCUSSION AND CONCLUSIONS

The research question asks how the implementation of dynamic governance structures affect the lifecycle value of large industrial- and infrastructure investments. We have addressed this question through conducting a case study performed within the container logistics industry, where we outlined the lifecycle financial value creation of a deep sea containership. Using the results from this, we have defined the impacts from implementing dynamic governance structures, and modeled the lifecycle NPV. The case study result indicates a clear increase in the lifecycle financial value creation potential of the deep sea containership by utilizing dynamic governance (Scenario E). This is a result from increased revenue and decreased operational expenditure. The results in Table 3 (Appendix) indicate that the main impact is in increased revenue potential.

Implementation of dynamic governance structures with active involvement of technology providers in the investment design (Scenario B) result in a higher utilization rate through technology, which increases the lifecycle financial value creation potential. This potential cannot be reached if the investment utilization rate is reduced due to commercial- or operational limitations. Risks of reduced utilization rate due to commercial limitations can be minimized through dynamic governance structures that are based on measuring and predicting the need of capacity during investment decision making. An investment with poor technology can still be feasible through a lack of commercial- (Scenario C) or operational limitations (Scenario D) on the utilization rate. Operational limitations are reduced through the introduction of dynamic governance structures that are based on increasing collaboration between all relevant operational actors.

Limitations of the study is that the calculations are based on estimated figures and rough calculations. However, the authors stress that the purpose is not to provide an accurate prediction through the calculation, but to understand the lifecycle value in structuring the calculations, and to understand how different actors affect the lifecycle value. For this purpose, the method used has been practical. It can be seen that the results in Figure 4 provide an indication of the benefits, nevertheless a more accurate and real data based calculation should be conducted in order to gain a more precise understanding. We argue that the method can be applied to other industries and investments. This would allow to form comparable case studies to find generic dynamic governance structures and their benefit. An interesting topic for further research would be to investigate why dynamic governance is not being implemented. We have presented a clear example in the container logistics industry where all data and information is available to use in planning containership investments to match the capacity according to demand. Yet the industry is currently suffering highly from overcapacity. We see this as a general governance research question, coupled to business ecosystem research.

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APPENDIX

	Land transport	Port operations	Shipping
Function	Land transported containers (TEU) Distance Time	Port throughput (TEU) Time	Transported containers (TEU) Distance Time
Investments	Roadway infrastructure Railway infrastructure Truck Railway vehicle Intermodal terminals	Port infrastructure and yard equipment Terminal infrastructure and equipment Containership Roadway infrastructure Railway infrastructure Roadway vehicles Railway vehicles	Containership Multi-purpose ship Barge
Global position	Local National Continental	Local	River Short sea area Deep sea route
Operational	Truck company Railway company Logistics Liner	Port authority Terminal operator	Liner Terminal operator (+ other services)
Commercial	Sender Freight forwarder Logistics com	Sender	Liner Freight forwarder
Financing	Government PPP Truck company Railway company	Port authority Terminal operator Other services Government Bank Financing institution	Liner Ship management Bank Financing institution Private sector
Technological	Road infrastructure provider Railway infrastructure provider	Infrastructure provider Port equipment provider	Shipyard Ship design bureau Propulsion system provider Cargo handling system provider Ballast water cleaning system provider Gas cleaning system provider
Financial index	Concrete price Steel price Land transport rate	Concrete price Steel price Terminal handling charge Port dues Other services	Freight rate Time charter rate
Political/Legal	Local government	Local government	IMO Classification society
Psychological/ Sociocultural	Demand on sustainability	Demand on sustainability	Demand on sustainability

Table 1 System definition of container logistics industry

Variable	Unit	Scenario A	Scenario B	Scenario C	Scenario D	Scenario E
q_{nom}	TEU	10000	10000	10000	10000	10000
U_{tech}	%	85	95	85	85	95
q_{max}	TEU	8500	9500	8500	8500	9500
$F_{d,18knots}$	ton/day	100	100	100	100	100
FE_{tech}	%	0	5	0	0	5
$RT_{full,t}$	roundtrips/year	2	2	2	2	2
$RT_{clim,t}$	roundtrips/year	4	4	4	4	4
SD_t	sailing days/year	270	270	270	270	270
U_{com}	%	85	85	95	85	95
U_{op}	%	90	90	90	95	95
FE_{op}	%	0	0	0	5	5
$C_{TEU,ml,t}$	TEU	41310	46170	44370	43605	52345
$C_{TEU,rl,t}$	TEU	20655	23085	22185	21803	26173
μ_{20}	%	20	20	20	20	20
μ_{40}	%	80	80	80	80	80
$C_{cont,t}$	containers/year	72000	72000	72000	72000	72000
μ_{dl}	%	20	20	20	25	25
μ_{tl}	%	10	10	10	15	15
$\mu_{dl,tl}$	%	5	5	5	10	10
μ_{sl}	%	65	65	65	50	50
L_l	lifts/year	58500	58500	58500	52200	52200
$\alpha_{ml,t}$	$/TEU	830	830	830	830	830
$\alpha_{rl,t}$	$/TEU	600	600	600	600	600
β	$/container	180	180	180	180	180
γ	$/ton	600	600	600	600	600
Rev_t	$	46 680 300	52 172 100	50 138 100	49 273 650	59 149 850
$OpEx_{CH,t}$	$	12 960 000	12 960 000	12 960 000	12 960 000	12 960 000
$OpEx_{F,t}$	$	16 200 000	15 390 000	16 200 000	14 580 000	13 851 000
$R_{op,t}$	$	13 146 300	19 569 600	16 604 100	17 602 650	28 317 200
$CapEx_{t=0}$	$	95 000 000	100 000 000	95 000 000	95 000 000	100 000 000
$CapEx_{t=5}$	$	1 000 000	1 000 000	1 000 000	1 000 000	1 000 000
$CapEx_{t=10}$	$	1 000 000	1 000 000	1 000 000	1 000 000	1 000 000
$CapEx_{t=15}$	$	1 000 000	1 000 000	1 000 000	1 000 000	1 000 000
$CapEx_{t=20}$	$	1 000 000	1 000 000	1 000 000	1 000 000	1 000 000
$NPV_{t=25}$	$	22 934 991	76 239 542	54 321 580	63 385 458	155 641 857

Table 3 Key values of the different scenarios