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STRATEGIES FOR COMPLEX SUPPLY NETWORKS: FINDINGS FROM THE OFFSHORE WIND POWER INDUSTRY

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ABSTRACT

Purpose

This paper explores the challenges facing companies that operate within complex supply networks and the strategies they employ to manage such complex supply networks.

Design/methodology/approach

The paper employs mixed methods, combining in-depth case studies with an executive forum with senior industry stakeholders. The two in-depth supply network case studies were carried out through multiple interviews with focal (or 'developer') firms that supply energy through offshore wind power and key suppliers, such as wind turbine manufacturers.

Findings

The findings show the challenges the offshore wind power industry faces that result from complex supply networks, including attempts by several actors to exert their power and control. Despite the networks facing similar complexities and challenges, two distinctly different strategies for orchestrating and governing supply networks are uncovered: one strategy resembles an interventionist strategy, while the other is based on delegation.

Research limitations/implications

Based on the findings we identify and develop a classification of complex supply network divided into intervention and delegation strategies, thereby adding to existing research on ways to manage complex supply networks.

Practical implications

We identify strategies for focal firms for managing in complex supply networks, based on control and intervention or coordination and delegation.

Originality/value

Existing research on supply network strategies has largely focused on non-complex contexts. Our paper draws from complex adaptive systems and organisational behaviour perspectives to contribute original insights into supply network strategies in complex supply networks.

Keywords: complex supply networks, supply network strategies, offshore wind power

STRATEGIES FOR COMPLEX SUPPLY NETWORKS: FINDINGS FROM THE OFFSHORE WIND POWER INDUSTRY

1. INTRODUCTION[1]

Supply chains are inherently complex and therefore best conceptualized as networks (Carter *et al.*, 2015). This realization has given rise to alternative ways of describing supply chains, in particular, as supply chain networks (Lambert and Cooper, 2000) or simply supply networks (hereafter SNs) (Harland, 1996; Choi and Dooley, 2009). Despite the understanding of SNs as inherently complex (Braziotis et al., 2013), little research to date (Choi *et al.*, 2001; Choi and Hong, 2002) has sought to conceptualize the different dimensions of SN complexity (Pathak *et al.*, 2007) and understand the different strategies for managing complex SNs.

Some industries involve inherently complex SNs e.g. oil and gas, construction of offshore-wind power (OWP) farms where a very large number of actors are involved both upstream and downstream and where products consist of complex product systems or complex product-services. The context of our research is OWP, which is strategically important to many countries to move away from fossil fuels towards renewable energy. One of the key challenges for the OWP industry is that it is a relatively new and developing industry and its SNs are complex because of, e.g. the size and diversity of the supply base (EWEA, 2014). Furthermore, OWP projects span several phases, including development, installation, operations and maintenance, and the SNs relevant to each phase change over the course of these phases. OWP SNs have been described as *distributed* as they are characterized by many actors that try to control them (Andersen and Drejer, 2008) leading to complex and dynamic interactions.

In recent years, concepts such as procuring complex performance (Lewis and Roehrich, 2009; Howard and Caldwell, 2014) have emerged to address the unique challenges of complex industries, including the need to understand supply and delivery of complex product-service packages over a long life-cycle that spans from conceptualization to production, operations, service and maintenance. However, to date little research has examined SNs in such industries, leading to a lack of understanding of the challenges posed by SN complexity and strategies used to manage complex SNs. Therefore, this paper addresses the following two research questions:

What are the specific challenges facing companies that operate within complex SNs and what strategies do they employ to manage complex SNs?

We build on two theoretical perspectives. Seeking to understand SN complexity and governance, we draw from Choi *et al.*'s (2001) work that has sought to conceptualize SNs as complex adaptive systems (CAS), which in turn draws from complexity theory (Kauffman, 1995). This perspective is gaining traction in the supply chain literature, also in *Supply Chain Management: An International Journal* (Statsenko *et al.*, 2018; Touboulic *et al.*, 2018). In

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developing an understanding of SN strategies, we also build on the concepts of managerial intervention and delegation originating in the organizational behaviour and organizational economics literature but with a specific focus on how these concepts are applicable in a SN context (Lamming, 1996; Johnsen, 2011). Within our study of the OWP industry, we draw from two embedded case studies of OWP SNs and a workshop with senior industry practitioners. The findings contribute to SN theory, in particular the existing frameworks on strategies for managing different types of SNs.

2. LITERATURE REVIEW

2.1. SN strategy classifications

Despite many classifications of inter-organizational networks (e.g. Grandori and Soda, 1995; Hinterhuber and Levin, 1994) and supply chains, none had attempted to classify SNs until early 2000. Lamming *et al*. (2000) proposed the first classification of SNs based on two dimensions: *degree of product uniqueness-innovativeness*, and *degree of product complexity*. Harland *et al*. (2001) introduced two dimensions: *degree of dynamics*, and *degree of focal firm SN influence*. The first dimension referred to dynamics in internal operations process and external market, and industry maturity. The second factor was a function of a focal firm's ability to influence the SN. SN influence has been explored, typically from a *power* or *relational* perspective. Thus, Chang *et al*. (2012) classify SNs into four different types defined by the power position of the focal firm relative to its suppliers and buyers: upstream network dominance, focal firm dominance, focal firm obedience and downstream network dominance. This links closely with research by Cox and colleagues (e.g. Cox *et al*. 2002) and the wider literature on power in buyer-supplier relationships (e.g. Ireland and Webb, 2007).

Most attempts to classify SNs or supply chains have concentrated on the lean-agile dimension (e.g. Vonderembse *et al*., 2006), typically based on analysis of highly dynamic and turbulent contexts, such as FMCG. However, these SN classifications tend to be private sector, high volume and repetitive manufacturing industries that face different complexities compared with a product-service and public-private sector context, such as OWP, with a strong focus on whole-life management that includes installation, production, operations and maintenance.

2.2. Supply Network (SN) Complexity

Among the definitions of SN complexity in the literature, Choi and Krause (2006) define supply base complexity as a function of the *number of suppliers* in the supply base, the level of *supplier interaction* or *inter-relationships*, and *supplier differentiation*. The greater the number of suppliers, their variation and level of interaction, the greater the *operational ''load''* borne by the focal company in managing its supply base (Choi and Krause, 2006, p. 639). Vachon and Klassen's (2002) multi-dimensional definition of supply chain complexity likewise includes *numerousness* and *interconnectivity* but adds *system unpredictability*. Bozarth *et al*. (2009) distinguish downstream from upstream complexity and dynamic complexity. Downstream complexity includes the *number of customers*, the *heterogeneity of customer needs*, the *average length of the product life cycle*, and the *variability of demand*. Upstream complexity includes the number of supplier relationships to manage, delivery lead-time, reliability of suppliers, and extent of global sourcing.

Choi *et al*. (2001) conceptualize SNs as complex adaptive systems (CAS). The CAS perspective includes the following ideas: *self-organization*, *emergent structures and behavior*, *simple interactions* among SN entities, and *non-linear dynamics*. Although there have been some attempts to use CAS to better understand SN complexity, the majority of these is concerned with modeling of complexity from a technical or operational research (OR) perspective (e.g. Hearnshaw and Wilson, 2013; Pathak *et al*., 2007). Recent studies have attempted to use CAS to analyse specific types of SNs, such as regionals SNs (Statsenko *et al*., 2018) and sustainable SNs in the food industry (Touboulic *et al*., 2018).

Pathak *et al*. (2007) distinguish between *complexity* and *complicatedness*, identifying that where complicated systems may be intricate, complex systems involve *nonlinear dynamic interactions* amongst individual parts. SNs may be *complex*, therefore, not only because of their structure but also because of interactions between and dynamics amongst SN actors and changes in SNs over time in accordance with the CAS tenet of emergent behaviour.

From a business unit i.e. internal firm perspective, Aitken et al. (2016) discuss whether supply chain actors should seek to reduce or absorb complexity. They argue that supply chain complexity may not always have an adverse impact on performance, such as complexity caused by product customisation, and that instead the key is to identify necessary (strategic) and unnecessary (dysfunctional) supply chain complexity and respond accordingly. Thus, it may be appropriate not simply to reduce but to absorb complexity.

2.3. Procuring complex performance and product-service systems

The literature on Procuring Complex Performance (PCP) and Product-Service Systems is relevant because it involves complex industries. PCP focuses on the challenges of managing total supply chain operations during the lifecycle phases of a major project or programme including design, build, service support and disposal (Lewis and Roehrich, 2009; Caldwell and Howard, 2011). PCPs may involve capital-intensive public-private collaborations where there is an increased risk of oligopolistic market conditions and frequent *political interference*. PCP typically defines complexity in terms of the extent to which infrastructural components of the whole system are highly *customized*, the number of *stakeholders* and *the length of planning/contracting negotiation and construction phases* (Roehrich and Lewis, 2014). These are dimensions that are not typically included in CAS research.

PCP often involves the delivering of high-value product or platform infrastructure, with long-term requirements for in-service support. PCP draws on the work on Complex Product-Systems (CoPS) (e.g. Davies *et al*., 2006). CoPS involve engineering-intensive products or systems supplied in units of one or small batches, usually tailored to meet the precise requirements of each customer. Where CoPS can be viewed as *"…a subset of projects concerned with the development, manufacture and delivery of complex capital goods"* (Davies and Hobday, 2005, p22), PCP adds whole-life support and maintenance. The CoPS literature is relevant to the OWP context, which is characterized by multi-firm projects, highly engineered, customized, capital intensive products in small quantities along with operational support and maintenance.

Focusing on contracts and governance mechanisms for handling complex procurement involving many actors, Olsen et al. (2005) identify the importance of *incentives*, *authority* and *trust* in the governance of procurement in the oil and gas industry. Where much of the literature on complex SNs focuses on the number and diversity of actors and the relationships between these, Olsen et al. (2005) and other studies, applying a similar perspective on industries such as defence or healthcare, focus more on *political* and *regulatory influences* and the often-conflicting goals of stakeholders. These industries tend to span both private and public sectors and often involve public-private partnership (PPP) contracts (Zheng et al., 2008).

The OWP context involves many supply chain entities with, at times, conflicting goals of stakeholders. For example, with the wide-spread use of contractual governance in OWP, despite the recognized need for innovation and cost reduction, SN entities often do not focus on innovation, preferring to focus on meeting the terms of their contracts. Much of the literature that study public-private buyer-supplier relationships focus on different governance arrangements, drawing from earlier contributions by e.g. Poppo and Zenger (2002) and Mahapatra et al. (2010). The consensus is that using both contractual and relational mechanisms generates more efficient outcomes than the use of either in isolation (Zheng et al., 2008), ensuring clearly articulated terms and conditions, remedies, and processes of dispute resolution. As Roehrich and Lewis (2014) point out, studies in PCP are limited by their relatively narrow conceptualization of complexity that focuses on the size of a system and its number of component parts. Like much PCP research, Roehrich and Lewis (2014) are more concerned with dyadic relationship governance and less concerned with wider SN management issues.

2.3. Strategies for managing complex SNs: theoretical perspectives

The literature on SN tends to conceptualize SN complexity from a structural perspective largely based on a mass-production or repetitive private-sector manufacturing context. In comparison, the literature on PCP and complex product systems focuses on industries that are inherently complex because of being project and lifecycle-based; these industries tend to cross private and public sector and are influenced by a wider group of stakeholders who often have conflicting objectives. This literature highlights the role of relationship governance through contracts, considering risk and reward sharing arrangements and incentive structures. The review points to two theoretical perspectives related to the question of "management" SNs: to control or self-organize from a CAS perspective, and to intervene or delegate from a behavioural perspective.

2.3.1. Complex Adaptive Systems (CAS) perspective: control or self-organizing?

Choi et al. (2001) discuss the question of SN *control* versus *emergence*. By depicting SNs as CAS, they argue that SNs are self-organizing structures that emerge rather than being deliberately designed and controlled by individual SN actors. Choi et al. (2001) state that:

"We propose that many supply networks emerge rather than result from purposeful design by a singular entity. Imposing too much control detracts from innovation and flexibility; conversely, allowing too much emergence can undermine managerial predictability and work routines. Therefore, when managing supply networks, managers must appropriately balance how much to control and how much to let emerge." p. 351

Thus, each SN entity or node may attempt to manage a portion of its SN but must accept that distant parts of the network are essentially not in its direct control. (Carter *et al*., 2015). Choi *et al*. (2001) state that the environment exists *external* to the SN and consists of agents and their interconnections that are not part of the given complex adaptive system. The boundary between the supply network and the environment is fluid and changes in CAS occur through alterations in boundaries, as agents are included or excluded, and such change alters the underlying patterns of interaction.

Recent research has applied the CAS perspective to explore the emergent aspects of SN sustainability strategies. Touboulic et al.'s study (2018) suggests that individual actors within an SN as well as actors in the external environment, such as consortia, play a critical role in shaping the direction of strategy, although strategies develop through a process of self-organisation and emergence rather than top-down control.

2.3.2. Organizational behaviour and economics perspective: Intervention and delegation

The concepts of intervention and delegation are used in organizational behaviour as alternative ways to manage employees. Within organizations, delegation is entrusting or empowering employees (Thomas and Velthouse, 1990). Delegating responsibility is a way to motivate employees (Osterloh and Frey, 2000) and requires trust in employees to carry out their tasks without overt managerial control. In contrast, intervention implies authoritative action; it often has a negative association, although it can also be regarded more positively. Intervention can also be due to opportunism (Williamson, 1996) and can restrict creativity and be damaging to overall value creation.

Although terminology may be different, the supply chain and network literature uses similar concepts to describe different ways of exercising managerial control. Where delegation is used in an intra-organizational context, the supply chain literature talks about *cascading* decisions, enabling first-tier suppliers to manage their own (2nd tier) suppliers and so forth. Supply chain tiering is a delegation strategy combined with modularization where first-tier suppliers assume the full responsibility for design and development of an entire module, supplying a full system (Sanchez and Mahoney, 1996). Much of the more recent supply chain management literature on modularisation links product design with supply chain design (Pero *et al*. 2010); Khan *et al*., 2012; Pashaei and Olhager, 2015). Pero *et al.* (2010) find evidence that modularity reduces supply chain collaboration complexity, although this increases with increased product innovativeness and may depend on the industry context (Doran et al., 2007).

Comparing cascade and intervention strategies, Lamming (1996) argues that *intervention* is operationalized in supply chains as a customer interfering in a supplier's decision making. Johnsen (2011) takes this view a step further by conceptualizing intervention as a way for a customer to intervene in a supplier's SN, thereby degrading the supplier's ability to control its own network. Whereas SN delegation (or cascade) is clearly a signal of empowerment and trust in suppliers, intervention is therefore exercised through power. Power can be exercised in different ways, using coercive and non-coercive means. Coercive exploitation of power is often viewed negatively and might backfire (Hausman and Johnston, 2010; Ireland and Webb, 2007) and exploitation of power can impact negatively on trust (Jain *et al*., 2014). Linking delegation and intervention strategies to SN-enabled innovation, Narasimhan and Narayanan (2013, p30) argue that the effective utilization of supplier capabilities and technologies must consider the firm's "position with respect to the SN, complementarity of technologies within the SN, and the method with which the focal firm controls the suppliers in the network."

2.4. Summary

Our definition of SN complexity goes beyond the definitions based on CAS, which define SN complexity largely in terms of structural complexity i.e. horizontal complexity, vertical complexity, and spatial complexity (e.g. Choi *et al.*, 2001). Building on PCP and CoPS, we define SN complexity both in terms of structural complexity (but also including stakeholders e.g., regulators) and product-service complexity (including customization and life cycle operational support and maintenance). Even though a SN cannot be fully controlled by any party (Choi et al., 2001) one might influence the ways in which it organizes itself. Thus, we expect some generic strategies for the management of complex SNs: balancing self-organization (emergence) and direct control (in the CAS perspective), intervention versus delegation or cascade approach (in the organization theory perspective) and product modularization and modular supply chains (in the organizational economics perspective). The unanswered question is: *what types of complexity drive firms to choose specific SN management strategies?*

3. METHODOLOGY

This paper aims to answer two questions: (1) What are the specific challenges facing companies that operate within complex SNs, and (2) what strategies do they employ to manage complex SNs? Thus, given the aim to explore SN complexity and the strategies companies employ to cope with this complexity, we decided to adopt an in-depth case study strategy (Ketokivi and Choi, 2014) followed by an executive forum. Case studies allow us to develop an understanding of inter-organizational dynamics by collecting data through interviews with multiple network actors (Halinen and Törnroos, 2005). We report on the findings from two SN case studies where each case is defined in terms of an *inter-organizational SN* that centers on a focal firm: what is known in the offshore industry as a developer firm. The paper adopts a qualitative research approach utilizing a comparative case study (Yin, 2014). The case study approach allows for the investigation of a phenomenon of interest in all its richness in its natural context (Johnston *et al.*, 1999; Narasimhan, 2014) and allows alternation between theory and empirical-knowledge in the research-process (Yin, 2014). We selected two cases that offer a sharp contrast in the offshore wind industry: one with a powerful focal firm (developer) and one with a more dispersed structure. Although the two cases are separate, suppliers often supply several developers and are part of several networks upstream.

A semi-structured interview guide was developed through an abductive process (Dubois and Gadde, 2002), identifying concepts through literature review and exploring themes and interview questions through industry partner collaboration in the research project. Appendix A shows an abbreviated version of this, including the main literature references that underpinned the concepts explored in each section (an adapted version was used for supplier interviews). Initial versions of an interview guide and protocol were refined through exploratory interviews with our existing industry contacts. In addition to contextual questions, the themes included: project, lifecycle and structural supply network complexity, actor relationships and inter-dependencies, power balance and control, and governance such as risk and reward sharing arrangements and contractual issues (see Figure 1).

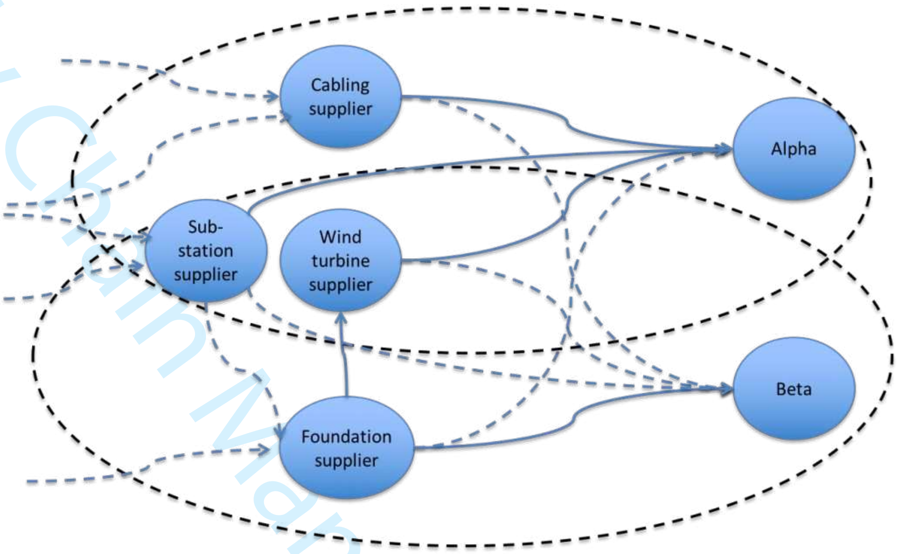

Figure 1. Mapping of Alpha and Beta SNs and their overlaps

We conducted altogether 12 interviews in six companies (two developers and four suppliers). The interviewed suppliers included a wind turbine manufacturer, a foundation supplier, a substation supplier, and an installation/O&M supplier. These were seen as key supply network partners. We also interviewed a professional body as a key stakeholder to gain further insights on the OWP industry. Each interview lasted 1.5-3.0 hours with two interviews in each company except one. The major themes of the interview guide included company background, role in the SNs, project and lifecycle complexity, issues around governance complexity such as power and dependence, supplier relationships, sourcing strategies and integration mechanisms (see Appendix A for detailed interview guide). The interviews involved drawing of the SNs using a flipchart to gain a visual overview of the SNs and estimation of some SN complexity dimensions. Figure 1 shows a condensed version of the two maps and overlaps across the SNs. All interviews were recorded, fully transcribed, coded and categorized (Miles *et al.*, 2014). We consolidated and clustered our codes into two sets of meaningful themes, one for SN complexity (Table 1) and another one for SN complexity management strategies (Table 2). Finally, we checked for errors and aligned the authors' understanding and interpretations of the content of the themes (DeCuir-Gunby *et al.*, 2011).
After completing the case studies, we held a one-day executive forum to complement the case study findings and to present the initial case findings to industry stakeholders for validation. Eleven senior industry executives participated in the forum, including some of the representatives of developers and suppliers already interviewed. In addition, representatives from industry associations and a small number of suppliers and developers not already interviewed were also present. Figure 2 illustrates the analytical boundaries between the two SN case studies and the executive forum. Where each of the two case studies focused on one SN, the executive forum involved both SN actors, who participated in the case studies, and other developer firms, suppliers and service providers (such as consultants) and industry associations.

The forum took the form of an interactive workshop where one senior research team member facilitated a discussion around the same topics as explored through the case study interviews.

The topics were: drivers of OWP supply network complexity, consequences of OWP lifecycle, and actions or initiatives to reduce or manage supply network complexity. As this was a discussion we did not stick to a pre-developed set of questions but invited the participants to provide their insights around these three topics. Our intention was not to link answers from participants specifically to either of the two SN case studies but the findings from the executive forum were instrumental in providing a wider understanding of the industry context and its challenges and thus helped to interpret the case study results. In addition, the forum aided in our understanding of the driving forces of complexity and the SN strategies applied by developer firms to manage this complexity. The workshop was recorded, transcribed and coded. The research members also took notes during the forum to reflect on the discussion.

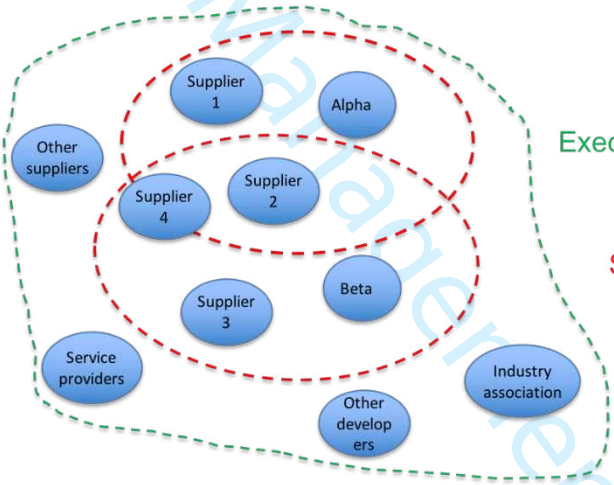

Figure 2. Case study and forum boundaries

4. OWP industry background, case studies and findings

4.1. Background

This section presents background of the OWP industry to assist understanding of the complexity facing the industry. An offshore wind project goes through four distinct phases: project development & concession, installation and commissioning, operations & maintenance and decommissioning. Typically, each phase entails a set of different actors constituting the SN. Hence, SN actors often change from phase to phase (Stentoft and Mikkelsen, 2016). The industry faces high market and industry uncertainty and dynamics due to changes in political decisions. The political demand for local content and cost reduction have forced changes in the SN: "*… there is a push for lower CoE [cost of energy], but at the same time [they] push for local content. There are some contradictions [in this] …*" (exec. forum participant). The increased size of offshore projects and the fact that projects move further and further offshore and onto deeper waters add technical and weather challenges in planning and managing the SN, in particular, during the installation phase (case study 1: Alpha). As one executive forum participant put it: "*Every site is different – tower, foundation etc…. different products and circumstances for every project.*

Moreover, the industry suffers from a lack of industry-wide standards driving complexity and hence cost (exec. forum discussion). The fast change in technology is a source of further complexity decreasing economies of scale (EoS) potential and hence driving cost up "*… missing economies of scale in general in the business, because [the high] speed of technology* *development and high investments and low quantities... CoE [cost of energy] is the target, but technology is moving so fast that it is hard to deal with that*" (exec. forum participants).

Even though the supply base is practically identical for the different offshore players (at least for regional offshore wind projects), SNs of individual projects differ in complexity and in the ways each SN members operate, govern, interact, manage risk, etc. These differences are mostly defined by the way the offshore wind project 'developers', or the hub or focal firms, operate. In this paper we adopt the focal perspective of the developers of the two SNs.

As part of the same industry, both SNs faced many of the same types of complexities and challenges; however, they employ different strategies to cope with the challenges. In the following section, we report the findings from each case study, taking the perspective of the developer or hub firms in order to analyse and bound each SNs. We use pseudonyms to disguise the real names of the SN actors involved.

4.2. Case study 1: Alpha SN

Alpha is a major OWP developer with approximately 1500 employees allocated to the offshore wind business. Alpha operates in all the markets in the North Sea (notably UK, Germany, Denmark, and the Netherlands). Alpha's SN consists of a large number of actors, scattered globally, but mainly concentrated in northern Europe. The actors in the SNs often change in each phase and project lifecycle so the SN structures constantly change. Furthermore, as Alpha is a project organization, suppliers often change from project to project due to prices, technology, capability and availability.

Alpha is powerful, not only due to its size and large continuous pipeline, enabling the company to leverage its power over 1st tier suppliers, but also due to reputation and perceived expertise. Until recently, Alpha and other developers were highly dependent on one wind turbine manufacturer. However, as one other major wind turbine player has recently emerged, followed by other players, this dependency has begun to decrease. Hence, power in the Alpha SN is concentrated on Alpha as a large developer firm and the two major turbine manufacturers. In larger offshore projects, products and services are typically dual sourced as a risk reduction strategy. Foundation manufacturers, array cables and installation companies have less power within the SN as their products or services are more or less standardized. They are all dependent on Alpha and turbine manufacturers.

However, no frame agreements are made between Alpha and its 1st tier suppliers. As one of the interviewees stated: *"… as we don't know if we will need them [products or suppliers] for the next project"*. Being a large and financially strong company with long-term internal expertise on offshore wind projects, Alpha can take a large amount of risk. Perceiving itself as excelling in managing complex projects, Alpha governs the SN activities by detailed multi-contract management, including contracts directly with selected 2nd tier suppliers, e.g., by specifying steel manufacturers for foundations and they produce detailed component specifications for suppliers to follow. Engaging in 150-180 CAPEX (capital expenditure) contracts for a typical project is not uncommon. Thus, Alpha takes upon itself much of the risk of project coordination from engineering, procurement, construction and installation (EPCI) of an offshore wind project, including detailed product specifications. Alpha believes that this detailed management and interventionist approach takes cost out of the SN because *"…what we are really good at is to run and manage large scale complex projects … and getting contracts [working] together…"*

Due to the inherent narrow "weather windows" for installing foundations, cables and offshore wind turbines, planning is a complex and challenging task. Increasing project and turbine sizes coupled with projects moving farther and farther offshore into deeper waters also increase project-planning challenges. As one 1st tier interviewee stated: *"… because of that [seasonality] … makes it difficult to plan, and therefore complicated to manage … and the weather that impacts our project…"* Even a minor delay on foundations, turbines or transport material will significantly affect project cost and duration. Alpha performs scenario analysis to test whether the turbines, foundations, vessels and so forth are available according to plan and that the plan does not entail conflicting activities. Most important are export cables and substations: if a few turbines lack installation, or are not connected, power can still be generated. If a substation or the export cable (cable connecting the offshore and onshore substation) is not in place no power is transferred despite the amount of power being generated. As another risk-mitigating strategy, Alpha has its employees placed at some suppliers' premises to interact and ensure quality during manufacturing.

4.3. Case study 2: Beta SN

Beta acts as the focal company in the second SN and employs approximately 160 staff dedicated to developing and installing offshore wind projects. Compared to other developers, Beta is a minor and less prominent company. Beta is a recent entrant in the offshore wind industry, so their project pipeline is limited, scattered and non-continuous. The company operates in Denmark, Germany and France but not yet in the UK offshore wind market. Beta faces many of the same complexities and challenges as Alpha. Its SN requires the same types of suppliers although operating within a narrower geographical market. Unlike Alpha, Beta interacts with only a few (three or four) main suppliers in each project who in turn coordinate and control sub-tier suppliers. Beta is winning larger projects, but due to its limited financial size, Beta cannot take on the very large projects. Like Alpha, Beta also faces the lack of standards on health and safety regulations.

Beta's business model and strategy is based on risk avoidance and management. Projects need to be financed up front with a traditional split of own equity and external funding of 30/70. As institutional investors are risk minimizers, Beta calculates all risks into projects up front, before securing investment. Consequently, suppliers - especially turbine manufacturers – that account for approximately 40% of CAPEX, must be "bankable" (i.e. proven technology). Therefore, only tested and proven technology and suppliers are allowed onto their projects; as the CEO at Beta stated regarding their risk aversion: *"… so it is much about our position [in the market]… but also the general risk profile … we have to be sure that as much risk as possible is quantified and [harnessed] … and on turbines we play safe."*

Unlike Alpha, Beta envisions itself not as a wind farm owner and operator, but as a key player in bringing investors together and creating profitable investment projects. Projects are developed and operated to present them as a viable financial venture for institutional investors; operating an offshore wind farm is not in itself Beta's objective. The project is merely seen as a conveyer for generating cash flow and earnings by selling equity from concession to power connection to the grid. Thus, Beta works more in line with a property developer rather than a construction firm. However, in recent years, they have moved towards some asset ownership in operating wind farms to generate a continuous cash flow in order not to be overly dependent on the timing of securing projects. Given Beta's dependency on wind turbine manufacturers, the power in this SN lies with the turbine manufacturers.

Beta's lack of power is evident by the fact that Beta sometimes experiences a lack of interest when requesting tenders for new projects.

Beta has contractual relationships with 1st tier suppliers but seldom engages with the second-tier suppliers and beyond. Beta's strategy to decrease complexity and risk is to use systems sourcing arrangements, delegating risk and responsibility to suppliers for coordination tasks such as installation and detailed planning. For example, the turbine supplier is responsible for installation including crew and vessels. The respondent at Beta stated: *"… we have an opinion about who the [tier 1 suppliers] use as tier 2 suppliers and the level of quality etc., but the supplier the [tier 1 suppliers] choose is secondary. We do not want to take upon us risk by interfering …"* Naturally, this adds to Beta's dependency, but Beta's strategy is that it takes a coordination responsibility for the various installations – cables, foundations, turbines and substations. Beta does not have long term "frame agreements" with 1st tier suppliers as their fear is that it will *"get locked in with a supplier while another supplier comes with a new and better solution or cost level … and you never know if you win the project."*

Even if Beta does not install as far offshore as Alpha the actors are still exposed to planning challenges due to seasonality and weather conditions for installation of the wind farm, although not to the same degree, and risk is often shared with suppliers. However, as Beta bids on more and larger projects further offshore, this type of challenges is likely to increase in the future.

4.4. Cross case analysis

4.4.1 Challenges and SN complexities (developer perspective)

Table 1 shows the sources of complexity identified and compares how these were evident in the two cases. Based on the two SNs researched, we identify a variety of SN complexity sources, related to structural, lifecycle, relational, integration and technology complexity. Structural dimensions are generally used to define SN complexity in the literature (Choi and Krause, 2006). In OWP, structural complexities come from three major sources: (1) the use of large wind turbines installed in deep water, (2) the number of suppliers of different sizes and geographical coverage (3) changing political and stakeholder demand and regulations. These three sources can influence each other, depending on the geographical location and its political stability.

Both cases demonstrate how lifecycle complexity is created as a result of changing SN actors from one project phase to another. Both cases show the challenges and complexities of changing SNs throughout the phases in a project lifetime and from project to project. As one executive forum participant put it: "*you cannot get the commitment that you will get the next ten projects so you can cover your investment… You are only 'in bed' with the costumer project by project"*. Both developers are confronted with project complexity originating from differences in standards in terms of e.g., health & safety regulation between countries. However, while Alpha faces challenges of balancing resources and management attention between overlapping offshore wind farm projects, Beta struggles more with challenges of projects being sequential and scattered.

Relational complexity concerns the balance of power, interactions between SN actors, the use of modularization and standardisation and intervention by the end customers. Alpha directly manages many 1st tier suppliers, which creates structural complexity due to reduced task partitioning: "*… some of the processes [tasks] are extremely thinly sliced, which is not healthy* *if you want to drive out cost …"* (O&M supplier). At the same time Alpha uses its power to reduce relational complexity by coordinating interactions among its 1st tier suppliers. Even though the manufacturing of turbines is industrialized, the OWP industry is generally characterized by a low level of standardization and modularization as offshore wind projects are handled as 'one off' projects.

Both cases show how integration causes complexity due to the lack of logistics capacity and knowledge-sharing as well as a low level of transparency. Knowledge sharing is limited as actors do not know if they will work together or as competitors on the next project. Finally, technology adds complexity through the high rate of technological change. One outcome is that e.g., installation vessel providers seek customer commitment before investing in new and larger vessels, while customers request vessel providers to be ready before committing. Beta mitigates technological complexity by choosing proven technologies, although this restricts the sizes and types of contracts it can secure.

4.4.2 Challenges and SN complexities (supplier perspectives)

Overall, suppliers face less complexity because they focus on managing the SN of their own components or systems, except in the case of wind turbine suppliers, who face a high rate of structural and technological innovation due to turbine size and design. Increasing turbine sizes cause logistical challenges for other SN actors as modes of transportation, installation and lifting equipment may not be suitable for the new designs. Increasing turbine sizes represent an ongoing challenge on both land and at sea. For example, foundation suppliers are affected by the design and size of wind turbines as this alters both water depth and steel towers that connect foundations and turbines. Thus, interdependency between suppliers becomes a significant challenge.

Furthermore, the lack of standardization and the way that developers operate add further complexity for suppliers. The low level of standardization makes it hard for suppliers to forecast and optimize their operations. Even steel for the towers (e.g. in terms of thickness and size) are specifically designed for individual projects so although steel plates are a commodity, they can only be ordered once orders are secured. As expressed by a foundation supplier:

"… we cannot produce to stock, as we never know [if we get the job]….. You cannot source before you get the order for the project … so no frame agreement … at the same time there is a high penalty for late deliveries, so OTIF [On Time In Full] is very important …"

The distinct operating modes of different developers causes further complexity for suppliers. In some instances, suppliers act as 1st tier suppliers, where they may take part in the design process, while in other instances they operate as sub-tier suppliers where they may even be required to act as subcontractor to their peers or even to competitors. Such changing roles in different situations clearly adds to supplier complexity: *"… we are often faced with being both a supplier and competitor or customer and competitor in different contexts, and that you need to be able to handle"* (Substation supplier).

The structure of the tendering process further adds complexity for suppliers. Typically, more than one developer submits wind farm project tenders. In the same vein, each developer invites more than one supplier to bid for their part of the project (e.g. for foundations). Hence, the further upstream in the supply chain the more suppliers are involved in bidding for the same project. Consequently, suppliers often find themselves preparing multiple offers for the same project but for different customers requiring different turbine brands with different specifications or scope. Suppliers therefore need to have the capacity to bid simultaneously for multiple projects whilst being pushed for both cost and time:

"one thing is pretty clear in the industry … that time windows for fabrication and supplying are getting smaller and smaller, from year to year … and it is never the same design that the customers want … It's adding complexity that's true, and at the end of the day it adds costs". (Foundation supplier)

Table 1. Sources of complexity

Complexity dimension	Sources of complexity	Case comparison (developer and supplier perspectives)
Structural	❖ Physical size of wind farms and components ❖ Deep water installation ❖ Political stakeholder influence e.g. demands for local content ❖ Governmental regulations ❖ Diverse suppliers (size & geographical)	• Beta faced less structural complexity than Alpha due to lower number of 1st tier suppliers, but Beta's 1st tier suppliers faced a high structural complexity • Alpha suppliers faced less structural complexity than Beta suppliers (except wind turbine manufacturers)
Lifecycle	❖ Product-service system spanning long lifecycle ❖ Suppliers and service providers change over lifecycle	• Both developers faced high lifecycle complexity • Suppliers less affected by lifecycle complexity
Relational	❖ Distributed power: not one actor controlling SN ❖ Inter-connected SN actors ❖ Customer intervention in supplier choice ❖ Modularisation and standardization at early state in parts of SN	• Both Beta and Alpha faced high relational complexity; Alpha more power to control • Major suppliers faced inter-connection problems (e.g., between foundations, steel tower, wind turbine)
Integration	❖ Lack of logistics capacity ❖ Lack of knowledge sharing ❖ Low level of transparency	• Both developers faced lack of integration • Alpha faced higher coordination load due to large number of 1st tier suppliers • Very limited integration and knowledge sharing among upstream suppliers
Technology	❖ Fast changing technology	• Beta faced less (still high) technological complexity than Alpha by choosing relatively proven technologies • Rapidly changing technologies e.g. wind turbine and foundation: suppliers expected to constantly innovate

In summary, the sources of SN complexity identified in our cases reflect those that we set out to investigate, including the number and diversity of suppliers and the inter-connections amongst these. In addition to these, our findings illustrate how the varied political stakeholders exert influence on several SN issues, for example, related to sourcing and local content decisions. On relational complexity, the issues of power were less surprising than the importance of customer intervention in supplier selection that reflected attempts to exert power and influence beyond dyadic supplier relationships. Clearly, also lifecycle complexity added an extra dimension to SN complexity, especially as suppliers and service providers frequently change over the course of OWP project stages.

4.4.3 Strategies for managing complex SNs (developer perspective)

In this section we focus on a hub or lead firm ('developer') perspective because they hold the power as downstream customers to influence their SNs. In comparison, most suppliers (except for the wind turbine suppliers) merely cope with developer demands and, sometimes, 1st tier suppliers; generally suppliers do not have a complexity management strategy.

The findings show that the two developers operate in distinctly different ways when it comes to managing SN complexity. Table 2 captures our case study comparisons divided into SN structure, risk management, project complexity and change, and governance and relationship management. SN structure and project complexities and changes are important contextual factors that influence the chosen strategies, which centre on choices of governance and relationship management approaches.

Each case reveals a very different focal firm SN strategy. Where Alpha tries to govern and control its SN through intervening in sub-tier decisions and reducing dependency by using multi-sourcing arrangements, Beta only has a few major contracts. Beta has no power to intervene (especially in relation to wind turbine generator suppliers), and therefore relies on delegation. Exploiting its power advantage, Alpha manages a large number of contracts with 1st tier suppliers and attempt to influence sub-tier suppliers. Alpha takes on many project management and engineering tasks instead of delegating these to suppliers. Alpha seeks to mitigate risk through a strategy of detailed scenario planning, detailed contracts and intervention, while Beta minimizes risk by delegating coordination and risk to suppliers through systems sourcing strategies.

Table 2. Strategies of Alpha and Beta SNs compared

		Alpha SN (control & intervene)	**Beta SN (coordinate and delegate)**
SN structure	SN structure	Large number of 1st tier suppliers Detailed multi-contracting: 130-180 contracts in typical project	Few 1st tier suppliers: systems suppliers Often only 3-4 main contracts in typical project with only few EPCI contracts.
	Focal firm size	Large offshore Developer Financially strong	Minor offshore developer Limited financial strength
Project complexity & change	Project and lifecycle complexity	SN often changes from project to project Increased size of projects Projects further offshore on deeper waters Differences in regulations & lack of standards	SN often change from project to project Increased size of projects, but Beta does not engage in very large projects Differences in regulations & lack of standards
	Pipeline line up	Large and continuous projects line up	Limited and scattered projects line up
	Driver of project development	OWP development and operation Late investor involvement	Cash flow and infusion generation Early investor involvement
SN strategy: Governance & relationship management	Governance, power & dependency	Relies on tight control and intervention (e.g. to 2nd tier) Wind turbine generator (WTG) producers powerful but power shift towards large developers as new WTG producers emerge Other actors seen as less powerful/highly dependent on developer (Alpha) Mutual dependency developer - WTG. Alpha is free to select suppliers	Project coordination and control of sub-suppliers delegated to 1st tier suppliers WTG producers are powerful due to limited number. Others are less powerful. Developer highly dependent on WTG manufacturers: some WTG actors neglect developer tenders Suppliers "bankable": narrow supply market Investors are influential

	Relationship Management	Open tendering process (public) Hub firm: moving from semi-close towards arm's length relationships towards 1st tier No frame agreements between developer - 1st tier suppliers Some frame agreements with strategically important suppliers	Controlled tendering process (private) Hub firm: Arm's length (avoid risk of lock in) towards 1st tier No frame agreements between developer & 1st tier suppliers Some frame agreements with strategically important suppliers
	Risk sharing & approach	Risk (and gain) concentrated at developer Late Investor Involvement	Hub firm: Risk avoidant. Risk (and gain) distributed through systems sourcing Early Investor Involvement
	Knowledge sharing	Most knowledge sharing through developer as hub but not intentionally shared	Knowledge sharing - not intentionally shared

Alpha is the powerful actor in the industry and within its SN due to its sheer size and perceived expertise in OWP that enable it to exert significant power over its suppliers. However, as wind turbines remain a bottleneck, wind turbine manufactures also perceived as holding power in the SN. Turbine suppliers need to present a liable track-record for investors to enter new projects. The major developers are very aware of the challenge presented by relying on a few powerful suppliers, so they encourage new turbines from new suppliers. Other suppliers do not create the same dependency. However, this may change, as the supply market consolidates. Neither of the developers has framework agreements with its first-tier suppliers; as one developer articulated it *"... we don't want to be locked to a specific supplier ... just imagine if another supplier came up with something new, and we're stuck with old technology."*

4.4.4 Strategies for managing complex SNs (supplier perspectives)

Suppliers try to get closer to customers to access information as soon as possible on, for example, the type of turbine considered by the customer. They do this to reduce integration complexity and to be able to address issues on product interphases and processes up front, especially as suppliers realise that Alpha has a strong record of winning concessions at very low prices. Therefore, suppliers are aware that they need early involvement with developers to enable them to deliver the required low cost. As expressed by an O&M supplier:

"... we try to get customers to understand that two cost structures exist. One thing is the 'raw product cost' and then there is the cost embedded in the current process ... so, we are now entering a dialog with two customers on how to lower process cost, by challenging conventional wisdom - e.g. what is 'need to have' and not just 'nice to have'...."

Some 2nd tier suppliers have initiated discussions of relationship mutuality and a need to increase transparency and improve integration in order to reduce cost. When suppliers interact with developers such as Beta this is particularly important, as they leave technicalities to suppliers to work out. As the O&M supplier explained: *"... the dialog with them is that they just need 'a kit' with an uptime so and so, can we deliver this? Yes, we can do that at this cost, and they rarely interfere technology wise ..."*

Alpha strategy of SN control and intervention means that suppliers have far less freedom to act. For example, Alpha influences some sub-tier supplier selection decisions, leaving 1st tier suppliers little choice but to accept Alpha's decisions. As our interview with a wind turbine supplier explained:

"After all, it is a little difficult for us because... they sometimes have some opinions about certain suppliers, where they say: we do not want them. And we have a bit of a hard time... if they push us hard enough to make sure the bits that come in their mills come from that supplier. But as a starting point… we simply have to be able to control it ourselves..."

Intervention in sub-tier supplier selection - directed sourcing – could therefore leave 1st tier suppliers in a difficult position. However, wind turbine manufacturers themselves would also sometimes employ a similar strategy, thus mimicking Alpha's strategy, and leave its own suppliers in a similar situation.

5. DISCUSSION

Extant research has conceptualized supply chains and networks as inherently complex and dynamic (Carter *et al*., 2015) but some industries are faced with higher levels of complexity than others. Choi and Hong (2002) describe SN complexity in terms of horizontal complexity, vertical complexity, and spatial complexity from a structural perspective i.e. the number and diversity of suppliers, the number of tiers and the extent of global sourcing. Complexity in OWP can arise from horizontal, vertical and spatial complexities (Alpha) and one or more of these dimensions of complexities (Beta). Our study indicates that these structural aspects of SN, indeed, contribute to complexity. However, other elements of SN complexity dominated in the OWP SNs. For example, uncertain challenges induced by weather, non-repeatability of tasks such as installation challenges vary depending on the location of the wind farms, political influences and variability in government regulations, power/dependence relationships with few, major wind turbine manufacturers and the need for risk mitigation.

Our study shows both focal firms ("developers") faced complexities due to SN changes throughout the different phases of a project: suppliers may change from project to project, due to supplier technology, capability, availability and prices and likewise they face a lack of industry standards, not only technology standards, but also governmental standards such as differences in health and safety regulations in different countries. Neither developer encourages knowledge sharing in their SNs to prevent knowledge leaks, but this means that there is a general lack of information sharing and information is unevenly distributed amongst SN actors.

Despite the extensive use of CAS to conceptualize complexity in SNs (Choi *et al*., 2001, Choi and Hong, 2002; Choi and Krause, 2006; Bozarth *et al*., 2009), our case studies do not offer conclusive evidence of self-organization, emergence or rugged landscapes. The Alpha SN is purposive rather than emergent since their strategy for managing their SN emphasizes tight control coupled with multi-tier contracting with suppliers. Alpha uses tight control over its SN extending deep into their SN (suggestive of an "interventionist strategy" to manage their SN). Beta, in contrast, manages its SN through fewer contracts with its tier-one suppliers, delegating authority to them to manage sub-suppliers (suggestive of a cascading, or delegation, coordination strategy). Although Beta controls its tier-1 suppliers via contracts, the delegation approach offers limited opportunity to witness emergence in its SN. Both case studies suggest that self-organization characteristic of CAS is not present in the wind power industry. We conjecture that there are two principal reasons for this: 1) OWP industry is in early stage of its development with few options for suppliers and sub-suppliers (e.g. wind turbine manufacturers). The rate of growth in this regulated industry is insufficient to promote rapid and sizeable expansion of the SN. The volumes of transactions are smaller compared to the manufacturing context where concepts of CAS have been shown to hold promise as theoretical perspective; and 2) the overwhelming importance accorded to risk mitigation and risk management by the developers.

In contrast, our case evidence mirrors the tenets of organizational behaviour theory and organizational economics. For example, both Alpha and Beta seek to control and coordinate their SN through carefully tailored contracts. The case studies also suggest that contractual governance dominates relationship management. We find evidence for the interventionist and cascade approaches to managing complex SNs. The case studies also support the PCP and CoPS perspectives. PCP addresses the challenges in industrial sectors such as OWP that face high levels of complexity and where the focus is on securing both products and services over a long period of time. The case studies exemplify the conditions that the PCP perspective addresses, in that Alpha and Beta pursue capital-intensive public-private collaborations where there is an increased risk of oligopolistic market conditions and frequent political interference. Our case studies comport well with Roehrich and Lewis (2014) who assert that PCP defines complexity in terms of the extent to which infrastructural components of the whole system are highly customized, the number of stakeholders and the length of planning/contracting negotiation and construction phases. These dimensions that are not typically included in CAS research indeed contribute to complexity in OWP industry. The CoPS perspective stresses product-service bundles: both cases suggest that this perspective might be more useful than the CAS in managing complexity in OWP SNs. These inferences based on our case studies are suggestive and not conclusive. They merit further investigation in other complex SNs in industries such as ship building, oil and gas and aerospace.

Our findings indicate that although it may be possible for one developer firm to exert a large amount of control over its SN, power and control are distributed across several powerful actors, even though both developers faced similar complexity and challenges. Alpha pursues a strategy, in which they engage in multi-sourcing/contracting and multi-tier arrangements, seeking to govern and control all the interphases in the project, including technology interphases, sometimes even employing the crew for installation; specify lower tier suppliers and activities they exert their power throughout the SN. Alpha takes upon itself the risk of coordination errors, but at the same time aims to reduce cost through an SN intervention and control strategy, seeking to optimize interphases in a belief that their project management capabilities provide a competitive advantage. Furthermore, given its size and pipeline of projects in the industry, Alpha seeks internal process optimization and learning from project to project, pursuing what is termed a project factory i.e. standardizing project management processes. In contrast, Beta opts to engage in a delegated SN strategy, relying on systems and delegated sourcing arrangements with a small number of 1st tier suppliers. Beta assumes a coordination responsibility but mainly between the four major installations turbines, substations, foundations and cables, delegating coordination and risk further down the chain to 1st tier suppliers. This strategy resembles an SN coordination and delegation strategy. Given its size and buy strategy on project capabilities, Beta can employ an opportunistic strategy towards which projects to bid for and take upon them. Building on our case findings we therefore propose a classification of two different complex SN strategies in Table 3.

Table 3. A classification of strategies for managing complex OWP SNs

	SN control & intervention strategy	**SN coordination & delegation strategy**
Governance	Tight control and detailed interface management	Delegated responsibility and systems sourcing
Power use	Sub-tier intervention Engage with many 1st tier suppliers	1st tier delegation of responsibility Engage with few 1st tier suppliers
Contracting	Detailed multi, and multi-level, contracting	Few contracts, mainly with 1st tier suppliers
Risk sharing	Interface risks on complex projects Risk taking	SN partners carry risks through turnkey contracts Risk sharing
Project portfolio management	Seek optimization of a portfolio of projects Project factory	Opportunistic approach to project selection – no pipeline

In addition to SN complexity literature, our classification builds on the taxonomy by Harland *et al*. (2001) in that it concerns the level of influence of the focal firm. We thereby contribute to existing SN classifications, especially those that include a complexity dimension (Lamming *et al*., 2000; Caniato *et al*., 2011), although our cases represent a higher level of complexity and include aspects of complexity e.g. lifecycle and regulations that are not considered in extant SN classifications. We also build and expand on Johnsen's (2011) concept of SN delegation and intervention, which in turn builds on Lamming's (1996) concepts of supply chain cascade and intervention, organizational behaviour (Thomas and Velthouse, 1990; Osterloh and Frey, 2000) and organizational economics (Williamson, 1996) literature. To date the concepts of delegation and intervention have not been applied in a complex SN context. Our research shows how one developer firm applies an SN control and intervention strategy through its SN governance, intervening in interface and risk management and contracting in sub-tier relationships. In contrast, the other developer firm adopts a strategy of coordination and delegation using systems sourcing strategies to delegate and empower 1st tier suppliers to manage its own sub-tier relationships. Clearly, this is an attempt to mimic a modularization approach, aiming to reduce the number of mountain peaks in the landscape and thereby decrease the number of interfaces and inter-dependencies (Choi *et al*., 2001; Kauffman, 1995). As found by Pero et al. (2010), product modularity reduces supply chain collaboration complexity, which is clearly an issue for the OWP industry. However, the OWP industry has a long way to go before it resembles the modular structure found in, for example, the automotive industry (Doran *et al*., 2007) and the nature of the OWP industry may not easily develop in that direction as power is more distributed amongst typical SN actors and political stakeholders.

One managerial implication of our research is the identification of more strategies for focal firms for managing and maneuvering in complex SNs. The strategies depend on several factors such as the level of power and influence of the focal firm over other SN actors. Our classification of strategies concern both appropriate ways to manage dyadic relationships and ways to manage - or manage within - the wider SNs. Another managerial implication is that suppliers in complex SNs should foresee the operational models to co-exist and develop flexible business models and value propositions to honour different operating models. For example, 1st tier suppliers need to be able to concurrently act as a component and a systems supplier, with all the challenges this induces. As the OWP industry matures it is likely that we will see increasing standardisation and modularisation; both developer firms and suppliers therefore need to be clear about which SN strategy they will pursue.

In deciding on alternative strategies, managers should consider the firm's SN position, the complementarity of technologies accessible from different SN actors, and the method with which the focal firm controls suppliers. These factors will influence the ability of a firm to capitalise on innovations through its SN. Whereas intervention in suppliers' operations is a way to control SNs and thereby reduce risk, a delegation strategy may be more likely to facilitate technological innovation by empowering suppliers to pursue innovative solutions.

Although we would caution against drawing managerial implications beyond the OWP industry, the themes and methods we highlight in our classification framework would appear to resemble those found in other complex SNs that may therefore still gain inspiration from this framework.

6. CONCLUSION

This paper has discussed generic strategies for managing complex SNs, focusing on the OWP industry. This industry is of strategic importance to many countries that have invested heavily to reduce the reliance on fossil-based fuels and shift towards renewable sources of energy. The industry is truly complex not only due to the size of the product-service systems involved, which means large supply bases, but also because of the changing phases that involve development, installation and operations & maintenance. SNs change over the course of these phases, posing different challenges within and across each phase. OWP SNs are *distributed* because of the number of actors that try to control them (Andersen and Drejer, 2008) but complexity is also high because of the nature of these actors as these include political stakeholders. OWP SNs include many powerful actors (stakeholders) who seek to exert their power and influence. Such complexity is not considered in the existing research on complex SNs (e.g. Choi *et al*., 2001).

Our initial findings do not allow us to compare the two SN strategies and associated decisions in terms of performance. Hence, we cannot at this stage determine superiority of one approach over the other, or under which circumstances, but merely observe that two distinct different strategies are in operation in the same industry facing the same complexities and challenges. This is a future research avenue that could be explored. The argument that extensive control may detract from innovation and flexibility was not observed in our cases, as Alpha is a successful developer firm. Hence, a future research avenue is to explore if this argument only holds for specific circumstances (e.g. industry type and maturity, type of control mechanisms in use, focus for intervention etc.). Beta's reliance on system sourcing is a step towards the use of modular product architectures that may over time result in modular SNs. This would decrease the current high levels of SN complexity. However, the OWP industry is not yet a mature industry and the project nature of the industry, with SNs changing over time across different project phases, and individual projects, may also present challenges in mimicking the modular SNs in, for example, the automotive industry. Modularity and its impact, in such an industry (large complex projects) would likewise be an interesting research path to follow. As in other case study research, ours is not without its limitations. The case study firms were selected purposively to gain access to firms with interest in our study. The data also represent a limited sampling of the SNs of the two firms. It would be useful to gather data from more suppliers within SNs via other methods (as case studies are time and effort intensive). The findings from our case studies may not generalize to other contexts.

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Appendix A: Abbreviated Interview Protocol

	Sources
General background information:	
• Your role and responsibility in organization? • Major products, services? • Customer requirements? Core competencies of organization? • Major strategic development in your company and industry?	
Project & lifecycle complexity:	Baccarini (1996) Lamming et al, 2000) Bozarth *et al.* (2009) Pathak *et al.* (2007) Caniato et al. (2011) Roehrich and Lewis (2014)
1. What key functions are involved in different phases of OWP projects and how are they dependent on each other? 2. What are challenges in managing different competencies in different stages of OWP project? 3. At which OWP project stage(s) are your products/services procured and delivered? 4. Would you describe products and services of your organization as technologically complex? 5. Initiatives to reduce project complexity (challenges/examples)?	
Structural complexity (SN) questions and mapping:	Baccarini (1996) Lamming et al. (2000) (Choi et al. (2001) Choi and Hong (2002) Choi and Krause (2006) Vachon and Klassen's (2002) Bozarth *et al.* (2009) Pathak *et al.* (2007) Roehrich and Lewis (2014)
6. Which actors are involved during several OWP project stages and how? 7. Other important actors e.g. commissioning organisations? 8. While mapping the supply network please a. Types of suppliers and locations – include key tier 2 suppliers? b. Number of suppliers? c. Other aspects that make coordination with them difficult? 9. How does your organization integrate/coordinate with these? 10. Do you use full systems or service providers? 11. Initiatives to reduce project and/or supply network complexity? 12. What is your supply chain integration strategy? How do you try to integrate and influence supply network? 13. Which integration mechanisms or tools are used to manage supply network?	
Relationships and inter-dependencies/power balance (governance complexity):	Baccarini (1996) Choi and Krause (2006) Vachon and Klassen's (2002) Bozarth *et al.* (2009) Olsen et al. (2005)
14. Your sourcing strategies with your various suppliers e.g. single, dual and/or multi-sourcing arrangements? 15. Which suppliers or service providers are classified as strategic and how are your relationships with these? 16. Risk and reward sharing arrangements with key partners? 17. Who are most powerful in supply network and why? 18. How do they control supply network? 19. Is balance of power in supply network changing and how? 20. Any actors influence your supplier selection (e.g. customers or political actors)? 21. What kind of contracts do you have with your most important partners? 22. What else makes your supply network complex?	