The More the Better?

Investigating cost, time and operational performance of the Danish and Swedish offshore wind farm cluster

Journal of Financial management of property construction and real estate.

Volume 19, Issue 1, 2014.

This a copy of the final manuscript without proof reading. Tables are entered after the text

Christian Koch
Construction Management, Chalmers University of Technology,
Sven Hultinsgata 8, Gothenburg, Sweden
email: kochch@chalmers.se

Biography

Christian Koch is professor in process management and innovation and conducts research in operation strategy, management and construction of renewable power plants using a multidisciplinary approach. He has published widely on construction management issues.

Structured Abstract

Purpose: To develop a combined social constructivist, internal and external conceptualisation of the process of realising offshore wind farms, and to investigate costs, time, delays and operational performance results of offshore wind farm power plant projects in Denmark and Sweden with a view to possible strategic misrepresentation.
Design/methodology/approach: Desk study of a sample of seven Danish and Swedish offshore wind farms using triangulation of publicly available material.
Findings: Some of the wind farm projects are successful and some less successful. In the latter group, budget and time overruns and under-performance are found. The paper discusses specific elements of possible strategic misrepresentation but finds a contradictory pattern. Also competences developed on the basis of experience do not produce clear results, since more recent wind farm performance is poorer than earlier.
Research limitations/implications: If desk research were combined with other methods, it would be possible to detect projects' internal phenomena better.
Practical implications: There is a need to improve the efficiency of the wind farm building process and to improve the quality of offshore wind turbines, their foundations and cabling.
Originality/value: Renewable energy power plants comprise an important societal investment, yet their costs and possible cost reductions are poorly understood.

Keywords: offshore wind farm, Denmark, Sweden, strategic misrepresentation

Article Classification: Research paper

The More the Better?

Investigating cost, time and operational performance of the Danish and Swedish offshore wind farm cluster

Structured Abstract

Purpose: To develop a combined social constructivist, internal and external conceptualisation of the process of realising offshore wind farms, and to investigate costs, time, delays and operational performance of offshore wind farm power plant projects in Denmark and Sweden with a view to possible strategic misrepresentation.

Design/methodology/approach: Desk study of a sample of seven Danish and Swedish offshore wind farms using triangulation of publicly available material.

Findings: Some of the wind farm projects are successful and some less successful. In the latter group, budget and time overruns and under-performance are found. The paper discusses specific elements of possible strategic misrepresentation and finds a contradictory pattern. Competences developed on the basis of experience do not produce clear results either, since some more recent wind farm performance is poorer than earlier.

Research limitations/implications: If desk research were combined with other methods, it would be possible to detect and analyse projects' internal phenomena better.

Practical implications: There is a need to improve the efficiency of the wind farm building process and to improve the quality of offshore wind turbines, their foundations and cabling.

Originality/value: Renewable energy power plants comprise an important societal investment, yet their costs and possible cost reductions are poorly understood. The adopted

theoretical approach, thoroughgoing interpretivism, appreciates the complex set of social (and technical) aspects.

Keywords: offshore wind farm, Denmark, Sweden, strategic misrepresentation

Introduction

The installation and operation of offshore wind farms are complex endeavours. They encompass large power plants of wind turbines as well as smaller near-shore farms, and the growth in demand for installations is significant. For example, the EU member states' energy renewal plans for 2020 alone represent investments in around 43 GW offshore wind farms (EWEA 2012). These investments are being made under the present harsh financial conditions, which should generate particular interest in producing renewable energy power plants that are just as cost efficient, and are able to yield maximum benefit in the form of produced power. In relation to this situation, the aims of this study are twofold:

- First, to develop a combined social constructivist internal and external conceptualisation of the process of realising offshore wind farms, and
- Second, to investigate costs, time, delays and operational performance of offshore wind farm power plant projects in Denmark and Sweden with a view to possible strategic misrepresentation (Flyvbjerg 2009).

Strategic misrepresentation conceptualises the situation in which project promoters first purposely reduce the cost and time required, and then lever the project's positive impacts in terms of its operational performance and its value for future users in order to make the project attractive (Flyvbjerg, 2011). Pursuing the stated aims makes it is possible to discuss whether a cluster of successive projects leads to other patterns of cost, time and operational performance than would projects that stand alone.

The theoretical framework developed below adopts a social constructivist approach (Latour, 2005), more specifically thoroughgoing interpretivism (Woolgar and Grint, 1997). The empirical material encompasses data on seven offshore wind farms, six Danish and one Swedish, constructed between 2001 and 2010.

The paper is structured as follows: It begins with a method, followed by theory, case description, discussion and a conclusion.

Methodology

The research design matches the two main aims of the article:

The first research question, which involves the theoretical framework, is answered by combining both external and internal perspectives on offshore wind farms. The external perspectives are critical studies of megaprojects (Flyvbjerg, 2009; 2011) and complex engineering project management contributions (Davies and Hobday, 2005; Miller and Lessard, 2008). The internal perspectives are formed using operation strategy and operation management concepts (Slack and Lewis, 2008; Slack et al., 2007). Science, Technology and Society (STS) approaches (Hughes, 1983; Latour, 1987; 2005; Grint and Woolgar, 1997) act as the overall framework within which the understanding of offshore wind farms is achieved. This implies, essentially, that they are thoroughly negotiated, have inseparable social and technical aspects and operate in a semi-public environment involving a substantial amount of public performance – i.e. they are present in a public space (with e.g. media and political attention).

The second research question, which involves the empirical part, is answered by investigating the external and internal aspects. The external aspects are costs, time, delay and operational performance in relation to strategic misrepresentation; the internal aspects are the operational strategy elements.

The investigations of both aspects are carried out in an exploratory investigative manner with focus on a core set of data from a selection of Danish and Swedish offshore wind farms that comprises the largest farms in this geographical area that have also run for some time. They therefore encompass operational experience that makes it possible to evaluate the aspect of possible strategic misrepresentation. The sample includes six Danish farms and one Swedish (Horns Rev I, Horns Rev II, Lillgrund (SE), Middelgrunden, Nysted, Rødsand II, and Samsø), which also constitute a considerable basis of experience for a recurrent group of companies. The selection excludes some smaller Danish and Swedish wind farms from this study, such as Frederikshavn (DK), Sprogø (DK), Vindeby (DK) and Yttre Stengrund (SE).

The central tool for the empirical work has been a desk study using internet sources (such as www.4Coffshore.com). The analysis thus relies on secondary data from publicly accessible sources. This is justified by the characteristics of engineering construction (i.e. the public presence) described above. For each of the figures and pieces of information presented regarding costs, time and performance during operation etc., triangulation is achieved (Bryman and Bell, 2007) on the basis of several independent sources. Most of this material is not referenced as it would lead to a very extensive reference list, and some of the material is in Scandinavian languages. The sources range from short newspaper announcements (e.g. regarding initiation of a project's construction activities), to articles in the business press (e.g. regarding the contract sum), to business-specific websites (such as www.energy-supply.dk) and reports and articles based on research by public wind industry associations and universities (such as Gerdes et al., 2005 and Wiezcorek et al., 2012). The available public information does have some weaknesses however, resulting for example from difficulties in measuring the start and finish of a construction phase and currency conversion.

The study is limited in that it relies on desk research, but it does provide a basis for future research. If combined and supplemented more systematically with other methods, it would be possible to detect more internal phenomena (such as transfers of resources between projects) and capture more details regarding labour and material costs. Three further minor limitations should be mentioned – these aspects have not been studied: first, impact on wind power farm costs of the limited Danish and Swedish market (Deloitte, 2011; Wieczorek et al., 2012); second, the overall economy of the projects, which involves income from negotiated feed-in tariffs; and third, the impact of regulation and permission procedures.

Literature Review

This section first encircles the phenomena of offshore wind farms as sociotechnical undertakings, and then performs a selective literature review on causes of cost and time overrun as well as under-performance in construction projects. This review leads to the theoretical framework consisting of an overall, an internal, and an external perspective.

The establishment of offshore wind farms has generated a cluster of installing companies, manufacturers, three main clients (DONG, Vattenfall and E.on), operating companies and interested citizens (BTM, 2010; Kaldellis and Kapsali, 2013; Wieczorek et al., 2012). Therefore, the term ‘offshore wind farm’ is used not only to denote the installations, but also the community of social players around them, based on a sociotechnical viewpoint (Hughes, 1983; Koch, 2007; Latour, 1987, 2005). The power plants encompass installations from 5 MW capacity and upward, usually consisting of a number of MW turbines with an internal cable grid, a sub-station for transforming electricity, and an export cable connecting to a national grid (Gerdes et al., 2005; IEA, 2005; Kaldellis and Kapsali, 2013; Snyder and Kaiser, 2009; Zhixin et al., 2009).

The understanding of offshore wind farms as sociotechnical projects can be further elaborated by defining them as complex engineering projects (Davies and Hobday, 2005, p.6) that are ‘high-cost, technology-intensive, customized capital goods, systems, networks, control units, software packages, constructs and services’. The strength of this definition is that it merges a business approach (capital goods) with a technical approach, emphasising the scope and bundles of technologies associated with the product, and appreciating the interconnection with the customer and the service aspect. The downside, however, is that the technology side is conceptualised on a too abstract level, and with too little appreciation of the intertwinedness of the technical and social.

In their discussion of cost and time overruns in construction projects, Hampton et al. (2012) provide a set of seven categories of causes behind delay: client-, contractor-, designer-, financial-, labour-, material and plant-related factors. Moreover, they characterise delays in terms of excusable, inexcusable, compensable and uncompensable. Thus, through the seven categories combined with these characterisations, they allude to the sociotechnical character of construction projects and encompass both a project's external and internal factors. Similarly, Love (2011) identifies a series of possible explanations for overrun that encompass practice, tasks, circumstances, organisation, system, industry and tools. Love unearths internal issues such as design errors and coordination problems. Kaming et al. (1997), look at high-rise projects and find a series of causes of overrun such as inflationary increases in material costs, inaccurate material estimations and project complexity. For time overruns, the main causes of delay are design changes, poor labour productivity and inadequate planning (Kaming et al., 1997). All these found factors can be characterised as 'internal project' explanatory factors.

Flyvbjerg (2009, 2011, 2013) represents a different, externalist approach. He claims that especially projects operating in a public-private interface tend to be influenced by political mechanisms that lead to a far more complex task for project management. The studies of cost and time overruns by Flyvbjerg (2009, 2011) within transport infrastructure (tunnels, roads, railroads, bridges) show a long series of examples of considerable overruns. Also in later studies, Flyvbjerg and others document similar patterns (Cantarelli et al., 2012; Flyvbjerg, 2009). Flyvbjerg et al. (2003) showing that cost underestimation is a global and long-term phenomenon that does not diminish over time. They also document that cost underestimation cannot be explained by error, but rather by 'optimism bias' and 'strategic misrepresentation'.

Optimism bias describes when planners of complex projects underestimate – or are not fully aware of – the time and costs necessary to realise a project. Estimations are often based on assumptions (Kahneman, 1994). Strategic misrepresentation, as already explained, conceptualises the situation when planners and other players involved in planning a project purposely reduce the required cost and time and then manipulate the project’s positive impacts in terms of its operational performance, benefits and value for future users in order to make the project attractive (Flyvbjerg, 2011).

Public and private players, including clients, decision makers, civil servants, engineering companies and contractors, who join in alliances to launch a project often practice strategic misrepresentation. Project promoters may possess knowledge about how much a client for a complex engineering product can afford to pay, or at least the budgetary constraints that may exist (Flyvbjerg et al., 2003). Such knowledge can be used to accommodate budgets and schedules to such constraints rather than to present a realistic calculation of the project risks. Also, on a public-private arena, a ‘point of no return’ is likely to exist; once a project is initiated, it cannot be stopped in practice, even if it runs short of funding (Flyvbjerg et al., 2003). The concept of strategic misrepresentation thus involves presenting an argumentation to the customer that combines underestimating time and costs and overestimating the performance of the completed product (Flyvbjerg, 2009). In relation to wind farm power plants, this would be equivalent to overestimating the actual power production, based on unrealistically high expectations for production time and availability, and underestimating maintenance time and service costs. Flyvbjerg et al. (2009, 2011) argue that rather than technical explanations, psychological and political-economic explanations are prevalent, which is contrary to other studies of project overrun (Hampton et al., 2012; Love, 2011 a.o.; see also Vanston and Vanston, 2004). Political-economic explanations, however, explain inaccuracy in terms of strategic misrepresentation, which is more likely to occur in wind farm projects than optimism bias, since these projects involve a series of interactions with public authorities, the press and the public.

Flyvbjerg’s critics, such as Love (2011), point out that the delimitation of Flyvbjerg’s approach and concepts leaves an uncharted space between the initial event and the final outcome, since the emergent events, resource limitations, and other aspects of the project process that lead to project overruns are not investigated (Love, 2011). Moreover, Love (2011) characterises this reasoning of strategic misrepresentation and optimism bias as counterfactual causation (Love et al., 2011). By adopting a focus on input and outcome measured in time and costs, Flyvbjerg overlooks the content of the project, which is rarely fixed as the project develops.

Liu and Napier (2010) claim that optimism bias can be widely found within the construction industry. They note: “[…] It has been recognized that in preparing estimates, estimators are likely to make ‘self-protective predictions’, influenced by self-interest in securing contracts’ (Liu and Napier, 2010). Similarly, contractors’ tender prices are often not only a product of the estimating department but also other actors, such as managers, who may intervene to reduce bid prices in an attempt to win a contract (Liu and Napier, 2010). Finally, clients may strategically underestimate costs to ensure that the project is launched and to obtain funding. Therefore, the more internal perspective on cost and time overrun that is represented by Hampton et al., (1012), Love (2011), and Kahming (1997) is necessary.

Theoretical Framework

The theoretical framework therefore combines the internal and external perspective through the overarching perspective of thoroughgoing interpretivism (Grint and Woolgar, 1997), which appreciates the dynamic renegotiation of a sociotechnical community like offshore wind farms. Thoroughgoing interpretivism implies that the process involves emerging issues, unforeseeable events and conditions, decision making under conditions of incomplete knowledge and information, as well as processes of negotiation and conflicting interests. Tactics are employed in the interaction between stakeholders that include a complex private-public interaction that encompasses financial, political and public media mediation (Hampton et al., 2012). The thoroughgoing interpretive perspective appreciates the indeterminate features of cost, time, service provision, contracts and enterprise organisation and strategy, and views offshore wind farms as ‘texts’ in an anti-essentialist manner (Grint and Woolgar, 1997; Sismondo, 2010). Throughout the project’s lifetime, the figures and features characterising it are negotiated over and over again, both in the public sphere and internally in the contributing companies.

The external perspective – strategic misrepresentation

The mobilised external perspective views strategic misrepresentation as a combined practice that underestimates time and cost and overestimates the benefits from using the final product (Flyvbjerg, 2009). For example, fixed sum contracts generate ‘backwards’ control of expenses and/or attempts to enlarge the fixed sum through various types of claims. And project-based accounting involves controlling the hours spent using a portfolio of projects and activities rather than just one project, which means that project costs are not necessarily allocated to the accounts to which they belong.

The internal perspective – operation strategy

The internal perspective builds on operations strategy (Slack and Lewis, 2008), operations management (Slack et al., 2007) and project management (Liu and Napier, 2010; Love, 2011). It focuses on contracts, planning, equipment and competences. Slack and Lewis (2008) define operation strategy in the following way:

> […] the total pattern of decisions which shape the long term capabilities of any type of operation and their contribution to overall strategy, through the reconciliation of market requirements with operations resources (Slack and Lewis, 2008:18)

The main elements of operations strategy are, according to Slack and Lewis (2008):

- Capacity Strategy
- Supply Network Strategy, including purchasing and logistics
- Process Technology Strategy
- Development and Organisation

Capacity Strategy deals with how capacity and facilities in general should be configured. In an offshore wind farm context, contracts with wind turbine manufacturers and a range of other suppliers are central. Wind turbine manufacturers' capacity and quality of delivery are important; normally, they do not carry out installations directly but contract other companies.

Supply Network Strategy, including purchasing and logistics, is concerned with how operations relate to suppliers and customers. In the context of wind farms, this is understood as the configuration of contracts with suppliers of products and processes for erecting the offshore wind farms so that the description and analysis disregard relations with clients and customers.

Process Technology Strategy concerns the choice and development of systems, machines and processes. This is here simplified into examining the equipment used.

Development and Organisation is concerned with the long-term decision that governs how the operations are run on a continuing basis. In the offshore wind farm context, this occurs across projects and is here viewed as an issue of how project organisation is conceptualised as well as how competences develop. Competences are seen as a measure of whether the operational strategy is developing across projects. Project management also encompasses project planning. Project management literature (Atkinson, 1999; Olewale and Sun, 2010; Reichelt and Lyneis, 1999) often portrays the balancing of time, cost and quality as a question of project management skills and tools that involve various budgeting, cost estimation and forecasting and planning techniques; however, the project management literature also explains how phenomena like 'scope creep' (increase in the number and content of project tasks) complicate this. Love (2011) identifies a series of possible internal explanations for project overrun that encompass practice, tasks, circumstances, organisation, system, industry and tools (including design errors and coordination problems).

To summarise, the social constructivist framework, which combines an external and internal sociotechnical understanding of offshore wind farms, provides an appropriate framework for evaluating both the external strategic misrepresentation and the internal operations strategy for offshore wind parks. These are here condensed into examining contracts, planning, equipment and competences. The thoroughgoing interpretivist perspective implies that texts on budget, time and costs are continually renegotiated. Moreover, the text approach is taken to mean here that even the most detailed components of the technological constellation encompass social issues such as cost, design approaches etc.

Case Study Analysis: Selected Danish and Swedish offshore wind farms

The seven offshore wind farms investigated in this study are Horns Rev I, Horns Rev II, Lillgrund, Middelgrunden, Nysted, Rødsand II and Samsø. Lillgrund is the only wind farm placed in Swedish waters, while the rest are placed in Danish waters. Middelgrunden is the oldest and began operation in 2001. The youngest, Rødsand II, was operational in 2010.

Place Table 1 Technical features about here

Table 1 shows that there are a number of similarities in the technologies used in the wind farms, but also some diversity. They all belong to, what is labelled the 20-20 segment, i.e. they are placed less than twenty kilometres ashore in a water depth of less than 20 metres (Snyder and Kaiser, 2009).During the period studied here, 2001-2010, offshore wind farm technologies became relatively mature and went through further incremental developments, which means small differences between the farms over time. In terms of size they fall in two groups, the large and the small, which is reflected in the number of turbines (MW production capacity) and the absence of substation for the two small. The sample encompasses two farms with Vestas 2.0 MW turbines and five with Bonus/Siemens 2.3 MW turbines. The foundations are either gravitation or monopoles which were considered as alternative during the design phase in all seven cases. There are also variations in the layout and placement of the turbines at the sites – some are in rectangular lines, others in soft curves.

Place Table 2 Cost about here

Table 2 shows that three out of seven wind farms exhibit cost overruns. Two farms were completed with costs exactly as budgeted, whereas two farms used less than budgeted (up to 10 percent). Four can cautiously be considered to exhibit acceptable performance for clients and contractors, also considering uncertainty connected with the calculations.

Place Table 3 Time about here

Table 3 shows that four farms exhibit time overruns compared to the initial schedule, and that these overruns exceed 10 percent. Conversely, three farms were completed before time, even as much as 20 percent. It is found that the small farms, Middelgrunden and Samsø, with relatively short initial schedules, were more vulnerable to unplanned events. Horns Rev 1 experienced very extensive problems with the turbine technology.

Power production performance during operation

Planned production of wind farm power plants is often expressed by an expected capacity factor, the MW-hours to be expected from the MW-capacity provided (Feng et al., 2010: 4; Kaldellis and Kapsali, 2013)). The factor is around 35 percent for offshore wind farms (BWEA, 2008; Levitt et al., 2011). Danish experiential figures show a ‘lifetime’ capacity average of 37 percent for 12 long-term operational offshore farms (DEA, 2011), including those examined here (lifetime means from installation some 20 years back to the present, see table 4). Four wind farms in the present sample have actual capacity factors that are above the average (BWEA, 2008; Kaldellis and Kapsali, 2013, Levitt et al., 2011), and three wind farms with actual capacity factors that are below the average. Compared with the simple average of 29.4 percent for some UK wind farms during the period 2004-2007, most Danish/Swedish farms perform better. Only one, Middelgrunden, is significantly lower (25.2 percent compared to 35 percent). Both Middelgrunden and Nysted suffer from ‘shadowing’, which reduces their power production since less wind is available than anticipated during planning.

The operational offshore wind farm power plants exhibit higher levels of maintenance time than planned. All offshore wind farms have scheduled service and maintenance, but the many examples of extraordinary unplanned issues lower the wind farm’s availability. These include unplanned replacements of generators, gearboxes, cabling, shafts etc. The owners of Samsø had to carry out repairs of the export cable in 2004. Vattenfall, owner of Horns Rev, announced in April 2010 repair of transition pieces (between the monopile and the tower). Such extraordinary repairs affected British wind farms as well (Koch, 2012).

Place Table 4 about here

Discussion

The discussion below first examines technical features, then costs, time and performance during operation. It then moves on to a more general analysis of the results.

The *technical features* of the farms in the sample share a number of similarities, which makes their establishment comparable. For example, the common shallow depth of the water is an important enabling and constraining factor for the construction. It requires tackling sand banks and the like. Using monopoles or gravitation foundation are considered close competitors in shallow waters and was indeed chosen more or less ‘half and half’ here. It should be noted however that the construction of the farms spans a period of ten years;

therefore, due to developments in turbine technology, the technology differs slightly from farm to farm.

Three out of seven wind farm construction projects led to *cost overruns*. Two farms were completed with costs as budgeted, whereas two farms were constructed for up to 10 percent less than budgeted. In the latter four cases, this can cautiously be seen as acceptable performance for clients and contractors, also considering that such calculations involve uncertainty.

When it comes to *time*, four farms experienced overruns compared to the initial schedule that exceeded 10 percent. On the other hand, three farms were completed before time, and one long before time (20 percent). The small farms, Middelgrunden and Samsø, were initially planned with short intense schedules that made them more susceptible to unplanned events, which led to overrun in one of them. Horns Rev 1 experienced very extensive problems with the turbine technology from Vestas.

Four wind farms *perform operationally* above the average, meaning they produce more power than average. Three wind farms perform below average. Compared to UK wind farms, most Danish/Swedish farms perform better. Only one, Middelgrunden, lies significantly lower in performance.

The Danish and Swedish cases thus show an interesting mixture of projects exhibiting compliance with articulated time and cost budgets and operational goals, and others with cost and time overruns and underperformance during operation. There is no difference between small and large projects in this small sample. Judging from budgets and schedules, there is thus no clear picture of strategic misrepresentation. Lönker's (2005) findings on the Nysted farm even indicate elements of proactive project scheduling by using two summers rather than one winter, while compliance with the budget can be said to demonstrate well exercised project management. Seen from a thoroughgoing interpretivist perspective, it can even be argued that ending up with zero deviation in relation to the budget is conspicuous, since it is likely that internal efforts to meet such a goal have been directed toward allocating costs elsewhere in the company's accounts to ensure this result.

Strategic misrepresentation also involves overestimating the benefits of the projects (Flyvbjerg, 2009), i.e. overestimating power production on the basis of unrealistically high expectations for production time and availability and underestimating maintenance and service costs. The present sample does not exhibit important deviances from planned capacity, with the exception of Middelgrunden. Two farms are even significantly higher than the Danish average (DEA, 2011).

What these cases, along with the UK cases, demonstrate is that the companies are involved in gradual development of the operations strategy. This encompasses planning for the weather and using onshore assembly of either Siemens or Vestas turbines and barges and jack-up vessels as central equipment. Installation methods are improving from single-wing to three-wing assembly. And competences are developing as the projects are carried out, yet in a sometimes disruptive manner that hampers experiential knowledge being translated and used as the companies grow.

Contracts

Project management of the installation phase of offshore farms has to operate under a complex set of contracts. For example, Horns Rev 1, realised in 2003, had 69 contracts (4Coffshore, 2012), and Horns Rev 2 had 91 (4Coffshore, 2012). Contracts are also occasionally reported to involve the main contractor's representatives directly in the wind turbine and (for example) the steel pipe manufacturing processes (Lönker, 2005). Contracts for Danish, Swedish and UK wind farms built between 2000 and 2012 all clearly encompass a small group of recurrent firms. The multinational firms, Siemens Windpower and Vestas, share the installations between them (with 51 percent and 39 percent of the market, respectively (Wieczorek et al 2012)), and only in Holland and Germany are other turbine suppliers found to be present (Nordtank and RE power; (4coffshore, 2012; Wieczorek et al., 2012)).

Planning

The projects exhibit examples of both well exercised and less well excercised planning. Lönker (2005) finds that the Nysted farm, where planning works well, appears to have benefitted from project management personnel recruited from Horns Rev I.

Equipment

While the early farms tended to be erected using ad hoc equipment from the oil and gas offshore industry or from bridge building, the later installations use a more and more advanced set of specially designed vessels. Up to 60 different vessels are involved in installation (Wieczorek et al., 2012), but the A2SEA company continues to have a central position in Danish, Swedish and UK wind farms (Koch, 2012). Another important feature is the appropriation of harbour facilities, such as the nearby harbour for Rødsand 2, which also involves the possibility for onshore assembly of turbines.

Competences

When comparing the development of Danish and Swedish wind farms with the UK farms developed over the same period (Koch 2012), it appears less clearly that the centrally placed and recurrent companies are learning and becoming more competent with time. A tendency exists for some of the more recent wind farms to continue to have time and cost overruns and insufficient performance, which is counter to the expected learning curve (Junginger et al. 2004). The wind turbine manufacturers appear to have considerable problems with quality and defects in their deliveries to the UK, which impact on both the installation and operation phases (Koch 2012). The worst example in a Danish context is found at Horns Rev I, which experiences heavy overruns due to quality problems with Vestas wind turbines.

Conclusion

The aim of this paper was first to develop a combined social constructivist, internal and external conceptualisation of the process of constructing offshore wind farms; and second, to investigate costs and time delays as well as operational performance results of offshore wind farm power plant projects in Denmark and Sweden, with a view to possible strategic misrepresentation. The results show that combining the internal and external perspectives gives a more precise understanding of why complex offshore wind farms come to operate well or less well. This learning alludes to the unique social and technical constellation that such undertakings represent, even when investments in similar projects become clustered.

The investigated wind farms do not exhibit a clear pattern of strategic misrepresentation. Rather, there are examples of project management that emerges as being successful, even when the process is disruptive and full of complications. On the Danish, Swedish and UK markets, a strong concentration of a few players was found during the period studied and in the portfolios of the projects investigated. However, learning effects and development of competences exhibit a less clear picture. Some of the farms installed later actually perform less well than some of those installed earlier. Across these projects, the construction companies seem to contribute in an ambiguous manner to the societal need for efficient installation and operation of renewable energy. Renewable energy power plants comprise an important societal investment, and this article contributes to a better understanding of their cost dynamics and the possibilities for cost reductions seen in the context of social and technological conditions. Cost and time overruns and poor operational performance cannot be entirely explained through the concept of strategic misrepresentation, since this embraces only generic social explanatory elements and disregards the more precise technical (and social) content of the project that rests on a strongly contextual set of factors. Future research in this area should continue to appreciate the contextual social-technical as well as the internal/external elements of constructing offshore wind farms. Increasing the number of wind farm projects does not automatically make them generic.

References

4Coffshore (2012), Wind farm data, available at: http://www.4Coffshore.com (accessed several times during 2012).

Atkinson R. (1999), "Project management: cost, time and quality, two best guesses and a phenomenon, it's time to accept other success criteria", *International Journal of Project Management*, Vol. 17 No. 6, pp. 337-342.

Byman A. and Bell E. (2007), *Business Research Methods*, 2nd edition, Oxford University Press, Oxford.

BTM Consulting (2010), "World market update 2010", available at: http://www.btm.dk (accessed February 2, 2011).

BWEA (2008), *Annual Review 2008*, British Wind Energy Association, London.

Cantarelli C.C., van Wee B., Molin E.J.E. , Flyvbjerg B. (2012), "Different cost performance: different determinants? The case of cost overruns in Dutch transport infrastructure projects". *Transport Policy*, Vol. 22, pp 88–95.

Davies A. and Hobday M. (2005), *The Business of Projects. Managing Innovation in Complex Products and Systems*, Cambridge University Press, Cambridge.

Kaldellis J.K. and Kapsali M. (2013), Shifting towards offshore wind energy—Recent activity and future development. *Energy Policy* vol. 53, February, pp 136–148

DEA (2011), "Register of wind turbines", available at Danish Energy Agency website www.ens.dk (accessed February 2011).

De Bruijn H. and Leijten M. (2008), "Megaprojects and contested information", in Priemus, H., Flyvbjerg, B. and van Wee, B. (Eds.) *Decision-Making on Mega-Projects' Cost-Benefit Analysis, Planning and Innovation*, Edward Elgar, Cheltenham, chapter 5.

Deloitte (2011), *Analysis on the Furthering of Competition in Relation to the Establishment of Large Offshore Wind Farms in Denmark*, Deloitte and Garrad Hassan, Copenhagen.

EWEA (2012), "Green Growth – the impact of wind energy on jobs and the economy", available from the European Wind Energy Association - April 2012 at http:// www.ewea.org (accessed November 10, 2012).

Flyvbjerg, B. (2009), “Survival of the unfittest: Why the worst infrastructure gets built – and what we can do about it”, *Oxford Review of Economic Policy*, Vol. 25 No. 3, pp. 344-367.

Flyvbjerg, B. (2011), “Over budget, over time, over and over again – managing major projects”, In Morris, P., Pinto, J. and Söderlund, J. (Eds.), *The Oxford Handbook of Project Management*, Oxford University Press, Oxford, pp. 321-344.

Flyvbjerg B. (2013), “Quality control and due diligence in project management: Getting decisions right by taking the outside view”. *International Journal of Project Management* Vol. 31. pp. 760–774.

Flyvbjerg, B., Bruzelius, N. and Rothengatter W. (2003), *Megaprojects and Risk: An Anatomy of Ambition*, Cambridge University Press, Cambridge.

Gerdes, G., Tiedemann, A. and Zeelenberg S. (2005), *Case Study: European Offshore Wind Farms - A Survey for the Analysis of the Experiences and Lessons Learnt by Developers of Offshore Wind Farms*, Deutsche WindGuard GmbH, Deutsche Energie-Agentur GmbH, University of Groningen, Groningen.

Grint, K. and Woolgar, S. (1997), *The Machine at Work*, Polity Press, Cambridge.

Hampton, G., Baldwin, A.N. and Holt, G. (2012), "Project delays and cost: stakeholder perceptions of traditional v. PPP procurement", *Journal of Financial Management of Property and Construction*, Vol. 17 No. 1, pp.73 – 91.

Hughes, T.P. (1983), *Networks of Power: Electrification in Western Society, 1880-1930,* John Hopkins University Press, Baltimore.

IEA (2005), *Offshore Wind Experiences*, International Energy Association, IEA Publications, Paris.

Junginger M., Faaij A., Turkenburg W.C. (2004), “Cost Reduction Prospects for Offshore Wind Farms”. *Renewable Energy and Wind Power*. Vol. 28, No. 1, Pp. 97-118

Kahneman, D. (1994), “New challenges to the rationality assumption”, *Journal of Institutional and Theoretical Economics*, Vol. 150, pp. 18-36.

Kaldellis J.K. and Kapsali M. (2013), “Shifting towards offshore wind energy—Recent activity and future development”. *Energy Policy* Vol. 53, February, pp. 136–148.

Kaming, P.F., Olomolaiye, P.O., Holt, G.D. and Harris, F.C. (1997), “Factors influencing construction time and cost overruns on high-rise projects in Indonesia”, *Construction Management and Economics*, Vol. 15 No. 1, pp. 83-94.

Koch, C. (2012), “Contested overruns and performance of offshore wind power plants”, *Construction Management and Economics*, Vol. 30 No. 8, pp. 609-622.

Latour, B. (1987), *Science in Action: How to Follow Scientists and Engineers through Society*, Harvard University Press, Cambridge.

Latour, B. (2005), *Reassembling the Social*, Oxford University Press, Oxford.

Levitt, A.C., Kempton, W., Smith, A.P., Musial, W. and Firestone, J. (2011), “Pricing offshore wind power”, *Energy Policy*, Vol. 39 No. 10, pp. 6408-6421.

Liu, L. and Napier, Z. (2010), “The accuracy of risk-based cost estimation for water infrastructure projects: preliminary evidence from Australian projects”, *Construction Management and Economics*, Vol. 28 No. 1, pp. 89-100.

Love, P.E.D. (2011), “‘Plugging the gaps’ between optimum bias and strategic misrepresentation and infrastructure cost overruns”, *Procedia Engineering*, Vol. 14, pp. 1197-1204.

Lönker, O. (2005), “Operation Offshore”, available at Neue Energie, 2005-1 http://www.neueenergie.net/index.php?id=731 (accessed November 2011).

Miller, R. and Hobbs, B. (2005), “Governance regimes for large complex projects”, *Project Management Journal*, Vol. 36 No. 3, pp. 42-50.

Miller, R. and Lessard, D.R. (2008), “Evolving strategy: Risk management and the shaping of mega-projects”, in Priemus, H., Flyvbjerg, B. and van Wee, B. (Eds.), *Decision-Making on Mega-Projects’ Cost-Benefit Analysis, Planning and Innovation*, Edward Elgar, Cheltenham, chapter 8.

Olawale, Y.A. and Sun, M. (2010), “Cost and time control of construction projects: inhibiting factors and mitigating measures in practice”, *Construction Management and Economics*, Vol. 28 No. 5, pp. 509-526.

ONS (2011), “Statistics”, available at Office of National Statistics website http://www.statistics.gov.uk (accessed November 2011).

Reichelt, K. and Lyneis, J. (1999), “The dynamics of project performance: Benchmarking the drivers of cost and schedule overrun”, *European Management Journal*, Vol. 17 No. 2, pp. 135-150.

Renewable U.K. (2010), *Annual Review 2010*, Inspiring Excellence, London.

Sismondo, S. (2010), *An Introduction to Science and Technology Studies*, Wiley Blackwell, Chichester.

Slack, N. and Lewis, M. (2008), *Operations Strategy*, 2nd edition, Prentice-Hall, Harlow.

Slack, N., Chambers, S. and Johnston, R. (2007), *Operations Management*, 5th edition, Pearson, London.

Snyder, B. and Kaiser, M.J. (2009), “A comparison of offshore wind power development in Europe and the U.S.: Patterns and drivers of development”. *Applied Energy*, Vol. 86 No. 10, pp. 1845-1856.

Vanston, J.H. and Vanston, L.K. (2004), “Testing the tea leaves: evaluating the validity of forecasts”. *Research-Technology Management*, Vol. 47 No. 5, pp 33–39.

Wieczorek, A. J., Negro, S.O., Harmsen, R., Heimeriks, G.J. and Hekkert, M.P. (2012), “A review of the Western European Offshore Wind Innovation System”, in the *Track A*

Transition of Energy Systems proceedings of the IST Conference in Copenhagen, Denmark, pp. 72-104.

Zhixin, W., Chuanwen, J., Qian, A. and Chengmin, W. (2009),”The key technology of offshore wind farms and its new development in China”, *Renewable and Sustainable Energy Reviews*, Vol. 13 No.1, pp. 216-222.

Table 1 Technical features

Wind farms	Power capacity	Turbine	Foun-dation	Water Depth	Infield Cable	Export Cable	Offshore Sub-stations
	MW	MW		m	kV/km	kV/km	No.
Horns Rev I	160	2	M	6-11	30/63	150/21	1
Horns Rev II	209	2.3	M	9-17	33/70	150/42	1
Lillgrund SE	110	2.3	G	4-8	33/24	130/7	1
Middelgrunden	40	2	G	3-6	30/5	30/3.5	0
Nysted	166	2.3	G	6-10	33/48	132/11	1
Rødsand II	207	2.3	G	6-12	33/75	132/80	1
Samsø	23	2.3	M	10-13	30/3.5	30/4	0

Foundation types: M = monopole, G = Gravitation

Table 2 Cost Analysis

Wind farms	Power Capacity MW	Initial Budget Mio. Euro	Actual Cost Mio. Euro	Cost overrun %	Cost per MW Mio. Euro
Horns Rev I	160	229	278	21.4	1.74
Horns Rev II	209	470	470	0	2.25
Lillgrund SE	110	167	197	18.0	1.79
Middelgrunden	40	46	49	6.5	1.23
Nysted	166	269	269	0	1.62
Rødsand II	207	450	446	-0.9	2.15
Samsø	23	33	32	-3.0	1.39

Table 3 Time Analysis

Wind farms	Power Capacity MW	Initial time Month	Actual time Month	Time overrun %
Horns Rev I	160	10	16	60
Horns Rev II	209	21	17	-19.0
Lillgrund SE	110	20	23	15
Middelgrunden	40	4	6	50
Nysted	166	19	18	-5.3
Rødsand II	207	20	17	-15
Samsø	23	7	9	28.6

Table 4 Actual Capacity Factor

Wind farms	Power Capacity MW	Year in Operation	Actual Capacity Factor %
Horns Rev I	160	2003	39.9
Horns Rev II	209	2009	46.7
Lillgrund SE	110	2008	33.8
Middelgrunden	40	2001	25.2
Nysted	166	2004	36.1
Rødsand II	207	2010	42.1
Samsø	23	2003	38.9

Source: DEA, 2011; LORC, 2012