

Offshoring strategies in Norwegian ship production

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Abstract: For the past several decades, Norwegian shipyards have focused on innovative, customized, and technologically advanced ships, often serving the offshore oil and gas industry. Usually, a significant part of the production of the ship is offshored, especially steel-related tasks. That is, such tasks are carried out in a country with lower factor costs. The Norwegian yards focus on the more advanced outfitting tasks, such as the installation and commissioning of machinery and deck equipment, electrical systems, and accommodation. Nevertheless, the amount of work performed abroad before the Norwegian yard takes over and continues production differs among the various yards. Some only offshore block construction, others construction of the entire hull. Yet others finish the ship to such a degree abroad that it does not need to be recovered from the water in Norway and all the remaining work can be done from the quayside. This paper introduces a typology of shipbuilding strategies that differ in how much of the steel and outfitting work is performed in a country with lower cost levels. The strategies are discussed and compared in terms of relevant build strategic elements, such as pre-outfitting, concurrent execution of engineering and production, yard capabilities, and vertical integration. The strategies' likely effect on performance is also addressed, in terms of costs, quality, delivery dependability, delivery time, and flexibility. The results are based on a qualitative study of Norwegian yards and their offshoring strategies.

1. Introduction

Throughout history, Norway has played a central role in the design and production of ships and marine constructions. Until some decades ago, yards along the entire coast built various types of ships, such as tankers, bulkers, ferries, roll-on/roll-offs, and fishing boats of different sizes. During the 70s, the competition from Eastern Asia rose, benefitting from significantly lower labour costs. The larger yards in Norway could not adapt and scale down, and they eventually closed down and their properties were adapted for other, typically urban purposes. In the 90s, mainly the smaller yards on the West coast managed to survive, focusing on ship conversions and repairs as well as an increasing specialization towards ships serving the offshore oil and gas exploration and extraction industry. Since then, a big portion of all larger ships delivered from Norwegian yards has been made up of such customized, technologically advanced offshore support vessels (OSVs). Other types of customized, advanced ships, such as fishing vessels, live fish carriers, research vessels, cruise ships, mega-yachts, and naval ships have also been relevant market segments. Though of far less historic significance over the last 20 years, they have helped counteract crises in the offshore segment over the years.

The labour cost differences forced a strategic rethinking. During the 90s, the Norwegian yards offshored most steel-related tasks, i.e., they moved them to countries with lower cost levels. Today, most larger ships delivered from Norwegian yards have a significant part of their steel structure produced at locations in Eastern European countries, such as Poland, Ukraine, and Romania, or in Turkey. Hourly labour costs in these countries continue to be several times lower than in Norway (<http://ec.europa.eu/eurostat>). Steel processing and welding has traditionally involved a considerable amount of manual work, competence has been widely available, and quality relatively easily controlled. Performing such work in areas with lower man-hour rates can therefore yield considerable cost savings at sufficient quality. An additional advantage from offshoring steel work is that foreign sites often have several yards as customers. The total steel volume is thus higher, which allows economies of scale in steel processing. It also gives increased purchasing power and lower steel

material costs. As a consequence, the total cost of a steel construction is often several times lower abroad.

The Norwegian yards focus on outfitting of the ship, such as the installation of pipes and machinery; cabling and electrical systems; heating, ventilation and air conditioning; and accommodation and hotel functions. An important part is the installation and commissioning of main equipment, such as engines, propulsion systems, on-deck machines like cranes and winches, and other complex systems. OSVs are equipment-intensive, technologically complex constructs with countless systems integrated on limited space and going through rapid technological development and frequent changes. Outfitting and commissioning such ships, therefore, requires advanced knowledge and experience in system procurement and integration, as well as effective project management and coordination. In this sense, the yards in Norway have the typical characteristic of today's European shipyards: They focus on assembling complex ships, with 60-80% of the value of the ship procured as systems and modules from a wide network of suppliers (Held 2010).

Norwegian yards are typically small and compact, with short distances for workers, materials, equipment, and information. They are effectively organized and have long histories in building advanced ships. The work force is educated, skilled, multi-disciplinary, and efficient, with knowledge and experience built up through generations of seafaring and workshop workmanship. The yards are often located in rural areas and play a central role in the local community, with the employees normally loyal and proud of their jobs. Differences in salaries are small, and jobs secured by a well-developed social welfare system. Organizational structures are flat and informal, distances between workers and management are short, and worker autonomy is high. Decisions and changes are often made at the worker level, with little bureaucracy and without any formal requests. Norwegian yards belong to a maritime cluster providing proximity to many of the leading ship design offices, owners of one of the largest offshore fleets in the world, as well leading suppliers of main equipment (Mellbye et al. 2015). They are also close to the deep waters needed for sea trials. These characteristics are likely to play a central role in the Norwegian yards' persisting competitiveness in installing, inspecting, and testing innovative, technologically advanced, and customized solutions despite higher wages.

OSV outfitting skills and expertise are increasingly available at yards in low-cost areas as well, but they are not normally as experienced as the Norwegian yards, nor do they have the same social, cultural, organizational, and geographical benefits. Wrong sequencing, incorrect tool usage, and improper execution of the work are examples of why things do not get done first time right and need rework. Workers tend to be less multi-disciplinary, and fewer decisions can be taken locally. In addition, higher volumes at foreign yards do not necessarily allow economies of scale the way they do in structural steel work.

The Norwegian yards largely agree on this overall division of work. Labour-intensive steel work is performed where labour is cheap; complex outfitting and commissioning are carried out where the necessary knowledge, capabilities, infrastructure, and environment are available. Nevertheless, the amount of work performed abroad before the Norwegian yard takes over differs among the various yards. Figure 1 shows a typology of strategies for ship production based on the number of production stages performed at a foreign, low-cost location before a Norwegian yard carries out the remaining work. It consists of four generic strategies that can be placed along a continuum according to the point in production where the Norwegian yard takes over. Strategy I (complete Norwegian production) is at the extreme point of the continuum where all work is performed at the Norwegian yard. In strategy II (Norwegian block outfitting), some or all steel blocks are constructed and partly outfitted by a foreign builder, before they are transferred to the Norwegian yard. The Norwegian yard completes block construction and outfitting and carries out all the remaining ship production stages. In strategy III (Norwegian dock outfitting), all blocks are constructed, to a limited degree outfitted, and assembled into a ship structure at a foreign yard. The complete steel structure is then towed to Norway for dock and quay outfitting as well as commissioning and testing. In strategy IV (Norwegian quay outfitting),

finally, the ship is to such a degree completed at the foreign yard that, after towing to the Norwegian yard, all remaining work can be completed from the quayside.

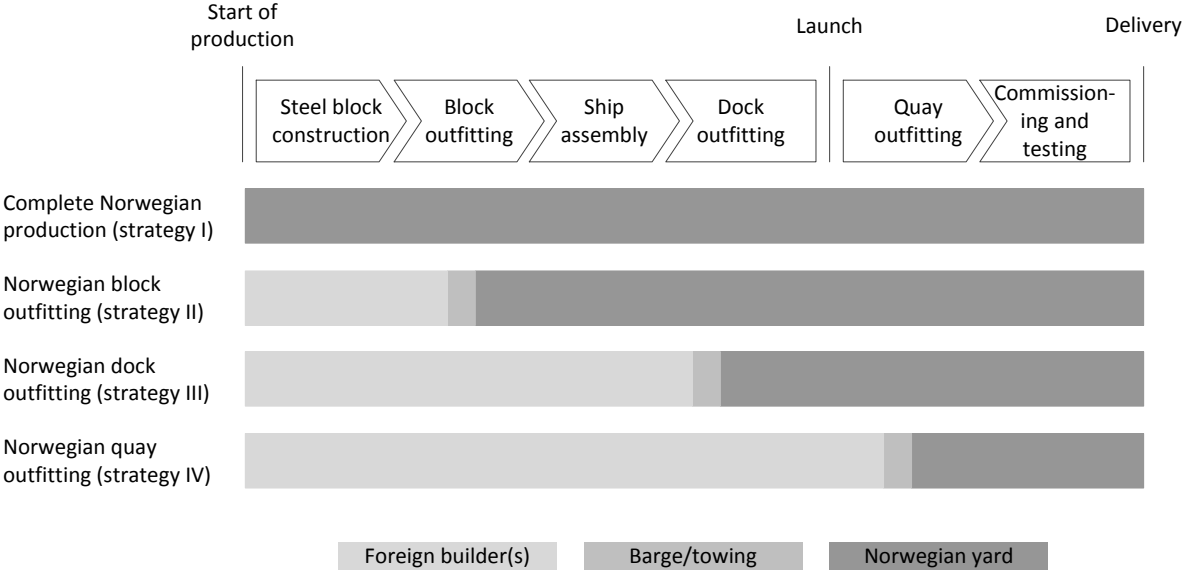


Figure 1: Four strategies for Norwegian ship production, differing in how production is divided between foreign builder(s) and a Norwegian yard

Figure 1 shows how these four strategies differ in the division of work between foreign, low-cost site(s) and the Norwegian yard. It indicates approximately the point in production when transfer to Norway takes place. A key difference between the strategies is thus the number of outfitting stages performed in Norway. This is reflected in the name selected for each strategy. The purpose of this paper is to characterize the strategies, compare them, and discuss likely differences in their effect on performance. This understanding is necessary in order for decision-makers at shipyards to select and implement appropriate manufacturing and build strategies, which can have a critical impact on costs, times, quality, flexibility, and other performance objectives (Beckman and Rosenfield 2008). Sound offshoring strategy choices help compete with other Western yards. More importantly, they are critical in competing with yards in other regions of the world, in particular China, which continues to benefit from significantly lower cost levels (U.S. bureau of labor statistics), and has over the past decade increased its OSV newbuild market share from approximately 20% to over 60% (IHS Maritime World Register of Ships).

2. Methodology

The concepts and results developed in the present research are based on a study of Norwegian yards and the OSVs they delivered between 2010 and 2016. Three of the largest Norwegian shipbuilding groups were included in the study, operating in total 8 yards. Each of these groups pursued a different offshoring strategy for its OSVs. Shipbuilding group A operated five yards in Norway and used strategy IV as the main strategy. Group B operated one yard and practiced strategy III as well as various hybrids between strategy II and III. Shipbuilding group C, finally, operated two yards. Its main yard predominantly employed strategy II, the other usually strategy III. The selection of shipbuilders thus provided a good empirical basis to assess and compare the different offshoring strategies and their consequences.

Data was collected from open sources, such as news articles, public company reports, conference presentations, web pages, etc., as well as from IHS and DNV GL’s databases. A number of yards employing different strategies were visited and relevant issues discussed with key personnel. Moreover, several of the authors had been working in the Norwegian maritime industry or carried out

research with the involved yards for many years and followed their development closely. These data and knowledge were synthesized into a characterization and comparison of the three types of offshoring strategies. The goal was to build concepts, typology, and theory. A qualitative study seemed most appropriate for this purpose, as it allowed a holistic assessment of the characteristics and implications of the various strategies. To the author's knowledge, this had not been done before for offshoring in shipbuilding. At the end of the paper, opportunities related to quantitative validation are highlighted, which constitute an important path for further research.

As Table 1 shows, the yards included in the study were similar in terms of number of ships, ship types, and ship sizes, with yard C1 however having a noticeably higher total volume than the rest. It is noteworthy that all the three offshoring strategies were in use for different types of OSVs and in good as well as bad market times. All of them were practiced for small as well as relatively large OSVs, yet no strategy III applications to very large OSVs could be identified among the yards studied.

Table 1: Number, types, and sizes of ships delivered from the yards included in the study between 2010 and 2016, as well as each yard's main offshoring strategy.

Yard	Yearly number of ships delivered		Ship types				Sizes of the OSVs (minimum; average; maximum)		Main offshoring strategy for OSVs
	2010-2016	Total	PSVs	AHTSs	Other OSVs ¹	Other types ²	Gross tonnage ³	Length overall (LOA)	
A1	3; 2; 4; 2; 3; 1; 3	18	10	4	3	1	3515; 5756; 8975	81,7; 96,4; 120,9	IV
A2	2; 1; 2; 5; 4; 0; 2	16	1	3	8	4	3580; 9721; 25000	81,7; 113,8; 177,9	IV
A3	4; 4; 3; 4; 4; 1; 0	20	18	0	2	0	3315; 4690; 6754	81,7; 92,9; 103,3	IV
A4	1; 3; 5; 3; 3; 3; 1	19	7	8	4	0	3527; 7345; 19290	81,7; 100,7; 156,7	IV
A5	4; 3; 3; 4; 1; 1; 2	18	8	1	7	2	3639; 9439; 22689	86,8; 114,9; 160,9	IV
B	2; 4; 4; 5; 2; 3; 2	22	12	1	8	1	3636; 6688; 12983	83,4; 94,5; 130	II; III
C1	5; 4; 5; 5; 5; 3	32	11	6	13	2	4528; 6943; 19700	85; 98,8; 149,8	II
C2	4; 2; 2; 1; 3; 2; 1	15	5	2	5	3	3140; 7467; 12433	79,7; 97,8; 127,8	III
Total	25; 23; 28; 29; 25; 16; 14	160	72	25	50	13	3140; 7204; 25000	79,7; 100,9; 177,9	

PSV, platform supply vessel; AHTS, anchor handling tug supply vessel.

¹ Other OSVs include offshore construction vessels, seismic research vessels, subsea construction vessels, diving support vessels, pipe layers, and cable layers.

² Other types include windmill support vessels, fishing vessels, yachts, and naval ships.

³ In this case, gross tonnage is used as a differentiator, because the compensated gross tonnage factors are not very robust for OSVs.

All the yards had outfitting quays, cranes, and various outfitting workshops, such as pipe shops and machine shops. Some also had a ship assembly area, either a drydock or a slipway, and some had a floating dock. Moreover, some had steel processing, block construction, and block outfitting facilities. A lot of the facilities were indoor for better working conditions. It should be noted that the yards did not necessarily use all available infrastructure and equipment when building their OSVs. Several yards had docking facilities or slipways which they predominantly used for conversion or repair work. In some cases, equipment from other yards was used for certain tasks, for example a floating dock or a mobile crane. Infrastructure and equipment needs for newbuilds are closely related to the choice of offshoring strategy and will be addressed as a part of Chapter 4.

The number of on-site production employees at each of these yards, including subcontractor personnel, depended heavily on the demand situation and varied between 0 and in the order of 1000 during the period of analysis. Each yard typically had a few hundred own employees and several hundred contracted workers in addition. Even own employees were temporarily laid off in periods of low demand.

3. Literature review

3.1. Shipbuilding and ship production

Shipbuilding is a complex process that involves numerous related activities, such as design, tendering, negotiating and contracting, engineering, procurement, production, commissioning and testing, delivery, and guarantee service. The different activities and their relationships have been discussed in, for example, Lamb (2003) and Kanerva et al. (2002). The present paper takes a closer look at different ways to carry out physical production. Hagen et al. (1996), Kanerva et al. (2002), Eyres and Bruce (2012), and Hagen and Erikstad (2014) describe the various stages in the physical production of a ship. For the purpose of the present research, six stages are distinguished as shown in Figure 1. The figure also shows how these stages relate to the three critical milestones start of production, launch, and delivery. As indicated in the figure, subsequent stages often overlap. For simplicity, pre-fabrication as well as blasting and painting are not shown separately, but considered part of the construction and outfitting stages. The reader is also reminded that the way the outfitting workload is distributed over the three outfitting stages can vary considerably among projects.

3.2. Manufacturing strategy

A manufacturing strategy can be defined as “... a pattern of decisions which determine the capability of a manufacturing system and specify how it will operate, in order to meet a set of manufacturing objectives which are consistent with the overall business objectives” (Platts et al. 1998). The content of a manufacturing strategy is often described by means of two elements: decision categories that are of long-term importance in the manufacturing function, and performance objectives (or competitive priorities) based on corporate and business unit goals (Leong et al. 1990, Hallgren and Olhager 2006). Examples of decision categories include: organizational structure and controls; facilities, resources, and capacities; process technology; production planning and control; sourcing and distribution; and human resources and competence (Miltenburg 2005). Performance objectives may be categorized into (adapted from Spring and Boaden 1997, Beckman and Rosenfield 2008)

- Cost: produce and deliver at low cost
- Quality: produce and deliver with high quality or performance standards (aesthetic, reliability, durability, safety, and serviceability of the product)
- Delivery dependability: meet delivery schedules
- Delivery time: keep the time from customer order to delivery short
- Flexibility (Slack et al. 2010):
 - Product flexibility: have the ability to introduce new or modified products
 - Mix flexibility: have the ability to produce a wide range or mix of products
 - Volume flexibility: have the ability to change the level of output
 - Delivery flexibility: have the ability to change the delivery dates

The link between decision categories and performance objectives is that the decisions in each category have an impact on performance, so they need to be aligned with the performance objectives. For example, a company focusing on low-cost will have a fundamentally different manufacturing strategy than a company competing on flexibility (Beckman and Rosenfield 2008).

Bruce and Garrard (2013) define a shipyard's manufacturing strategy as a description of how it currently carries out its ship production activities. They distinguish it from the build strategy, which is the application of a manufacturing strategy to a particular contract. A build strategy specifies what is to be produced, how, when, where, and with what resources (Bruce and Garrard 2013). Clark and Lamb (1996) discuss the relationship between manufacturing strategy (termed shipbuilding policy in their article) and build strategy, and they propose lists of the typical elements each of them contains. Spicknall (2003) defines three strategies for ship production for different degrees of product customization. Semini et al. (2014) use the customer order decoupling point to distinguish between

two strategies for designing and constructing customized ships. Lamb and Hellesoy (2002) study the factors affecting shipyard labour productivity and found the overall level of technological best practice, focus, the percentage of production employees, and vertical integration to be the most important parameters affecting productivity. Pires et al. (2009) perform data envelopment analysis to assess shipyard performance. Their results can provide insights into how certain strategic yard attributes may be related to performance, such as the level of technological maturity.

None of these papers, however, investigate the fact that many larger ships delivered from Norwegian and other Western yards today are partly built in low-cost countries. There is a lack of studies on this strategic choice, which affects other strategic decision categories as well as ship production performance. The present work has thus been precipitated by the absence of discussions in prior studies addressing strategies for ship production with different degrees of ship completion in low-cost countries. As the concept of offshoring is central in this respect, it is now also briefly reviewed.

3.3. Offshoring

Offshoring can be defined as the situation of buying from a vendor in a low-labor-cost country instead of a vendor in a high-wage country, or establishing a manufacturing operation in a low-labor-cost country that replaces a facility in a high-wage country (Hogan 2004). Hull production in Eastern Europe is a typical offshoring situation for Norwegian yards, where the main drivers are reduced factor costs (direct and indirect labour and material). Other important drivers of offshoring in general include market proximity and access to resources (Kinkel and Maloca 2009). Risks include loss of control, poor quality, higher transportation costs, lower reliability, supply disruptions, increased transaction costs, insufficient quality of infrastructure on site, lacking availability of qualified personnel, intellectual property loss, and reduced ability to innovate (Jahns et al. 2006, Beckman and Rosenfield 2008, Kinkel and Maloca 2009).

Several studies have addressed the negative effect of distance between R&D and production. Proximity to design and engineering helps ensure manufacturability and thereby quality (Beckman and Rosenfield 2008). It allows design and engineering to support production effectively, which is particularly important when introducing new, modified, or customized products. Physical and cultural distance can have negative effects on product innovation and flexibility (de Treville and Trigeorgis 2010, Gray et al. 2013, Tate 2014). The importance of the interfaces between engineering and production for costs and competitiveness has been emphasized repeatedly (Clark and Fujimoto 1991, Novak and Eppinger 2001, Mello 2015). Production offshoring typically makes the flow of information between the parties involved in engineering and production more challenging.

Products and processes with high labour content, low value creation, large production volumes, and limited variety, tend to be most attractive for offshoring (Kinkel and Maloca 2009, Chopra and Meindl 2016). According to Aron and Singh (2005), offshoring is most likely to succeed when work can be codified clearly and process quality can be measured precisely. Offshoring steel processing is largely in accordance with such literature, especially as long as it entails considerable manual work. From an offshoring perspective, the strategies discussed in this paper can be seen as differing in the number of production stages offshored to foreign builders.

The degree of offshoring applied in a certain industry or for a certain product is often seen in relation to the life-cycle stage. Initially, most manufacturing is performed domestically. As the industry or product matures, more and more operations are moved to lower-cost regions (Beckman and Rosenfield 2008). Specifically addressing shipbuilding, Koenig (2016) concludes that in order to constitute a business opportunity in the developed world, the industry needs to be driven by product innovation.

Offshoring is often discussed in relation to outsourcing, and the two terms are sometimes misinterpreted as aligned or even used interchangeably (Jahns et al. 2006). Here, Chakrabarty's (2006) view is taken, where offshoring refers to work across geographical borders, outsourcing is work across

organizational boundaries. Outsourcing is thus closely related to vertical integration, i.e., the question of which processes to perform inside the organization, and which to have performed by external suppliers. Hicks et al. (2001) introduced a typology of vertical integration alternatives for engineer-to-order companies in the U.K. In this typology, a company providing engineer-to-order solutions may either both produce components and assemble the product in-house (type I), only perform high value-adding assembly processes in-house (type II), or even outsource production completely (type III). With purchasing costs in the order of 60-80% of the total ship value, Norwegian yards would most appropriately be classified as type II, no matter how much steel construction is offshored. Hicks et al. (2001) identified systems integration and the coordination of internal and external processes as the competitive advantages for this type of companies. Compared to type I companies, they benefit from lower overhead, but risk losing critical capabilities related to manufacturing, as well as making suppliers potential competitors. Halse (2014) specifically addresses the vertical integration decision within the context of Norwegian shipbuilding when a part or even all of the physical production of the ship is offshored. Her findings indicate that vertical integration with the offshore yard facilitates coordination with and knowledge transfer to it. They, however, also suggest that reverse knowledge transfer back to design and engineering in Norway is limited, no matter the vertical integration choice.

Finally, Nujen et al. (2015) recently studied drivers for bringing previously offshored manufacturing back in-house, both geographically and organizationally. In particular, they identified critical success factors for knowledge re-integration. Their study is based on one particular Norwegian shipbuilder who reopened its slipway in 2004 and restarted to assemble ships in-house (implementation of strategy II). While Nujen et al. (2015) focused on knowledge re-integration, the present study aims at a holistic understanding of alternative offshoring strategies and their effect on performance.

4. Four strategies for ship production in Norway

The case study indicated that the four strategies for ship production introduced in Chapter 1 differed predominantly in the following build strategic elements:

- Structural steel work performed abroad
- Outfitting work performed abroad
- Work-in-progress transported to the Norwegian yard
- Pre-outfitting
- Concurrent execution of engineering and production
- Engineering and production interfaces
- Yard capabilities, infrastructure, and equipment
- Value creation and vertical integration

The way these elements relate to offshoring strategy is now briefly explained, before they are used to characterize and compare the strategies in more detail.

Structural steel work performed abroad: The main driver of offshoring in shipbuilding has been to perform steel work in lower-cost areas. Some of this work may still be carried out at the Norwegian yard, for example in order to perform outfitting in parallel, or, in periods of low demand, in order to use own capacity. The degree to which the steel structure is completed abroad is one of the central differences among the offshoring strategies studied.

Outfitting work performed abroad: The later an outfitting task is performed, the more difficult and time-consuming it usually is. Therefore, the more ship production stages the foreign site performs, the stronger are the incentives to offshore not only structural steel work, but also outfitting tasks. This needs to be traded off with the benefits from outfitting in Norway, as described in Chapter 1. While it is usually cost-effective to offshore simpler outfitting tasks, expensive and sensitive equipment is often preferably installed in Norway in order to keep full control of quality and functionality. Certain tasks

have to be performed in Norway due to class regulations or ship owner requirements. The desire to have a Norwegian-built ship, e.g., in order to benefit from state loans, also puts an upper limit on how much work can be offshored. Capacities, capabilities, and availability of materials and drawings also affect the distribution of outfitting tasks between the two locations.

Work-in-progress transported to the Norwegian yard: If only some block construction and outfitting is offshored, the blocks are typically transported on barges. If the foreign yard also takes care of ship assembly, tug boats tow the semi-finished ship to Norway.

Pre-outfitting: When the ship is assembled at the offshore builder, all the outfitting work to be performed by the Norwegian yard needs to be done on a closed ship structure. This restricts the overall degree of pre-outfitting.

Concurrent execution of engineering and production: Opportunities for concurrence are inversely related to the degree of pre-outfitting. Outfitting in Norway gives more time to complete drawings, including the weeks during which work-in-progress is transported to Norway. Especially for highly innovative and customized ships, concurrence is considered important for lead time compression because of long engineering periods.

Engineering and production interfaces: Offshoring increases the number of parties involved in engineering and production, as well as the geographical and working-cultural distance between them. The interfaces between engineering and production become more complex. Foreign sites are often not as experienced with OSV production as the Norwegian yard, and they often require more detailed drawings. Protection of intellectual property may also hamper prompt and smooth information exchange at the interfaces.

Yard capabilities, infrastructure, and equipment: The more ship production stages the foreign yard performs, the higher are the requirements regarding its infrastructure and capabilities. While steel-related capabilities are widely available, the number of yards capable of outfitting OSVs is relatively scarce. Considerable maturation is required in order to carry out such work with a satisfactory level of quality and effectiveness. For the Norwegian yard, offshoring leads to reduced needs for infrastructure and equipment.

Value creation and vertical integration: The strategies have different implications for value creation and vertical integration. The net value creation at the Norwegian yard decreases as more and more of the production of a ship is offshored. At the same time, the incentive to acquire the foreign facility can increase in order to control of costs, quality, and delivery, to reduce supplier dependency, and to facilitate coordination. This would then keep the value creation in-house, even though at a different geographical location.

4.1. Complete Norwegian production (strategy I)

In the complete Norwegian production strategy, all the stages in the physical production of the ship are performed at the Norwegian yard. The yard is vertically integrated and constructs, assembles, outfits, commissions, and tests its ships. It is the traditional way of building ships and described in, for example, Eyres and Bruce (2012). As explained, none of the yards studied practiced this strategy, but it is included in the typology in order to provide the full spectrum of options available.

Outfitting can be spread over the various ship production stages and each outfitting task carried out whenever most appropriate. The full potential in pre-outfitting can be exploited. There are no restrictions on the degree of concurrent execution of engineering and production either, but pre-outfitting is common and pushes the deadline for many drawings to an earlier stage in production.

Complete Norwegian production implies geographical and cultural proximity between designers, engineers, and production workers during the entire physical production (as long as engineering is not

offshored). Communication is likely to work well, the work force at the yard experienced in putting drawings into practice, and any issue requiring clarification can be addressed effectively.

4.2. Norwegian block outfitting (strategy II)

In the Norwegian block outfitting strategy, some or even all steel blocks are constructed and partly outfitted in a country with lower factor costs. Typical blocks produced abroad include the foreship, cargo/midship areas, and the aft ship. They may weigh anything between a few hundred and over a thousand tonnes. They are either produced at a single location or spread across several sites abroad. 80% or even more of all structural steel work would typically be performed at offshore builders.

After block transportation to Norway, the Norwegian yard performs a quality control and completes block outfitting. Complex and equipment-intensive blocks, such as the engine module, the bridge, and the accommodation module, may still in their entirety be constructed at the Norwegian yard. Such blocks require a lot of often complex outfitting, so it can be beneficial to perform it in Norway and in parallel with the steel work (e.g., deck by deck). The Norwegian yard then assembles the ship. Also all the remaining production stages are performed in Norway.

In terms of the division of block outfitting tasks, steel outfitting and other simple outfitting tasks can be expected to be performed satisfactorily abroad at significantly lower cost. For certain tasks, this is important because of restricted access at later stages, for example the installation of pipes below deck. The blocks also need to be surface-treated sufficiently before they can be transported on the sea, and it is advantageous to carry out steel outfitting before surface treatment. The capabilities of Norwegian yards suggest that more complex outfitting tasks are best performed there. An additional argument for limiting the degree of outfitting at the foreign yard is that outfitted blocks are more difficult to transport safely. Blocks are open structures, and materials may easily be exposed to climate and sea.

Foreign construction of steel blocks implies a small constraint on pre-outfitting: An outfitting task to be performed in Norway cannot be done in parallel with block construction, but has to be executed on a complete block. It provides the rationale for constructing complex blocks in Norway. The degree of pre-outfitting can generally be high also in this strategy. It requires drawings to be ready early, however, which is often challenging when the ship is novel and customized.

In terms of engineering and production interfaces, all the necessary drawings, instructions, and documentation need to be communicated and understood across nations and culture. Their volume and complexity depend on the work to be performed abroad, which is however limited to steel structural and simple outfitting tasks. The offshore builders would not normally do much engineering themselves, so the main issue is that the Norwegian yard provides them with necessary information in a timely and understandable manner.

The capabilities required at the foreign block builders are rather standard and there is no need for them to be shipyards or have specific OSV-related capabilities. Small workshops can often offer lower prices per kilo of steel, due to lower fixed costs and overhead, lower wage levels, and a more compact layout. The risk that these workshops abuse intellectual property and become competitors is very low as they do not have ship assembly capabilities and only receive drawings of simple blocks. The cost of switching to a different workshop in case of unexpected problems is also relatively low, and there are opportunities to leverage competition and achieve lower prices. Incentives to own these workshop are therefore at least initially limited. Vertical integration may, however, eventually become an option in order to develop and modernize them, as well as to prevent acquisition by competitors.

4.3. Norwegian dock outfitting (strategy III)

In the Norwegian dock outfitting strategy, a foreign yard is responsible for constructing blocks, assembling them into a one unit, and launching it. The yard is sometimes called hull yard, even though it may also construct the superstructure of the ship. The steel structure is towed to the Norwegian yard for dock outfitting in a drydock or, in some cases, a floating dock. Equipment is moved aboard

from the top, from the sides, as well as from the bottom. Access is improved by means of temporary cutouts in the steel structure. Eventually, the semi-finished ship is launched (again) and outfitting continued from the quayside. Commissioning and testing stand for an increasingly large part of the total work performed in Norway, compared to strategies I and II.

As in strategy II, certain outfitting tasks are usually carried out at the foreign yard, in parallel with steel construction. The minimum amount of outfitting to be performed abroad is typically somewhat higher, as access will be more limited when the closed steel structure arrives in Norway. Warm outfitting is often to a large degree carried out abroad. So is the installation of many pipes, especially large pipes and pipes below deck. The foreign yard may also to varying degree engage in blasting and painting, both outside and inside.

More outfitting may be offshored to benefit from lower costs and better access. In some cases, expensive equipment can be placed at the right location at the foreign yard, such as engines, even though proper installation only takes place at the Norwegian yard. Generally speaking, however, a characteristic of the Norwegian dock outfitting strategy is that a lot of outfitting is performed at the Norwegian yard. This strategy has the clearest split between steel work and outfitting. The former is carried out where labour is cheap, the latter where the necessary capabilities are available. This also implies that numerous detailed drawings are only needed long after production of the steel structure has been initiated. Rough drawings are often sufficient to determine the routings of the (large) pipes to be installed abroad. Bulkhead and deck transits for pipes may be based on approximate positions and dimensions. Detailed arrangement drawings are often not needed to know the filling of trays and tray penetrations, and locations of passages may be approximate. Local structural reinforcements can be completed based on footprint drawings, even though the foundation is not designed in detail yet.

The critical disadvantage is that a lot of outfitting is performed late, on a closed ship structure. This is a key difference from the other strategies, as shown in Figure 2. It implies that pre-outfitting opportunities are strongly reduced, which can increase costs remarkably especially for large and outfitting-intensive ships.

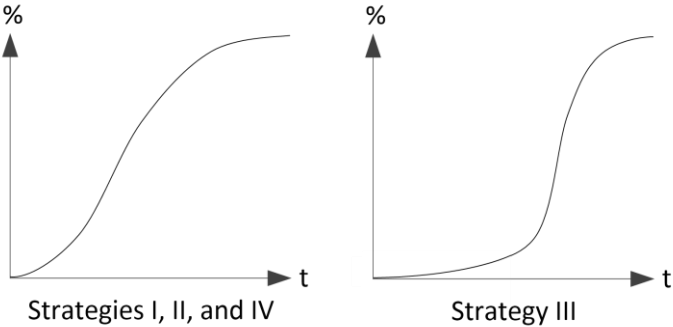


Figure 2: Curves showing the principal difference in how outfitting tasks are distributed over the production period. The x-axis shows time, the y-axis % of outfitting completed. The point is that in strategy III, outfitting is postponed

Strategy III implies increased complexity at engineering and production interfaces, compared to strategy II. More drawings and instructions need to be shared with and understood by foreign parties. Certain engineering tasks may be performed at the foreign location, which further increases the number of parties involved. Nevertheless, since mainly relatively simple work is offshored, the need for information sharing is moderate. Installation of complex equipment and systems is mainly taken care of in Norway.

The Norwegian yard can, therefore, also protect much of its critical intellectual property. This reduces the risk that the foreign yard eventually develops into a competitor. The strategy also allows the use of relatively immature foreign yards with only basic, standard capabilities. This gives a wider choice of available yards and it can leverage competition resulting in lower prices. Incentives to acquire foreign

yards are limited, and they often do not outweigh the required investment and the risks associated with acquisition. On the other hand, the offshore builder may eventually seek opportunities to encompass larger parts of the total value creation (more outfitting), and it may as a consequence move to other customers. Strategy III seems to depend on the low prices offered by relatively little developed yards. As prices increase, this strategy may not be competitive anymore because the Norwegian yard can no longer balance out unexploited pre-outfitting opportunities with lower prices for steel work. The Norwegian yard therefore risks that it has to look for alternative suppliers, with the associated costs of establishing and developing the relationship.

At a Norwegian yard employing a pure dock outfitting strategy, the role of the steel discipline is relatively small. It takes care of minor steel outfitting tasks, which for various reasons were not performed abroad, for example the installation of certain foundations. In this strategy, both locations require considerable investments in appropriate facilities; the foreign yard for effective assembly, the Norwegian yard for effective dock and quay outfitting.

4.4. Norwegian quay outfitting (strategy IV)

In the Norwegian quay outfitting strategy, finally, a foreign yard constructs and outfits all blocks, assembles them into a ship, completes dock outfitting, and launches a semi-finished ship. After towing to Norway, all remaining work is performed from the quayside. Parts and equipment are moved into the ship from the top and from the side. Also in this strategy, access is sometimes improved by means of temporary cutouts. Commissioning and testing of all systems and equipment constitutes a central part of the Norwegian yard's tasks.

The amount of outfitting performed at the foreign yard is much larger than in the other strategies. In addition to steel outfitting and piping, also many cables and electrical components, ducts, insulation, etc. are installed abroad. All outfitting jobs on the outside of the submerged portions of the hull, such as installation of rudder, propeller, and thrusters, need to be finalized and approved. Also other, even expensive equipment such as engines, may be installed abroad, although it is only connected to power in Norway. This strategy significantly differs from the other strategies in the sense that also complex, advanced outfitting tasks are offshored. The motivation is to benefit from lower cost levels as well as to exploit pre-outfitting opportunities.

Mainly outfitting tasks strongly benefitting from locational advantages are performed in Norway, such as the installation of advanced deck equipment. Outfitting work to be performed at the Norwegian yard must be postponed to a relatively late stage in the production of the ship, entailing the disadvantages of late outfitting, but giving engineering more time to complete drawings.

In this strategy, advanced technical information needs to be communicated and understood across engineering and production teams at both locations. Often, teams with different traditions, language, and culture work on the same complex systems. The transfer of partly completed work, both in terms of drawings and physical equipment, can be challenging. Effective coordination and communication are therefore of critical importance.

An important feature of this strategy is that the Norwegian yard gradually develops and integrates the foreign yard so that it can perform more and more outfitting itself, at lower cost than in Norway. Even though the development of capabilities can be challenging and take many years, the foreign yard thus performs an increasingly large share of the total work and value creation. It receives a lot of intellectual property about the design and production of OSVs from the Norwegian yard, enough to eventually produce complete ships itself. Protection of intellectual property therefore gives incentives to vertically integrate the foreign yard. It also helps ensure control of cost, quality, and delivery times, which is critical when such a large share of the total work is offshored. The drawbacks of vertical integration include the risk of reduced performance at the foreign yard because it does not have to compete for orders externally. Vertical integration also makes it more difficult for the Norwegian yard to switch to a different yard in case of problems, such as political instability. Furthermore, it involves a

significant investment with its associated risks. Smaller, independent Norwegian shipbuilders may neither have large enough volumes to justify such an investment, nor be willing to take the risks.

The infrastructure at a Norwegian yard employing strategy IV consists mainly of quays with space for a certain number of ships, as well as various outfitting workshops. The foreign yard, on the other hand, needs to have most physical facilities required to build complete ships.

Table 2: Important differences between the four strategies for ship production in Norway

	Strategy I: Complete Norwegian production	Strategy II: Norwegian block outfitting	Strategy III: Norwegian dock outfitting	Strategy IV: Norwegian quay outfitting
<i>Structural steel work offshored</i>	-	Block construction (besides the most complex blocks)	Block construction, ship assembly	Block construction, ship assembly
<i>Structural steel work performed in Norway</i>	Block construction, ship assembly	Construction of complex blocks, ship assembly	Minimized. Opening steel structure for outfitting	Minimized. Opening steel structure for outfitting
<i>Type of outfitting work offshored</i>	-	To some degree outfitting of simple blocks	Simple outfitting tasks, such as steel outfitting	Both simple and more complex tasks
<i>Outfitting stages performed in Norway</i>	Block outfitting, dock outfitting, quay outfitting	Block outfitting, dock outfitting, quay outfitting	Dock outfitting, quay outfitting	Quay outfitting
<i>Work-in-progress transported to the Norwegian yard</i>	-	Blocks, usually on barges	Steel structure towed	Partly outfitted ship towed
<i>Degree of pre-outfitting</i>	Higher	Higher	Lower	Higher
<i>Concurrent execution of engineering and production (Timing of drawings with respect to ship delivery date)</i>	Drawings often fixed at relatively early stage	Drawings often fixed at relatively early stage	Many drawings only fixed at late stage and after work-in-progress transfer to Norway	Some drawings fixed early, before ship transfer to Norway, others later
<i>Engineering and production interfaces</i>	Few and simple	Relatively few and simple	Relatively few and simple	Many and possibly challenging
<i>Required capabilities at foreign facilities</i>	-	Steel processing, block construction, piping, painting	Steel processing, block construction, piping, painting; ship assembly	Construction and outfitting of OSVs
<i>Main infrastructure and equipment needs at Norwegian yard</i>	Facilities for steel processing, block construction, ship assembly, and outfitting	Facilities for steel processing, block construction, ship assembly, and outfitting	Drydock or floating dock, quays, outfitting facilities	Quays and outfitting facilities
<i>Value creation at Norwegian yard</i>	Higher	Medium+ (Simple blocks produced by external suppliers)	Medium- (Steel structure produced by external yard)	Lower, but vertical integration keeps value creation in-house

Table 2 summarizes the main differences among the four strategies. Note that they represent ideal types along a continuum with a decreasing amount of work performed in Norway. At the yards studied, some ships were built with a hybrid strategy. For example, the steel structure of a ship was sometimes partially assembled at the foreign yard. It was then towed to Norway, where assembly was completed by mounting a number of additional blocks, such as the superstructure (hybrid between strategy II and III, best classified as strategy III). A second example is a strategy where the Norwegian yard performs

a large part of the total outfitting work, but most of it from the quayside (hybrid between strategy III and IV, also best classified as strategy III).

5. Effect of strategy on performance

This chapter discusses how the different offshoring strategies can be expected to affect the Norwegian yard's performance objectives cost, quality, delivery dependability, delivery time, and flexibility. Each of the strategies has its strengths and weaknesses in terms of performance, and none can in general be said to be superior to the others. It should also be emphasized that business performance is not only affected by the offshoring strategy, but the whole way a business is organized and run, the strategic and operational decisions taken at all levels and functions, as well as many factors in the external environment, such as demand and wage costs. For example, offshoring choices may affect the delivery time of a ship, but demand volumes, the ship's size and complexity, as well as yard capacities and capabilities may have a more significant impact on it.

Mellbye et al. (2015) found in a recent survey factors related to quality, delivery time and dependability, and product flexibility to be the most important reasons why customers selected yards in the Norwegian Møre region. Most major Norwegian OSV yards are located in this region. Also when it comes to productivity, the maritime industry in Møre scores higher than the same industry in countries such as Denmark, the United States, and South Korea (Mellbye et al. 2015). When asked about the reasons for this superior performance, Norwegian yards often refer to their social, cultural, organizational, and geographical environment (see Chapter 1). High productivity is necessary for Norway to reduce the wage cost disadvantage. Yet, differences in wages are so high that even with better productivity, it is challenging for Norwegian yards to match the prices offered by competitors in other regions. After 2000, there have not been direct subsidiaries to Norwegian yards, e.g., on the basis of contract volumes, which could have strengthened their financial competitiveness. Some governmental support for building ships in Norway is provided by means of building loan warrants, as well as favourable loan terms for (a) foreign ship owners and for (b) ships to be engaged in foreign trade or in the offshore market (OECD standard terms). The following discussion must be seen within the context of these general competitive features of Norwegian ship production.

Table 3 provides an overview of how the choice of offshoring strategy is likely to affect the performance of the Norwegian yard. The remainder of this chapter separately addresses each of the performance attributes in the table. The reasoning is qualitative and based on the study of yards as well as a general understanding of shipbuilding. The approach pursued here allows focusing on the direct effect of offshoring strategy on performance, which can be more difficult to isolate in quantitative, empirical performance comparisons. Nevertheless, quantitative validation constitutes an important direction for further work, and some food for thought on how to carry out such follow-up studies is given in the Chapter 6.

Table 3: Presumed differences in performance at Norwegian yards from employing different offshoring strategies (assuming other things equal). For each performance attribute (row) in the table, the following ordinal scale is used for horizontal comparison across strategies: Lowest, lower, medium-, medium, medium+, higher, highest

	Strategy I: Complete Norwegian production	Strategy II: Norwegian block outfitting	Strategy III: Norwegian dock outfitting	Strategy IV: Norwegian quay outfitting
Variable costs (including costs incurred at offshore builder)				
Steel and other bulk material	Higher	Lower	Lowest	Lowest
Steel-related work	Highest	Medium	Lowest	Lowest
Outfitting-related work	Medium+	Medium-	Highest	Lowest
Engineering	Lowest	Lower	Lower	Highest
Coordination	Lowest	Lower	Medium	Highest
Transportation of blocks or semi-finished ship	-	Higher	Lowest	Lower
Fixed costs				
Facilities and infrastructure	Highest	Higher	Medium	Lowest
Quality of the end product				
Quality risks	Lowest	Medium	Medium	Highest
Delivery dependability				
Risk of late delivery to the ship owner	Lowest	Lower	Medium	Higher
Delivery time				
Time from contract signing to delivery to the customer	Shorter	Shorter	Longer; reduced through concurrence	Longer; reduced through vertical integration
Flexibility				
Product flexibility	Lower	Higher	Higher	Lower
Volume flexibility	Lowest	Medium	Higher	Highest

5.1. Costs

With offshoring, labour and purchasing costs partly incur at the offshore builder rather than the Norwegian yard. Via purchasing or internal transaction costs, they still contribute to the total cost of building the ship and affect the Norwegian yard's cost competitiveness. The following discussion of how these costs depend on the offshoring strategy therefore addresses their total, not just the part incurring at the Norwegian yard.

5.1.1. Steel and other bulk material

Prices for steel and other bulk tend to be higher for Norwegian yards than for offshore builders. First, the latter can often benefit from economies of scale and higher purchasing power. Second, they may be more conveniently located with respect to transportation and logistics. A higher degree of offshoring will, therefore, often lead to reduced raw material prices. It should, however, be noted that purchasing-related capabilities can also have a critical impact.

Prices for systems and main equipment are not the same way affected by offshoring, as they are customized, project-specific solutions often developed by suppliers in proximity and close collaboration with the Norwegian yard. Even though they are more and more frequently produced in low-cost areas as well, reduced transportation costs from installation abroad must be weighed against the increased need for the suppliers to send personnel to foreign locations for installation and supervision.

5.1.2. Steel-related work

Steel-related work has traditionally involved a lot of manual work and, thus, been considerably cheaper abroad. The total labour cost would therefore normally decrease from strategy I to strategy IV, with the most significant reduction occurring between strategy I to strategy II.

Note, however, that steel processing costs in Norway may be reduced by increased levels of automation. Robots are becoming more and more affordable and easier to program. At the same time, their capabilities and performance are improving (Boston Consulting Group 2016). See Lee (2014) for a recent review of robotics in shipbuilding. As a consequence of these changes, there is an increasing number of tasks where the cost of automation has dropped below the cost of labour, and automation is becoming more and more accessible also to smaller manufacturers (Boston Consulting Group 2016). By itself, automation may still not economically justify domestic steel processing. In combination with other benefits, such as more pre-outfitting and shorter delivery times, it may be sound to carry out some of the structural steel work in Norway. Labour and raw material cost levels and exchange rates also play a role.

5.1.3. Outfitting-related work

Also outfitting involves a lot of manual work, and many tasks can be expected to be cheaper at the foreign yard despite higher productivity in Norway. When rework is needed after arrival in Norway, the cost advantage from foreign outfitting is reduced. The more outfitting done abroad, the higher is also the risk of late arrival of the ship, leading to overtime costs in Norway. Total outfitting costs depend not only on where outfitting is performed, but also on its distribution over the various ship production stages. Table 4 shows how the various offshoring strategies differ in these aspects and thereby impact total outfitting costs.

Table 4: Factors leading to differences in total outfitting costs among the four offshoring strategies

Strategy	Factors increasing outfitting costs	Factors decreasing outfitting costs	Expected overall level
I	<ul style="list-style-type: none"> All outfitting performed at the Norwegian yard with high labour costs 	<ul style="list-style-type: none"> High degree of pre-outfitting 	Medium+
II	<ul style="list-style-type: none"> Considerable amount of outfitting at the Norwegian yard with high labour costs 	<ul style="list-style-type: none"> High degree of pre-outfitting 	Medium-
III	<ul style="list-style-type: none"> Relatively low degree of pre-outfitting High amount of outfitting at the Norwegian yard with high labour costs Non-value adding activities of drydocking and relaunching ship 		Highest
IV	<ul style="list-style-type: none"> All Norwegian outfitting needs to be done from the quayside, including rework in case of quality deficiencies in work performed at the foreign yard 	<ul style="list-style-type: none"> High degree of pre-outfitting High amount of outfitting at a relatively mature, foreign yard with low/medium labour costs 	Lowest

5.1.4. Engineering

Typically, engineering costs can be expected to increase as more production is offshored, with the largest difference between strategy III and IV. More and more drawings and technical documentation of systems need to be communicated and understood, handled, and processed at the foreign site. Foreign shipbuilders often need more detailed drawings and work instructions than their Norwegian counterparts. A good team leader at a Norwegian yard does not need detailed instructions on, for example, sequencing, tools, and required certifications. Isometric drawings are usually sufficient, separate spool drawings are not needed. Pipes below 2 inches are not normally included in arrangement drawings. Especially costs related to fabrication engineering are therefore likely to increase remarkably. There may also be extra, non-value-adding processing due to intellectual property issues.

5.1.5. Coordination

The more work offshored, the more relevant become geographical and cultural differences, and the greater the need for coordination with the foreign yard. The designer, the Norwegian yard, the Norwegian main equipment suppliers, and the ship owner typically need to have people present at the foreign yard for supervision and follow-up. When the semi-finished ship arrives in Norway, the various

disciplines continue outfitting work with new teams. This take-over of partly completed work can create challenges, as several organizations and teams work on the same complex systems, with different traditions, language, and culture. The need for coordination can therefore generally be expected to increase as more production is offshored. It may even increase more than linearly with the amount of work offshored, as later stages in the physical process involve more complex drawings, specifications, and tasks. Long-term relationships, integration, and appropriate organizational structure and controls can facilitate coordination (Mello et al. 2015). Limiting the overlap of engineering and production can be a means to reduce coordination needs (Loch et al. 2003).

5.1.6. Transportation of blocks or semi-finished ship

Strategies II, III and IV incur a cost related to the transportation of blocks or semi-finished ships from foreign locations to the Norwegian yard. In strategy II, open block constructions have to be shipped, exposed to climate and sea. Related costs are likely to be higher than in strategies III and IV, where complete, closed hull structures can be towed as one unit. Yet, in strategy IV, extra costs can incur because of the need to protect sensitive materials and equipment installed abroad.

5.1.7. Fixed costs

Offshoring reduces the need for infrastructure, facilities, and equipment at the Norwegian yard, thus also its fixed costs. The lower the fixed costs, the less it is dependent on a regular number of yearly contracts in order to achieve the gross profit needed to cover them. Norwegian yards with considerable fixed costs must ensure a sufficient level of activity, but need to balance this with reduced worker effectiveness due to a crowded work place on the dock, quay, and on board of the ship, with long waiting times and complex management. The yards will therefore normally seek to use available capacity for advanced, high value-adding tasks in order to maximize their profit margins, at least in periods of high demand. In strategy II, for example, one would typically try to offshore as much block outfitting as possible, and only keep the high-margin tasks in Norway.

5.2. Quality

The later the Norwegian yard takes over, the less control it has of the quality of the final result. This is particularly problematic for outfitting, as offshore builders are often less experienced and quality control after arrival in Norway can be difficult because of hidden deficiencies. For example, materials used may not be in accordance to specifications, cables may be connected improperly, and there may be damages on sensitive equipment that has been exposed to dust, humidity, or impacts. Such deficiencies can reduce the lifetime of materials and equipment and significantly increase the need for maintenance during the operating phase. To ensure quality of outfitting work performed abroad, on-site presence and monitoring of the work performed will often be necessary.

5.3. Delivery dependability

The risk of delays outside the Norwegian yard's direct control also increases with more offshoring. Opportunities to get back on schedule through (costly) extra efforts locally are also reduced. Transportation to Norway also depends on uncontrollable, external factors such as weather and climate. Moreover, unexpected need for rework due to quality deficiencies can occur after arrival in Norway, which further increases the risk of late ship delivery to the customer, unless extra resources are available. If ship delivery to the customer is late, the yard often has to pay contractually agreed-upon daily fines.

5.4. Delivery time

Delivery time is here defined as the time from contract signing to delivery of the ship to the customer. A number of properties of strategies III and IV can have a negative impact on the delivery time because they are likely to affect activities on the critical path of the project:

- Reduced direct control of progress at the foreign yard
- Towing of the semi-finished ship to Norway, which takes a few weeks at least

- Outfitting tasks allocated to the Norwegian yard need to be performed on a closed ship structure
- Reduced opportunities for the various disciplines to work in parallel when outfitting is split between two locations
- Complex engineering and production interfaces (especially in strategy IV)
- Possible dependence on external yard capacity, which may be scarce in times of high global demand

In strategies I and II, most critical tasks are performed at an experienced, effective Norwegian yard and they can be done whenever most appropriate. The yard can have full control of progress, communication channels are short, and workers and teams can stay largely the same throughout the whole process. Other things equal, delivery times are therefore likely to be somewhat longer with strategies III and IV than with strategies I and II. In strategy III, concurrence can be an effective means to compress them. In strategy IV, compression can be achieved through vertical integration with the offshore builder.

5.5. Flexibility

In shipbuilding, product flexibility implies the ability to introduce innovative and customized solutions as well as to accommodate change orders. As stated earlier, high product flexibility is among the Norwegian yards' strengths, and offshoring to foreign yards can therefore affect product flexibility. The timing of drawings also affects it. Strategy III is likely to provide the best conditions. A lot of outfitting is done at the Norwegian yard, and many drawings are only needed at a relatively late stage. Unless changes affect the steel structure built abroad, they can be accommodated long after the start of production. In strategy IV, a complex network of geographically dispersed actors, less autonomous and inter-disciplinary work organization at many foreign yards, as well as early need for drawings can make product flexibility harder (or, at least, more costly) to achieve. Strategies I and II largely benefit from the strengths of the Norwegian yard. Certain drawings are typically needed early for pre-outfitting, but short production times keep the period between when drawings need to be fixed and when the ship is delivered short. It should be noted, however, that yards using strategy I risk to be large organizations with long distances between functions, which leads to slower material flows, information flows, and decision-making processes. Especially the transition to new types of ships can be challenging as facilities and organization are streamlined and adapted to a limited number of ship designs or types.

Volume flexibility generally increases with decreasing fixed costs. From the perspective of the Norwegian yard, it is therefore likely to increase as more and more work is offshored. From the perspective of its owner, strategy IV would, however, often lose much of its flexibility because the foreign yard is vertically integrated. From such a perspective, strategy III is likely to be the least volume-dependent, even though the need for external yard capacity can reduce its ability to rapidly increase volumes. In strategy II, fixed costs are likely to be somewhat higher, but there is no dependency on external ship assembly capacity.

6. Conclusions and further work

This paper has described four ship production strategies that differ in how much work is performed at a foreign location before a Norwegian yard takes over and finalizes production. The strategies differ in the level to which the primary steel structure is completed abroad, as well as in the degree to which the steel structure is outfitted abroad. They can be placed along a continuum, ranging from complete production in Norway at the one extreme, to barely quay outfitting in Norway at the other. The paper has discussed the various strategies in terms of relevant build strategic elements. It has also conjectured and argued for likely differences in the strategies' effect on performance.

The main contribution of this paper is the introduction of a typology of ship production strategies with different degrees of offshoring, including a discussion and comparison of the different strategies' implications. For practice, it should help decision-makers make appropriate strategic choices for ships to be built, as well as for more long-term, strategic decisions related to yard capacities and capabilities. For theory and education, it contributes to a body of knowledge on shipbuilding that addresses the specifics of high-cost shipbuilding nations.

A limitation of this study is that it is at this stage predominantly qualitative and conceptual. An important continuation is to find quantitative support of the relationships between the strategies and the resulting performance in terms of financial as well as non-financial measures. Several types of quantitative, empirical studies may be carried out to support this paper's arguments and compare the different offshoring strategies. The unit of analysis may be either individual shipbuilding projects or, alternatively, yards as a whole. If shipbuilding projects are used, the study may focus on one individual yard that has employed different offshoring strategies for its ships. An appropriate sample of ships may be selected and differences in shipbuilding project performance investigated, as well as whether they are likely to be at least partly a consequence of differences in offshoring strategy. The advantage of such a study is rich data accessibility and relatively equal company and yard characteristics across the shipbuilding projects included. If shipbuilding projects at several yards are included, a larger sample can be obtained and a wider range of different offshoring strategies studied. The direct effect of offshoring strategy may be more difficult to assess, however, as differences in project performance may be caused by other strategic and operational differences among the yards. Data accessibility is also likely to be more restricted. Shipbuilding is a competitive business, and one can expect a reluctance to share especially performance-related data with competitors. Nevertheless, some useful data are available from various databases such as IHS Maritime's Sea-web, and some are accessible from other sources. Certain performance attributes may be measured sensibly with indirect measures. The authors are currently performing several quantitative follow-up studies of this kind.

Rather than comparing the performance of building individual ships, one may study the performance of yards as a whole. This was the approach chosen in previous studies on shipbuilding performance, such as Pires et al. (2009), Colin and Pinto (2009), and Lamb and Hellesoy (2002). Challenges related to availability and meaningfulness of performance data need again to be addressed, but especially certain operational measures can again be retrieved from databases and provide meaningful insights, such as output volumes, the variety of ships produced, and production times. Such data can be combined with information about the capacities, capabilities, configurations, and strategies employed at various yards. Yards may be more willing to share this type of information than costs and other financial numbers. While Lamb and Hellesoy (2002) experienced disappointingly low response rates in this kind of a survey in 2002, the use of an internet-based tool and appropriate incentives, such as immediate return of various analyses based on the data provided, may increase the number of data points. Such a survey may also contain questions about the yards' perceived performance relative to competitors. It may give the data basis needed for an international yard study providing some novel, quantitative insights into manufacturing strategies, performance, and their relationship in shipbuilding. With respect to offshoring strategies in particular, it can provide insights into the use and consequences of offshoring in shipbuilding not only in Norway, but also in other high-cost countries with shipbuilding knowledge and experience, such as the Netherlands, Germany, the United States, and Japan.

Multivariate statistical data analysis seems to be an appropriate analysis method for the proposed studies, as exemplified by Lamb and Hellesoy (2002). Hatten et al.'s (1978) model of the U.S brewing industry provides an example from a different sector. Another analysis approach is data envelopment analysis, a non-parametric method from operations research which may be used to benchmark yards or shipbuilding projects and identify the best-performing units across several measures, as proposed by both Pires et al. (2009) and Colin and Pinto (2009).

Besides quantitative studies of the relationship between strategy and performance, there are also opportunities for further qualitative studies. The present paper has focused on the characteristics and consequences of different offshoring strategies; in addition, a longitudinal study of the strategies employed at the various yards could provide additional insights. Why have they pursued different strategies, despite seemingly similar markets and environmental conditions? What were the factual bases, the historical decisions, and the path dependences that have led to the strategies employed today? Nujen et al. (2015) address some of these questions for one particular yard.

The transferability of the present research to other high-cost shipbuilding nations should also be studied more closely. How do differences in environment and history affect the meaningfulness and relevance of the offshoring strategies discussed here? For example, can former high-volume yards in such nations adapt to changed market conditions and make the transition to building more specialized ships in lower volumes? What are the inertial forces, such as capabilities and working practices, that make such changes challenging? Finally, as the various physical and non-physical activities in shipbuilding become more and more distributed across organizations and regions, there is a need to better understand how to effectively configure, manage, and control global, project-based shipbuilding constellations.

Acknowledgements

This work was supported by the Research Council of Norway and the industrial partners in the SUSPRO and the Manufacturing Network 4.0 projects (Research Council of Norway grant numbers 225356 and 247637). We thank Giuseppe Fragapane for his support in making Table 1 and we thank Jørn Vatn for his general help related to the paper. We also thank various employees at the involved shipbuilding companies for sharing their knowledge and for interesting discussions. Finally, we thank the anonymous reviewers for constructive comments on an earlier version of this paper.

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