FRONT END LOADING AS AN INTEGRAL PART OF THE PROJECT EXECUTION MODEL IN LEAN SHIPBUILDING

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ABSTRACT

This paper addresses issues related to planning within the pre-contract phase of shipbuilding projects – issues that will facilitate lean execution of later construction phases. In the existing literature on Front End Loading (FEL) there can be identified a certain gap with regards to application of FEL in shipbuilding industry, which this paper attempts to partially fill. The first part of this paper reviews literature on the concept of FEL (also referred to as Pre-Project Planning, Early Project Planning, Feasibility Analysis). The literature review focuses on application of the FEL approach in different project-oriented industries, with major attention paid to application of FEL in megaprojects and building projects. Based on this study of theoretical concepts and experiences of their use, an adequate FEL concept tailored to shipbuilding industry is proposed in the second part of the paper. The paper also features the analysis of opportunities of transition and adaptation of some of the Value Improving Practices (VIPs) used in megaprojects to the shipbuilding industry. Vard Group AS, a Norwegian shipbuilder constituting together with the majority owner Fincantieri Group the fourth largest shipbuilding group in the world, is taken as a case company.

KEYWORDS

Front End Loading, Pre-Project Planning, Lean Project Planning, Lean Shipbuilding.

INTRODUCTION

Front End Loading (*FEL* in short) is quite a widely used term in different information sources related to project management or, more specifically, to project planning. Independent Project Analysis (IPA), a global consultancy in project evaluation and project system benchmarking, defines FEL as "the process by which a company develops a detailed definition of a project that was initiated to enable the company to meet its business objectives" (Weijde 2008). (Merrow 2011) sees FEL as "the definition of a project, from the formation of the core team until full-funds authorization is achieved".

Construction Industry Institute (CII) at The University of Texas in Austin prefers to call virtually the same process *Front End Planning*. CII defines this as "the process

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of developing sufficient strategic information with which owners can address risk and make decisions to commit resources in order to maximize the potential for a successful project" (Construction Industry Institute 2012).

According to CII the term *FEL* can also be referred to as Pre-Project Planning, Feasibility Analysis, Conceptual Planning, Programming/Schematic Design, and Early Project Planning (Construction Industry Institute 2012). Some authors refer to *FEL* as just *Front End process*, others may call it *Front End Development*. All definitions, however, imply and emphasize the extreme importance of a front-end phase of a project "when it exists only conceptually, and before it is planned and implemented", which includes "all activities from the time the idea is conceived, until the final decision to finance the project is made" (Williams and Samset 2010).

The front-end is critical in a number of industries due to their high engineering content. This is one of the reasons why FEL has become a part of a research project called NextShip between Vard Group AS (hereinafter Vard) – a major designer and builder of offshore- and specialized vessels – and a number of research institutes including Møreforsking Molde AS.

Analysis of statistics related to the level of success of projects of different budgets executed in different industries shows clearly, that poor planning, and especially planning in the early phase of projects, represents one of the main reasons of problems with projects (Emblemsvåg 2014b, KPMG 2013, Magnussen and Samset 2005, Olsson et al.). Despite its importance, FEL is still underrepresented in the literature, especially concerning shipbuilding.

Thus, in this paper, we pursue two objectives. First, we try to define which, if any, of existing FEL models, frameworks, principles and best practices may be applied to shipbuilding in general and Vard in particular. Secondly, we attempt to partially fill the gap in the existing literature concerning application of FEL to shipbuilding projects. The first part of this paper reviews literature on the concept of FEL, while the second part is a discussion on development of a FEL concept tailored to shipbuilding.

LITERATURE ON FRONT END LOADING

The majority of sources indicate direct correlation between the quality of FEL activities and the overall project success (Antoine et al. 2000, Bendiksen 2012, KPMG 2013, Magnussen and Samset 2005, Moreno-Trejo, Kumar, and Markeset 2012 etc.). In (National Research Council 2001) it is even stated that "typically, a project will not be better than its front-end planning process". Wang and Gibson Jr (2010) identify pre-project planning as having direct impact on the project success in terms of cost and schedule performance after having used statistical analysis and Artificial Neural Networks techniques to develop models for predicting cost and schedule growth from the pre-project planning data (PDRI[1] score sheets) collected from 62 industrial projects and 78 building projects. Weijde (2008) also used statistical methods to determine correlation between the quality of front-end development work and project success in terms of cost predictability, cost

[1] Project Definition Rating Index (PDRI) is an indicator, developed by CII, that is used to measure the front-end scope definition level (i.e. the quality of the front-end development work).

effectiveness, schedule predictability and schedule effectiveness. Weijde (2008) based his calculations on data from 458 Shell Global Solutions' downstream, gas & power and non-traditional projects: FEL-index[1] at Final Investment Decision (FID); Team Development Index at FID; Major Late Design Changes. He found that each of the FEL inputs mentioned above is significantly correlated with at least one of the project success indicators (Weijde 2008). Impressive statistics are provided by CII – according to the survey executed in 2009 based on a sample of 609 projects worth $37 billion – owners with high FEL usage achieved (in comparison with those with low usage) 10% less costs; 7% shorter delivery time; 5% fewer changes (Construction Industry Institute 2012).

The importance of FEL is shown in Fig.1.

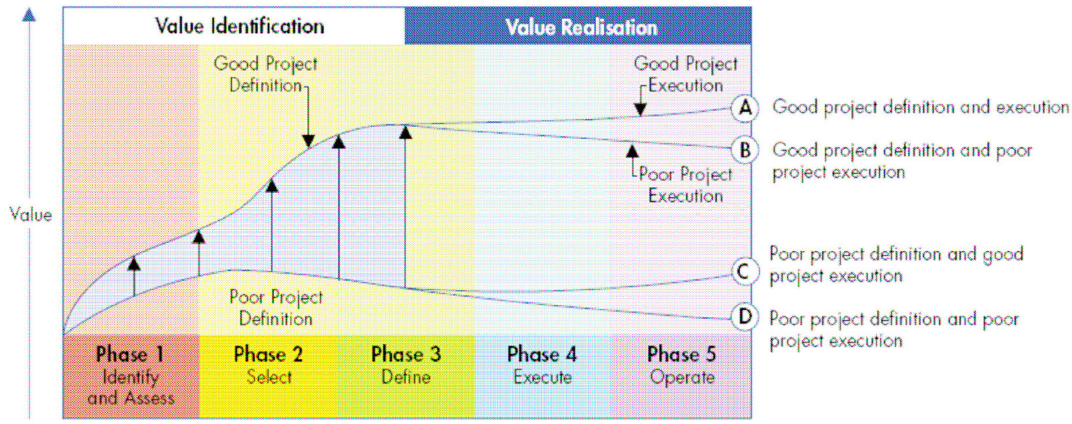

Figure 1: The influence of FEL on the value of a project (Hutchinson and Wabeke 2006) (Figure 2.1 in (Weijde 2008))

However, we agree with Williams and Samset (2010) that even though the importance of front-end decision-making phase in projects "is being increasingly recognized", FEL is still underrepresented in the literature.

Almost all of the literature the authors managed to find on FEL could be related to the two areas: 1) Construction (Building Projects and Industrial projects; Megaprojects – projects with capital expenditure >$1 billion); 2) New Product Development (NPD) (development of new products from different industries ranging from nanotechnology (Oliveira and Rozenfeld 2010) to aerospace manufacturing (McManus, Haggerty, and Murman 2005)). Information sources on FEL in construction industry consider only those construction projects where the construction site is individual for each specific project. This entails significant differences between these types of construction projects and, e.g., shipbuilding projects, where the construction work is undertaken in shipyards, which represent prepared facilities already customized for shipbuilding before the actual start of a specific project. The

[1] IPA's FEL-index – an index, developed by IPA, that is used to measure the level of definition a project has attained at a moment in time. FEL-index is one of the six key performance indicators in IPA benchmarking (Weijde 2008).

peculiarities of, and differences between, construction and shipbuilding industries are scrutinized by e.g. Emblemsvåg (2014a). The fact is that the literature available on FEL in construction industry is by far broader and deeper than in any of the other industries. The literature on FEL in construction industry is represented by:

- Hands-on guidelines and frameworks aimed at assessment and improvement of the quality of the front-end development work. There exist two most commonly used guidelines/FEL-quality indicators: 1) A framework developed by CII (assessment tool: PDRI); 2) A framework developed by IPA (assessment tools: FEL-index; percentage of applicable VIPs[1] used; Team Development Index; and Project Control Index).
- Best practices of FEL application (Bendiksen 2012, Construction Industry Institute 2012, KPMG 2013, National Research Council 2001, Weijde 2008, Westney Consulting Group 2008, etc.)
- Research papers and works (Haji-Kazemi, Andersen, and Krane 2013, Wang and Gibson Jr 2010, Williams and Samset 2010, etc.)

The literature on FEL in NPD touches upon problems connected to performance of activities preceding the formal development of *conceptually* new types/makes of products. Hence, it is logical that FEL in NPD is oriented mainly on definition of those new products that should provide revenue and competitiveness for the business rather than on successfulness of the new products' technical development (Oliveira and Rozenfeld 2010). Evidently, we may conclude that FEL in NPD is virtually a one-off process w.r.t. each product being developed before it is commercialized. Oliveira and Rozenfeld (2010), e.g., believe that integrated application of such practices as Technology Road Mapping and Project Portfolio Management facilitates "the selection of the best new product concepts for the development and launch of successful products" and thus should constitute an integral part of FEL in NPD.

As already mentioned, in the literature there exist a number of slightly different FEL frameworks or models. We will not scrutinize all of them here, but rather give a brief overview of some of them. Models (1) and (2), listed in Table 1, are related to construction projects, while models (3) to (9) are applicable mostly in NPD.

Table 1: FEL models

#	Introduced by	Description
1)	Construction Industry Institute (CII)	FEL is divided into three main phases: Feasibility, Concept and Detailed Scope. Figure 2 provides the detailed breakdown of this classification (tailored for construction industry). Each phase ends with assessment of the front-end development work using PDRI tool. Based on these assessments, a decision should be made whether the project

[1] Value Improving Practice (VIP) – here: a repeatable technique or methodology that, through experience and research, has proven to facilitate a better execution of a project in its FEL phase.

		work should move forward to design and construction phases. Typical activities and products of FEL may include: options analysis; life-cycle cost analysis; cost and schedule estimate; process design basis; initial engineering design; space planning; project execution approach, including project control plan; procurement plan etc. (Construction Industry Institute 2012).
2)	Independent Project Analysis (IPA)	A stage-gated FEL model is depicted in Figure 3. FEL work process is divided into phases or stages with a pause for an assessment and decision about whether to stop, recycle, or proceed. The decision points are called gates. "The gate assessments should examine both the economic/business and technical aspects of the project at that point" (Merrow 2011). At each gate, FEL indices are calculated.
3)	Robert G. Cooper (1995)	The three major steps in the FEL phase (see Figure 4) are: Idea generation; Preliminary assessment; and Concept definition. It is "in its simplicity one the most referred models of the pre-project stages" (Nobelius and Trygg 2002).
4)	Smith and Reinertsen (1991)	Authors call the three Cooper's pre-project stages "The Fuzzy Front End" and identify the following pre-project activities: Opportunity identification; Idea generation and selection; Market acceptance and Business opportunity analysis; Product planning; Planning for financial and human resources (Nobelius and Trygg 2002).
5)	Khurana and Rosenthal (1997)	Authors stress the existence of "project-specific elements and non-project-specific elements (called foundation elements) and their inter-relationships" and present the Front End process as consisting of the following "project-specific elements": Preliminary opportunity identification, Product concept and definition, Project planning (Nobelius and Trygg 2002).
6)	Nobelius and Trygg (2002)	Authors indicate that choosing one of the existing Front End models is "difficult due to different use of language, contexts, etc." That is why they suggest to synthesize all of the proposed activities of the Front End models they studied in order to identify their version of what elements the Front End process consists of (Figure 5).
7)	Clark and Wheelwright (1993)	The model shows four FEL activities: Technology Assessment and Forecasting; Market Assessment and Forecasting; Development of Goals and Objectives; the Aggregate Project Plan (Oliveira and Rozenfeld 2010).

8)	Coen *et al.* (2001)	The model includes five FEL activities: Opportunity Identification; Opportunity Analysis; Idea Generation and Enrichment; Idea Selection; and Concept Definition (Oliveira and Rozenfeld 2010).
9)	Crawford and Di Benedetto (2006)	The model suggests three FEL activities: Opportunity Identification and Selection; Concept Generation; and Concept/Project Evaluation (Oliveira and Rozenfeld 2010).

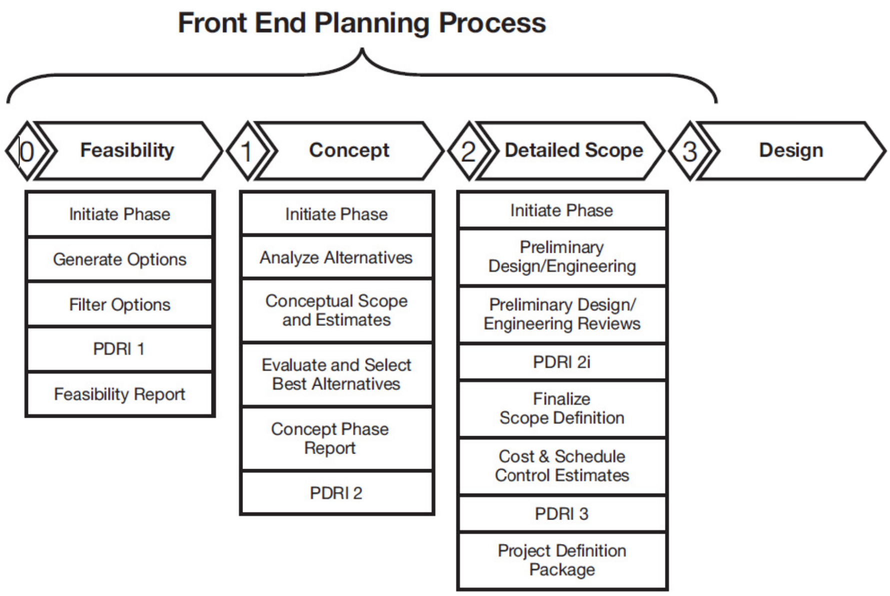

Figure 2. CII Front End Planning Process Map (Fig. 1.01-1 in (Construction Industry Institute 2012))

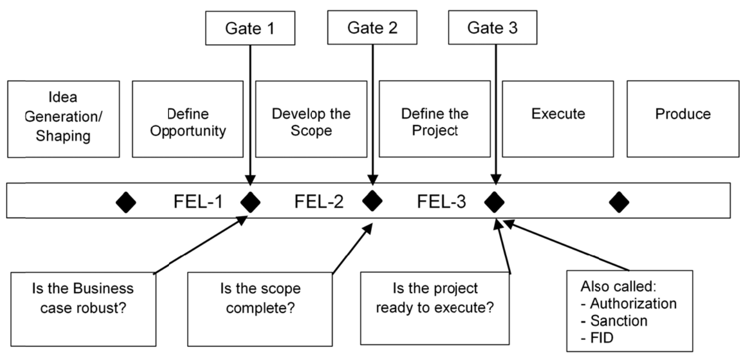

Figure 3. IPA stage-gated FEL Map (adapted from Fig. 10.1 in (Merrow 2011))

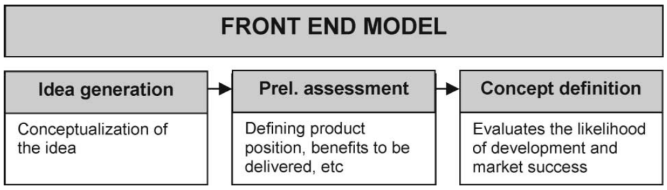

Figure 4. Pre-project activities according to Robert G. Cooper (Fig.1 in (Nobelius and Trygg 2002))

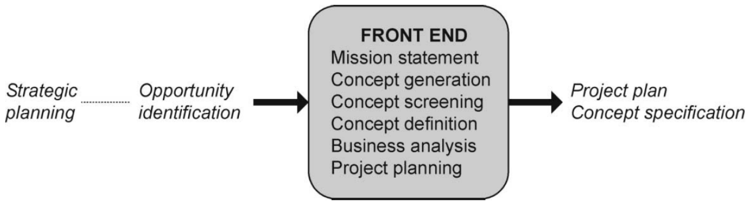

Figure 5. A synthesized input, activities, and output description of the Front End according to Nobelius and Trygg (Fig.2 in (Nobelius and Trygg 2002))

Finally, we need to say a few words about the cost of FEL phase. Weijde (2008) refers to (De Groen *et al.* 2003) that states that the FEL phase of a project varies from 1% to 7% of the total capital expenditure. CII provides the following evaluation: ”The Front End Planning effort is typically identified with 2 to 5 percent of the project total installed cost (TIC), depending on the type and complexity of the project” (Construction Industry Institute 2012). Merrow (2011) assesses eventual FEL costs as follows: “In general, the costs to the end of FEL-2 are no more than about 0.5 to 1.5% of eventual total cost” and “To go from the end of FEL-2 to a ready-to-sanction project costs in addition from 2 to 4% of eventual total capital cost”, which means from 2.5% to 5.5% in total. Additionally, time spent on FEL cannot be used for project execution. For instance, Nobelius and Trygg (2002), having studied FEL phases of three different projects, came to a conclusion that Front End activities amounted to at least 20% of total project time. Therefore, for each project there must be found an optimum at which “FEL is performed in a way that maximizes value and minimizes risks during project execution without being overly expensive and time-consuming” (Weijde 2008). To achieve this optimum, (Weijde 2008) referring to (Turner and Payne 1999; Bosch-Rekveldt 2007), suggests that the FEL process “depend on specific project requirements, i.e. making the [FEL] process fit the project”. Nobelius and Trygg (2002) also indicate that there is a need for development or adapting the Front End model according to “the type of project, staffing situation, and overall company situation”, hence “the Front End activities need to be sequenced, prioritized and properly staffed depending on the specific context”.

In summary, we find that there is no explicit information about FEL in shipbuilding. Neither FEL approaches in construction industry, nor FEL in NPD may be directly transferred to shipbuilding. Projects in shipbuilding are similar to both construction and NPD projects, but have certain peculiarities that must be addressed by a FEL approach customized for shipbuilding.

APPLICATION OF FEL IN LEAN SHIPBUILDING ENVIRONMENT

Before we go further with discussion of the development of FEL model tailored for shipbuilding, in order to understand how FEL approach may fit into the frameworks of the concept "Lean Shipbuilding" and enhance existing project planning approaches in this industry, we need to say a few words about their evolution. A review of this evolution is executed by Emblemsvåg (2014a,b). In brief, to date, one of the more advanced and successful approaches in project planning in shipbuilding industry is Lean Project Planning (LPP) approach explicated by Emblemsvåg (2014a,b). LPP was developed from the Last Planner System (LPS) to overcome shortcomings in the Earned Value Management (EVM) approach and LPP is "essentially a synthesis of EVM and LPS with an explication of planning as a communication process and not focus on the plan *per se*" (Emblemsvåg 2014a). To date, LPP approach is implemented and used by some yards in Vard. For more information about LPP please review (Emblemsvåg 2014a).

We believe that the FEL framework developed by IPA and, more importantly, experience of its usage by Shell could become a good baseline for developing FEL customized for shipbuilding. Since (Merrow 2011, Weijde 2008) provide a good and detailed introduction to FEL, we will here elaborate on a common problem in the Oil & Gas and shipbuilding industries – the problem of late design changes.

One of the ways in which FEL can benefit the project is the prevention of design changes (Weijde 2008). Having reviewed the IPA closeout evaluation documents of Shell projects, Weijde (2008) found that the key to preventing late design changes, according to IPA, is a combination of the following conditions: 1) having a good, integrated project team in place (measured by team development index); 2) using good project control measures (measured by the project control index); 3) having a well-defined scope at FID (measured by FEL-index) and 4) properly and timely applying relevant VIPs (predictive maintenance, design-to-capacity, value engineering, waste minimization and 3D CAD (Computer Aided Design)).

There are some peculiarities in application of Value Improvement Practices (VIP) as described in the literature, see Table 2, and analyzed by (Weijde 2008): (McCuish and Kaufman 2002) and IPA Institute recommend that execution of VIPs be facilitated by a person *external* to the project team; according to IPA Institute and (Schoonbee 2007) it is important to conduct VIPs in a *repeatable* way (formal, documented, structured approach); the VIPs should be applied to the *entire scope* of the project; most VIPs are best suited for application in the FEL phase of a project (De Groen *et al.* 2003).

Table 2: Definitions and objectives of selected VIPs (based on (Nissen 2003)).

VIP	Definition and Objectives
Constructa-bility	Definition: Analysis of the design usually done by experienced construction managers to reduce costs or save time in the construction phase. Objectives: Reduce total installed costs; Reduce schedule durations; Develop construction driven schedules; Ensure the project is fundamentally constructable; Develop an ongoing "log" for tracking ideas
Design to Capacity	Definition: An evaluation of the maximum capacity of each major piece of equipment. Often equipment is designed with a "safety factor" to allow for additional catch up capacity of some production increases.

	Objectives: Maximize the project NPV; Identify and set basis for capacity decisions/design allowances that align with Sponsor's objectives; Clarify the impact of capacity decisions of major equipment on the capacity of the overall facility and future expandability; Provide clear communication and alignment of capacity decisions to the business sponsors and project team members.
Value Engine-ering/ Process Simplifi-cation	Definition: A disciplined method used during design, often involving the use of an internal or external VE consultant, aimed at eliminating or modifying items that do not contribute to meeting business needs. Objectives: Confirm the value of selected components of a project; Improve the economics of the project by elimination of, reduction, or substitution of these components with lower cost alternatives that perform needed functions; Increase the project teams understanding of the functional requirements of critical system components.
Customi-zing standards and specifi-cations	Definition: An evaluation of the actual needs of the specific facility to be designed. Engineering standards and specifications can affect manufacturing efficiency, product quality, operating costs, and employee safety. However, sometimes the cost of a facility is increased by the application of codes, standards, and specifications that exceed the facility's needs. Objectives: This practice is to optimize facility life cycle costs through establishing the minimum acceptable standards that align Project Objectives. This is not be confused with using standard industry specifications.
Technology Selection	Definition: A formal systematic process by which a company searches for production technology outside of the company (or, in some instances, in other divisions within the company) that may be superior to that currently employed in its manufacturing plants. Objectives: Select technology that best meets business objective such as: economic criteria, operability, on-stream time, integration, utilities consumption, flexibility, raw materials, environmental impact.
3D CAD	Definition: Extensive use of 3D Computer Aided Design (CAD) during FEL and detailed engineering. The use of 3D CAD also improves visualization for operations and maintenance input and training. Objectives: This VIP will improve visualization of the facility for owner input and training. It also reduces the frequency of dimensional errors and spatial conflicts that cause design changes during construction.
Waste Minimi-zation	Definition: A disciplined approach for minimizing the production of waste products via design, and it might add additional equipment or examine alternate process technologies that have lower waste side-streams. Objectives: To add value to the project by reducing/eliminating non-useful streams that minimize environmental impact. This VIP provides methods and reports that facilitate and document the decisions to minimize this impact.

We suggest that a list of VIPs customized for shipbuilding projects needs to be developed. The full list of VIPs proposed by IPA, those VIPs adopted, adapted and developed for their projects by Shell (they refer to them as PVPs – project value processes) and VIPs proposed for the shipbuilding industry are provided in Table 3.

Table 3: Value Improving Practices (based on (Weijde 2008) and (Koskela 1992))

IPA VIPs	Shell's megaprojects	Shipbuilding
Technology selection		Specification and Maker's list
	Building the project team	Building the project team
Process simplification		Process Simplification

		(ease of project execution)
	Opportunity framing & project goal setting	Contract and specification
Classes of facility quality		
	Contracting and procurement strategy development	Contracting and procurement strategy development
Waste minimization		
	Risk management	Risk-to-profit
Constructability review	Constructability	Constructability
Process reliability modelling		
	Design class	
Customizing standards and specifications		Customizing standards and specifications
	Project assurance process	Compliance with class society and authorities
Value engineering	Value engineering	
Design-to-capacity		
	Lessons learned	Lessons learned
Energy optimization		Hull lines and fuel consumption
3D CAD		3D CAD
	Operations implementation planning	Project- and production planning
	Availability assurance/ reliability modelling	
Predictive maintenance		
	Human factors engineering	
	External benchmarking	External benchmarking

The rest of this paper concerns FEL at Vard.

APPLICATION OF FEL AT VARD GROUP AS

Vard has been working for several years with the implementation of *lean principles* in its *project execution model*. An essential element has been to develop the ability to rapidly evaluate and maneuver out of the consequences of late changes. Integration of the FEL approach into Vard's project execution model is a step forward in this respect.

Vard has a business model based on a collaborative shipbuilding process. This process typically starts out with a stage in which the shipowner, design company and

Vard discuss the vessel to be built either in relation to a specific tender or based on more long-term considerations such as fleet renewal or preempting foreseeable developments in certain markets. Vard naturally tries to move this process into the direction of previously known design solutions to benefit from some economies of scale, but often the end result is a prototype because the shipowner or Vard find ways to build a better vessel. Crucially, these ideas are allowed to surface and enter the project during execution. This can only be achieved through close collaboration between the parties in the project execution hence leading to a collaborative shipbuilding process.

An alternative to the collaborative approach in shipbuilding is an industrial approach, which implies development of standardized ships, ship platforms or reuse of reference projects in similar shipbuilding projects. Both collaborative and industrial approaches have their advantages – the first one provides the highest level of ship customization with regards to the customer's needs, while the second one offers economy of scale (both cost and time) for the shipbuilder and should normally lead to lower prices to the ship-owner. Standardization of solutions may also reduce training costs of crews for the ship-owner, improving quality over time as solutions can be fine-tuned and so on.

As stated earlier, the composition and the level of integration of the project team could be identified as being one of the key conditions of preventing late design changes and, consequently, having direct impact on the overall success of the project. It would be logical then for every project manager to create a team consisting of the members representing all of the parties and functions involved in project execution already at the front-end phase. However, Vard project team includes representatives of the ship-owner, design company and Vard itself (project manager; project planner; HSEQ, engineering, production and procurement coordinators), but usually does not include any representatives from the strategic suppliers' side. This is explained by the fact that the ship-owners can choose from a limited selection of suppliers from the Maker's list in the contract. This makes it difficult to involve strategic suppliers in general, in the project before the contract is settled. Obviously, if main components are settled in the pre-contract stage the suppliers of these can be involved. This is an inherent part of the collaborative shipbuilding approach.

Concerning the FEL processes outlined in this paper, Figure 3 provides the most realistic situation for Vard. However, there is one significant difference – the execution of the project entails often defining the project in detail. Yet, the contract is often signed based on conceptual information such as a rough specification, General Arrangements (GA), Maker's list and a set of defined standards. This means that FEL processes are hard to manage and we end up in a reactive mode as opposed to a proactive mode, which is normally the essence of FEL. This said, Vard is currently working on a standard project execution model that will facilitate a better FEL process than today, which is one of the motivations for this research in the first place. In this process there is a defined stage called pre-contract stage in which the following important issues relevant for FEL will be settled: 1) Procurement plan for Long-Leading Items and main components in general, 2) Resource planning for design and engineering, and 3) Pre-approval of equipment.

With these issues targeted, it will be interesting to see what can be achieved of improvements concerning FEL in a collaborative shipbuilding process. It will also be equally interesting to see what can be achieved in a more industrialized shipbuilding process where the freedom of making changes is reduced and/or the project is at the very least better defined at the kick-off.

CONCLUSIONS

The words of Sir Winston Churchill uttered in a speech at the Mansion House in London City in late 1942 ring to mind; "Now this is not the end. It is not even the beginning of the end. But it is, perhaps, the end of the beginning". We have in this paper approached FEL in shipbuilding from some of the literature, but more work must be put into developing a best-practice process for both collaborative as well as industrial shipbuilding. Depending on findings, it might be conceivable that the findings can be used to argue in favor of one shipbuilding business model or the other. The early stages of a project, is after all where the greatest impact on a project is made and no company can afford to ignore this.

This question can be approached by studying the procurement processes of a prototype and a sister vessel where the prototype will be the iconic image of the collaborative shipbuilding process whereas a sister vessel will obviously serve as a proxy for an industrial approach.

The availability of technical documentation as well as drawings will be the big difference between the two approaches. The possibility of buying large blocks of components and then call off on project-basis is currently not possible to simulate like this since that will require not a few sister vessels but a genuine standardization across many projects. Therefore, whatever results will be on the conservative scale, i.e. in real life there is an even greater difference of FEL in industrial shipbuilding compared to FEL in collaborative shipbuilding.

Also, lean practices in a collaborative shipbuilding are quite different from lean practices in industrial shipbuilding since collaborative shipbuilding is less structured and put premium on maneuverability whereas industrial shipbuilding achieves higher productivity at the expense of some maneuverability. This reduction in maneuverability in industrial shipbuilding must be managed by a better FEL process otherwise industrial shipbuilding may lose out in the marketplace as ship-owners may find the value offered by an industrial shipbuilding process less attractive (more restrictions with unattractive cost savings). Essentially, it is a question of the utility of maneuverability versus productivity in the offshore and specialized vessel market segment.

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