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Steinar Kristoffersen

NEXTSHIP - LEAN SHIPBUILDING

State of the art and potential to be "lean" in multifariously distributed maritime design, engineering and construction

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Steinar Kristoffersen

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Abstract

This report surveys a selection of historical and domain specific articles and essays pertaining to lean shipbuilding and high value adding manufacturing in general. It purports to give an impression of the field’s state of art, with an empirical backdrop and some critical reflections, which may in the next instance serve as a vantage point for a topology of this class of management ideologies.

Preface

This report corresponds to deliverable 4.1 “State-of-the-art Report on Lean construction in shipbuilding” from work package 4 of the NextShip–project. It reviews information stemming from three sources, namely

i) the classical background literature of so-called “lean” production systems, with variances towards lean manufacturing, lean construction, lean planning, and finally, lean shipbuilding.

ii) The literature is scarce on the area of lean shipbuilding, thus, I have supplemented the report with observations and ideas from empirical work in the STX OSV Søviknes Shipyard, which at the time was under management of Dr. Jan Emblemsvåg who is also on the steering committee of this project.

iii) Finally, I have drawn upon ethnomethodological analysis of planning as such, which have been influentially published in other subject areas, in order to create a balance against the predominantly reductionist perspective of operational science logistics.

Thus, this report represents a perspective of the potential of modern shipbuilding to become “lean”, which in this report will be denoted with a capital L in Lean when it signifies this particular management ideology, as well as referencing and commenting some of the pertaining literature of the field.

Steinar Kristoffersen Molde, December 2012

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Introduction

The current report examines the state-of-the-art of academic and practitioner contributions towards making shipyard construction work more efficient. It approaches the question from several angles, using literature studies, empirical examination of work in the planning and management functional areas of a shipyard, as well as some theoretical and methodologically informed critical reflection.

It has not been the objective to submit the most voluminous report ever written on Lean. The classical literature is, indeed, classical and easily recovered. Thus, this report does not enter uncritically a survey of articles published by proponents of Lean. Instead, I have sought to examine Lean's internal (in)consistencies as well as the eventual fit that it furnishes vis-à-vis the maritime domain. The mandate of the research of which this report is a part, clearly points in the direction of examining its potential in that regard. The idea the so-called "Lean" construction may be applied to shipbuilding, and that it provides a candidate solution to increasing efficiency, has been launched by many authors [1], but turns out to be difficult to prove consistently [2, 3].

The question, which also has been asked before is of course, whether it is possible and meaning for a shipyard to work towards lean shipbuilding. Indeed, when Lean is seen as simply an enhancement of mass production methods [4], then other conceptual methods such as agile, resilient, flexible or, indeed, "leagile" might be equally readily considered [5, 6]. Agile techniques are sometimes treated akin to Lean, sometimes as exactly the opposite, and usually as a related development [7]. This is a hint towards the lack of a stable ontological foundation, which in a post-modern perspective is hardly surprising albeit in stark contracts to the realist orientation of Lean research in general [8]. Hence, some explicitly critical examinations of the notion of Lean has been reviewed as well [9, 10], with no intention from this report at the same time to contribute to dismissing the notion of Lean as such.

A first premise of this report would simply be to provide an overview of state-of-the-art in modern manufacturing, including and mainly, but not exclusive of Lean. It seems unproductive to focus only on Lean since the practical implementation of its principles varies tremendously. At the same time, it has been an ambition to come across as balanced with regards to the selection of articles as well as the portrait that we draw of Lean.

This paper is therefore not going to try to establish a common and definite set of delineating definitions; rather it is going to provide sufficient footing to decide when and why the notion of Lean is *being* used in the literature, and what the effects of "talking lean" are in an organizational as well as a theoretical perspective. It should be clear, thus, that this paper is not as such a "methods" paper, insofar as it prescribes a way of becoming lean, for which other articles can be found among related publications [11].

Second, analysing the role of knowledge management and the reconciliation of diverse organizational cultures is going to be an important part of any case study pertaining to complex, high-value adding manufacturing and construction (such as shipbuilding) [12]. This is because the work taking place in this domain is seen as unequivocally competence and skill-based, and the

transfer of work from one “station” to another is not simply a logistical problem. The production processes and the artefacts thus produced are sufficiently complex for there to be many simultaneous points of view of what was wanted, what was designed and, finally, what has been built [13].

Third, this state of the art survey is going to be largely practical and empirically oriented. We are contributing to an action-research endeavour in relatively large scale, and hence need to work out descriptions and analysis of the theoretical background that is useful in a wide range of contexts, such as workshops and training courses at the shipyards.

Finally, our aim is ultimately to support and demonstrate better planning processes for internationally distributed shipbuilding projects. This means a focus with communication, decision-making and risk management. Strategic development and design will also need to be taken into consideration when we study the “Lean talking”. This may not lead unanimously toward a recommendation of Lean, as such, but hopefully a better understanding of what it entails.

The Lean history

Notwithstanding the fact that reports are to be found of Lean applied to shipbuilding [14, 15], Lean is, arguably, seen by most as predominantly an implementation of mass production or certainly an extension [10].

Whilst the many contesting views concerning where and how lean may actually be implemented, support the assumption that Lean does not furnish a particularly stable ontology, but rather an expression of ideological pragmatism, the background of Lean is historically clear. Lean originated from the Japanese automobile industry, starting perhaps as early as the 1950s [16]. In order to compete with American brands, which had a significantly higher production volume and therefore lower unit costs, a more efficient approach to industrial production was necessary in order to be able to meet the market’s expectations with regards to customizability [17].

The Lean principles

There are many different practices, ideologies and techniques that come together under Lean, as an umbrella term, which usually comprise what is otherwise known as *Just-In-Time* production principles (JIT), *Total Quality Management* (TQM, a widely scoped preventative maintenance programme and human resource management. Moreover, it concerns itself heavily with implementation of notions of production pull and flow. Indeed, the semantically “shared baggage”, signified by a syntactically similar, yet increasingly semantically different interpretation of terms, between Lean and its predecessors, may have contributed (allegedly) to the ontological confusion and internal inconsistencies of much Lean literature [18]. The challenges go deeper, however [ibid]:

> A greater source of confusion, however, is the more substantive disagreement about what comprises lean production and how it can be measured operationally [18].

It is simple enough to describe the intentions of Lean at a relatively abstract level, e.g., that:

- Processes need to have low overhead to be set up correctly, together with a tight monitoring system and reactive check and redesign of the process (Plan-Do-Check-Act [19]).
- Maintenance should be reactive, in the sense that it contributes to furthering productivity, rather than refactoring the product.
- It is imperative in Lean to engage the employees on all levels.
- Lean manufacturing is also required to comprise a set of practices focused on reducing wasand non-value added activities from the company's manufacturing activities.

It is, however, hard to find representative and credible management strategies, which would admit to aim for a set of objectives that were starkly in contradistinction to the ones above. Clearly, a more instrumental approach is needed to supplement such principles. The [some] slightly more concrete, and hence important guidelines of "the Toyota way" are expressed henceforth [20]:

- Long-term philosophies should govern short-term strategies.
- Create a continuous and transparent value flow that makes weaknesses identifiable and repairable.
- Repair at once when errors are found.
- Use "pull" rather than push to avoid stocks and overproduction.
- Level out the workload (Heijunka).
- Standardize tasks; it is needed for improvement and empowerment.
- Bring problems to the surface, visualize.
- Use well-known and familiar technology.
- Educate leaders and employees.
- Respect and challenge partners and suppliers.
- Investigate uncertainty and reduce human bias, personally (Genchi genbutsu).
- Make decisions slowly; implement decisions rapidly.
- Support relentless reflection (Hansei; it may also mean "consideration").
- Support continuous Improvement (Kaizen).

Lean manufacturing

Manufacturing is an alternative "perspective" of the background of Lean [21], as it deals with large volumes and small margins, usually (or therefore) in combination with extensive re-configuration of the factory and assembly line, which in the next instance means more cost. However, Lean deals, it seems, historically better with variation inside the larger volumes, than traditional manufacturing, which fits with the background of it in Japanese automobile construction, where manufacturers needed to be competitive in a marked where buyers has less money to spend on each item, but perhaps combined with stronger wills and opinions traditionally to request adaptation and variances, although an equally plausible explanation might have been that larger volumes very needed in an initial phase of the market, where manufacturers did not know well what the customers wanted or needed. In American automobile manufacturing, the volumes might have grown over time, which gave the actors a foothold of marked knowledge to produce larger series of identical cars that

customer wanted to take home from the shop. This might not have been the case in Japan, nor at the same or later stage of development, in Europe.

The larger series in total and the opportunity to explore the customer preferences in a undersupplied home market, may have given early adopter of Lean, less incentives to focus on risk and the need to "plan their way away from" mistakes.

Studying lean manufacturing supply chains in particular, we find that some, on the surface, ignore planning and risk (uncertainty) altogether, and instead focus on other dimensions [22]:

- Price and quantity of orders
- Inventory decisions
- Cycle lengths and inspection intervals
- Optimal batch size and number of kanbans[1]
- Reduction of waste [20]:
    - Defects in production
    - Overproduction
    - Stocks
    - Unnecessary processing, movement of people or transport of goods
    - Waiting

Lean construction

The transformation of Lean from a production philosophy through manufacturing to construction has been the topic of many papers, e.g. [23], and many different aspects have been brought to the fore.

Manufacturing will certainly fully comprise design and prototyping, but they results in a model only, which is to be multiplied later (and efficiently). In contradistinction to manufacturing, construction only builds one example, which are at the same time the prototype and the product. The exploration stages through conceptual design, evaluation, engineering and testing are prevalent. It may be claimed that construction is *place bound*, for instance in such a way that the physical cells that might be conceived for a factory that moves parts and partly finished products around is replaced by an artefact that *is* in itself the factory and thus needs to move the de facto cell with people and tools around. Interpreting *construction* quite literally, one might also see construction as an industrial process, which is heavily influenced of its social, cultural and in particular, physical surroundings. Also, it maybe distinguishable from manufacturing inasmuch as the product having to be used in the place where they were build, rather than in manufactured for use where- and whenever the customer chooses [20].

We may also indicate that the state of the art of Lean prescribes a bottom-up approach to planning, in which ones starts with weekly work plans and work upwards to the project schedule.

[1] A kanban is a message transmitted manually or automatically back upstream in the supply chain top signify depletion of a part that is needed to manufacture the product.

Communications about requirements and deliveries have to be personal and visible (à la kanban) and so are commitments, which are individually requested and given [20]. Moreover, in the same project management philosophy, the look-ahead to constraints needing to be alleviated in order to complete the tasks as indicated, and revise and elaborate the phase plans and the master schedule [20].

Moving to lean construction, we may also have to take into due consideration that the physical cells of production and the "designed layout" of the workshop floor which makes implementing some of Lean's principles rather intuitive, disappears. Lean construction extends the scope and need for visual inspection and human intervention with regards to quality control, the organization of work is virtual rather than physical and concurrent (re-)engineering becomes even more crucial. Its "sequentiality" is attenuated, compared to manufacturing. [24]

We want to add also, for future reference and study in the Next Ship project, issues of:

- Strategic development [25], e.g., of product lines
- Design [26]
- Planning [20]
- Decision-making [27]
- Risk management [28] and
- Communication and collaboration [29],

which are areas that each and one individually have been made the topic of research from a wide variety of academic and practitioner vantage points, including Lean.

Lean project management

Applying Lean to project management practices also seems to be necessary to make such guidelines relevant for shipbuilding, inasmuch as the planning stages and risk [crisis] management come across as crucial [20]:

- All product life cycle phases need to be considered
- Stages cannot be looked at independently of each other
- Product and process design is connected (which is some flavour of dialectics/historical materialism, perhaps), and
- Projects are governed through structuring work (planning) and controlling production.

Target value design is one approach, which both comprises many elements from lean (eliminate waste, do only the work that is requested), but also comes across as a set of management principles, and a philosophy that implements lean design/construction [29]:

- Objective of cost management: procure (construct) for less than allowable cost, using gain sharing (vs. minimize prize)
- Final cost vs. estimating tender limits
- Cost breakdown: Cost, profits and contingencies (vs. any cost)
- Set by feasibility study (vs. estimates)

- Functions change (innovation may be needed) vs. Cost change
- Interdisciplinary teams (vs. division of labour)
- Active client (vs. represented or distant)
- Project organization: value-based (vs. cost-based)
- Operating principles: Co-location (vs. project management tools)
- Contracts: Relational, incentive-based vs. transaction-based
- Risk management: Consolidated vs. risk-shifting down the value chain

Lean ship-building

The Norwegian shipbuilding industry pride itself by being able to build advanced vessels for demanding services offshore, which are delivered on time and an unsurpassed quality. The current distribution of construction work, typically with the bulk of steel work and welding to create either modules or a complete hull abroad [30], may be interpreted as evidence that the approach is too costly, however. There are historical reasons as well as demographic and structural explanations, for Norway's success in the maritime sector. For instance, there is a well-functioning maritime cluster, which in its turn may be bolstered by the distribution and activity of ports, as well as the geographical vicinity to rich natural resources [31].

The competitive advantages of a region are never guaranteed to last, of course, and international capacity to deliver hulls and modules will potentially form the basis for stern competition in the future. Thus, cost and speed of delivery will continue to be significant areas of improvement, in order for the lead in the *offshore specialized vessel* category to be maintained. It is in this perspective that the turn towards Lean shipbuilding needs to be assessed. There seems to be limited empirical evidence that Lean will, as such, cut costs [32], however, like most management strategies, implementation is probably more important that theory.

The major elements of Lean, in the shape that they take when they are made in particular applicable to shipbuilding, is in one instance referred to as [33]:

- Precisely specifying the value of each specific product
- Identifying the so-called "value stream" for each product
- Make the value flow uninterrupted
- Let the customer initiate transaction (pull)
- Pursue perfection, reducing effort, time, space, cost, and mistakes while offering a product that keeps on converging towards the ideal for the customer.

There are several additional traits, which concern Lean in construction (rather than manufacturing), however, which also needs to be considered carefully for shipyards looking towards Lean as an organization principle for their production:

- The site itself is a resource.
- The production facilities have to be set up anew for each new build; indeed, the building project is in itself the production facilities.

- The production facilities as well as the teams and workers, are placed on the site and in relation to another.

In addition to this, there are other adaptations (and effects) of Lean thinking (with its origin of Lean manufacturing), that has been proposed in order to pitch it more suitably for construction type processes:

- Objectives need to be well and fully understood.
- Cross-functional teams may be concurrently active in the value stream.
- Design is likely to be shifted along the value stream, i.e., it is not all done up front
- Cycle–times are reduced
- Continuous improvement ought to be an integral part of the process

The problem, of course, is that these are not easily operational assertions.

On quite the other end of the scale, towards concrete recommendations and techniques, we find e.g., the notion of measuring waste and efficiency by "percentage completed of planned work (PPC)" (per week), which is promoted by Ballard [20], together with the notion/tool of "last planner" and look-ahead planning, using [34] :

1. PPC efficiency metrics
2. The last planner principle
3. Look-ahead exercises; the purpose of which is to smoothen work flow and maintain a suitable backlog of assignments that are sound, i.e., that the actors themselves judge to be executable *or* that the contingencies necessary to make the activities sound are identified and workarounds proposed.
4. Bottom-up planning, i.e., that the look-ahead plan and last planner inputs are allowed to shape the master and phase schedules.

In the next section we shall look at how the historical origin and the basic tenets of Leans is "lived" at a Norwegian shipyard, which is specialized in offshore service vessels.

Empirical studies

We have attended several meetings at STX OSV (as well as other shipyards previously) concerning the production process in general, documentation and planning more specifically. In the following itemized list of observation, the impressions from our fieldwork is linked to Lean guidelines:

The notes indicate that ship-building, in general, as well as observably at STX OSV, might still altogether be a long step away from truly implementing Lean production philosophies, inasmuch as:

Referenced principle	*Comment*
1. Long-term philosophies *do not* govern short-term strategies	The tasks assigned to an assembly yard in Norway is not long-term strategically decided, but rather a judgment of capacity in the short-term, which is made by the board of the group rather than the director of the local yard. This does not seem

	to be part of a long-term philosophy.
2. Creating a continuous flow is hampered by the product-as-site nature of construction at the shipyard	The so-called Toyota-way calls for a continuous flow, which is the conceived non-interrupted and monotonously forward-driven nature of a process. It is problematic to implement in a setting that has some very large (and relatively few) critical process steps or machines in place, which is typically the case for shipbuilding with its cranes and docks. Typically, a situation was described to us in one of our meetings, which entailed the blockage of physical movement of one module by work on another. Finally, striving for continuous flow would seem also seem to try to reduce the change orders, since they by definition introduces back flows. Such back flows, on the other hand, are associated in shipbuilding with high-value work carrying better margins than work that proceeds according to plan, and hence it may be more difficult to eliminate, notwithstanding that there was not any indications given that the relationship between continuous flow and lucrative back flows had been explored in detail. Also, there was a distinct cultural explication of the differences between yards in Norway and e.g., Romania, which in which the local yards were described as having more of an artisan (in contrast to industrial) history and hence, intuitive eye for shipbuilding, which made local workers understand intention better. This is a notional approach, which in addition travels poorly since distance and differences (cultural or otherwise) makes it more difficult to communicate. This part of our field work observation, regarding communication is not the only pertaining component. In addition is was recounted how the drawings were never finished, for various reasons, 3D drawings are poorly translated into 2D instructions, since the former is concluded in a more holistic way. The main point to notice here is not the explanations, but rather that the *expectations*, which thus reified the notion of a cultural difference, was that the steel yards in Romania needed precise drawings and instructions in order to do their work without waste of time and materials, whilst the Norwegian yards excelled exactly in managing well without those detailed drawings. The same argument covers plans and planning as well, and is observable by the statement that “ideally, our mangers want to be handed a plan that says ’build ship’”, and the non-informativeness of planning. The latter can be seen in two way, first that plans are usually re-used on the macro-level, when they look like component lists, and relatively static and non-communicative on the lower levels. Again, the issues of communication is brought to the fore.
3. Using “pull” rather than push to avoid stocks and overproduction, may jeopardize supply security	The need to secure deliveries of very large and sometimes complex (or both) goods, which are not necessarily available from a production line with unlimited capacity (such as thrusters, streamers, lighting and subsea capacity), stocks are necessary in ship production

4. The workload is probably quite conjuncture-dependent (making Heijunka unrealistic)	The workload is at the macro level not under the control of the shipyard, it may just as much be seen as due to the oil price (a little crudely stated, but still), and in addition the board of the STX OSV group decided on short notice where and when to allocate new builds to the yards. On top of this, repairs and modifications arise frequently; the after market is important as well.
5. Repairing at once when errors are found may be incalculable vs. risk, cost and the future development of technologies and policies.	Even if errors are known, they may not be repaired at once, since the "cost of repair" is excessive compared to the cost of delays. For instance, a steel plate which is cut to small may only be repaired by welding, an operation which may wait until assembly since the amount of welding work needed is likely to be defendable. On the other hand, the "broken" process might have been repaired, but only if the error is recurring or more expensive than delays of this particular construction project. Moreover, it is in that light one needs again to inspect the "cultural differences" (drawing on a valuation of accuracy vs. independence of workers vs. the cost of man hours), indeed allowing it to reflect back on the reason for using the subcontracted "inaccurate" cutter in the first place. If an improved process raised the cost, it seems reasonable to expect that the customer will look around for other options, which are cheaper. On the other hand, later builds may require different subcontracting policies or production processes and new technology (for automating welding, e.g.), may be in place *anyway*, so that in this regard, the uncertainty of making the error-correction decision is higher than it might seem at first glance. For instance, the group may decide to tender work at an independent yard later, in which case the "repair" of flawed cutting would have to be seen as a waste in itself, under Lean terminology.
6. Standardized tasks are needed for improvement and empowerment, but may be elusive	Given that the workplace is also the storage *and* part of the constructed mechanical structure; that it develops therefore throughout a process which is subject to variation due to the paradox of variation of parts if stock is eliminated vs. the lack of slack in space and suppliers production capacity, which may be strained, as well as the manpower-demand which is great overall, but not usually a static resource (people will be sick, take holidays and retire, require (re-)training or attend to their families during projects that go on for a year or more), tasks are less likely to be standard-izable.
7. Bringing problems to the surface may reduce flexibility and trust	The initial response from subjects that we have talked to in the shipbuilding industry has throughout the project period been that "everything is under control". This is understandable. Products are complex; construction is completely delegated and orders, as well as funding relies on trust. On the other hand, problems do, in fact arise, and hence it may be concluded that increased transparency reduces flexibility. Visualization (and documentation in general) must be seen in light of this.
8. Using known technology is	The tradition of shipbuilding as a manual craft comes through

sometimes seen as backwards and defensive	clearly when we discuss the usage of integration service hubs, such as those implemented on top of Sharepoint (eventually to be complemented or replaced by Aveva). The tools seem to be less familiar to management than might be expected, if, indeed, the planning and process management aspects of the job is being upgraded to support lean construction and next generation planning techniques. On the other hand, management is expected to exploit the commercial potential of new technology.
9. Educate leaders and employees takes time and is part of a larger dynamics	In our field work, STX OSV has provided an account, artefacts and demonstrations of a competence-oriented management style, in which people are constantly made aware of the core elements of lean shipbuilding. The interpretation of Lean (at the management side) varies from text book explication, however, and foremen and workers differ in the next instance even within what they have been taught. Evaluation of the learning outcome seems necessary.
10. Respect and challenge partners and suppliers; this is an ideal (human) ambition that is always challenging.	The relationship between the STX OSV yard(s) in Norway and their Romanian partner yards seem to still being in formation, and it was being characterized by differences in history, tradition, culture and technology, as well as economy. The full ramifications of this has not been explored or described by our project, so far, but this is certainly one issue that should be put on the agenda. This was no indication that strategic or operational management had fundamentally different values from their employees and subcontractors locally.
11. Investigate personally (Genchi genbutsu); this seems to be bolstered by a strong management culture	The management of STX OSV has a deep personal involvement and is willing and able to carry out necessary research and analysis activities, insofar as we have been able to discover.
12. Make decisions slowly, implement them rapidly; decision-making and the realization of decisions is multi-faceted	We have not been able to discern details about the decision-making process, but there have been indications going both ways, on the concrete and instance-based level of allocating jobs (builds and repairs) to the yards, as well as varying commitment to “lean” among middle-level management, which may indicate that the decision in favour of the approach might need even better anchoring.
13. Support relentless reflection (Hansei) and	We do not have the necessary insight to assert that the level of reflection is neither unsupported nor relentless. The participation of STX OSV in the Next Ship project is a positive sign.
14. Support continuous Improvement (Kaizen)	The activities of STX OSV that we are being exposed to in our research are a positive sign in themselves.

Similarly, we may move on toward even more concrete recommendations of implementing “lean” in construction, adhering to more operational guidelines:

Referenced guideline	*Comment*
15. Precisely specifying the value of each specific product	This element is probably in need of adaptation and translation to the specific circumstances of shipyards. What is

	for instance, “each product”?
16. Identifying the so-called “value stream” for each product	This is possibly implemented in the “earned value” approach to planning, however, we did not find it widely operationalized during our short field study and visits. This should be further researched.
17. Make the value flow uninterrupted	Today, there are interruptions, as commented above, largely due to extraneous factors which are not easily eliminated.
18. Let the customer initiate transaction (pull)	Inasmuch as the entire value-chain needs to be handled inside the same paradigm, it can be necessary to note that even the customer does not in a one-side fashion, represent a definite and unequivocal “pull”. Ships are sometimes ordered to secure a slot in the production capacity system, moreover, owner know that the sales/contracting efforts that they have to start (and conclude) before ships are finished, may require the specifications to be re-written, and so does the yard. On a lower (more downstream) level, the yard itself has to order work and parts before the drawings have been finally approbated, even if they know this is likely to lead to redesigns. A completely non-concurrent engineering life-cycle would take too long time to complete. The yard also has to secure production capacity with suppliers, and thus, order might need to be placed in a slight “push” rather than wait until they are pulled. The “product” in question is not only (or even mainly) a physical artefact that is “needed” in a concrete and given form, the sales efforts may be initiated further upstream, by a design office, consultants or even the yard itself, if they have contracted a ship from themselves to cover by risk and belief that the in the right time a buyer will be available.
19. Pursue perfection, reducing effort, time, space, cost, and mistakes while offering a product that keeps on converging towards the ideal for the customer.	The idea that there exists one ideal product for the customer seems ambitious, in a situation where market demand, financing and technology vary. These core factors need to be analysed with regards to decision-making under uncertainty and perhaps in relationship to each other, in particular. One may in general suspect that uncertainty is largely ignored [35], which may [ibid] be brought to the fore in such analytical endeavors, which complement the traditional planning orientation.
20. Objectives are well and fully understood	We have had no opportunity to gather information about the extent to which objectives are shared, but we received indication that the group structure might be more brittle than name and logo might indicate. Yards within a group (notwithstanding the relationship with suppliers and partners who also have competitive bids going with other yards) may in the future be competitors again (we were told), in the event of a breakup of the group, and the employees are aware of it. Moreover, we do need to ask if the objectives of management who wants a more predictable process and less expensive vessels produced in semi-series, are shared by their staff, suppliers and subcontractors, and indeed, if it is shared by the customer.

21. Cross-functional teams are concurrently active in the value stream	We have reason to believe that this is the case.
22. Design is shifted along the value stream, i.e,. not all done up front	This is a critical issue, which we perceived was *de facto* the case already (i.e., the steel yards and outfitters had to improvise and adapt to deal with the dynamics of the supplies, technology and incompleteness of drawings at certain stages). On the other hand, tension is raised, potentially. Management will want to implement a predictable process, which, given that it is one-off (largely) one cannot expect. Repeat construction (manufacturing) may be tunes and empirically estimated with precision, but the same is hardly the case for big, unique projects.
23. Cycle –times are reduced	There may be a lack of realism inherent in the usage of the term ”lean shipbuilding”, at least unless one manages to unite around a goal of building many-copied, simpler designs, comprising more standardized solutions and mainstream components and technology.
24. Look-ahead, the purpose of which is to smoothen work flow and maintain a suitable backlog of assignments that are sound, i.e., that the actors themselves judge to be executable or that the contingencies necessary to make the activities sound are identified and workarounds proposed.	This level of rationality and oversight is definitely an aim to strive for, however, it may be difficult to achieve given the incompleteness of information (which points towards a judgement of non-sound activities) vs. a multi-stakeholder universe in which each actor is not, as it were, free to make such calls independent of other and more powerful agents.
25. Bottom-up planning, i.e., that the look-ahead plan and last planner inputs are allowed to shape the master and phase schedules.	This is an expression, as we see it, of the need in planning to be responsive on the top of an appreciation of inter-team communication [36, 37], which has been relative well attended to as part of the lean literature.

One of the current most precarious need of a modern shipyard, is to be able to monitor, record and analyse progress, insofar as that sets them up for being able to deliver the vessel that was specified on the date that it was promised. We have also shown that it is an industry which is variable, indeed that it makes a good earning from change orders, within the Norwegian maritime cluster that it needs to be innovative and responsive, in order to compete with low-cost countries, and hence that Lean may not be the most appropriate way forward, according to some research [19]. On behalf of Lean, on the other hand, it may be seen as encouraging that other projects of a similar nature have enjoyed great success with Lean, allegedly, and that measures have thus been proposed to deal with the inherent complexities of small lot, high complexity and value adding engineer-to-order and manufacturing, such as *last planner, weekly work plans, look ahead processes, phase scheduling* and *evaluation (learning from failure) [20].*

State of the art of Lean today may also be seen as playing a pivotal role in the transition from very traditional, mechanistic and top-down "pre-emptying" approach project management, into an agile and situated approach to project management, which is typically described as more organic and bottom-up ("sourced"). Classical project management, thus, is based on the assumption that the plan somehow does reflect the state of affairs, and that changing the plan will (contribute) to changing that external world. Hence, it also follows that if the plan is inaccurate or wrong, it is due to errors, lack of insight or information or a change of direction, and that it needs to be continuously updated in order to serve as a map of future processes as well. The opposite perspective of planning, which is not particularly new anymore either, is that plans are resources that more or less productively are used by members of the organization to indicate, and indeed, plan what they want to do, but that in actually doing they respond to the concrete and detailed circumstances of the setting that they are in, matching the map with the new reality rather than the other way around. Hence, a map may be a more or less accurate representation of what has been going on, but it is not useful in a normative way [38].

The most crucial aspects of "Project Management 2.0", which is where this transition is the projected to end up, is to establish [39]:

- A shared global awareness of a dynamic situation: This entails rich and meaningful information being exchanged continuously between members of the organization, who may have to be advanced users of communication solution in order to get the data that they need without suffering information overload.
- Rapid responses to unexpected events, which is made possible by highly motivated and competent workers combining local resources based on a global overview, and the urge to create value for the client and minimize waste, hence adhering also to the principles of lean construction.
- There is, arguably, a relationship to plans, when authors talk about inspection intervals, and clearly, the lengths of cycles as well as testing and inspection represent approaches to dealing with uncertainty and risk. Batch sizes and the numbers of *kanbans* are also, according to some researchers, like Parveen and Rao [22], linked to the consideration that rework can and will take place.

Thus, even in the "lean" case of STX OSV, it might be fruitful to look at the investment needed to maintain optimal inventory and the mutual auditing procedures (MAP[2]), which involve inspection, testing, rework, etc., not like "waste", but rather as a way of minimizing it.

Doing away with the tools/vehicles to minimize waste based on a misguided apprehension that these are in themselves waste is potentially a source of even more waste.

Discussion

Ship builders seem reluctant to implement the tight integration of the supply chains that is necessary for "just in time" to work. It could be because they worry about lack of confidentiality or the cost of

[2] This could perhaps be a conceptual contribution of Next Ship

communication [22] . In contracts to Parveen and Rao [ibid], however, we hypothesize that the co-ordination costs actually increase if they do not.

Quality control is a core part of lean, we venture that this is according to very narrow quality criteria, meaning low variance. The Norwegian shipbuilding-model, however, affords variation and improvisation, in order to stay innovative. This is another, non-translatable quality notion, to the one that is commonly discussed in "lean".

There have been other issues discussed elsewhere as well, e.g., the relationship between the supply chain and end user demand, which cannot be independent of each other for lean manufacturing to be possible, according to some [40]. Similarly, Cochran et al. claims [41]:

- Manufacturing needs to have a shared co-ordination mechanism, which contributes to reconcile the manufacturing strategy.
- Manufacturing needs to be accommodating the required flexibility.

We cannot help noticing the statement from STX OSV managers that sales and marketing accept and place orders at yards, regardless of their capacity and current working relationship further upstream towards the hull yards and manufacturing processes, which intentionally are not pitched towards flexibility (although the Norwegian yards are), which may implicate a permanent state of conflict, which Lean cannot possibly alleviate. We may also have to ask if the Norwegian "approach" as such is a turn against "lean" since it "buffers" suppliers contact through the maker's list, i.e., stops communication directly between suppliers and the customer [42].

Looking at the "just in time" aspect of lean shipbuilding, it seems that the advantages of "reduced inventories, reduced lead times, higher quality reduced scrap and rework rates, an ability to keep to schedules, increased flexibility, easier automation and better utilization of workers and equipment [22, p. 183]" , do not really apply in this domain, since objective the cost of any would be negligible compared to the cost of a ship, with one exception (which is contradictory to the others), and that is to keep the schedule. We may refer again to the field work, where we have heard managers at STX OSV several times quoting the importance never, ever letting the final delivery date slip.

Shipbuilding may be a particularly challenging domain onto which to implement lean systems [43], since they come from a tradition of fixed price and time contracts, which is at risk both with regards to the realization cost and profitability for the yard, but also because when requirements change, the variation orders, which may, indeed, disrupt the schedule and interfere with capacities planned for other projects, are still an opportunity for the yard to increase the profitability of the project [20].

Karolis and Oterhals in contrast, recommend simplification, visualization and information flow [43] as an approach to improve efficiency. They also comment on the lack of control of phases and their transition, and assert that this

[…] means a significant increase in project cost, disruption of workflow and planned work sequence, overburdening of workforce, which ultimately, can result in late delivery of the final product [43p. 325].

This supports our suspicion that a contradiction of objectives may strongly inference with the plan of becoming "Lean" among Norwegian specialized shipyards. A brief discussion of some core issues and aspects of this is certainly warranted.

Heijunka in Lean shipbuilding

There have been even more recent papers published on Lean in shipbuilding however, e.g. [44], in which it is claimed that

Whereas the one sided welding technology is implemented in the panel lines of the shipyards of most Western European countries, this in and of itself is not lean manufacturing. The implementation of one piece flow as opposed to creating large bed plates and then placing the longitudinals and welding is required. Determining steps necessary to transform traditional panel assembly to lean one-piece flow manufacturing is necessary. The waste that is inherent in traditional panel lines and which can be eliminated in lean panel lines includes overproduction, waiting, unnecessary motions, overprocessing, transport and inventories, and defects [ibid, p. 20-21].

It is claimed, in particular, by Kolić et al., that it is necessary to transform the traditional ship block assembly process with a "leaner" *one piece flow*, in which uniform plates are outfitted and wielded with longitudinals before they are assembled, rather than the other way around. This affords robotic wielding and leveled production to a larger extend, due to an equaling of *takt*-times when panels are not assembled until the transverse ribs have to be mounted.

Genchi genbutsu (investigate personally) in Lean shipbuilding

The tradition of Norwegian shipyards is for management to be delegated to the foremen and co-ordinators of individual builds. Expereince from the prelimiary investigations carried out as part of the action research part of Next Ship as well as other, related projects at Møreforskning Molde AS, indicates that there is potential to implement *Genchi genbutsu* as part of a Lean strategy. On the other hand, we were also told in explicit terms that strategic management and the large-scale resource allocation decisions (where to build, when to bid and commission, etc.) were made one-sidedly by the board of directors of the shipyard group, rather than local management. Thus, there seems to be room for a "leaner" approach, indeed, if this is judged to be a more important strategic imperative than short term meeting the requirements of the market.

Hansei (reflexive approaches) in Lean shipbuilding

Hansei means reflection and consideration, which indicates a consciousness of work and impact that work has on its surroundings. At least pointing towards the need for a wider perspective on learning and improvement, we might for this Lean guideline be able to indicate a need to look at the wider ecology of the supply chain and aim to support mutually beneficial learning across sites and firms, which are partners or customer-suppliers [45].

Kaizen (continuous improvement) in Lean shipbuilding

In the ambition of *Kaizen* (continuous improvement), there is usually an orientation towards encouraging and supporting all workers in inputting suggestions to how a step or a process may be improved. Similarly to *hansei*, it may in some instances prove more difficult to bolster such feed back from the factory floow, when incitement programmes and company cultures are as different as they

seem between a hull yard in Romania and an assembly yard in Norway. It seems productive in order to achieve such learning (from each other), especially on a deeper, double-loop level [46] that explicit mechanisms be but in place to bridge the differences between the yards.

Conclusion

The question needs to be asked, thus, in conclusion of this report, why shipbuilding seems to be different from other types of construction and engineering work, when it comes to implementing lean principles.

We have in Lean seen promoted a notion of so-called "sound" activities, and it seems reasonable to assume that the presence of each of the seven conditions for sound production will affect the ability to be "lean". These activity constraints are, in summary [47]:

Information needs to be present in due time, so that everybody can plan their work properly;

Previous activities have to be completed as planned prevents release resources upon completion;

Sufficient manning reduces the possibility of stress, improvisation and non-takt performance; Takt is the fixed-pace allotment of resources, which is sufficient to deal with the maximum complexities of any given subset of operation, and it is a notion that have also been studied with regards to implementing Lean in shipbuilding [15].

The *right equipment* and a *proper and well-organized construction site* also reduce the risk of disruptions.

It has been claimed that "sound activities perhaps make it easier to stay in the space of non-chaos [48]." It might be tempting therefore, to conclude that boxing in activities in a "sounder" landscape will make them leaner, however, one needs to carefully investigate the distinctly intractable nature of shipbuilding and the challenges thereof:

- The site and the product evolving throughout the project into a merger, inasmuch as the product (i.e., a vessel) in itself also becomes the space available to plan and conduct the work (the process) as well as storing parts and tools, even the lodging of workers. The external workplace ("factory") comprises large, inflexible structures such as cranes, docks, quays and
- Due to the "one off" nature design, engineering and supply-chain management takes place in parallel. Even of sister ships the learning effect is reduced, since
    - The work space is unique (yards usually cannot accommodate an assembly line of many ships) due to size, and work processes on the micro-level certainly, depends on the dynamics of the building taking place to create product that encompasses the work itself.
    - The building schedule is sufficiently long-lasting to on the on hand expect the optimal price-performance mix of components to change due to technological development and re-negotiation of prices, *and* the change of assignments by the owner due to

changing market condition, which in their turn implicates changes to the requirement specification. Indeed, owners may in high times order ships simply to have them in the pipeline, thus avoiding to have to battle for limited yard capacity once work orders comes in. One also has to bear in mind that these kinds of changes are usually the result of contractual change orders (COs), which are profitable for the yard.

- A high percentage of the value-added work comprises pre-fabrication and outfitting of modules elsewhere, before they are shipped to the commissioning yard for assembly and testing. Moreover, engineering to a large extend departs from a parts-list and a list of suppliers who have a long-lasting, functioning relationship with the yard. The robustness and "engineering-ability" of parts as well as safety of deliveries are probably paramount to cost and speed-of-delivery.
- A closely related point to the previous is that the advantage of geographical proximity between actors in a supply chain network, even in a global industry. This may be due to the innovativeness and competitive nature of the business, which leads to significant customization throughout the phases.

It might seem that the fundamental "logistical equation" is somewhat different, with regards to at least some of the "soundness" factors recounted above.

Our paper clearly points towards similar findings to those that some authors report from the building and construction industry [9]. They report that the removal of capacity from the system that is a result of Lean's ambition to reduce waste and increase the utilization degree of workers, also remove flexibility to deal with inherent complexity and uncertainty. On the other hand, we have also complemented and deepened this for our domain specifically, for instance by pointing to the differences between a host of factors that is sometimes glossed as "cultural difference". Is has been simple to see that the strategic ambition of developing a "lean" and low-cost steelyard, which has voluminous and traditionally tiered organizations abroad, sits poorly with the opposite heritage and pride to be pre-dominantly a design- and assembly-yard at home, in terms of role and management-structural modelling

This report is intended to provide input to a further discussion of these issues in the Next Ship project, to even more clearly establish the fundamental differences (and similarities) of the maritime cluster activities and firms in our region vs. more trivial construction and degrees of mass manufacturing. There are, in conclusion, many ways of becoming "lean", and it is interpreted and implemented differently depending on its target domain and ambition. Moreover, the scope of the implementation process, e.g., with regards to the degree of which it includes the entire supply chain, is variable and influential. Indeed, for further research this dimension should in and by itself be included as a research topic, as should other reasons and effects of companies and their managers claiming that Lean constitutes one of their core values and intentions.

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MØREFORSKING
MOLDE

MØREFORSKING MOLDE AS
Britvegen 4, NO-6410 Molde

Telefon +47 71 21 40 00
Telefaks +47 71 21 42 99

mfm@himolde.no
www.mfm.no

Høgskolen i Molde
Vitenskapelig høgskole i logistikk

HØGSKOLEN I MOLDE
Postboks 2110, NO-6402 Molde

Telefon +47 71 21 40 00
Telefaks +47 71 21 41 00

post@himolde.no
www.himolde.no