INTEGRATION OF COLLABORATIVE LPS-INSPIRED AND RATIONALISTIC PLANNING PROCESSES IN MECHANICAL ENGINEERING OF OFFSHORE DRILLING CONSTRUCTIONS

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ABSTRACT

Our focus in this paper is the design of LPS-inspired planning processes in engineering in a case taken from the mechanical offshore oil and gas construction industry. An integrated project engineering delivery system based on design and engineering theory is presented in the paper. Our conceived operationalization is based on a combination of traditional rationalistic models and iterative and inclusive approaches like the ones found in the Last Planner System.

The developed model is being tested out in a company setting in an ongoing study, and what are presented here are our preliminary findings. We have uncovered a need for considerable changes, above all to the phase plan and lookahead plan, both of which need radical rethinking to be applied in engineering. Limiting the phase planning timeframe to a few weeks, focussing on detailed milestones based on different levels of maturity in the engineering knowledge that emerges is suggested. A significant finding is that within engineering, it often seems necessary to rely on "making do" as a way of working; hence, the criteria for declaring activities sound must be adjusted accordingly.

This paper is a contribution towards better knowledge about challenges associated with implementing LPS-inspired planning processes within mechanical engineering in the offshore construction industry.

KEYWORDS

Engineering, Offshore construction, Mechanical industry, LPS, Quality Control

INTRODUCTION

Offshore projects tend to be large-scale, the financial impact of delays is significant, and the environmental and human consequences of engineering failure are likely to be very serious. Severe accidents offshore have provided the impetus for several improvements of technical safety regulations (Kalsaas 2013). Engineering for these conditions may be bordering on the extremes of previous experiences with drilling depths, climate and wave conditions, and fire risk. Due to the context, a strict QA and QC[2] regime applies to offshore construction projects.

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[2] The NORSOK STANDARD S-001 on technical safety applies to the oil industry on the Norwegian continental shelf. The classification society DNV has its own standard (DNV-OS-A101); this is similar to the NORSOK standard, and applies globally.

On the production side, the industry seems to use planning strategies inspired by "stage gate" (Cooper 1988) and "waterfall" (Conklin and Weil 1998) models. Christensen and Kreiner (1991) have characterized this linear approach to planning as rationalistic. In their most exaggerated form, such models are based on the machine metaphor with a focus on optimization within the triple constraints of time, cost and quality (Tryggestad 2012). Experiences with rationalistic approaches have shown that they fail to capture the dynamics often found in Design Engineering, where knowledge and problem solving develop gradually in learning processes based on experience (Kolb 1984; Kalsaas 2012). Conklin and Weil (1998) illustrate this in what they call "the earthquake", where problem comprehension and problem solving takes place during all four phases of a waterfall model: 1) gathering data, 2) analyzing, 3) formulating and 4) implementing solution.

This is the background against which more iterative and inclusive methods for planning design and engineering must be sought in order to improve the predictability and quality of drawing deliveries. And this is where "LPS-inspired design" comes in as an alternative to the rationalistic approaches to organizing and managing engineering processes. Other collaborative directions also exist within planning, such as "Scrum" (Schwaber and Sutherland 2011), characterized by some authors as "Agile planning" (e.g. Wysocki 2009). Lean Project Consulting have launched what they describe as "Responsibility-based Project Delivery"[3], a concept aimed at Design of onshore construction projects that builds on Scrum and agile adaptation (Macomber and Bettler, *undated*) combined with ideas from Lean. The Scrum methodology is taken from the IT project discipline, whose knowledge processes have many similarities to those found within engineering.

Hence, **the research question addresses how to develop an integrated project engineering delivery system based on design engineering theory.** The fact that we use design engineering theory as our starting point distinguishes our approach from the generic project management approaches, such as stage gate, waterfall, PMI's model (PMI 2013), etc. Furthermore, our approach accords with Ballard and Koskela's (2012) idea that the starting point for theory about management should be sought in production, not in management and organization theory.

Important requirements of such an integrated delivery system is that it must ensure necessary control of quality, progress and cost while including the iterative and inclusive approach adapted to design and engineering understood as learning and knowledge processes. This means integrating not only iterative concepts, but also linear ones, as the latter are considered necessary for the ability to report on progress, cost and quality. The Last Planner System[4] does not include such functionality.

The method used here is based on action research (Reason and Bradbury 2008). We are in the process of introducing an engineering management system of the kind suggested above in a case company, as part of a company project named "Inclusive Planning Execution" (IPE). The work is ongoing; thus the focus of this paper is to discuss the model upon which the work is based, and to report and discuss experiences from its implementation so far.

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The case company for this development work – described henceforth as "the Vendor" – is a supplier of engineering, fabrication and installation of mechanical structures for the oil and gas industry. Typical products are various types of mechanical modules for drilling rigs and ships, for example mud modules, derricks, drilling floor with sub-structures, and other topside modules.

In the following section of the paper we focus on the phenomenon of engineering design before describing and explaining the operationalized integrated engineering project delivery model. This is followed by a presentation of findings from the studied case related to theory on design engineering in general, and findings that are specifically related to the proposed model for integrated engineering project delivery.

THE NATURE OF DESIGN AND ENGINEERING WORK

With the traditional linear planning models in mind, Reinertsen (1997) argues that existing descriptions of the nature of design do not reflect the practical world. This is in line with Austin et al. (1999), who argue that traditional planning techniques are not suitable for design work because they are incapable of dealing with iterations in the design process. Koskela et al. (1997) found clear evidence in their review of the literature that chaos and improvisation are substituted for planning and control, leading to flaws. Ballard (2000) introduced the concepts of "negative iteration" and "positive iteration". The starting point for positive iteration is that in order for alternative solutions to be understood, good designs must be produced for the incomplete or provisional outputs.

Reinertsen (1997) argues that the due-date delivery problem in design is rooted in the general variability of the design process. Arguing that probability distribution functions should be used to describe the duration of activities, Vatn (2008) follows up on this point. According to Reinertsen's (1997) data, the design effort ceases when the designers run out of time. This can be interpreted as meaning that the ideal solution is unattainable, and that decisions must be made in terms of what solution can be regarded as good enough (Bølviken et al. (2010).

Male et al. (2007) identify three problems that are particular to design, namely: 1) requirements are often vaguely stated and interpretations of problems are subjective; 2) problems become progressively clearer as solutions evolve; and 3) the process is multidimensional, highly interactive, and represents the interests of many stakeholders.

Winch (2002) describe the challenge in construction projects as the "wicked problems", these are problems that are uncertain in the sense of being ill-defined and without an optimal solution, which can be linked to the involved dependencies between disciplines. Thompson's (1967) concepts of dependency and coordination can help create a deeper understanding here. Thompson distinguishes between sequential and reciprocal dependency, identifying the coordination technique tied to the former as planning, and to the latter as mutual adjustment. Kalsaas and Sacks (2012) argue that planning often fails to produce the desired result as a result of failure to understand the qualities of the different dependencies involved. When Smith and Eppinger (1997) describe coordination as negotiation between technical specialists, this exemplifies mutual adjustments, which we regard as a fundamental coordination method in design. At the same time, however, more traditional planning techniques must also be used in order to handle the sequential dependencies.

Ballard and Koskela (1998) argue that design processes should include three perspectives: conversion, flow and value generation. In terms of method and practice, the conversion perspective is associated with WBS (work breakdown structure), CPM (critical path method) and organizational responsibility chart; the flow perspective with rapid reduction of uncertainty, team approach, tool integration and partnering; and the value generation perspective with rigorous requirement analysis and systematic management of customer requirements.

THE ENGINEERING CASE

The Vendor's engineering department deals with the disciplines of layout, main steel, outfitting steel, pipes, pipe support, weight control, electricity, IT, HVAC, and technical safety. Main steel is typically the first discipline involved. It depends on information about the machinery to be installed and used on the completed platform, such as winches, rough necks, pipe handling machines, etc. Next in line are the major pipes and cable ducts which connect the drilling equipment and the outfitting steal, whereas minor pipes and cables are routed around the main structures. Escape and access routes during the operation phase are an important part of the final layout. Moreover, pipe support constitutes a crucial interface between steel and pipes.

The main case described in this paper the Vendor engineer modules for a drilling vessel. Decisions are yet to be made as to who will fabricate the designed and engineered products. The Vendor is part of a long supply chain, whose end customer, a Brazilian oil operation company, has contracted out the design work to a specialist naval architecture and marine engineering company. This company has contracted out the equipment design to a drilling equipment supplier with global operations; which has in turn contracted out some of the work to our case company, the Vendor. The main case has a budget of 76,000 engineering hours (approximately 10 mill US dollars) for the Vendor.

The engineering process means that the customer provides the Vendor with a concept and a set of requirement specifications. These include elements such as a rough sketch of the location where the drilling equipment will be used, and functional requirements following from the conditions that will be surrounding its use (ocean depth and geography/climate). Based on the provided information, the Vendor will start to build a 3D model. Fabrication feasibility is an important concern when engineering solutions are chosen by the Vendor. However, this concern must be carefully weighed against user interests tied to the finished product – including HSE solutions – which are determined during the design phase, and encompass the lifespan perspective. These are important aspects of delivering customer value, which is a central concern in Lean Construction.

OPERATIONALIZATION OF THE INTEGRATED PROJECT ENGINEERING DELIVERY SYSTEM

The operationalization is illustrated in Figure 1. The types of plan mentioned in the figure are as follows:

- Level 3 plan: A rough milestone plan that is included in the contract with the customer / the letter of intention

- Level 4 plan: A strategic network plan. Budget figures are linked to the main activities. Used to report back to the customer on progress and financial status, and for internal control of costs and progress.
- Phase Schedule: This is a multi-disciplinary iterative planning process which uses the method of reverse scheduling. The idea of the reverse approach is to generate upstream pull in the value chain, both internally and externally.
- Lookahead schedule: Its main purpose is to certify that activities are sound before they are implemented, and make up an arena for registering changes. The schedule is prepared and updated at interdisciplinary meetings, and the focus is on dependencies between different disciplines.
- Action plan: This is a plan for the week during which the work is implemented. Each discipline prepares an action plan – a schedule of activities – for its own employees. The plan is prepared by the head of the discipline in cooperation with his or her team members.
- Quality Control: Engineering has prepared the use of a commissioning system (PIMS) for its detailed follow-up and quality control.

The level 4 plan is a traditional CPM-oriented plan made up of tasks and milestones represented as a Gantt diagram. The Quality Control System, PIMS, is based on using work packages as input, and then applying stage-gate logic to monitor and control these packages throughout all phases of the design process. The phases can also be regarded as a value chain for design objects, and there is quality control of every link in the chain. The iterative and inclusive elements of the operationalized system are the phase plan and the lookahead schedule.

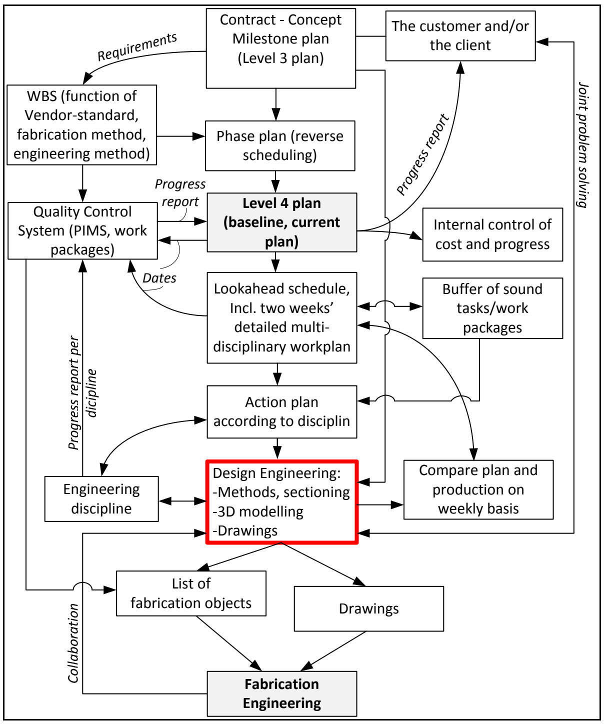

Figure 1: Operationalized integrated project engineering delivery system

In terms of the three perspectives proposed by Ballard and Koskela (1998), the Level 4 plan and the QC system represent the "conversion" perspective; the phase plan, the lookahead schedule and the action plan represent the "flow" perspective; and the "value generation" perspective is captured in the translation of the customer requirements into engineering method, and in the collaboration with the customer during problem solving. The routines for reporting back to the customer can also be seen as part of this third perspective.

The QC system is not a planning system, and dates for the work packages are derived from the Level 4 plan, which is prepared on the basis of the phase plan. The Lookahead schedule process is used to update the set dates in the QC system in our operationalization. Each engineering discipline reports on its progress in the QC system, and reports from this system are imported into the Level 4 plan, under which periodic reports about progress and costs (time use in relation to budget) are submitted, according to contract, to the customer. Work packages identified in the QC system are declared sound in the Lookahead schedule. Furthermore, buffer activities are identified in the Lookahead schedule, which provides input of sound activities to the Action plan. A comparison between planned and implemented activities is also included, as illustrated in Figure 1.

FINDINGS

This section is divided into two parts. The first of these deals with findings related to the theories on design presented above; the second discusses preliminary findings related to the process of implementing the integrated project engineering system.

DESIGN ENGINEERING

It has been confirmed beyond doubt that understanding of problem scope as well as ideas for possible solutions develop gradually among the participants across the different phases; it thus makes sense to speak of the knowledge involved in terms of different levels of maturity. This confirms the theories referred to above. The implications of this for the declaring of activities as sound will be addressed below.

Furthermore, we find that there is considerable cooperation aimed at solving engineering challenges two tiers upstream in the Vendor's value chain in this project, which includes the Vendor's customer, the drilling equipment supplier, and the main contractor for the client. The Vendor's engineering manager finds the project very engaging since what the customer wants is clearly expressed, comparing it to another project where the customer had few visions beyond wanting a drilling vessel that would be approved by the actual classification society. In the case project, the perception of the engineers is that they learn a lot from the joint problem solving process. This collaborative process is also very central for value generation; confer the three perspectives on a design process.

As to the point that the ideal solution is unattainable, an experienced project manager claims that in his experience, engineers manage to reduce the weight of the drilling vessel or platform if allowed extra time. This is important for the end product and for the amount of steel eventually used. However, allowing the process to include this extra weight-reducing stage is not always possible for budget or progress reasons.

Furthermore, this project confirms that customer requirements are often vaguely stated and that for some elements, no scope for some elements is provided until far into the project. In a system where everything is mutually connected, this can generate many technical changes at a later stage. In one case the engineering manager refers to a meeting with a customer and the customer's client that lasted several hours but resulted in few if any decisions, interpreting the problem as a case of Mr X being unwilling to make decisions because he feels that there is too much uncertainty involved. The Vendor's engineering manager relates that "a full overview is only achieved when the engineering project is virtually ready for delivery", arguing that the work must concentrate on minor technical matters, temporary decisions must be made on the basis of these, and iterative work must be done on minor as well as more major aspects, systematically removing uncertainty. In addition, there may be commercial interests tied to late decision making on the customer side, as it might saves the cost of having to pay for changes.

It hardly comes as a surprise that reciprocal interdependency is a major aspect of the engineering process. A couple of handfuls of different engineering disciplines are simultaneously working on the same object to gradually ensure that the solutions for its different parts and larger units become more mature, making the mutual adjustments achieved through formal meetings and brief but frequent informal conversations throughout working hours on a daily basis across different disciplines absolutely essential. Especially during the early phases, the engineering work is a matter of trial and error in the search for potential technical solutions to the problems defined by different disciplines, not only one's own. When this is achieved through mutual adjustment, it can be associated with "positive iterations".

Preliminary experiences in the effort to implement the integrated project engineering delivery system

Many weeks into the work on the main engineering project studied in this paper, a contract had yet to be established. Combined with numerous delays on the part of the customer, the lack of a contract created a degree of planning uncertainty. An agreement ensuring that the Vendor is paid for the work done was, however, in place.

The engineering project consists of four modules. Initially, a phase plan was made for the engineering of a mud module. The plan had a timeframe of 4 months, and was prepared in the traditional way of establishing milestones and placing activities for the different disciplines sequentially on the timeline. In reality, this plan has collapsed, and could barely be used even as a basis for the Level 4 plan. There are many reasons for this. One reason is that no suitable engineering WBS had been established. This must be understood in light of the fact that the engineering department had no previous experience of managing projects in a detailed manner. Furthermore, it would appear that detailed planning of engineering activities beyond a horizon of a few weeks is impractical due to the inherent variability and the need to take into account that problems become progressively clearer as solutions evolve. In the phase plan we identified a large amount of necessary information that must be collected before the engineering work can begin. We also saw, however, that the work commences even without this case-specific information, building on the experience gathered from past projects, especially by the most experienced engineers.

A phase plan for a Top Side (TP) module has later been prepared. As a basis for this work, the engineering department decided to divide their engineering work into four phases: 1) Layout, 2) Design, 3) Detailing, and 4) Drawing.

In the work of making a phase plan for the TP module, we made changes based on the experiences from the failed first phase plan attempt. We now established a rough milestone plan for the entire project period, concentrating on the nearest milestones. Two maturation levels were defined for the Layout phase: ML1 and ML2. The content of these milestones was also defined. In other words, we answered the question “What engineering must be completed at what maturation level for the different disciplines?” This was done jointly three weeks prior to the deadline for ML1. As it turned out, ML1 collapsed for all of the disciplines except main steel, whose clarifications for continuing the work towards ML2 had been secured. The rest of the disciplines were still waiting for vital information from the customer. This also suggests that there may be good reasons for differentiating the milestones along discipline lines. Furthermore, it shows that in this type of mechanical engineering, what matters above all is that the main steel engineering work can continue, as it lays the basis for the other disciplines. Release of sections for pipe support can serve as another important milestone of this type.

Another experience from the phase planning for TP module is that when we asked “what must be done in order to succeed at meeting ML1”, the disciplines produced responses that included a series of actions, such as meeting the customer to produce decisions and requirements regarding structural loads, etc. In our model, such items belong to the action plan, not the Level 4 plan.

Despite several attempts, we have not yet succeeded in activating the Lookahead schedule. One reason is that the QC system has not been sufficiently integrated; another is the continuing uncertainty linked to lacking information and decisions from the customer. The designed concept for declaring activities sound in the engineering lokahead rests on four factors: 1) external information, 2) internal information, 3) preceding activity, and 4) staffing. In terms of factor 1, we are faced with the dilemma that we must expect the information to be limited. Thus it is rather a matter of whether sufficient information has been made available for commencement of the work to make sense, and to proceed from there, possibly in collaboration with the customer, to increase the maturity.

We see that engineering is different from fabrication and physical construction in the sense that in those areas, work should not be started until all of the seven flows are in place, in order to avoid the waste-generating mechanism of “making do” (Koskela 2004). In engineering, “making do” can be regarded as part of the normal work process of design engineering, provided that it is a matter of positive iterations.

Thus far into the project, reporting on costs and progress from Level 4 has not yet commenced. This is due to the fact that we have not yet progressed sufficiently in the endeavour to integrate the QC system with the other elements.

The planning meetings are integrated with weekly technical design review meetings, and during discussions between the disciplines of different technical solutions relating to the 3D model projected onto a wall, actions and needs for decisions are simultaneously and collectively identified and written down on a whiteboard. This seems to function adequately.

CONCLUSION

Based on experiences from implementing the proposed integrated project engineering delivery system so far, we have identified some necessary modifications to the operationalized system. The improvements should focus on establishing milestones defined according to content and discipline, and on identifying the actions required to reach these milestones. The necessary actions and decisions must be detailed on a rolling basis and limited to a short-term perspective of no more than a few weeks. Identifying additional milestones for the different phases based on different levels of maturity still remains. This also means that the actual engineering activities should play a relatively less important role in phase planning. In this scenario, the level 4 plan seems to become and instrument for reporting costs and progress, and for managing the overarching milestones.

The detailed focus that is emerging as being the role of phase planning means that we need to rethink the Lookahead schedule in engineering. Before we do so, however, we need a better understanding of the QC system and of how it can be integrated with the overall system. A significant finding is that within engineering, it often seems necessary to rely on “making do” as a way of working; hence, the criteria for declaring activities sound must be adjusted accordingly.

In projects spanning both engineering and fabrication from the outset, and where engineering is regarded as the start of fabrication, we see, based on experiences referred to above, a need for two parallel planning processes. One process where delivery milestones from engineering are integrated into the fabrication plan’s phase plan; and a separate planning process for engineering where the focus is on how to navigate a network of different milestones so that delivery can be made by the fabrication deadline.

Experiences from the project so far confirm previous findings and theoretical points from the literature – for example that understanding of scope and possible solutions emerge and mature over time; that the reciprocal interdependencies are considerable; and that the ideal solution is regarded as unattainable. This latter point can be exemplified by the fact that the longer the solutions are allowed to be iterated by the different disciplines, the greater the final weight reduction. Moreover, we see that requirements are often vaguely stated, creating a great need for interpretation. Technical solutions are found by the technical experts in negotiations and joint learning processes. The rationalistic and linear models for project execution seem incapable of handling design and engineering as witnessed in the case company during this engineering project. Hence, although considerable changes must be made to the operationalized model, the iterative and inclusive methods will be at the basis of its further development.

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