Using a change control system and BIM to manage change requests in design

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Abstract

There are different types of changes in construction projects. Some have dramatic consequences, are costly and time driving, while others are insignificant. Today, there are few satisfying control systems to handle internal design changes or changes from the client. The changes are often handled manually and implemented without identifying possible consequences. It is essential to get control of changes because of the cost and schedule impact. Could changes in construction projects be better controlled with a change management tool that uses building information models (BIM) to identify consequences? This paper introduces a system for controlling changes; internal changes or changes to initial requirements from the client, and assesses how BIM can be used to identify impact and consequences of changes. Findings are based on experiences from major oil and gas projects. Data is gathered from case projects in Kvaerner, a Norwegian EPC (engineering, procurement and construction) contractor. A new change management process is introduced to the construction industry, based on experiences from the oil and gas industry. This research shows that changes can be managed using a change control system (CSS). When a design change request is created in CCS, it is presented in a Change Board, and then considered by relevant disciplines. BIM are used to see the consequences and which disciplines are affected. The input will return to Change Board where the request is processed and either rejected or approved. If it is a client-driven change, the client will be added in the decision and presented for a cost and schedule impact. The paper assess how CCS combined with the utilization of BIM can reduce the impact of changes and manage internal or external changes in the design phase through efficient identification, evaluation, approval and implementation of changes.

Keywords: Building Information Modeling (BIM), change control system, change management process

1 Introduction

In the beginning of the design phase, everything change because there is a design development that by nature is a period where various concepts and alternative solutions are developed and evaluated. Before going into detail design, the conceptual development should be concluded and concept/design frozen. When construction starts, changes can be initiated by the contractor if it turns out that what is already designed and released on drawings are impossible to build. The client can come up with new requests or there can be changes to what the client already has requested.

Project teams often implement changes without fully understanding the potential impact on the cost and duration of the project, or the effect on contractual aspects or requirements as specified by the client. According to Isaac & Navon (2009) this is because the tools currently used for project planning and design are not able to evaluate the consequences of a specific change, before the plan and design are fully updated. As a result, deviations from the client objectives, caused by changes in the project, are often revealed late in the project or after its completion. The cost of rework in construction projects can be as high as 10–15% of the contract value. (Sun & Meng, 2009)

Previous research has pinpointed that project teams can be able to identify implications of a change as soon as it is proposed, using a change control tool. This will make it possible for the engineers, and other stakeholders such as the client project manager and contractor, to know in advance if a change could cause the project to deviate from its original goals, or if special measures have to be implemented. In recent years, the use of building information modeling[1] (BIM) has become widespread. There is a potential of combining a change management system and BIM. This could allow the development of a tool that is able to link the different requirements and relationships between these. The tool could identify the impact of a proposed change of a certain requirement. (Isaac & Navon, 2008)

The research objective is to introduce a change management process to the construction industry, initially developed for use in major oil and gas offshore (and onshore) projects. This paper introduces a change control system (CCS), which is a tool that handles internal changes or changes to initial requirements from the client, in the design phase. The paper assesses how a 3D design environment[2], or BIM as the corresponding term is in the construction industry, can be used to identify impact and consequences of changes. There are two aspects related to a 3D design environment (hereafter called BIM) and change. The first is to use BIM as part of handling change requests in a change management process. The second is connected to milestones and the use of BIM related to frozen design.

The research is qualitative, conducted as case study research. Findings are based on experiences from project execution in major oil and gas projects through Kvaerner, one of Norway's largest EPC (Engineering, Procurement and Construction) contractors. The data has primarily been gathered from two case projects at Kvaerner. These offshore projects are delivery of topsides of production platforms in the North Sea, executed as EPC contracts, and one with engineering on a subcontract. An EPC contract in the oil and gas industry corresponds to a design-build contract in the construction industry, where the engineering and construction services are contracted by a single builder or contractor. Data has primarily been collected through documentation and interviews. Background information and detailed descriptions have been accessed through relevant company and project documentation. Interviews have been conducted with resources in key positions.

2 Background

2.1 Definition of change

According to Sun et al. (2006) and Sun et al. (2009), a change in construction projects refers to an alteration (or modification) to (pre-existing) conditions, assumptions or requirements. Being a project-based practice, the construction industry is normally disposed to a high degree of changes. Kvaerner has defined change as "any unplanned, out-of-sequence design development or change to execution method/sequence". (Kvaerner, 2012c) An unplanned development in design can refer to what is defined as an "unintended change", where changes take place unintentionally without intervention of managerial actions. They result from low work quality, poor work conditions or external scope changes. Change to execution method or sequence can refer to "managerial change", which is changes that take place on purpose, and are implemented by managerial decisions. (Motawa et al., 2007) Similarly, an unplanned development in design can also relate to "emergent changes", which arise spontaneously and are not anticipated or intended. Change to execution method or sequence can also refer to "anticipated changes" which are discovered during the project and before they actually occur. (Sun et al., 2006)

Sun et al. (2009) define five different causes of change; "project-related," "client-related", "design-related", "contractor-related" and "external factors". Poor communication between the key partners in a project is a main cause for design changes and rework, and forms the basis for project-related change. Client related changes are common, especially during the design stages, and are usually caused by variations in clients' expectations and requirements. Design-related changes are

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[1] Building Information Modeling (BIM) can be defined as a digital representation of physical and functional characteristics of a facility. It is a shared knowledge resource for information about a facility and forms a reliable basis for decisions during its life cycle – from concept to demolition (NBIMS, 2007)

[2] A 3D design environment refers to a multi-discipline and object based 3D design software integrated with a number of information systems that serves as the main source of information for engineering and construction. The main purpose is to improve the coordination and consistency between the disciplines responsible for the design in the project. (Kvaerner, 2012a)

based on design errors and exclusions and changes in client's requirements during a project, which often result in design modifications. There can be errors committed by the contractor or in equipment deliveries that causes changes in design and schedule delays. This, in addition to poor site management and supervision and difficulty coordinating subcontractors often cause contractor-related changes. External factors are often caused by climate conditions, site and ground conditions, or changes in government legislation and regulation.

Kvaerner (2012c) has defined 18 characteristics to what constitutes a change. These characteristics can be categorized using the different types of change defined by Sun et al. (2009) Nine of the characteristics have to do with contractual changes and modifications and requirements that are instructed by the client, which go beyond the basis for the contract (contractual agreements). This refers to "Client related" change. Three of these are related to design modifications, which include alterations to frozen design and proposal for design improvements. This corresponds to ""design-related" change. Three are related to modifications of work scope for the contractor, either as increased work or quantities from what is agreed on in contract, when work cannot be performed according to schedule. This refers to "contractor-related" changes. The last three are related to external conditions, including force majeure, changes to laws and regulations and changes to rates and norms. This corresponds with "external factors".

2.2 Internal vs. client initiated changes

According to Kvaerner (2012c) there are two forms of change in the design phase: one is a design development initiated by the project team and the other is a client initiated change. These two forms of change can result in eight potential outcomes, which are categorized in wanted or unwanted changes, and paid or unpaid changes. This is illustrated in the matrix in Table 1. Green, yellow and red indicates if a combination is desired, avoided if possible or should absolutely be avoided.

Table 1: Different forms and outcomes of change

Wanted	(Client)	1A: Client initiated	3A: Client initiated
	(Project team)	1B: Design development	3B: Design development
Unwanted	(Client)	2A: External	4A: Design development
	(Project team)	2B: Client initiated	4B: Design development
		Paid (Client)	**Unpaid** (Client)

During the design phase, the client might initiate changes. If the cost and possible schedule impact (adjusted milestones and/or end date) are compensated for, these can be implemented. [1A] A design development is something that is usually linked to internal design processes. It may be the consequence of maturation and development of new (and improved) solutions initiated by the project team. If the change implies positive cost and schedule impact with fewer work hours and/or shorter execution time, and/or increased value for the client (and/or the end-users), the change can be accepted and paid for by the client. [1B] On rare occasions there might be external factors that influence the design process and cause a change that must be paid for by the client due to contractual obligations. [2A] There might be changes initiated by the client that have cost and schedule implications, where only the cost is compensated for. The consequences for the project team can be more critical if milestones are not reached than if the client pays for the change. If so, the change is not implemented. [2B] If the client initiate a change, but see the change as a design development and are not willing to compensate for the implications, it is a type of change that should be avoided by any means possible. [3A] If a change that is initiated from design development implies increased cost, and/or give marginal value for the client and/or end-users, the change can be rejected and thereby not implemented. [3B] The project team can initiate improvements during design development that have marginal cost and schedule implications. This is a type of change that is implemented but will not be covered by the client. [4A] Finally, design development may be the consequence of mistakes made by the engineers, omissions or lack of coordination between disciplines. That is an unwanted change the project team must cover and should avoid. [4B]

A design development that is unpaid is similar to what Sun & Meng (2009) has defined as "non-excusable causes", which are errors and omissions by the project team. A change that is initiated from the client is similar to “compensable causes”, which are usually related to requirement changes and client failures or delays. The project team can claim compensation from the client for any extra work resulted from changes by this type of causes. External factors that are beyond the control of the consultant and client are defined as “excusable causes”.

In change management, the principles are the same for internal or client initiated changes. Experiences from case projects indicate that the accuracy is often not the same as with changes paid by the client. The focus is rather to implement it as soon as possible. When there are changes paid by the client, the project team calculates more and is more rigorous about what the consequences are. It is often a matter of productivity; how much is driven by client influences and how much is driven by mistakes and shortcomings of the project team.

3 Change management process

According to Sun et al. (2006) the objective of change management is to anticipate possible changes, identify changes that have already occurred, plan preventive impacts and coordinate changes across the entire project. The change management process in Kvaerner consists of four main activities; “General Project Execution Phase”, “Change Board”, “Change Handling/Solving” and “Requests to the Client”. (AkerKvaerner, 2005) In the first, “General Project Execution Phase”, the change management routines are established. Possible changes are identified. Requests for changes with contractual consequences (variation to the contract) are reviewed. A list of changes from engineering, called design change requests (DCR), and potential changes from the client, called variation orders (VO), are updated and prepared for presentation to a Change Board – a board that consists of a change manager and relevant delegates from engineering, planning, construction, subcontracting, procurement and contract/legal. In the second main activity, "Change Board", the Change Board will formally process changes. This includes approving or rejecting changes, requesting additional change documentation and issue a message to the client when further handling or approval is required. In “Change Handling/Solving” changes are formally communicated with the client. Cost and schedule estimates of approved changes are completed and CCS is updated. Change implementation is coordinated with all relevant parties. Project schedule is revised with approved changes when required. Handling of each change is prioritized, progress is monitored and relevant change documentation is updated in CCS. In the last main activity, “Requests to the Client”, change order requests to the client, called variation order requests (VOR), are established and updated. VOR documentation is reviewed (with cost and schedule estimates) and sent to the client. Formal response from the client is received and instructions to the project team are issued. CCS is updated and progress of actions required to comply with client requirements is monitored. Changes and actions approved for each change are closed and CCS is updated.

The literature review has identified several attempts to create change management processes. A few of these are similar to Kvaerner’s process. Ibbs et al. (2001) developed the project change management system (CMS). The system is based on five principles. In the first, “Promote a balanced change culture” the focus is to establish overall goals and objectives, roles and responsibility, and project philosophy related to change. “Recognize change” is about identifying potential changes, assess potential impacts, and log potential changes. These two principles are similar to the “General Project Execution Phase” main activity. “Evaluate change” is about defining priority, analyzing and defining impacts, and authorizing or stop/deny change. This corresponds with the “Change Board” main activity. “Implement change” is about implementing and receiving final change approval, communicating and documenting change decision, and monitor implementation. The scope of this principle corresponds with the third main activity “Change Handling/Solving”, where internal changes are implemented. “Continuously improve from lessons learned” is to perform an evaluation, take corrective actions, compare to initial objectives and incorporate lessons learned.

Based on this research, Arain (2008) presented a similar change management system (CMS) with six principles; “Identify variations”, “Recognize variation”, “Diagnose the variation”, “Implementing variation”, “Implementing controls for variation” and “Learn from past experiences”. Here, variation corresponds with change. The main difference is the fourth principle, “Implementing controls for variation”, where the author introduces the process of selecting controls for variations, and documenting these. The first two principles correspond with the “General Project Execution Phase” main activity. The third and fourth principle are somewhat similar to the “Change Board” and the "Change Handling/Solving” main activity, respectively.

Sun et al. (2006) developed a generic change management process model in four stages. “Start up” prepare a project team for effective change management. “Identification and evaluation” seek to identify potential changes and evaluate these to assist with the decision-making process. These two stages are similar to the “General Project Execution Phase” and part of "Change Board". In “Approval“ the chosen change option needs to be approved by an appropriate member of the team, or by the client before it can be implemented. The internal decision process corresponds with part of the “Change Board” main activity. Part of the external decision process (towards the client) corresponds with “Requests to the Client”. "Implementation and review" is a two-step process. When a change is approved, it needs to be communicated to all affected team members. If necessary, the schedule needs to be adjusted. This corresponds with parts of “Change handling/Solving” and “Requests to the Client”. After the implementation, the project team needs to review and learn lessons from the change event.

Similarly, Motawa et al. (2007) introduced a change process model in four steps. The first step, “Start up”, defines requirements for effective project management. “Identify and evaluate” identify changes (including causes, types and effects) and those affected or involved in decision process, and evaluate change options. These first two steps are similar to the “General Project Execution Phase” main activity. The second step also covers the principles of “Change Board”. In “Approval and propagation”, the client will review potential changes and either approve, reject or negotiate these. If approved, the project team implements changes. Minor changes or changes that does not need client approval are implemented. The internal decision process have similarities towards “Change Handling/Solving”. The external decision process towards the client corresponds with “Requests to the Client”. In “Post change”, the focus is on finding a solution to potential disputes (if applicable).
The change management processes presented here are similar to Kvaerner’s process, but with focus on different aspects. This is summarized in Table 2. The change management process in Kvaerner is used as a benchmark. The number of process steps is presented on the horizontal axis and the different sources are presented on the vertical axis. Green, yellow and red indicates high, medium and low degree of similarity of the process within each step in Kvaerner’s change management process, compared to the different sources. The table illustrates that Motawa et al. (2007) has the highest degree of similarity, followed by Ibbs et al. (2001), Sun et al. (2006) and Arain (2008). It also illustrates that Kvaerner, unfortunately and in contrast to the other sources, does not have a corresponding main activity that focus on review of the process and learning from experiences.

Table 2 Change management processes compared to Kvaerner

Source	Step 1	Step 2	Step 3	Step 4	(Step 5)
Kvaerner (2012)	“General Project Execution Phase”	“Change Board”	“Change Handling/ Solving”	“Requests to the Client”	
Ibbs et al. (2001)	“Promote a balanced change culture”, “Recognize change”	“Evaluate change”	“Implement change”		“Continuously improve from lessons learned”
Arain (2008)	“Identifying variation”, “Recognize variation”	“Diagnosis of variation”	“Implement variation”		“Implement controlling strategies”, “Learn from past experiences”
Sun et al. (2006)	“Start-up”, “Identification and evaluation”	“Identificati on and evaluation”, “Approval”	“Implement-ation and review”	“Approval”, “Implement-ation and review”	“Implement-ation and review”
Motawa et al. (2007)	“Start up”, “Identify and evaluate”	“Identify and evaluate”	“Approval and propagation”	“Approval and propagation”	“Post change”

Change management is an overall work process that includes the proactive measures required to reduce the volume of changes, and to ensure that the cost, schedule and quality are under control, as well as the evaluation and implementation process. The sequence is defined as: Prevention – Identification – Filtration – Implementation. (AkerKvaerner, 2005) The first two parts of this sequence, "Prevention" and "Identification", is covered in the first main activity "General Project Execution Phase", where the routines are established (to prevent undesired handling of changes) and internal and external changes are identified. The third part of this sequence, "Filtration", is covered in the next main activity "Change Board", where the change requests are formally processed. The last part of this sequence, "Implementation" is covered in the last two main activities, "Change Handling" and "Requests to the Client". In "Change Handling", changes are communicated, implemented, and monitored. In "Requests to the Client", change requests that are approved from the client, and any additional change requirements from the client, are implemented and monitored. By following the four main activities in the change management process in Kvaerner, all four parts of the sequence will be covered.

4 Change control system

Kvaerner has developed a change control system (CCS), which is a system to store, control, report and follow up project changes and deviations. CCS is central in the change management process. A flowchart that visualizes the process from identification to implementation of a change has been developed (see Figure 1).

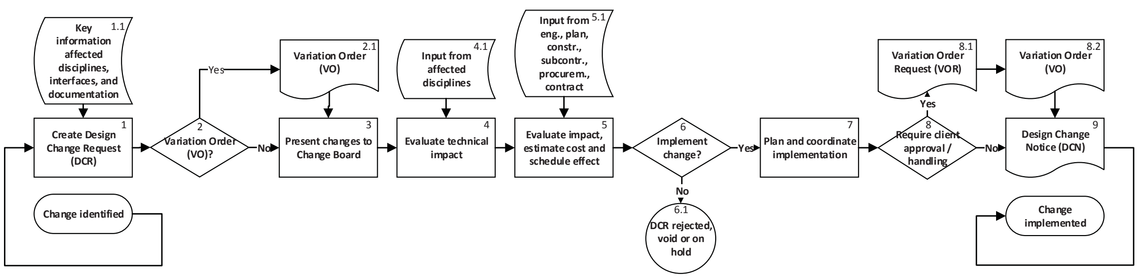

Figure 1 Flow chart for handling changes using DCR in CCS

A change in design is identified with a design change request (DCR). An exception can be changes that occur in the early stage of the design (e.g. prior to the first milestone in the design phase). Here, it may not be necessary to make a DCR, if the change does not affect any other disciplines. A DCR looks at which disciplines are affected and what the time and cost consequences of each of the disciplines are and the sum of these. (AkerKvaerner, 2005) A DCR, is created in CCS with a name and an assigned number. The change can be identified through a Tag number (or line number or coordinates in space), which gives a direct routing to the relevant part of the BIM. [1] All relevant key information about the DCR (including affected disciplines) is stored as general information. The responsible persons for discipline input and relevant interfaces are configured. Relevant documents and drawings can be added to the change object. This includes excerpts of the BIM and other documentation that will further describe the change or its consequences. A reference to other change objects in CCS can also be made. [1.1] When the information to the change object is revised, the status of the DCR can be updated. Available statuses for the DCR are "Initiate" (created), "Recommend" (ready for recommendation), "Evaluate" (approved for evaluation), "Decide" (evaluation complete or ready for decision) and "Complete" (pending client approval, approved for implementation, rejected, void or on hold). (AkerSolutions, 2008)

The DCR is presented to Change Board, who meets on a regular basis, often weekly or bi-weekly. The engineer who has identified the change describes it for their discipline to the Change Board, who will follow up any changes or proposed changes. [3] The project manager can receive a message from the client containing potential changes [2] If so, a variation order (VO) is presented to the Change Board. [2.1] Should these change requests be implemented or not? The Change Board needs to see the consequences and who is affected. [4] All disciplines that are affected by each change are listed. The Change Board tries to limit it to those they believe have something to do with the change, instead of sending it to everyone. According to Isaac & Navon (2009) it is difficult, if not impossible, for every team member in projects involving large teams to participate in every project review in order to answer questions concerning every proposed change.

For each change, the consequences for all relevant disciplines are described and reported back to Change Board. BIM can be used to identify consequences for the disciplines. The disciplines can give input to the change object, including plan, cost or weight information, engineering related data affected by the change, and the type of documents the change objects impacts. [4.1] When the disciplines have completed their input, the status is updated, and a notification mail to the responsible for the change object are sent, using CCS. Input to plan and cost for the various disciplines are summarized. The man-hours are summed up from the activity. The Change Board now has feedback on what the disciplines will do and the consequences, the need for rework and the hours needed. [5] The change can influence the project on several dimensions (e.g. construction, procurement, subcontracting, commissioning, etc.). It is therefore important to get input from all relevant delegates in the Change Board to evaluate the impacts of the change. One of the challenges is to appraise accumulative effects of having several changes. This will often have a schedule impact. [5.1] The Change Board now has the necessary information to decide if the change is to be implemented. [6] It may be that no matter how much the earnings (cost) are on a proposed change, the decision is not to proceed, because it has a schedule impact. There can be situations where not all consequences are identified, so that the DCR must be put on hold. Consequences if the change is not implemented shall be listed. In some cases, the DCR is for some reason no longer relevant and can be voided. [6.1]

If there is a decision to implement the change, it is planned and coordinated through the Change Board. [7] The change can be initiated as an internal change or a change from the client. Either way, a Design Change Notice (DCN) is created. [9] A DCN is an instruction for implementation, and is created on the basis of a DCR. The Change Board decides in practice if the change is something that is going to the client. [8] If so, a Variation Order Request (VOR) is created, which is a request to the client when a change has occurred. The argument is that the client has influenced the project team to make this change, and therefore must pay for the consequences. [8.1] A VOR can be created, and relevant data from the DCR is copied over to the VOR. The system will link the DCR and VOR together. If the VOR is accepted, a Variation Order (VO) is issued from the client, which are instructions issued from the client to perform a change. [8.2] This will result in a DCN (AkerSolutions, 2008) In a client-driven change, where a VO was received and presented to the Change Board, the client will be presented for cost and schedule impact of the proposed change. The project management can choose to earn more by implementing the proposed change. If there is a schedule impact and the consequence is that it is impossible to reach a milestone, it can be much more critical. The client can choose to implement the change, but then the relevant milestone must be adjusted and approved by the client.

There have been several attempts to create change management tools for the construction industry. Few of these are similar to Kvaerner's change control system (CCS), especially the use of a Change Board, and utilization of BIM to identify consequences of changes. One still worth mentioning is the change management toolkit (Sun et al., 2006). It consists of a standard procedure to identify, evaluate, approve and implement project changes, and a template for recording change events during a project. It also provides a tool to assess the likelihood of changes occurring and a workflow tool to assist in project rescheduling due to a change. The tool relies on extensive user inputs of project characteristics, which makes it difficult to use in practice. Another is the change control tool (CCT) developed by Isaac & Navon (2008), where change proposals are evaluated during the design and construction phases. The CCT is based on the building program and how that can serve as a framework for information management, with links to the client requirements and the building design. The CCT is designed to identify the implications of a proposed change by tracing the different relationships that exist between the requirements.

5 BIM and change management process

Changes in a project are many, but it is difficult, if not impossible, to pick up and register all. Changes are not identified because the engineers make a change on a frozen (finished) design, but tell no one about it. Then it becomes a clash afterwards that needs to be cleaned up. Costs are added up when changes have not been detected in time. When they are detected, it is often difficult to be able to define all the consequences. If there is a client affected change, the cost and schedule consequences must be identified and the contract must be negotiated. Educating engineers more commercially can increase the accuracy. They will then know the consequences if they do not report a change, or if they make a change without noticing. The culture in the case projects at Kvaerner is relatively good in the sense that people come forward and speak about defects - even if it is in their own work. This also characterizes the Norwegian culture. BIM is an integrated part of the engineering toolbox. It is updated continuously. If there is a design change request (DCR), the BIM is used to assess if it is feasible and identify what the downstream consequences of the change are. An extract from the BIM, which shows what the change is all about and who is affected, is taken out so that the disciplines that receive it can identify the change visually in the model. The disciplines can go directly into the BIM, and see what they should do with their part of the design that is affected by this change.

Change can be perceived as an internal or external alteration in conditions for the contract, as described earlier, or alterations to frozen design/design milestones. (AkerKvaerner, 2005) In the design phase, the design is gradually frozen, once milestones are passed. The milestones describe which part of the design each of the disciplines shall be frozen to a certain time. All frozen parts should not be changed. When using BIM in the design phase, objects are gradually being frozen, as they reach the milestones and fulfill the requirements to update the object status accordingly. Once the design is frozen and some of that still must be changed, the changes must be managed, and then the design change process begins. Either one of the engineers find out that there is a need to change the frozen design, or the client need to change something that is frozen design. One of the challenges is to avoid changes due to “nice to have” design updates. This can be avoided by not requesting any design changes to what is sufficient or good enough. If there is a change request to something that is frozen, the relevant disciplines has to react by creating a DCR and not change anything without notifying the Change Board.

Engineers understand when the design is frozen, but being faithful to the decision of not changing frozen design is another matter. Engineers often acknowledge that things could have been done better as the project progresses. They are often tempted to make changes, especially if the client put their attention to it. There is a human element to this, that cannot be replaced with any change management system. It can be managed, to some extent, by focusing on commercial aspects. Similarly, the client often needs to learn what is frozen, and understand that when a milestone is reached in the design phase, there are parts of the design that is frozen, and should remain so. If there are changes to that, there will be consequences. But the client often likes to have the privilege to change anything anytime.

The relation between CCS and the use of BIM is based on what is frozen. Color codes can be added to the objects in the BIM software, which identify what is still being developed and what is frozen. Color codes relate to the status (maturity) to each object. CCS relate to BIM in the sense that if there is a change that touches objects with the red color code (frozen) it must be addressed. This helps the engineer to not change anything where it is frozen. On the other hand, if there is a different color code (still in development) it is not certain that there is a need to do anything at all, other than making the change.

6 Discussion

This paper has introduced the change management process in Kvaerner, and related it to research that describes similar processes for the construction industry. The scope of the first three steps in the change management process is, to a certain degree, similar. Kvaerner has divided implementation of changes in step three and four, where “Change Handling” covers change requests that are handled internally, and “Requests to the Client” are those that require client approval and feedback. Sun et al. (2006) and Motawa et al. (2007) covers both internal and client changes, but in the same step. Ibbs et al. (2001) and Arain (2008) does not mention client changes. All research sources include a last step, which focus on evaluating the process and identifying lessons learned, as prevention for later projects. This could preferably be added as a fifth step in the change management process in Kvaerner. This would give valuable input to the first step, “General Project Execution Phase”, where the change management principles and routines for the project is established.

A change control system (CCS) is critical for handling change requests in the design phase in larger projects. The use of CCS follows the four main activities in the change management process. Using a design change request (DCR) as a starting point, internal and external changes are identified. The DCR contains a description of the change and identify any consequences for the discipline(s). BIM can be used to identify consequences of a change, which is often the difficult part in change handling. Relevant excerpts of the BIM can be attached to the DCR, in addition to relevant drawings and descriptions. Unlike other change management tools, Kvaerner has introduced the Change Board, that through a change manager and other relevant delegates, has a key role in deciding if a change is to be implemented or not. An important basis for decision is to identify consequences and relevant disciplines. In order to have an efficient process it is crucial that only those disciplines directly affected in a change is included. When the DCR is updated with input from the disciplines and status, the Change Board has the necessary information to decide if the change is to be implemented or sent to the client for consideration and approval. Either way, the result is a design change notice (DCN), which is an instruction for implementation of a DCR and is issued when the project is influenced. If the change is sent to the client, cost and schedule impact is identified. There are few similar systems developed for the construction industry. The change management toolkit (Sun et al., 2006) and the change control tool (CCT) developed by Isaac & Navon (2008) shows that the systems available have limitations. Despite this, having CCS that is based on many of the same principles, increase the relevance for use in the construction industry.

Color codes on objects in the BIM identify what is frozen. When the design is frozen and still must be changed, the changes must be managed. Before anything is changed, a DCR must be created, and the Change Board must be notified. Having a project team that is commercially astute in relation to change is important - whether it is client affected or internal change. The commercial, if it is internal change, is to correct it as soon as possible. Is it a client change, it should be identified as a client change and processed so that the client eventually will pay for it.

7 Conclusion

This paper has introduced a change management process in four steps, developed for use in major oil and gas projects. As presented in this paper, there are many similarities with other research that present similar processes in the construction industry. This makes the change management process in Kvaerner more relevant. The change control system (CCS) is close connected to and support the change management process. This paper has presented the principles of how the system works, from a design change request (DCR) is created to a decision of change implementation with a design change notice (DCN), and how it relates to the change management process. A central part of both is the Change Board, where a change manager and other relevant delegates use CCS to coordinate discipline input and manage change. A flowchart has been developed and the next step would be to define and set up a corresponding system for the construction industry. In the design phase, the design is gradually frozen, once milestones are passed. When the frozen design still needs to be changed, the changes must be managed. The use of BIM is essential and used to assess if the change is feasible and identify what the downstream consequences are. In addition, color codes are added to identify what is still being developed and what is frozen.

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