SUMMARY REPORT

Study of field development projects on the Norwegian continental shelf

English translation of the report «Utredning av feltutbygningsprosjekter på norsk sokkel»

Revision and Approval Form

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Summary – “10 commandments” of project development

Project development on the Norwegian Continental Shelf has greatly improved since the early 1970s and is currently at a high international level with respect to both HSE and value creation. In this this study one has chosen to summarise the accumulated experience from the industry in the “ten commandments” below. This is done because there are currently several new players, both as operators and partners, entering the Norwegian continental shelf. It is important that these are given the opportunity to start as high up on the existing learning curve as possible.

1. **Excellent HSE results = optimal value creation**
2. A high-quality concept select process, independent of company political strategies, is the foundation for all future value creation (and for excellent HSE).
3. The correct level of technical detailing/maturation at DG2 and DG3 combined with sensible use of new technology and solutions is key to a successful project.
4. The project organisation must secure experience transfer and learnings and have clearly defined responsibilities and delegation of authority. A «one team» attitude is of essence.
5. Early involvement of safety delegates and future operational personnel is crucial to the **HSE quality of the final product.**
6. Project and contract execution strategies must be adapted to the complexity of the project and to the capabilities in a market that changes over time.
7. Pre-qualification and evaluation of key contracts must emphasise, to a much larger degree than today, the contractor’s execution capability, risk understanding and competence level.
8. The operator’s project team must be competent within risk and project management, be familiar with the content of the contract and with the contractors’ culture and attitudes as well as secure continuity in key positions within contractor and own team.
9. Technical documentation and project reporting must always be 100% truthful and available for own management, license partners and government at any time.
10. Principles, criteria and responsibilities for commissioning, hand over to operations and start-up should be established early to secure a **safe production start-up.**

The study is documented in two reports, the main report and this summary. The main report is a comprehensive documentation and evaluation of the three projects Goliat, Aasta Hansteen and Ivar Aasen. This summary report is meant to convey the most important messages in a brief and summarising way.

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Abbreviations

CB&I	-	Chicago Bridge & Iron Company
DG	-	Decision Gate (decision point)
DG1	-	Decision Gate 1 (BOK)
DG2	-	Decision Gate 2 (BOV)
DG3	-	Decision Gate 3 (BOG)
DG4	-	Decision Gate 4 (production start)
EPC	-	Engineering Procurement and Construction
EPCI	-	Engineering Procurement Construction Installation
Feed	-	Front End Engineering Design
FPSO	-	Floating Production Storage and Offloading
GNOK	-	Giga (Billion) Norwegian Kroner
HHI	-	Hyundai Heavy Industries
HSE	-	Health, safety and environment
NCS	-	Norwegian Continental Shelf
Norsok	-	Norwegian continental shelfs competitive ability (similar to Crine)
NPD	-	Norwegian Petroleum Directorate (OD)
MPE	-	Ministry of petroleum and energy (OED)
PSA	-	Norwegian Petroleum Safety Authority (Ptil)
SMOE	-	Sembcorp Marine
UCCI	-	Upstream capital cost index

1 Background

Certain field developments on the NCS have faced major challenges from costs and delays over the past decade, with associated examples of quality and HSE problems – particularly in the start-up and production phases. Goliat is a case in point. The challenges in this project have attracted a great deal of attention from both the general public and the government. The White Paper on HSE in the petroleum sector Report no 12 to the Norwegian parliament (page 65) published in the spring of 2018 addresses this as follows:

> Most developments on the NCS are implemented within the uncertainty range for time and costs specified in the PDO. However, certain developments have faced challenges with substantial overruns for both costs and execution time. This may also be significant for quality and HSE in engineering and construction.

During the fall of 2018, PSA consequently initiated a study of three field developments on the Norwegian continental shelf. This study has aimed to identify any shortcomings in the implementation of the project and to suggest possible measures and learning points for improvements of the implementation methodology of the companies, and the supervision by the governments. The following projects were chosen:

- Goliat – operated by Eni (currently Vår Energi)
- Aasta Hansteen – operated by Statoil (currently Equinor)
- Ivar Aasen – operated by Det norske (currently Aker BP)

None of these projects are historically seen as NCS top 10 projects, either in scope, complexity or in the use of new technology. However, the projects were completed during a time of high activity in the supplier market.

The three projects have had considerable challenges during project execution, which they have handled in their own ways. Goliat is the project that has had most problems with regularity and HSE-incidents following start-up.

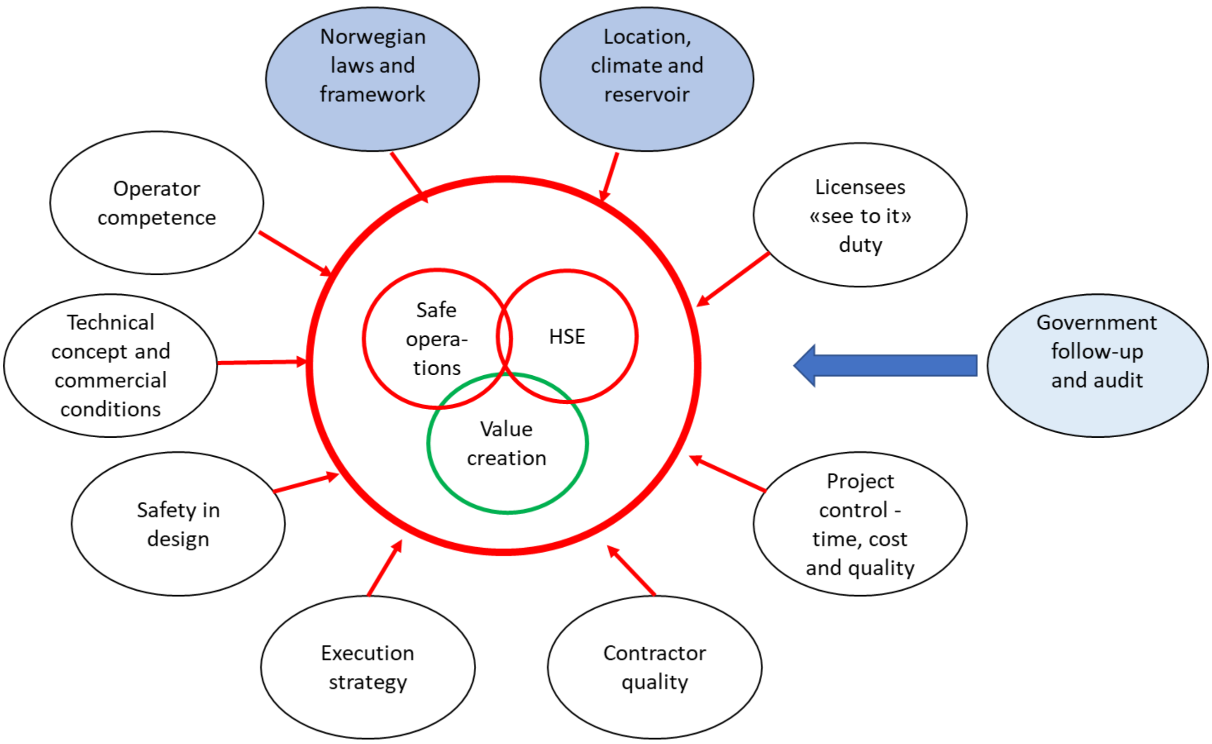

Figure 1-1. HMS and safe operations in focus (Source: Acona)

This study has applied PSA's definition of HSE «.. include safety, working environment, health, external environment and financial assets (including production and transport regularity).» Ref. Framework HSE regulations Section 1 guidelines.

Figure 1-1 provides an overview of important factors in the project's execution phase which influence and are significant for HSE-results and value creation in the overall project.

The measurable end-result of a project is a quantification of the end-result based on HSE-incidences, time and money spent as well as the quality (regularity) of the plant at start-up.

Goliat was chosen to be one of the three projects to be evaluated. As a first deliverable in the study, Acona were to recommend two additional projects from a list of 8 with PDO approved between 2010 and 2015. The projects under consideration were Gudrun, Valemon, Gina Krog, Aasta Hansteen, Martin Linge, Knarr, Edvard Grieg, and Ivar Aasen. The evaluation was based on documentation made available by PSA. Based on a set of pre-defined project characteristics and performance criteria, two additional projects were chosen. The result of the evaluation is shown in Figure 1-2.

Four of these projects have been executed with Equinor as the operator, while the four others were executed by other operators. Selecting three different operators was desirable in order to ensure the broadest possible basis for comparison in the study.

Among Equinor's projects, Aasta Hansteen stands out as the one which most resembles Goliat in size, concept, geographical location, contract strategy and choice of contractors. Aasta Hansteen had a delayed start in relation to its PDO.

Where the other projects are concerned, Martin Linge was dropped because of the lack of start-up and production data within the time frame specified for the study.

Of the three remaining projects, Ivar Aasen has an execution strategy which most resembles Goliat and Aasta Hansteen. At the same time, it shows a "green light" for all the result parameters, including HSE.

Criteria	**Ivar Aasen**	**Aasta Hansteen**	**Goliat**
HSE in project execution	[green]	[green]	[red]
HSE in operations	[green]	[green]	[red]
Schedule delays	[green]	[red]	[red]
Cost overruns	[green]	[green]	[red]
Quality at production start up	[green]	4Q 18 [light green]	[red]

Figure 1-2. Result measurement (Source: Acona)

For each of the production licences, the study will cover the operator company, the licensees and the government's role. The following will be included for the various phases in the actual study and cover

- the quality of the decision base for the various phases
- involvement of and collaboration with the workers
- involvement by government
- qualification, utilisation and follow-up of suppliers/contractors
- organisation of the work
- the company's own follow-up
- follow-up by the licensees.
- permits, approvals and consents
- supervision and the use of enforcement powers.

2 Descriptions of the three projects

Ivar Aasen lies in a North Sea area which is well known and where a developed infrastructure exists for oil, gas and supply services. The water depth is only 113 metres, permitting the use of conventional fixed platforms with wells conducted to the topsides level. Drilling can be performed by a jack-up rig. Export oil and gas are tied-in to existing pipeline systems (via Edvard Grieg).

Aasta Hansteen lies in the Norwegian Sea area known as the Vøring Plateau. The water depth is about 1 300 metres, and the combination of waves, winds and currents is among the most challenging on the NCS. It is a considerable distance from land and the area lacks infrastructure. Development depended on establishing a new infrastructure for gas, which involved laying the new Polarled gas pipeline to Nyhamna on the Møre coast. To handle the marginal condensate flow, the platform incorporates expensive and complicating storage for this product with a system for loading it directly to tankers.

Goliat lies in the Barents Sea, not far from Snøhvit. It was the first oil field discovered in the area, and infrastructure is lacking for both oil and gas exports. The water depth is about 350 metres, like northern parts of the North Sea and the Halten Bank. Waves, winds and currents are no worse than in areas of the North Sea, but Polar lows can occur. Low temperatures with possible snow and ice can occur, and light conditions are poor in winter. The crude is exported by offshore loading directly from an integrated store into tankers. The gas is re-injected into the reservoir for pressure support and could be recovered and exported at a later time.

Figure 2-1 shows an overview for some of the key data for the three projects.

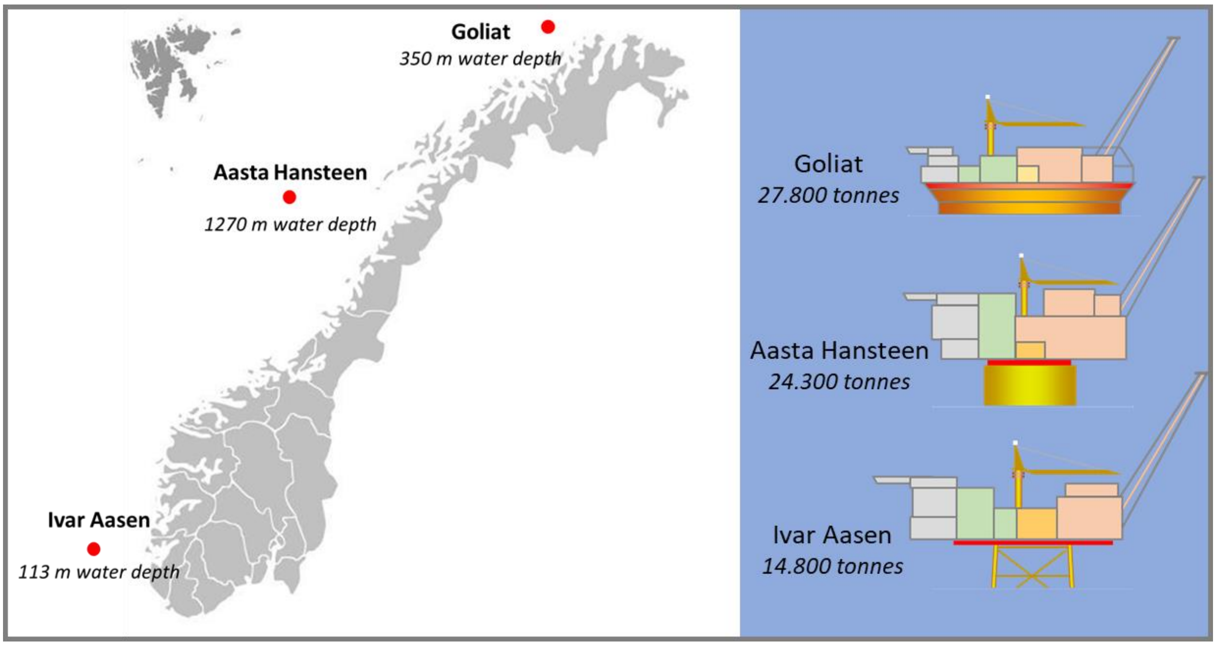

Figure 2-1. Project overview (Source: Acona)

3 Project execution and financial robustness

Projects are developed and matured through a series of decisions up to the final investment commitment, which is confirmed with the approval of the PDO. The project's value creation potential is expressed as expected net present value. Calculating expected present value is based on expectations of future market prices for oil and gas. Since great uncertainty prevails about price assumptions, emphasis is given to assessing the project's robustness to low oil prices.

History shows that oil prices fluctuate greatly, both in the short term and over rather longer periods. This may reflect imbalances in the market, generally created by global incidents, international crises, financial crises and so forth. Forecasts for future oil prices are based on observations of the present level, trends and analyses. The various oil companies have their forecasts and planning assumptions, and each licence partnership selects which of these will form the basis for illustrating the profitability of the project before a project decision is made.

In the period 2007-2009, the oil price was based on an estimate of 40-50 USD/barrel. In line with the development of the market price, the expectations for future prices increased. In 2013, the oil price was estimated at approximately 90 USD/barrel. After the oil prices dropped in 2014-2015, the expectations have once again been reduced. Currently, the expected price is at approx. 60 USD/barrel.

Figure 3-1 illustrates these conditions. The oil price shown is the market monthly average for Brent Blend. The planning assumption for the oil price used by the industry in financial analyses varies from company to company. The indicated curve is intended to represent a typical industrial level at the time. The UCCI is an international cost index for offshore projects, while the dotted line is a general cost index (inflation factor). The dramatic slump in oil prices during the last half of 2008 was caused by the financial crisis.

Historically, the level of costs in the offshore industry has varied in line with the expected oil price. This means that the breakeven price also varies over time and reflects expectations for the market price. The breakeven price generally falls within a range of 50 to 90 per cent of the expected market price.

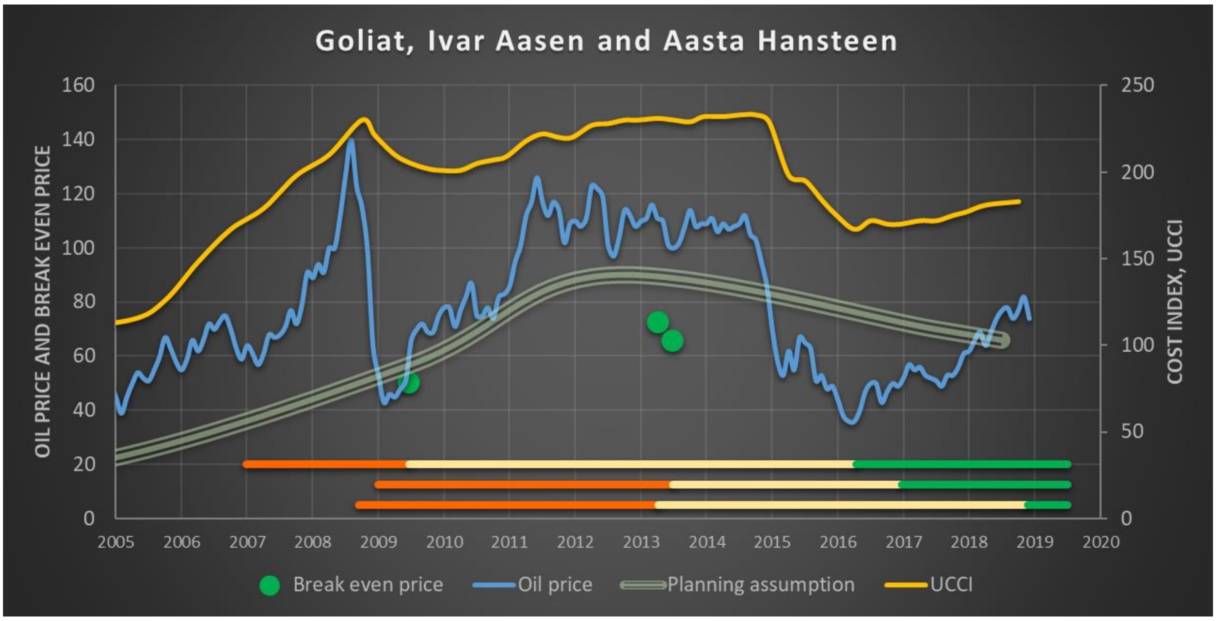

Figure 3-1. Price development and expectations 2005 – 2019 (Source: Acona)

4 Goliat: Summary and recommendations

4.1 Observations

The decision process in the license between DG1 and concept selection did not significantly differ from other projects. However, the project did receive significant attention from environmental organizations, local governments, the industry, as well as from central Norwegian and international stakeholders and NGO's.

Given the frame conditions of the project, the concept selected is a good and natural choice. In operation the platform has proven to be well-functioning in the Barents Sea. In addition, the platform has provided a good working environment for those working onboard.

Several parts of Goliat was completed in a successful way. The understanding of the reservoir and its conditions has not changed much since the approval of the development. The number of wells, in addition to the design of the subsea installations, have been consistent over time. Prior to its use, there were some issues and extra cost related to the drilling rig. The change from water-based to oil-based drilling improved the drilling performance to an acceptable level. The engineering, fabrication, and installation of the subsea installation went without problems and at expected cost. Maritime installation activities at the field, including tie-in of wells and risers, were completed without noticeable issues.

During the planning phase, high attention was experienced from the surroundings concerning power from shore. There were uncertainties concerned with the use of onshore electricity related to availability and supply regularity. It was, therefore, necessary to develop technology for new solutions. This part of the project was completed satisfactorily, and the solutions have proved to work well in the operation phase. The project and the operator should also be given credit for the way they have integrated with the local community by creating new jobs, giving employees efficient training, as well as establishing a knowledgeable oil pollution preparedness organisation for the production face.

Stakeholders with a wide range of perspectives, often with varying degrees of professionally funded opinions, have been a distraction for the project. This meant that some issues were over-focused while others were almost forgotten. All risks identified during the early phase have later been handled in a satisfactory way. Risks concerning the execution of the platform and topsides part of the project that showed to be the severest, were not included in the top 10 lists until the later stages of the project.

The project's greatest mistake was tied to the execution of the platform, especially the execution of the topsides. The study has identified four fundamental causes of delays, cost overruns, and poor quality, which in turn has resulted in poor regularity and significant HSE problems during the start-up phase. These are:

1. Insufficient quality and technical maturity of the project at DG2, DG3 and after the extended Feed.
2. Significant changes in contract and execution strategies during the project.
3. EPCI strategy, choosing a not fully qualified contractor for this type of contract.
4. A project team that was unable to regain full control of the execution of the work included in the contract.

The platform execution was more or less out of control the whole period from 2009 until 2017. This resulted in a 2.5 years delay in start-up, a total cost overrun of 65 % for the project, a platform arriving at the field with significant defects and inadequacies in addition to technical documentation that deviated considerably from the as-built documentation. This, in addition to the operator's over-eagerness to start production, resulted in a series of unwanted events and disruptions of production during the first two years of operation.

4.2 Inadequate maturity and quality by DG2 and DG3

The problems started when passing DG2. The DG2 was passed internally in Eni (currently Vår Energi) at the end of 2007. At this time, no concept selection had been made (four remaining concepts). The partners, which at the time were StatoilHydro and Det norske, rejected DG2, stating the lack of maturity, unrealistic plans and costs as their reasons. In April/May of 2008, a new attempt of passing DG2 was made. According to StatoilHydro's professional requirements to quality assurance, the project had not matured to a DG2 level. They stated that an acceptable technical DG2 level earliest could be in place at the end of 2008. The professional reviews were crystal clear in that plans and estimates were unrealistic. Still, the management of the former StatoilHydro chose to approve DG2 in May 2008.

Eni's requirements to technical maturity at DG2 and DG3 does not differ considerably from the requirements of other international companies. However, assessing the quality of the supporting underlying documentation for the two milestones, neither Eni's own, nor internationally acknowledged requirements were satisfied.

By late 2008 the operator put forward DG3 for decision, still with two different platform concepts. In December 2008, StatoilHydro's acquisition of Det norske's 15 % stake was finalised. From this point and onwards StatoilHydro had veto rights in the licence and thereby the opportunity to oppose all proposals by the operator.

In a meeting 22.12.08, based on their own internal QA/QC reviews, the management of StatoilHydro elected not to approve DG3. They wanted several specific questions to be further elaborated. A new and simplified approval process was conducted, resulting in approval of DG3 and the subsequent PDO submission approved by the management 06.02.09.

From the study group's knowledge and based on the information available at the time the decision was made, the Goliat project did not meet either of the companies' internal requirements of DG3 maturity. Consequently, the approval must have been based on a formal deviation approved by management. Maturing from DG2 to DG3 in 8 months is also unusually short time for a project this size, especially considering that two different concepts were developed simultaneously. Typically, this should take approximately a year, given that the basis of DG2 was satisfactory.

The PDO was submitted 18.02.09 based on a concept that was selected as late as in January the same year and without the usual maturity of a Feed study. StatoilHydro added several GNOK to the estimates of Eni, based on information from interviews. Hence, the economy was more marginal than what was visible to the authorities based on the official PDO document.

Many of the interviewed stated that this was a result of both Eni and StatoilHydro's wish to approve the PDO by the spring of 2009, before the 2009 general election in Norway, and before the planned submission of the management plan of the Barents Sea-Lofoten Area of 2010.

The rush to submit a PDO resulted in a lack of quality, which could have been eliminated had enough time been used to mature the concept technically before signing the contracts. This would have added a year to the plan for start-up from 2013 to 2014. This did not happen, and it resulted in an actual start-up in 2016.

The process of integrating satisfactory safety into the technical solutions was the focal point during the earlier phases. The circular topsides and the need for wind protection, combined with criteria for the explosion loads, created challenges for the project that surpassed what is common for projects of this size. Still, the chosen solutions appear to be appropriate.

4.3 Choice of contract strategy and follow-up

Following the official concept selection in January 2009, Sevan was granted a 'Post-Feed' contract to further develop the basis for a new bidding process. Also, a 'Concept-fee' for Sevan's concept was agreed on. An invitation to tender was announced in June 2009 to the following consortia:

- Aker Solutions/Samsung
- Saipem/DSME
- Hyundai Heavy Industries (HHI) (with CB&I as a subcontractor)

Hyundai was awarded the contract 05.02.2010. The subcontract for global engineering was awarded CB&I the following day. During this phase, it became evident that the technical basis provided by Sevan had large deficiencies. This mainly concerned the topside, which represents the majority of FPSO's costs.

The work following Feed showed an underestimation of the amount of equipment required, as well as lack of space in certain areas. This is illustrated by key figures for density and area utilisation at 752 tons (by DG4). Finally, during the fall of 2010 attention was given to weight increases. The estimated weight in the PDO report was 18 200 tons. At one point, the estimate of the topside dry weight was above 30 000 tons. A task force was designated to resolving the weight issue. During the spring of 2011, a consolidated estimate of approx. 28 500 tons was established, which remained relatively stable during the remaining period of execution. Figure 4-1 provides an outline of the FPSO weight development for hull and topside over time.

Figure 4-1. Weight development for platform structure and topside (Source: Acona)

State of the art practice of concept selection incorporates fabrication studies, including equipment layout, modularisation and interconnection, combined with proper weight estimation. Sevan's concept is not designed for efficient construction. It also appears that constructability was not regarded as an important issue before awarding the contract to Hyundai.

In the year following the award of the contracts, lack of progress in the detailed engineering was reported as a major issue. Hence, the decision to transfer the global engineering responsibility from CB&I and back to Hyundai turned out to be unfortunate and contributed strongly to the problems that followed.

The chosen construction method more resembles the construction of onshore installations, where simplicity in prefabrication was prioritised above than weight-optimisation. Weight increases were not regarded by Hyundai as their problem. The large number of deck sections built on board caused congestion of work on the platform itself, which in turn resulted in poor productivity.

According to the interviewed, the EPCI contractor did not fulfil the requirements of the contract or their responsibility in managing subcontractors. Consequently, reports of progress, costs, control of change orders, planning updates, and quantification of risk measures were not completed satisfactorily. In other words, the project had issues concerning management and the understanding of the associated risks and measures. The contractor, Hyundai, did not have enough knowledge of procurement and engineering, causing considerable delays from the start and onwards. The technical basis lacked maturity, and the execution of EPCI came off to a bad start.

The engineering was underestimated. When the contract was signed the estimate was 1.3 million hours, while using experience figures from analogues would have given over 3 million hours. Fabrication of the topside was estimated at 4 million hours but ended up exceeding 10 million hours. In total, nearly 20 million contractor hours were spent. Hours for offshore hook-up was estimated at 500 000 hours in the contract, and this increased to over 1.3 million hours. The carryover was estimated at 1.5 million hours but ended up exceeding 2 million hours.

From the onset the hourly rates and productivity were at a reasonable level. However, as large portions of the work had to be re-done and re-installed, the resulting project productivity was poor. The total costs of topside and platform, including the operator's management, increased from 18.5 GNOK at DG3 to 29.9 GNOK at DG4.

Another area that caused large problems with regards to quality of the plant as well as cost increases was procurement of materials and equipment. Hyundai was responsible for procuring, as well as follow-up of delivery of materials and equipment. The scope of work and delivery specifications were initially incomplete due to problems in engineering. Hyundai spent little effort in pursuing this part of its responsibility concerning EPCI. As a result, the follow-up was left to Eni's project group. This compensating measure came late, causing delays in delivery and inadequacy in delivery quality. In turn this required corrective measures, resulting in additional delays in the construction.

Parts of the construction was left to a shipyard 8 km from the offshore yard. The shipyard traditionally works with simple standard products. Productivity fell dramatically in the spring of 2014. The quality was so bad that the project lost at least 3 to 4 months of progress.

Due to the massive workload on the yard, the greater part of the workforce was hired from external subcontractors. A total of three fatal accidents were linked to the Goliat project. The root causes of all three fatalities were inadequate training and poor work supervision.

The EPCI contract included commissioning of the project, meaning turnkey of all systems. This included a yard stay in Norway estimated at 500 million NOK. During the construction phase, both commissioning personnel and commissioning systems were replaced, resulting in lack of continuity. Documentation of what had and had not been completed at the construction yard was incomplete and inadequate.

The correspondence between the actual state of progress and what emerged from punch-lists and other documentation was inadequate. This represented the greatest risk for the commissioning phase in Norway and for a safe start-up. Had these conditions been known, and they should have been, the project could have been paused to gain control of the remaining workload, prior to towing the platform out to the Barents Sea. This would have ensured safer start-up, better quality of the work completed, and improved regularity following start-up.

4.4 Project organisation of Goliat

From the start of the project to DG3, Goliat was organised as an integrated team with additional personnel from Statoil (later StatoilHydro). Following DG3, central functions were partially retracted to the base organisation in Eni and organised as project service deliveries. This contributed to an "us vs. them" attitude. Formally the CEO of Eni Norway became the project director, a role none of the shifting CEO's of Eni Norway in reality took on.

There were also considerable disagreements between the Norwegian organisation and the headquarters in Milan. It appeared that Milan did not understand or accepted the Norwegian working rules and ways of cooperation. HSE representatives and trade unions were excluded from all essential discussions concerning the project. This did not change until the arrival of Eni Norway's latest CEO.

From the start of the project, Eni did not have a department for operations of offshore installations in Norway. When the operation organisation eventually recruited personnel for operations, some of these were sent to Korea. They had difficulty being heard and had a lot of conflicts with the Italian project management. Most of the Norwegian consultants were eventually sent home. They were replaced with Italian personnel from Eni with limited knowledge of Norwegian requirements. A limited number of the key project personnel followed through to the operations phase. During the first year in the Barents Sea, the relationship between operations and project was strained, causing several notes of concerns being sent to PSA.

4.5 Operations start-up

The application for consent for the Goliat FPSO start-up was sent to PSA (Norwegian Petroleum Safety Authorities) on 13.02.15. By May 2015, Goliat FPSO was installed at the field. Eni was granted partial consent to utilise living quarters and cranes on the platform on 20.04.15, for the platform to house personnel and load supplies and materials on board. At the time, PSA was still processing Eni's application for consent, and the production start-up was postponed awaiting consent.

PSA completed five audits of Eni in the application process prior to granting consent (from 15.02.15 to 19.01.16). During the application process, PSA received seven different notes of concerns regarding the conditions at Goliat. Based on the findings from the audits, two major areas of concern remained: logistics and barriers (including electrical/ignition control). PSA asked Statoil to assess the basis of the operator's decision on the Goliat start-up. On 08.01.2016 Statoil sent a letter to PSA expressing that Eni's plan "contains the required activities that must be completed prior to production at Goliat." According to Statoil , the plan was feasible.

On their own, Statoil continued to review the points specified in the plan to evaluate whether Goliat FPSO was ready for production. In Statoil 's report from this verification, released on the 12.02.2016, it was concluded that the plan included all necessary activities. Statoil also noted that a great deal of work remained. The verification report from Statoil was used in risk reviews prior to start-up, attended by representatives from the project, operations and Statoil.

The conclusion from these reviews was:

- The platform is completed as much as practically possible before introduction of hydrocarbons.
- All systems were handed over from the project with a signed certificate of completion.
- Ignition source control is to a large degree achieved with some documentation outstanding.

Statoil questioned whether outstanding work transferred to after start-up was underestimated.

On 11.03.2016 Eni Norge and Statoil confirmed to PSA that the criteria for start-up of Goliat were met.

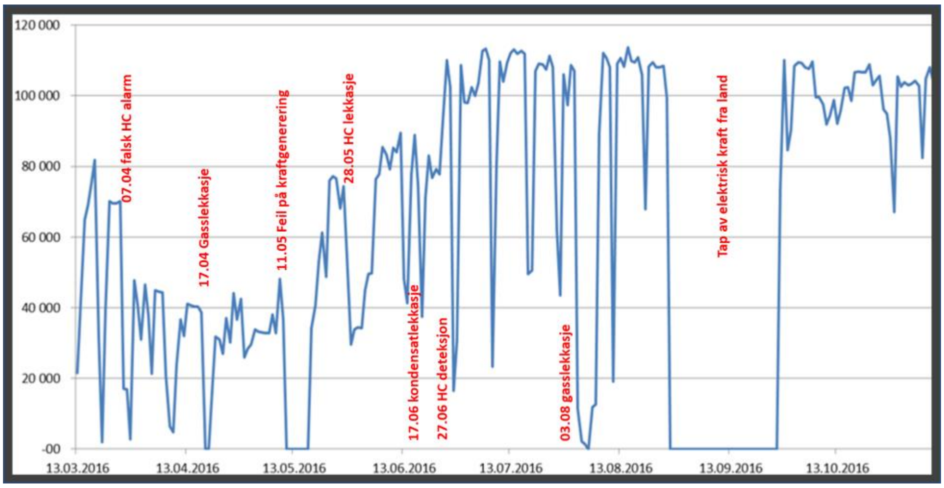

Figure 4-2. Operation regularity after start-up (Source: Eni)

The first months of operation was demanding. According to a report from September 2016, there had been 54 unplanned shutdowns 164 days (5.5 months) after start. See Figure 4-2 for more details.

4.6 Learnings

The management and headquarters of Eni should have gained knowledge of, and respected, Norwegian rules and regulations (NORSOK), as well as Norwegian labour laws and ways of cooperation. It appears to have been a cultural clash with Italian ways of thinking and working principles in both Norway and Korea.

There was non-compliance with Eni's internal requirements to technical maturity. It is the opinion of this study that StatoilHydro had a “see to it” duty as partner, a responsibility they did not take. The government, OD and PSA, also missed this fact.

The tremendous public interest in Goliat was a distraction for the project, especially for project management. The base organisation of the operator should have better shielded project personnel by establishing a separate group to deal with these issues.

Given the state of the project in 2009/2010, the overall project plan should have been revised, and the start of production postponed with minimum a year. Also, thorough risk assessments and an understanding of the associated consequences are missing. There has been little attention on mitigating measures and actions by the management both on project and company level.

Construction work started too soon, considering the maturity of engineering documentation, constructability, operability and so forth. When signing a contract with construction yards in the East, knowledge within the operator's own organisation on planning to a detailed level is required (interrelation between drawings, procurement activities, fabrication and installation activities). Furthermore, capacity and competence is required to support the contractor in areas where they may fall short. The most serious mistakes in the Goliat project at the point of time leaving Korea, were:

- Incomplete overview of remaining work.
- Poor quality control of work completed in Korea.
- Incorrect punch-lists with a lot of mistakes.
- Wrong decision to not utilise a yard stay in Norway before offshore completion.

Unclear responsibilities between the project and operations in the first part of the offshore completion phase was also unfortunate. The pressure from the management of Eni to start production early was by itself a safety risk. At the time of the start-up, there was still uncertainty about the remaining work.

Three years into operations there is still outstanding work from the project phase, which may be a problem when prioritising this remaining work, maintenance, and possible modifications. It is important that the operator, together with HSE representatives, make sound judgments concerning these priorities. Also, they should make use of Equinor's extensive operational expertise in these areas. PSA should consider conducting regular audits.

As documented by the operator, there were a series of unfortunate events and operational shutdowns during the first years. None of these events posed a major accident risk. The platform barriers have functioned according to design, and the platform was safely shutdown when events occurred.

Current Situation

- All who were interviewed state that the platform is currently in stable operation.
- The arrival of Norway's last director of Eni was the turning point.
- The conditions for cooperation are now in place.
- HSE is managed in the same way as on other NCS installations.
- The work environment is perceived as good.

5 Aasta Hansteen: Summary and recommendations

5.1 Observations

Aasta Hansteen is located in one of the toughest areas on the Norwegian continental shelf when it comes to waves and other climatic conditions. The field lies 300 km west of Bodø and far from other infrastructure. The water depth is 1300 meters.

There have been made several minor gas discoveries in the area. It would not be possible to develop these without a gas export route. Consequently, Aasta Hansteen and Polarled must in this context be seen as projects with marginal economics for the first phase, which in due time hopefully will trigger development of new reserves and by that add to the profitability of the area in the longer term. Statoil also succeeded in teaming up with local stakeholders, and at the same time deflecting critics in a good way.

The requirement to preserve the limited amounts of condensate from the field was the main driving force behind the concept selection. The selected concept was a Spar platform with integrated condensate storage. This gave the concept new technical functions that likely were underestimated in the early phase. This, combined with the choice of steel risers at the given water depth, necessitated an extensive qualification of technology to be initiated.

Today, Equinor appears to be one of the world's most competent operating companies with respect to field developments. This is also demonstrated at Aasta Hansteen through a successful qualification of technology, subsea equipment that were produced and installed without issues, and with satisfactory HSE-results. In addition, the performance in drilling and well completion exceeded expectations, saving 1.6 GNOK in costs.

5.2 Delays in the development plan

Statoil (currently Equinor) is also a partner in Goliat. Still, both EPC contracts (the Spar platform and topsides) were placed with Hyundai at a time when Goliat's problems with execution were known.

The complexity of the construction of the platform structure was underestimated. A design containing circular-cross sections are generally considered to be more difficult to construct than those with square cross-sections, and the construction of the circular cylindrical part, while in a horizontal position, made it even more difficult. Consequently, the construction of the platform structure was strongly impacting the time to complete the project.

Earlier Spar platforms did not have oil storage. This was regarded as a manageable extension of the concept. It is, however, clear that the decision to include a storage for condensate in the hull had greater consequence than what was first estimated. Hydrocarbons inside the main hull, combined with the need for safe access including lifts and stairs, increased the complexity greatly. The strict Norwegian regulations may also have contributed to a more expensive solution. In addition, an active ballasting system was required to control the platform's draft at different degrees of filling of the condensate store.

The construction of the Spar platform became critical in terms of the schedule. The project was not prioritised by Hyundai in the beginning and was consequently considerably delayed. The complexity/workload also increased, and the construction period went from 13 to 35 months in total. The work with the Spar structure was underestimated and the construction hours increased from 2.5 million hours to 10 million hours.

The production start-up of the platform was at an early point in time postponed by 12 months, to the third quarter of 2018. In the end, the total time spent from DG3 to DG4 was 71 months, which is far more than usual for equivalent projects. The spar structure including storage ended up costing approximately 6.5 GNOK, which exceeded the PDO estimate.

5.3 Learnings

Satisfactory project execution and completion of the platform in Korea was mainly due to:

- The willingness and ability to learn from experience (from Goliat and others)
- Good mitigating measures regarding the deficiencies of the EPC contractor (Hyundai), with close follow-up of engineering, procurement, and construction
- Good HSE-training and follow-up yielded good HSE-results
- Introduction of additional local inspectors to ensure quality

The close follow-up by Statoil of Hyundai resulted in the delivery of a cost-effective topside (low total price per kilo) with good quality.

From experience the offshore hook-up and commissioning of a topside of this size would be approximately 6 months in total, while 8 months was spent in this project. This was a result of errors/technical difficulties in certain equipment parts that had to be replaced. Even though the project had some challenges that caused delays in the offshore completion phase, it was never an issue to start production before the plant was completed in terms of relevant safety requirements.

Aasta Hansteen went into operation 16.12.2018 and gas was exported into Polarled the next day. PSA has only completed one audit following start-up (January 2019).

Following start-up, no reports or alerts have been made of serious incidents with HSE consequences, before a gas leakage 08.04.19. This incident was still under investigation when this report was completed.

Project results not as successful was:

- In total 15 months of delays regarding the plan approved in the PDO due to underestimation of workload and construction complexity for the Spar platform.
- The weakening of the total economics in the first phase due to less gas in Polarled from other fields.
- Start-up problems and disruptions during the two first months following start-up due to wells not sufficiently cleaned up by the drilling rig prior to start-up.

6 Ivar Aasen: Summary and recommendations

6.1 Observations

In the early phase, the operator, Det norske (currently Aker BP), focused on rental concepts based on the project's risk exposure and the company's financial situation. The partners (Bayerngas and Statoil at the time) disagreed, leading to additional rounds of studies.

The authorities requested, with good reason, an evaluation of a coordinated development of Edvard Grieg and Ivar Aasen. The somewhat unwillingly operators tried to bypass this solution. Many concepts and tie-in options were studied in this phase. The consequence was a one-year delay of DG3, relative to the first plan, and a conceptual compromise.

In December 2012, the PDO was forwarded to the authorities and approved in June 2013. Parallel to the treatment of the PDO, contracts with a value of 7.8 GNOK were signed, subject to the approval of the PDO by the authorities.

The work scope was based on a fixed platform with a jack-up drilling rig. Availability of capacity at Edvard Grieg "set" the start-up date to 4Q 2016. The engineering capacity in the market was critical. No engineering capacity was available in Norway. Consequently, the Feed work was set to London where Aker Solutions had an office under establishment. Clear requirements to use of NORSOK were made. No significant conceptual changes of the concept were made following DG2.

The weight of the integrated topsides increased, hence, the decision to change from a three-lift strategy to a four-lift strategy was made. This meant that the integrated topsides was split into two modules. The tenderers for the topsides were Kværner, Samsung, SOME, DSME, Aibel, and Heerema (the last two resigned).

The availability of a suitable drilling platform was a critical factor. Hence, by December 2011 a provisional deal with Maersk was made regarding the lease of a new jack-up platform of the type CJ-70 XLE. The drilling platform was made available before the plan and the drilling and completion activities were finished in record time, which led to a 30% reduction in costs for this part of the project. In monetary value this is approximately equivalent to the increased cost of the topsides.

The requirement to facilitate power from shore was the subject of discussions and extra rounds. Looking back, the chosen solution was satisfactory. The cooperation/negotiations with Edvard Grieg (Lundin) was demanding. However, after the deal was signed the cooperation has been successful.

The last 6 months of preparing for production start-up was characterised by good planning and control. The rapid production build-up and good regularity indicate that time pressure has not affected quality and safety. During the first year of production (2017) 3.04 MSm3 was produced, with good regularity. In October 2017, the production reached 60 000 barrels/day, which means that the production plateau was reached a year ahead of plan.

During this time period, Aker BP has been through great changes as a company. In 2014, Marathon's Norwegian company was merged with Det norske. This meant that a relatively large operational organisation joined the company. Further on in 2016, Det norske and the Norwegian part of BP agreed to create a new joint company, Aker BP. Consequently, more operations organisations became part of the new company.

As of today, a great deal of work is put into streamlining the different operations in Aker BP to common company standards. Ivar Aasen has also transferred the control room function onshore. Despite of the great pace of change and high level of activity, it appears that operations at Ivar Aasen is under good control with high regularity and satisfactory HSE-results.

6.2 Maturity and completion of the topsides

Early in the development phase it became clear that the technical description had weaknesses. This was the case for the topsides, which constitutes most of the platform costs. The lacking Feed quality made it necessary to increase/intensify follow-up during the execution phase. Also, it appeared that SOME was not completely qualified as an EPC supplier.

The relationship between Det norske and its main owner led to uncertainties and delays leading up to signing of the contract.

The number of engineering hours were more than doubled and lead to delays in the schedules from 2012 and up to 2014. The construction contracts for platform and modules with considerable interdependences were placed at different locations in different parts of the world, making communication more demanding.

Purchase orders were not properly followed up by SOME, in practice the operator took over this responsibility. This led to good quality and timely deliveries (with some cost increases). HSE and quality was prioritised over cost and time by the operator.

The project team's ability to cooperate with SOME led to no additional cost added to the construction cost, even though the number of hours increased (doubled). This cooperation climate yielded good HSE-results and quality, and timely delivery.

6.3 Learnings

Project success factors:

- «One team» attitude both internally in the operator organisation and towards the main contractors.
- Experienced, competent project employees and a hands-on project management.
- Focus on HSE and quality (over time and cost).
- A good understanding of risk and a management that responded quickly (and correctly) when problems occurred.
- No significant changes in the design basis or concept solution following DG2.
- Good support from own management and from the key partner (Equinor).

Compared with the amount of reserves in the ground, the concept is relatively expensive, which led to a high break-even price initially. A higher degree of integration between Ivar Aasen and Edvard Grieg, with for example only one field centre, might have given socioeconomic benefits.

The dependency of Edvard Grieg is a challenge – both considering production management, utilisation capacity, and regularity. For example, the dependency of power from Edvard Grieg has affected regularity from time to time.

It is viable for a new operator to successfully complete a project on the Norwegian continental shelf. The preconditions for success appear to be:

- Project management and personnel with NCS experience and a solid understanding of Norwegian practice.
- Strong support from the management and base organisation.
- Competent partners that can contribute with experience and professional support.
- Focus on quality and HSE (above time and cost).
- Involvement of HSE-representatives and future operation organisation.

7 Comparison of the three projects

The three projects are similar in that parts of the projects lacked enough maturity upon the signing of the main contract(s) for platform and topsides. An EPC strategy was chosen in a heated market and all three projects ended up in Asia. Goliat and Aasta Hansteen were constructed at the same yard, Hyundai in Korea. Ivar Aasen was constructed at SOME in Singapore. All three projects struggled with start-up problems in the main contracts. However, three different strategies were chosen to solve similar problems.

Goliat. Goliat had most problems with technical maturity. Initially, all problem solving was left to Hyundai, who was responsible for the delivery. Only long into the project did they initiate own measures. The delays were considerable, but Eni in Italy refused to change the production start-up date. When a new date finally was set, the new date was still unrealistic. The platform project simply was out of control.

Aasta Hansteen. In this project, the spar structure was the main problem. The complexity of including a condensate storage was underestimated and the workload increased. This, combined with a lacking capacity at the yard, made Equinor early on to postpone the project with one year. This ensured control of the construction of the Spar structure and contributed to the delivery of one of the most cost-effective topsides on the Norwegian continental shelf after year 2000. The HSE-result on the yard was good for this project. The main difference from Goliat was that Equinor took control of the EPC contractor from day one.

Ivar Aasen. The project was aware of the missing maturity, still the project chose to enter the market to ensure capacity in a very tight market, both for engineering and construction. The problems were many, delays arose from the start, and the engineering was lacking in quality. Aker BP chose to cooperate with SOME and took on the responsibility of the EPC contract in the follow-up of both procurement and engineering. For the total contract, the cost increase was significant. However, cost increases were avoided for the construction work. The platform was delivered according to plan, and with a good HSE-result.

Safety in design. The study of the three projects shows that the way safety in design was handled in the early phases, to a large degree followed the same methodology regardless of operator and development solution. This proves that the principles and methods defined by the Norwegian requirements and standards are well understood and implemented in the industry.

All three projects have been familiar with and have implemented the systematics developed for the Norwegian continental shelf that are reflected in regulations – PSA/Norsok. This is reflected by the fact that PSA has had few comments in the treatment of PDO. All three projects have chosen concepts and solutions that ensure safety – even though there are some examples of compromises being made.

The role of the partners. In Aasta Hansteen the partnership was not subject to great challenges. Both ConocoPhillips and Esso were proactive and constructive partners in the early phase. The current partners also appear to fulfil their roles in an efficient way.

In Ivar Aasen, Equinor initially had veto rights. Combined with a limited interest for the discovery and other priorities in the area, this gave the operator many challenges and added work. Following the unitisation of the licenses, the partnership consisted of several small, and to some degree inexperienced partners (six partners in total) that did not have so much to bring to the table. The main partner was still Equinor, that has given support, transfer of knowledge, and contributed with systems and reviews. The role of Equinor as partner at Ivar Aasen following the concept selection is, according to Aker BP, an important factor in the successful execution of the project.

In Goliat, Equinor was the sole partner. Experience from other projects has shown that this is a difficult position. Partnership should preferably consist of at least three participants.

Equinor offered the same type of assistance to Goliat as to Ivar Aasen during the project implementation, including assistance with technical standards, procedures, reviews and more. Still, Equinor could have contributed more with suggestions and support to reduce execution risks. As an example, the transfer of the engineering responsibility from CB&I to HHI in Korea involved a great and completely unnecessary risk. Equinor failed to meet their "See to it" duty to ensure quality at DG2 and DG3. Questions can also be asked if they stated sufficiently clear requirements to the operator in conjunction with the start-up.

The role of NPD. NPD does an excellent job in taking care of the interest of the state to ensure proper resource management, as well as in sustaining area interests. However, NPD does not appear to have had any role in or influence on the development phase between DG3 and DG4 for any of the three projects in question.

The role of PSA. According to Ivar Aasen, PSA had little interest in the project until after the concept selection had been made. PSA appears to have had a sensible and good spread of audits and themes during the project execution and operations phase on all the three projects. It is suggested that PSA could state their requirements and give their feedback even more clearly when operators (Eni in this case), have not sufficiently dealt with identified issues.

The government's overall treatment and approval of PDO appears to be a thorough process. Still it appears to have missed the target on Goliat where a far too immature PDO was approved. When reading the comments made regarding Goliat in national budgets between 2012 and 2016, it is apparent that the government were not properly informed of the real problems at Goliat during these years.

The role of licensees. In recent years, several new players have entered on the Norwegian continental shelf, some of limited size and specialisation (e.g. exploration companies). When discoveries are made by such companies, and they want to move into a development phase, the project organisation will utilise most of the technical resources of the company. This creates problems for the base organisation in carrying out independent internal controls. If the other licensees are small and inexperienced too, the "barrier" control is further weakened at the license level, making up an increased risk for both execution and for HSE-results. An attempt to illustrate the change from today's situation to the described new situation is shown in Figure 7-1.

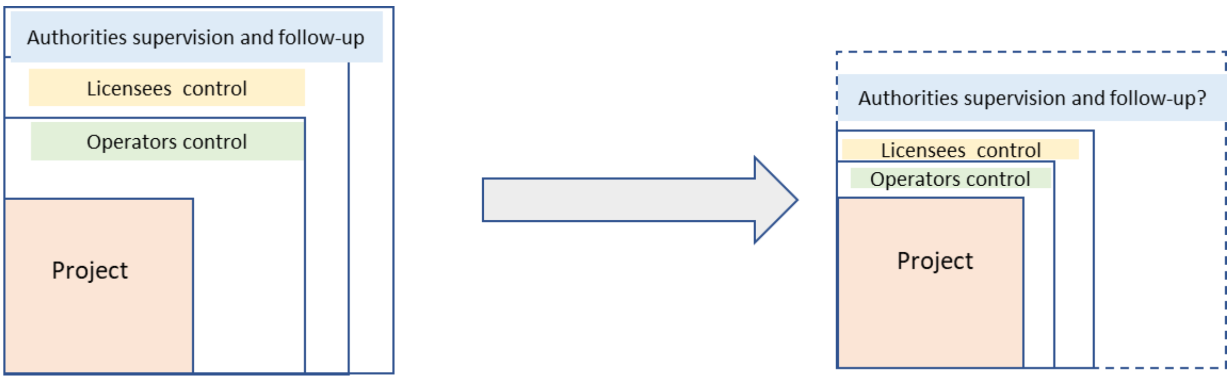

Figure 7-1. Changes in barrier control due to less experienced licencees (Source: Acona)

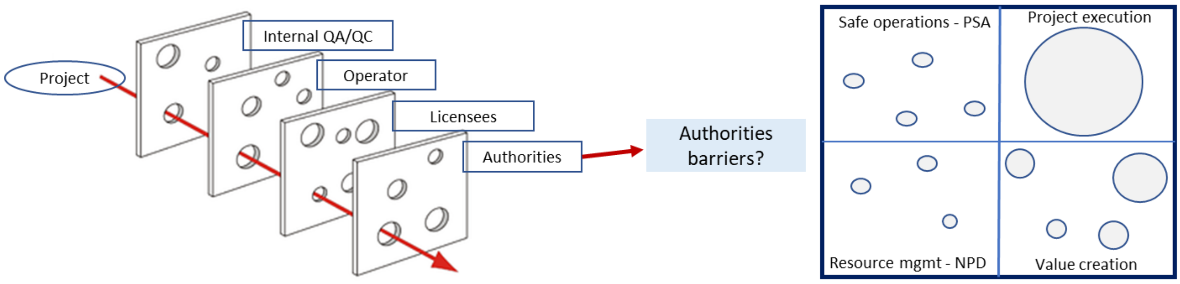

Figure 7-2. Barrier model (Source: Acona)

In this study, the project group have stated that the governmental bodies (NPD and PSA) are competent in carrying out their main responsibilities (PDO handling, resource management and ensuring safe operations). The follow-up during the development phase is limited, see Figure 7-2. It is the opinion of the study group that the government should consider to strengthen their own competence, enabling them to make more qualified reviews and supervisions with the companies and their development activities, and also make sure that both the operator and licensees meet their requirements and expectations.

8 Proposals for possible improvements

Based on the review of the three selected projects, the study has drawn up the points below as a checklist for safe, good-quality project execution. Many players already have most of these in place through their own requirements and management systems.

The nonconformities observed at the various players almost always represent deviations from their own guidelines and requirements. That is to say "compliance" represents the biggest improvement potential for virtually all the players. This means that, when planning work in the next phase of the project, all available methods must be deployed in relation to good quality plans and carefully prepared risk analyses with associated mitigating measures, which ensures that all the challenges normally faced in the relevant phase are thought through, planned for and taken into account.

8.1 Overview of operator's work process and methodology

- Have a fully detailed management system with clear requirements for maturity, quality assurance (internal and external), and continuous collaboration across all functions in the project both before and after the various DGs.
- Strengthen internal quality control and project follow-up in the operator companies.
- Define expertise requirements, with genuine checking for key posts. Ensure that own personnel occupy key positions (limit use of consultants).
- The project's mandate, organisation and responsibility must be clarified as early as possible.
- Ensure genuine involvement of the safety organisation and future operating personnel at an early stage, based the Norwegian tripartite model for collaboration between unions, employers and government.
- Do not pass DG2 or DG3 if the project/concept does not meet the maturity requirements (both commercial and technical).
- Have good plans for and full control over all technology development on which the project depends.
- Strive for continuity in key project posts and use team building actively to implement shared ambitions, goals and attitudes, not only throughout the project but also with the operator's base organisation, licence partners and contractors (one team attitude).
- The project's execution strategy should be established early and must take account of the operator's expertise/capacity, market availability, and project size and complexity. Acquire experience actively from other projects.
- The prequalification process must be thorough enough to weed out possible suppliers with high execution risk and low delivery quality.
- Contract evaluation must take account of all actual costs (transport, follow-up, productivity expectations and expected quality costs).
- The project must be assured that contractors train their own personnel on the desired HSE standard and quality standards (Norsok and so forth).
- Early identification of risk, establishing preventive action plans, genuine risk management and follow-up must be on management-meeting agendas at all levels.
- Good and realistic schedules with in-depth understanding of interactions across the project and between different contractors are crucial for success.
- Possible problems (time, cost and quality) identified must be got to grips with as quickly as possible and be reported to both own management and the partnership.
- Good purchases depend on knowing what is being purchased. Operators should make greater use of technical specialists in procurement processes. Such personnel are better able than people with other specialisations to help reduce the scope of overlapping and unsuitable requirements and to assess the risk/benefit of proposed

solutions. Technical specialists should supplement financial and legal expertise, not replace it.
- An overview of and control over all interfaces in the project must always be maintained, along with an overview of the consequences of changes made along the way (for the relevant contract, but also for other contracts).
- The principles of the operating philosophy must be in place at DG2. Production preparations, and making provision for safe work processes and procedures, must begin as soon as possible in detailed dialogue with those shaping the technical solutions.
- Requirements on the level of documentation and the operations system to be used must be clarified early enough for inclusion in the terms for all important deliveries.
- The division of responsibilities between project and operations must be crystal clear from mechanical completion of the first system until all the systems are handed over to operations.
- Requirements for the level of completion at the handover of responsibility must be established and never deviated from if this poses a safety risk.
- The main rule in the production phase: shut down if doubts over safe operation arise.

8.2 Partners and the partnership's responsibility

Pursuant to the PDO guidelines (updated in 2017), the licensees must:

- act as an internal control system in the production licence
- see to it that activities are conducted in a prudent manner pursuant to applicable legislation and that they ensure good resource management and HSE.

The following possible improvement areas (compliance) are identified for licensees:

- see to it and ensure that the operator's management system is up to the mark and implemented
- clarify the project's mandate, organisation and responsibility as early as possible
- establish common plans in the licence for reviews, quality assurance approval in both planning and execution phases
- do not approve DG2 or DG3 if the project/concept fails to meet the maturity requirements (both commercial and technical)
- be active in sharing experience from other licences and own business
- contribute to and support the operator in areas with identified expertise gaps
- assess the quality of the commercial and technical solutions presented as well as the realism of plans and cost estimates, and avoid time management affecting quality
- use expert consultancy support to cover gaps in one's own expertise profile
- see to it that the operator meets all clarified HSE requirements and quality criteria
- ensure that operations do not start until all necessary safety systems are in place.

8.3 Government's role

The following possible improvement areas are identified for the key players.

NPD

In addition to ensuring optimal utilisation of Norway's oil and gas resources, the NPD, together with the MPE, must be involved in planning and development of projects. It must be a driver in seeing that prudent resource management, good value creation and optimal social-economic results are secured. The NPD's resource management responsibility appears to be very well taken care of.

The NPD conducted a study of five finalised offshore projects for the MPE in 2013. Project execution received a larger place in the NPD's follow-up in the early phase following this report. NPD has started to put questions to the operator as early as DG2 on relevant issues such as the degree of engineering completion, qualification of suppliers, contract strategy and taking care of risk.

Since 2014-15, the NPD has also conducted meeting series annually with selected projects in the execution phase. This is additional to the annual project updates providing information for the government's Finance Bill. These meeting series have typically been directed at issues related to project execution, weight development, cost developments, risk and mitigating measures. The purpose is to secure an updated status for the projects and to inform the MPE of this. That focuses attention on project execution in the various companies and informs the NPD, so that its follow-up in the early phase and execution can be improved.

An improvement potential nevertheless appears to exist in assessing the realism of the technical concepts with associated execution strategies, schedules and costs, and consequent realisation of developments. Possible improvement areas are:

- seeing to it that a partnership has adequate expertise when PLs are awarded and when development decisions are taken
- further strengthening follow-up in the execution phase with expertise aimed at securing correct reporting and giving early warning to the MPE on upcoming execution problems, delays and cost increases
- establishing an even closer and better collaboration arena with the PSA, which could strengthen overall regulatory follow-up and supervision.

PSA

The PSA sees to it that HSE requirements are satisfied with an acceptable level of risk from choice of concept, through project development and into the production phase. It also gives consent to the start-up/commencement of defined operations.

This regulator has good technical expertise and takes a systematic and risk-based approach to which projects, disciplines and issues it wants to audit. Possible improvement areas are:

- seeing to it that a partnership has adequate expertise when PLs are awarded and when development decisions are taken
- strengthening expertise in analysing, following up and taking care of HSE issues in the actual development phase
- setting clearer requirements for operator action plans and deadlines when issuing orders and conducting investigations
- carrying out spot checks to ensure that agreed actions have been closed in time and in an adequate manner
- establishing an even closer and better collaboration arena with the NPD, which could strengthen overall regulatory follow-up and supervision.

8.4 Supplier industry in general

The responsibility of the supplier industry is to deliver the products and services ordered by the project at the specified quality, right time and agreed price. Possible improvement areas are:

- strengthen specialist training and HSE awareness in their own companies
- continuous improvement in working methods and safe work operations
- deliver the right quality through good work processes and adequate quality control
- be realistic in the tendering phase regarding capacity and expertise offered
- meet schedules and agreed milestones
- raise and help to correct errors by the operator as early as possible.

In both interviews and other arenas, the study team has noted that the Norsok standards could be improved and further clarified. A perception among engineers and operators in the field is that both form and language in the most recent updates have been generalised and made more academic. A new review administered by the Norwegian Oil and Gas Association ought therefore to be considered. Its purpose should be to determine:

- can the scope be further reduced?
- can a simpler, clearer and more direct language be used in the documents?
- can requirements and descriptions be harmonised and coordinated between different documents?