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Generating Cost Reduction in the Supply Chain by Coupling Surface Facilities with Reservoir Data in Integrated Asset Modelling

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Abstract

Integrated Asset Modelling (IAM) processes can be used to quantify and monetise reservoir potential during the concept design process. Through quantification, risks can be mitigated and managed to deliver greater certainty through the concept selection process. IAM can be deployed throughout the hydrocarbons upstream sector to deliver robust field development and concept design solutions with more robust project economics.

IAM offers significant value and potential to identify supply chain cost reductions across the full spectrum of upstream developments, from full field development planning to individual equipment item modifications. The process offers particular value in development planning; in identifying and assessing sensitivity options and in definition of the optimum concept.

Full IAM incorporates expertise in reservoir, flow assurance, facilities and project economics expertise into a single integrated asset model. The process defined here is most effective as it is built upon integrating industry and in-house software, a combination of which facilitates Life of Field analysis to be carried out within a single package. The process offers unparalleled speed and flexibility in identification and analysis of concept design sensitivity cases. The IAM approach offers significant advantages and benefits to operators in addressing the three main reasons for destruction of project value; poor estimation of reserves, schedule overruns and cost overruns.

This IAM process is configured for fast and robust evaluation to ensure the right decisions are made at the right time based on the right information. The process will therefore preserve project value for operators and reduce the risk of value erosion through over or under engineering, or project recycle.

Introduction

As major projects continue to fail the question continually asked by the industry is why.

In the fifteen years to 2014 the average exploration and production asset delivered only 60% of the value promised at the sanction decision gate (Ref 1). If project failure is defined as value destruction between potential recoverable value and the actual value realised, the three key reasons for value destruction are poor estimation of producible reserves, schedule overruns and cost overruns.

This is evidenced by the fact that of the projects completed in the ten years to 2014, actual P50 recoverable reserves fell outside of the P10 to P90 range 40% of the time (Ref 1). Therefore 40% of facilities designs are being guessed at, requiring costly design changes to be made if the facilities installed are to be suitable for the reservoir. With 30 to 40% of project costs arising from such re-work (Ref 2) it is no surprise that projects are failing. Of these projects, 60% were schedule driven (Ref 1).

Value destruction occurs because key stakeholders are making ill-informed business decisions founded upon poor understanding of the project uncertainties. Our key stakeholders must become better informed to address the critical path of complex decision making between discovery and commercial reality while preserving the maximum recoverable value throughout.

Decision making is impaired by lack of definition, lack of understanding, and lack of communication. When IAM is used all three of these can be addressed in one place. IAM is a holistic simulation approach for reservoir, flow assurance and facilities engineers to work collaboratively with development uncertainties. The most advanced IAM methods consist of full compositional reservoir data input, common thermodynamics across all components and concurrent thermal hydraulic flow assurance and facilities simulation.

Use of advanced IAM means that much closer models of reality can be made for complex developments which gives the industry the best chance of making it happen. The better reality is modelled, the more it is understood. The more reality is understood, the more reliable becomes business decision making, and the more value is retained in projects.

Value destruction in the oil and gas industry

Over the decade and a half to late 2014 the average Exploration and Production asset development delivered only 60% of the value promised at sanction, the remaining 40% of which was lost during asset development and execution (Ref 1). During this time historically high oil prices and oil company profits hid and perpetuated poor project performance. Of all the developments completed over that period, 70% eroded value. On a normalised basis less value was delivered 2 years after start-up compared with the value promised at sanction (Ref 1).

In order to maintain project viability it is critically important that the industry understands the reasons for poor project performance, and subsequently implements measures to reduce them.

There are three ways that projects erode value in order of importance;

1) **Producible reserves are poorly estimated**

Of the projects completed in the decade to late 2014, actual recoverable reserves updated two years after start up indicated that actual P50 recoverable reserves fell outside of the P10 to P90 range 40% of the time. This means that the facilities installed are often unsuitable for the reservoir. The most common

technical reason for this over-estimation was basing project scoping decisions on incomplete basic reservoir data (Ref 1). Poor scoping decisions lead to poor production performance and value destruction.

2) Growth in capital costs

On average projects overrun their sanction budgets by 20% in real terms (Ref 1). Facility topsides cost is significantly related to the weight, schedule and complexity of offshore projects. Controlling the weight growth of offshore facilities through project design stages is therefore important for retention of project value. Of 153 global offshore projects authorised between 2001 and 2012, and with a cost ranging from 11 million USD to 2 billion USD more than half had greater than 10% dry-weight growth from authorisation (execute) to completion (Ref 3).

A poor level of definition of the facilities in the front end design stages contributes to weight growth of offshore facilities. A greater level of understanding prior to execute correlates with a better weight predictability than projects with poor front end definition. The level of front end loading is a key factor in determining weight outcomes and predictability.

Setting aggressive schedule targets also erodes the benefits of good engineering definition. Projects with aggressive schedules often require engineering to be completed without enough data supported from available reservoir analysis, causing errors in determining the correct facilities capacities.

3) Prioritising speed over value

By prioritising speed over value, businesses often set up their projects for failure by chasing target startup dates, but subsequently ending up with slow and expensive projects that do not work. In reducing investment in the concept phase to achieve faster schedules companies are exposing themselves to three key reasons for project schedule, and therefore cost, overruns (Ref 4);

- 1) Insufficiently defined FEED, causing change orders, delays and cost overruns
- 2) Inadequate design basis for oil and gas rates and properties, leading to design changes
- 3) Inaccurate cost estimates caused by inadequate FEED definition.

Of the projects that were completed in the decade to late 2014, 60% were schedule-driven (Ref 1). The preference for fast schedules is not surprising because net present value (NPV), the most often used economic metric for projects, places a higher value on early production. Businesses are driven to fast first oil, however fast schedules come with trade-offs. The most damaging of which is production shortfall. Production facilities are designed for peak flowrates, after this the facilities are under-utilised. The trade-offs associated with fast schedules, such as compromising on the investment in the early project phases, cannot be ignored. Without a consideration of production over the life of the field and assessment of varied production rates and plateaus, process facilities are often not appropriate for maximizing value from the reservoir.

Collaboration and efficiency required to assist in reducing costs

Generating cost reductions in the supply chain has come into focus since mid-2014 as the fall in oil prices began, exposing the scale of inefficiency across the industry. Collaboration between operators and the supply chain is believed to be crucial to operator's future success (Ref 5). A key component of efficiency progress will be reducing costs in the supply chain in a sustainable manner. On the basis of a survey of

major capital construction projects across industries, 30 to 40% of project costs result from rework (Ref 2).

By focussing on faster and cheaper developments, operators are significantly increasing the risk of project underperformance due to costly rework. When there is insufficient front-end loading of design, or change is not managed effectively, project re-work grows quickly. The typically large range of early design options in upstream oil and gas, with uncertainty in subsurface data, places greater emphasis on the importance of getting the high value, high risk decisions right as the associated cost of getting them wrong is greater.

Press cuttings tell us all where our failings as an industry lie in inefficiency, cost overruns and technical shortcomings. Our focus must now be on implementing IAM as a matter of course to fix this.

Reservoir data uncertainty

Differences between estimated producible reserves and actual producible reserves post start-up are inevitable. Resulting from the necessity of appraising often large reservoirs with only few wells, uncertainty in reservoir data is significant. These subsurface data uncertainties have a significant impact on facilities design, therefore understanding them and their possible effects on facilities in the early facility design phase is necessary. The better the subsurface data the more closely the facilities will deliver on expectations. In common with many projects across industries, the success of a Field Development Plan depends on quality of information.

The extent of the impact of some uncertainties in reservoir data on facilities design is qualitatively shown in **Table 1** below.

Table 1: Impacts of Reservoir Data Uncertainties

Key Reservoir Fluid Parameters	Impact on Key Field Development Components			
	Process	Flow Assurance	Secondary Recovery	Subsea, Flowlines, Risers
Low API Gravity	High	Medium	Low	Low
High Viscosity	Medium	High	Medium	Low
Low Shut-in Pressure	Medium	High	High	Low
High Shut-in Pressure	Low	Low	Low	High
Low Temperature	Medium	Medium	High	Low
High Temperature	Medium	Low	Medium	High
Low GOR	Low	Medium	Medium	Low
High GOR	Medium	Low	Medium	Low
Fluid Composition	High	Low	Medium	High
High Asphaltenes	Medium	Medium	Medium	Low
High Wax Appearance Temperature	Medium	Medium	Medium	Low

It is difficult to make a decision on multi-variable stochastic problems. For financial evaluation, uncertainty in all parameters is usually integrated into a production profile, calculated for three different confidence levels; proven: 90%, probable: 50%, possible: 10%. Field development is based on one of these three values depending on the strategy and commercial risk profile of the operator. Typically 50% is used.

In projects with multiple reservoirs there are multiple scenarios with the same confidence levels. For example the project P50 is not the scenario with all the individual reservoirs on their own P50; the chances

of two reservoirs both being on P50 is 25% (P25). On such projects reservoir engineers must make a judgement call as to what the project P50 scenario is; reservoir A on P90, reservoirs B and C on P50, etc. However, what is a conservative estimate for one group of engineers (e.g. production engineers) may be under conservative for another (flow assurance and integrity management engineers). For example, what if the cold reservoir (B) or the high CO₂ reservoir (C) were much larger and the warmer, low CO₂ field (A) was smaller? This might be a less conservative deliverability scenario, but could be a much worse scenario for flow assurance or corrosion management.

Also, as identified above, the P50 reserves estimate are historically outside of the P10 to P90 range 40% of the time (Ref 1), meaning that only 60% of facilities are appropriate for the reservoir. Facilities are over or under engineered 40% of the time and project value is lost. With the costs of re-work often representing 30 to 40 % of project costs (Ref 2), the value of knowing these uncertainties and designing for them in the concept stage is apparent both to the cost of the project and the project performance post start-up. In the first instance it will make key stakeholders more informed at an earlier stage when they make project scoping decisions. Greater confidence and design certainty will enable operators to move away from compiling all uncertainties into a 50% probabilistic assumption.

Resolving the problems

The key reasons for value destruction are poor estimation of reserves, schedule overruns and cost overruns.

Investing in an extensive conceptual design stage that incorporates IAM with reservoir data and generates a more complete understanding of the residual uncertainties will bring clarity and reduce value destruction. The model can be continually updated throughout the studies, which means that the reservoir data can be continually revisited and refined by the operator, with its attendant effects on the facilities analysed by facilities consultants. This will provide greater facilities design certainty to assist control of subsequent weight growth, and as a process will inherently prioritise value over speed of execution.

Eventual success or failure of a project depends more on the robustness of project definition than the quality of execution. Poorly defined projects will always deliver a sub-optimal result regardless of how well the project is executed. Well defined projects which incorporate and retain the most understanding at the earliest possible stages can deliver successful outcomes even when project execution is poor. Investment in early definition, otherwise known as front end loading, to permit consideration and evaluation of the entire development, is the key to project success.

IAM in conceptual engineering

IAM brings clarity of understanding, helping to maximise front end loading.

It creates a common workplace with human interfaces to enhance understanding of prospective oil and gas developments; a playground of innovation where ideas can be tested to facilitate the optimum decisions for the development, ahead of investment commitment.

IAM is a holistic approach built around simulation for reservoir, flow assurance and facilities. It enables all parties to work collaboratively to achieve the best development outcome. A robust IAM reduces uncertainty and permits operators to commit to decisions with greater understanding of the residual uncertainty. IAM enables understanding of probabilistic models to quantify uncertainty, assisting asset delivery.

The approach enables subsurface and surface facilities to be modelled concurrently. In any typical oil and gas field the hydrocarbon pathway forms a continuous route from reservoir to gathering network, and then to the process facilities. It is typical to separate the engineering design into discipline specific domains. Reservoir, flow assurance and process facilities engineering are all handled separately, with separate data models and separate simulation tools, though they are dealing with common production problems. This creates a challenge in adequately designing gathering and processing facilities for the boundary conditions, domain specific assumptions and production constraints across the discipline fields. This hampers joined up thinking and identification of the best development outcome.

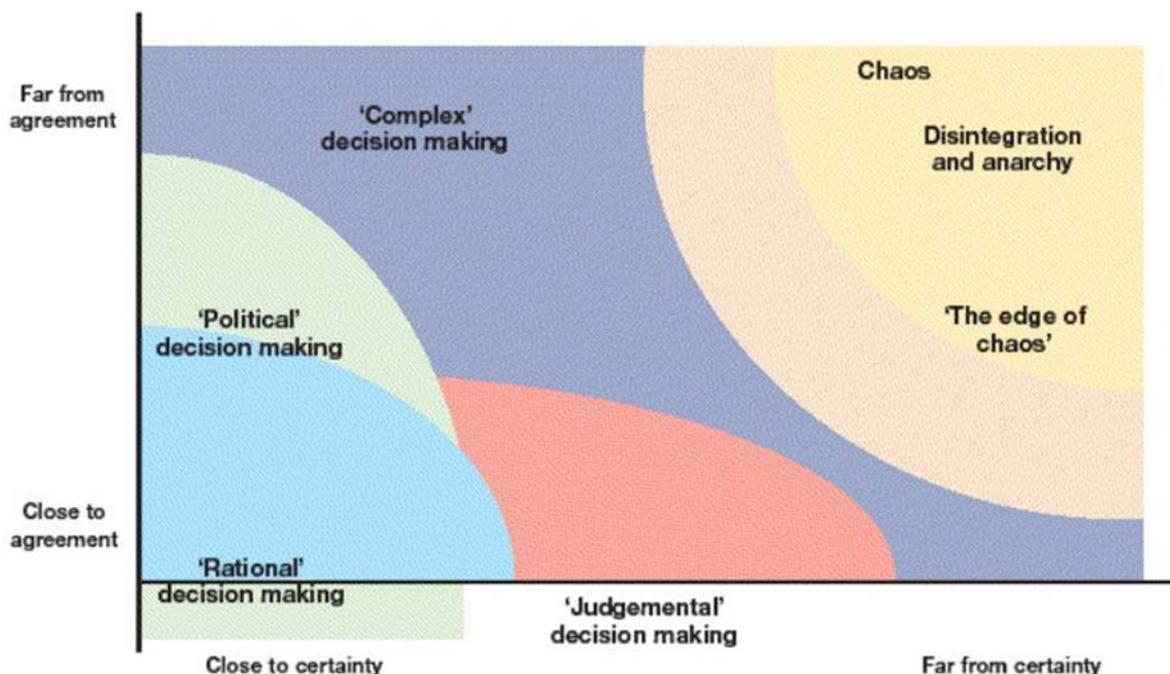
IAM serves to break down these interfaces between disciplines, removing the assumptions to build a simulation model of the entire oil and gas production system, for planning and optimisation. An IAM of the entire asset from reservoir to point of export from the process facilities provides decision support that accounts for the complexities of interactions between sub-surface and surface domains. The value of IAM over a traditional approach is the speed and flexibility it permits for assessment of a wider range of scenarios, uncertainties and development opportunities.

How will it help the industry?

The facilities design for oil and gas developments will either be realised through effective consideration and rational evaluation of uncertainties, or compromised through inadequate definition at the concept stage. Design compromised is a common state of affairs in the industry, with inherent destruction of project value.

Chaotic decision making is a characteristic of a design compromised. When little is understood about the project it is making it difficult to agree on decisions. The gap between design realised and design compromised is the bandwidth of uncertainty between chaotic decision making and rational decision making. This can be visualised in **Fig. 1** below, the Stacey Matrix (Ref 6).

Fig. 1: The Stacey Matrix



To move across the divide between from chaotic and complex decision making to a point where decisions can be made with clarity, the assumptions behind development decisions must be reduced by improving

the understanding behind the development as a whole. IAM provides visibility of the entire development and improves understanding of key technical issues by enabling a two way channel between what the operators need from a development and what they have in their reservoir data.

Facilities consultants can, in partnership with reservoir engineers, interrogate the reservoir data and articulate concerns about the impact of compositional and volumetric variations on designing the optimum facilities to suit the reservoir data whilst retaining maximum project value. IAM therefore provides greater design certainty and engineering definition prior to execute.

These benefits can be achieved with no discernible impact to a concept level schedule, because typically all the component parts of modelling are carried out to the same extent for a given oil and gas development. IAM simply joins them together to facilitate faster analysis of a wider range of sensitivity cases, providing the decision makers with enhanced knowledge at the earliest possible design stage.

What does IAM look like?

Robust IAM has the following features:

1) Full compositional reservoir data input

This means full value from the reservoir data is retained as the starting basis for the development. It enables movement away from over simplification such as black oil assumptions, and facilitates the incorporation of flow uncertainties such as variations in reservoir pressure, contaminants, GOR, watercut and viscosity.

2) Industry leading software with common thermodynamics across all components

Further benefits are derived if the IAM process is fully compositional and employs components with common thermodynamic simulation engines. This means that there are no errors in data calculation when the IAM transitions across what would be traditional boundaries between reservoir, flow assurance and process facilities. IAM with common thermodynamics has no requirement for lumping or delumping algorithms to transfer PVT data, or black oil assumptions, and hence does not generate computational variance during the process.

3) Concurrent flow assurance and facilities simulation

This enables the data flow to be displayed across the entire development at the same time, enabling instant identification of pinch points and rapid evaluation of all possible design measures. Simultaneous flow assurance and facilities simulation streamlines both the study scope and the process of defining the development.

These three features enable facilities consultants to:

- Identify all technical risks to gathering network and facilities design, such as GOR, water cut, pressure changes and variations in composition across the life of the field
- Preserve information value through reducing assumptions relating to translation of dissimilar thermodynamic packages or black oil models

- Optimally specify and size the gathering network and facilities for the reservoir
- Further define and align the development to operator strategy

This means that when operators reach the business decision gate they are better informed regarding the upside and residual risks; they will be able to make their decisions with clarity. Clear, well-informed decisions retain project value.

4) **Flexible Representations of the Reservoir**

The ability to allow the surface network and processing facilities engineers to quickly investigate multiple reservoir scenarios (such as the “what if the cold and high CO₂ fields were larger?” scenario discussed above) prevents excessive design margins in expensive pieces of equipment whilst removing an over reliance on one representation of the reservoir. Many of these problems may be solved with an alternative allocation plan; e.g. “reduce allocation to the cold reservoir if the temperature in the network gets too low”. Given the chance of this scenario occurring management by allocation may be much more preferable to management by expending CAPEX; more insulation in this case. An example of this type of study is given in Ref 7.

How does IAM provide greater collaboration between disciplines?

IAM with integrated reservoir data assists in strengthening collaboration in the design chain as it provides a constant feedback loop between field development teams and reservoir engineers. This ensures that at the concept level the operator achieves a design understanding that encompasses all uncertainties and requirements. Additionally it provides a smoother transition through to subsequent design stages, as boundary assumptions are based on good definition, rather than simply being formulated as best estimates. Moving forward the model provides the operator with greater understanding of the development and serves to assist business decision making:

- CAPEX vs OPEX
- Standardisation vs Improvement
- Proven Technology vs Innovative Technology
- Minimum Capacity vs Future Capacity

Applications

A fully compositional IAM method incorporating industry leading software components has a wide range of potential applications, all of which have become even more important in the oil and gas industry since mid-2014.

In Greenfield developments robust IAM can be used as a design tool, to aid communication between all disciplines and parties, to facilitate definition of the optimum development and its constituent decisions and components.

IAM has significant potential in Brownfield applications to transform the status quo of design compromised and reinvigorate the sector. It can be directly used as a diagnostic diagnostic facilities and subsea tool, to identify choke points, and to contribute to operator mature field and asset planning programmes. Its flexibility means it represents the best method available production forecasting for current operation and for additional well tiebacks, for specifying and optimising facilities modifications, and for asset performance optimisation. In what is becoming an important area of focus for operators the

modelling process also facilitates OPEX reduction analysis over the remaining life of the field, which could be used to further enhance mature field and asset planning.

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