"Do the Right Job, and Do the Job Right - Perspectives on Process Safety in Brownfield Modifications"

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The current economic climate in the oil and gas industries has put significant focus on the viability of investments. When oil prices are high, the rate at which the work can be done is often seen as the determining factor for whether a project is successful. However, when oil prices return to lower values, this haste is removed, and the focus returns to the business fundamentals of how you manage your plant, safely making more money.

There is a widespread recognition of how front end work is critical to the success of a project. This has been often expressed as "Do the right job, then do the job right". However, with limited funds for investment, and rightful focus of the regulator on not postponing critical spend on safety, the simple premise of "Do the right job" can be deceptively difficult, especially for brownfield modifications and upgrades.

This paper outlines some of the challenges in dealing with process safety in early project phases, from ensuring that an appropriate weight is given to process safety in the international context, to approaches and tools for risk assessment in concept selection, dealing with obsolescence, and common pitfalls in processes we have supported over the past 15 years, primarily in the brownfield context. It also presents some of the experience we have seen of good practice in this area, drawn from operations in the UK, EU, Middle East and USA.

Brownfield Modifications in Oil and Gas Production - "Do the Right Job…?"

The upstream oil and gas business can be a high risk/high return industry. When oil price is high, there is a huge reward for achieving flow as early as possible, and the relentless push can introduce significant potential to spend more to achieve earlier production. However, one of the fundamentals of the industry is that there is no real long term steady-state condition for a processing facility, in that no matter how large the reservoir, the hydrocarbon is not being replenished, and the combination of flow, temperature, pressure, composition and impurities will change with time. Plants tend to be designed around a particular operating point, and much of the offshore production equipment can be relatively robust but low complexity; fluid separators may be designed for 30 years of operation, from 0-95% water content hydrocarbon, and with a range of operating pressures, and can in many cases cover flowrates varying by a factor of 20-30. However, to keep the plant as safe as practicable, operating efficiently, and meeting the changing requirements, inevitably there will be the requirement to make changes. And like every business, there is not a bottomless pit of money, even in the high oil price environment, so there are always constraints, and always choices to be made in how to deal with a portfolio of options.

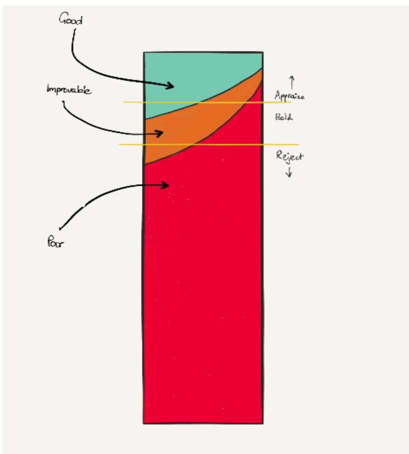
A number of companies describe this with the deceptively simple slogan "Do the right job, then do the job right".

But how do you select the right job? With a range of potentially competing business drivers, such as safety, environment, production, availability, what does "right" mean? And when you have selected and committed to a set of jobs, how do you ensure that they are "done right"?

If you imagine the portfolio of opportunities for your area, there are nearly always more potential changes than can be done, due to either monetary, resource or time constraints. We will never perfectly know where a proposal sits, but in general, a proposal is either (see Figure 1):

- Good, and should be proceeded with
- Poor and should be rejected
- Improvable, and should be reviewed in its current form to either reduce the cost, increase the benefit or look for an 80:20 solution.

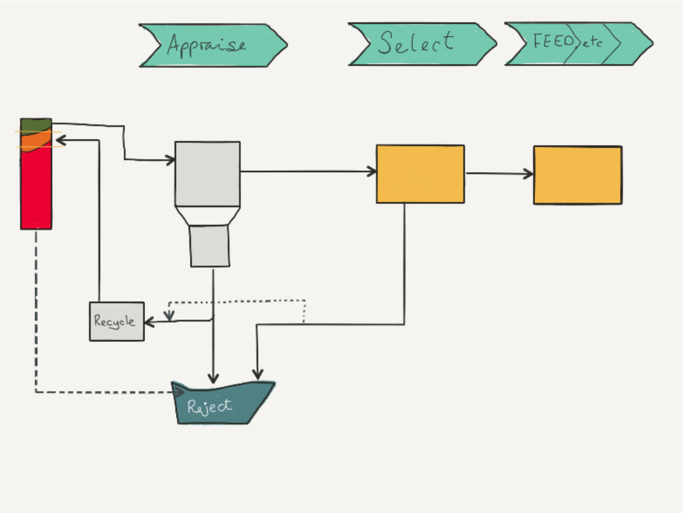
Figure 1. The Opportunities



We don't know which jobs are best to do, and we don't have sufficient time or resource in most cases to review all potential opportunities. As a result, in most cases, we will take a selection of the opportunities to an initial engineering stage, often referred to as "Appraise", to determine if the job is worth doing.

In *Appraise*, the job is reviewed initially to determine why it provides benefit, and to estimate how much benefit the job might have. At the end of *Appraise*, there might not be a significant amount of engineering carried out, but based on the improved knowledge of the opportunity, the job is approved to move into the next project phase, rejected, or recycled back into the opportunity queue for improvement (see Figure 2.)

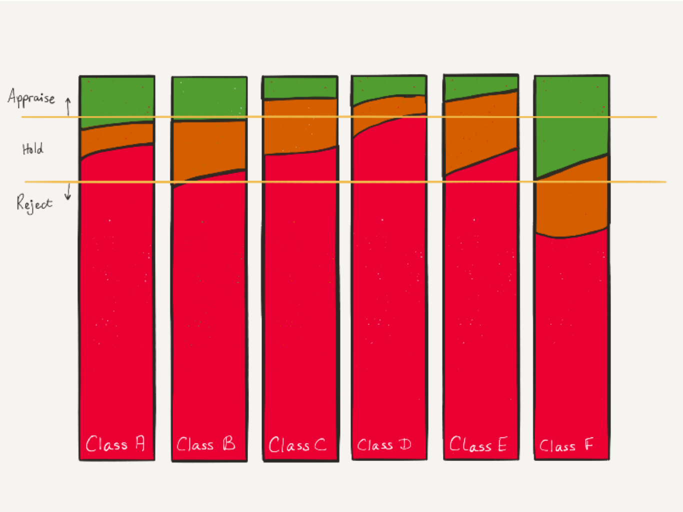
Figure 2. The Opportunity Hopper and Appraise



If our system is working well, then the majority of our jobs should succeed in Appraise, with fewer being rejected or recycled. We can then proceed to the later project phases, and deliver increased benefit to our companies.

However, it isn't that straightforward. It's not easy to determine where an opportunity sits on the overall benefit list, especially before some engineering and costing has taken place. Also, there's a wide variety of job types, from straight revenue generation opportunities, to loss prevention, be that personnel, health, environmental or business, to obsolescence and mandatory items, which makes it more difficult to compare. In a lot of companies, the opportunities are split out into different categories, and only compared against other items in that category. This may look something like in Figure 3.

Figure 3. Opportunities and Categories



Many jobs are not single-dimension, with safety upgrades required to support new production facilities, or trade-offs between reliability and production, etc. Depending on how we treat the categories, and how we draw the lines, it is entirely conceivable that we will leave some good jobs in the opportunity list, and in some cases carry jobs through the *Appraise* phase which are of less benefit than the good jobs we've left in the opportunity list, especially if we select the top five or ten jobs in each category for appraise. Also, by only comparing jobs to other jobs in that category, the system does not allow for cross-comparison to correct this.

Inappropriate Prioritisation

Given that we can't ever know the exact picture for any opportunity, and that the point of the *Appraise* phase is to test the benefit from a job, it's tempting to consider that we can do our best, and hope that we are getting the good jobs through. However, most systems can fall foul of inappropriate prioritisation problems, such as:

- Prioritisation "by seniority"
- Prioritisation "by volume"
- Prioritisation "by spin"

- Prioritisation "by engineering interest"

Each of these can skew where an opportunity sits in a list, and are described in more detail below.

Prioritisation by seniority is quite simply where the senior management teams have a strong say in whether a particular job is carried out, and the rest of the organisation responds to that. A story is told in Aberdeen about the Offshore Installation Manager on a Floating Production, Storage and Offloading facility (FPSO), who was discontent that his office did not have a window. He apparently asked the offshore construction crew how much it would cost to get a window put into his office, and got a cost and labour estimate for a marine-standard window. On this basis, he authorised the work.

Unfortunately, he had not reckoned on the fact that the wall into which he was making cuts was a structural wall, and a key part of the accommodation infrastructure. This required the wall to be retrospectively reviewed, analysed and certified at significant expense to ensure that the vessel would continue to meet classification requirements. Also, while there might have been a safety argument to allow the OIM to view quickly a developing situation on his facility, the window only looked out onto the sea, and in most weather conditions pointed away from any other infrastructure. The seniority of the requestor held sway here, but the job had little or no incremental benefit for the operation.

Prioritisation by volume is very similar to this, but comes from the point of view that if you complain loudly enough about something, it will move up the priority list by persistence, rather than by necessarily being the best thing to do.

Prioritisation by spin becomes particularly interesting in more difficult times. Most companies would regard safety as a core value, and in more difficult times, it is a matter of pride to many that they continue to invest in risk reduction and keeping their personnel and the environment safe. But if it becomes obvious that "only the safety jobs are being done", it is tempting to seek a safety justification for a pet project, hoping to get it into the "safety" list, and therefore make it happen. This can be dangerous from a number of areas, in that it can remove available investment funds from jobs that would actually reduce risk, and also devalues the company commitment to safety if left unchecked.

Prioritisation by engineering interest can also lead to inappropriate prioritisation. While most engineers would pride themselves on being realistic, and balancing business and engineering drivers, all other things being equal, we would tackle the most interesting projects first. These may well be more complex, more novel or more technically challenging. However, we can leave easier projects on the shelf.

We helped a client in the UK with their opportunity portfolio, and discovered one small debottlenecking option on the list. The price was modest, as it mostly involved changing a trim on a control valve, but it would unlock an additional 600 bbl/d of production. On the scale of the projects being considered, this was not a huge number, but the payback was actually so attractive that the economic model we were using could not easily calculate it. The job had been on the list for a few years, but seemed to have been left out of the plans, paradoxically, because of its simplicity.

There are other ways that inappropriate prioritisation can manifest; all can lead to jobs being prioritised ahead of other, better jobs, and challenge the business, either by making poorer returns, or failing to tackle the key risks.

Towards an Appropriate Prioritisation Approach

We operate in a business environment, and to an extent, the discussion above about prioritisation might arguably have little to do with safety. However, in parts of the world where the ALARP principle forms the heart of the regulation approach, ongoing investment and appraisal of risk reduction is a fundamental part of both doing good business, and being seen to do good business. The legal link between the ALARP principles of "doing as much to reduce risk as is reasonably practicable, in terms of cost, time or effort" and loss prevention is explicit in oil and production in the EU and Australia, but holds true in many other regions, even without the legal backing. It becomes more difficult in jurisdictions such as the United States of America, where the principle of ALARP does not have legal backing, with a result that the focus is on complying with local, national and industry standards, and ensuring that these standards are reasonable and in line with the industry requirements.

In any opportunity portfolio, the ideal situation would be where there is a single prioritised list with all opportunities, and a ranking approach that puts the jobs in the right relative order of attractiveness. This is often challenged as "trying to compare apples and oranges"; how can you treat a safety job with a production job, as they are clearly not the same? However, in this regard, it can be contended that both are in fact fruit, and that we can weight them up against each other by considering "is the amount of benefit to be achieved worth the cost?"

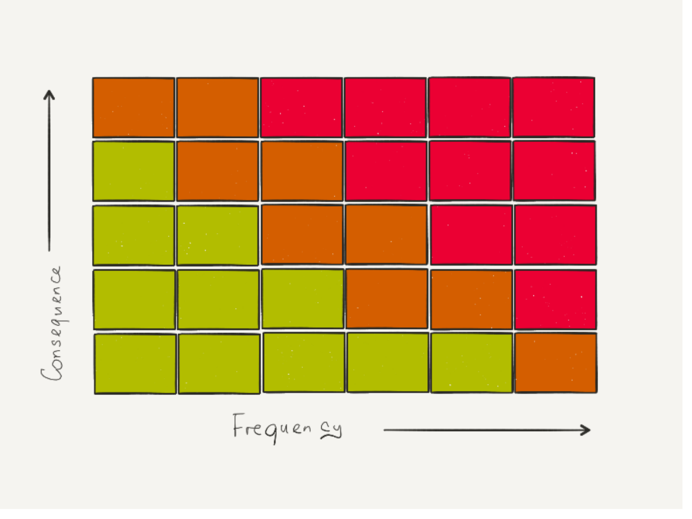
During initial prioritisation, the key question to ask is not "what does this opportunity require us to do?" but rather "why is this opportunity worth doing?" Most engineers are more interested in *how* to solve a problem, than *why*, so this initial challenge can be difficult for some to focus on. We have found that if an opportunity does not improve safety, environment, reduce production loss, improve production, make more money or in some way improve the company, it should be rejected.

There is no universally agreed approach to this, and as a result, many companies end up in similar places, with multiple ranked lists, queries over the prioritisation and a slow process. It is not unusual for a company with a few production facilities to have an opportunity list running into hundreds of items, often five or ten times more than the maximum number or values of project that could be liberated each year. Few schemes appear to be able to reject proposals, with the result that jobs that should never be done take up space in the queues; different oil companies have estimated lifecycle figures of £5,000+ per opportunity even if it never proceeds to *Appraise*, given the number of times it is reviewed, on the list for meetings, discussed, or even ignored.

For risk reduction jobs, the benefit may be difficult to formally quantify in some jurisdictions, as the cost of avoiding a single equivalent fatality is not available; ALARP jurisdictions, however, require a company to determine its definition of reasonable cost, and explicit guidance on this is even provided by some regulators. The risk-based approach is also inherent to a number of ISO standards, notably ISO-61508/511, which provide guidance on the level of risk reduction required and achievable by an instrumented protective system.

We have found that a powerful way to discuss and agree risk reduction benefit, especially in the early phases of projects, is to use an appropriate risk matrix, such as illustrated below in Figure 4.

Figure 4. Risk Matrix



These are common around most oil companies, and have a wide range of applicability, from day-to-day practical risk assessment to prioritisation of overall company risks. Some oil companies use the risk matrix to define the level of authorisation required to accept an ongoing risk, in a similar way to signing off on commercial expenditure.

If a risk can be located on the matrix, then it is relatively straightforward to calibrate the matrix based on justifiable spends from an ALARP point of view. This then gives a "benefit" in currency terms that can be compared with the cost to provide a prioritisation value. A similar approach can be taken for other risk categories, such as environmental or business risks, allowing comparison of benefits.

While using risk matrices is a common approach in the industry, they have to be used with some care. As an inherently qualitative expression of risk, simple interpretation of the risk score needs to account for a number of potential biases, including:

- People may be over-optimistic, and give a risk too low a value.
- People may be wary of giving a risk a realistic value if it will appear in a politically difficult region on the matrix, especially if this requires high level sign-off and hence scrutiny by senior management.
- The worst-case consequences can sometimes be combined with most credible frequency, giving an over-estimate of the risk.
- People may over-estimate the risk in order to promote an opportunity further up the list, and give greater weight to their favoured project.
- 'Groupthink', where validity of an assessment is limited by individuals thinking in similar ways.

Process safety hazards can by their nature be in the more difficult end of the estimation area, as they tend to be lower frequency and higher consequence, and as they are typically not within people's regular experience, it can be more difficult to quantify without good guidance. The most effective measure against the biases above is often simple challenge; if a justification of a frequency or consequence is not credible to a team of peers, then it is likely to be incorrect. Similarly, the cumulative risk for a facility can be informative.

In one company we worked with in the Middle East, the total personnel risk level across the opportunity register was the equivalent of tens of fatalities per year, based on the risk ranking. Not surprisingly, this was not their actual level of risk, and the fault was traced back to a calibration issue with a bow-tie analysis, which was internally consistent, but not formally calibrated to the corporate-level tool.

For revenue-related projects, it is common for economic modelling to be carried out, resulting in calculated payback times, internal rates of return, net present values etc. In order to compare these projects to the risk projects, they may require to be taken to a common basis; this can be done by conversion of the risk projects into an equivalent economic model, calculating a set of "pseudo" economic indicators. At *Appraise* level, it may be just as easy to calculate the benefit ratio for the project in terms of revenue/cost, and use this as a measure.

Should there be a single list?

There is an argument that personnel safety is fundamentally different to other business decisions, and should be treated differently. However, as Judith Hackitt pointed out (ref. 1), for companies, safety should be a "core value", and be part of all that they do, rather than some form of number one priority. While good safety should be good business, focusing exclusively on safety may not be.

We assisted a UK North Sea Operator with their opportunities list, using the Atkins ProRank methodology to determine an equivalent scoring for all jobs. ProRank uses a pseudo-economic approach to project ranking, using an economic model to carry out the cost-benefit analysis for risks by convert them to risked equivalent losses. On reviewing the ranked list, the operator was concerned that there were no safety-themed jobs in the top 30 list. Digging further into their recent history, it became clear that they had invested in risk reduction projects heavily in the previous years, and our opinion was they had effectively cleared the list of high-benefit safety jobs. To test this, we re-ran the analysis of the job list with a higher benefit accruing to the safety jobs, but this did not change the picture much. Our conclusion was that their admirable focus on risk had reduced their exposure, and while encouraging them to maintain their focus on real risk reduction, it was clear that the ranked list reflected the business requirements, and this could be agreed across the board.

Challenges of Application of Risk-Based Thinking

There are many challenges to the application of the risk-based thinking that a single opportunity list entails.

One of the most fundamental of these is the concept of assigning a cash value to the amount of money a company is willing to spend to avoid a fatality. This is part of the foundation of the ALARP principle, and is much more challenging to apply where ALARP is not accepted. We have seen companies try to get around this by implementing international standards which do not explicitly refer to any cash value, but calculate benefit in an analogous manner. However, this does mean that the application of the standard within the challenging jurisdictions may not be complete.

We also come across this to a lesser extent in countries where there is no explicit legislation embedding ALARP, and where there is not a strong or mature regulator. We find in these cases that the operators will apply the thought process in a similar way to how it would be applied in the EU, but always with a caveat that the arguments may not be accepted by the local authorities.

Another major barrier to application is the inherent resistance of companies to change, even if warranted. Getting a good view on the overall portfolio, and stopping jobs that might otherwise be engineered will inevitably cause someone to consider they have lost out, even if greater clarity on the benefit of the opportunities being pursued shows a better future outcome. We have seen people who have complained bitterly about the limitations of their current system turn to an "if it isn't broken, why fix it?" stance when we propose something new. This is clearly not just an issue for portfolio management. However, it is sometimes cynically said that you shouldn't let a good crisis go to waste. With the low oil price at present, we see a number of operators making strides towards a more defensible and auditable portfolio prioritisation approach.

Why, not How?

Arguably the biggest barrier to risk-based prioritisation is inherent to the engineers involved, in that we are inherently problem-solvers, and will therefore focus on how to solve a problem. There are many examples of projects which were progressed which did not deliver the benefit they promised, and we do not always question the basis for this.

An extreme example of this was a compressor upgrade project; a third-party tie-back was being examined, which would increase the molecular weight of the gas going through the gas-lift compressors. An initial study mistakenly considered that the capacity of the compressor would go down with the higher molecular weight (compressors in general will compress the same actual volume of inlet fluids to the same increase in head, which means that the capacity increases with increased molecular weight). A new compressor with new gas seal technology was designed, and was well through the design phases when a new project manager asked the question of why the increase in capacity was needed. This prompted a review of the basis, correction of the error, and ultimately the realisation that the plant could handle the revised demand without significant modification, saving the purchase of the new compressor, but wasting the significant design effort carried out to that point.

A focus on "why" the job is to be done, and a willingness to question the basis robustly, is a key requirement in conceptual development. The engineers need to recognise and quantify the business benefit, along with the technical solution, and be prepared to justify where a project sits in the ranked list based on a coherent assessment.

"…..and Do the Job Right"

From a process safety point of view, there are two aspects to doing the job right:

- For all jobs, how do you ensure that risks are managed and controlled appropriately during the project?
- For process safety-driven jobs, how do you do the work to ensure that the benefit will actually be accrued by the project?

While the phrase "Management of Change" is used in many companies to describe the overall processes a project will do, from a process safety point of view, it can have a more particular definition.

Management of Change - a Process Safety Definition

One of the most useful definitions of management of change in this context is provided by the US "Centre for Chemical Process Safety" (CCPS). Here "Management of Change (MOC)" is defined as follows:

"The MOC Element helps ensure changes to a process do not inadvertently introduce new hazards or unknowingly increase risk of existing hazards" (ref. 2)

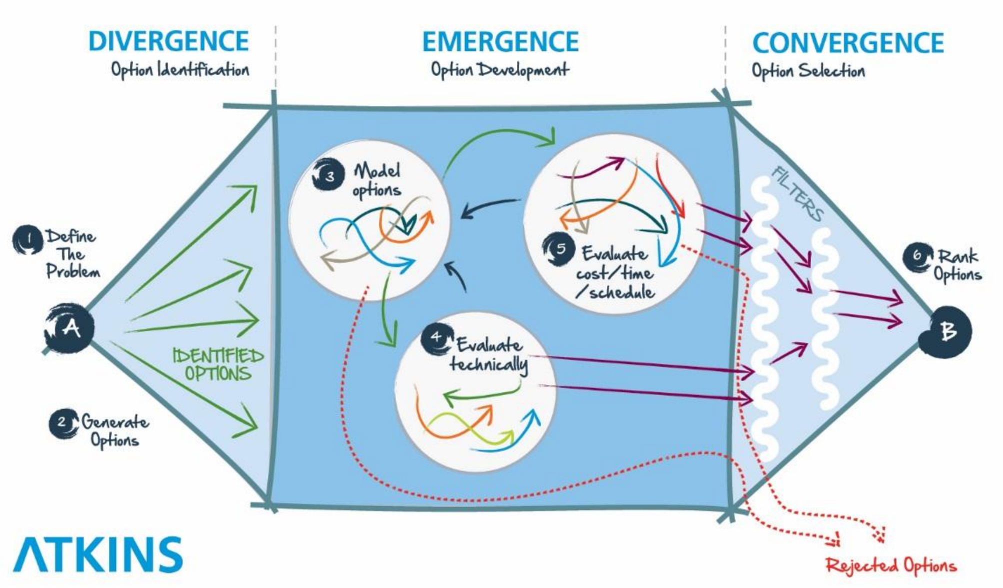
In this context, it is clear that the MOC process is not there to prevent change, but rather to manage the changes in risk appropriately. Key words in the definition are "inadvertently" and "unknowingly". Clearly, it is possible in making changes to a plant to increase the risk; for example, if an additional compressor train is introduced to a plant, this will introduce new inventory, new sources of leak, and overall, higher risk. This is allowable as long as the hazards are identified and managed appropriately.

Concept Development

The main set-piece hazard management techniques such as HAZOP and HAZID tend to be used most effectively in the FEED and Detailed Design stages of a project, where there is sufficient definition of the proposed solution to carry out the more detailed review. In the conceptual phases of a project, these tools are not available, and if used on a coarse basis, may be based on too many assumptions to be valuable.

Concept development can be a difficult process to explain, as it is inherently more of a creative process than later project phases, and often involves key design decisions being taken before the detailed analysis that would justify the decision. Atkins uses the conceptual model diagram in Figure 5 to describe conceptual development in the oil and gas context.

Figure 5. Atkins Oil and Gas Conceptual Development Model



While the process tends to be non-linear, it generally follows three phases, and six main activities as follows:

1. Define the Problem

As Yogi Berra said "If you don't know where you are going, you'll wind up somewhere else". With potentially competing goals and often significant uncertainty over the fundamental inputs and outcomes, it's not trivial to define the problem that is at the start.

2. Generate Options

The options generation phase is an inherently creative process, with a team of engineers taking the project objectives and finding a concept or concepts that may work.

This is like generating a new "Lego" model. With a wide knowledge of all the potential "bricks" in the concept box, candidate option or options are pieced together into viable concepts.

3. Model Options

A "model" is defined here as "a set of ideas, numbers and simplified representations that describe the present, and/or future state of a development". It encompasses the process, and also the structures, vessels, pipelines, people, systems and facilities required to support those processes.

In modelling options, the basic idea of each concept is tested to determine its likely outcomes in terms of product and requirements. The model needs to be as simple as possible, but no simpler, reflecting the particular constraints of the situation, and the uncertainties inherent in the inputs. It needs to be robust enough that the model can adequately describe the impact of any changes on the concept.

4. Evaluate Technically

Not every discipline can be represented in the modelling process, and the simplified representation cannot capture all of potential pitfalls. As a result, the design concept is presented to the wider engineering team, and often to the client and partners, to test the robustness of the concept. The goal is to uncover any fundamental issues with the concept that would make it infeasible.

The key is to be able to make decisions about the design that take account of the uncertainties inherent in the concept development. This conceptual evaluation ability is not universal amongst engineers.

5. Evaluate Cost/Time/Schedule

Engineering is often about the art of the possible, and the most elegant concept may fall down when it comes to how long it takes to implement, or how much it costs. This is likely to require high level cost modelling, and also understanding of the time and resources required to carry out the project. Where this involves brownfield modifications, scheduling work relative to other competing schedules and accommodating the time required for tie-ins and other modifications adds layers of complexity.

6. Rank the Options

With the project goals outlined in activity 1, and the costs, benefits and issues associated with the option or options worked up in subsequent phases, the concept phase is best closed with a ranking exercise. This may be fully quantitative, using an economic model to evaluate the options. More commonly, some tests may screen out options (e.g. maximum CAPEX, min/max schedule, etc.); the remaining options are ranked relative to each other, by a combination of qualitative and quantitative measures. This then informs the recommendation on which concept or concepts are taken forward to the next phase (pre-FEED or FEED).

The framework is itself a simplified model of the processes taking place during conceptual studies, with arrows in multiple directions to suggest the fact that, depending on the project, the steps may well be repeated, run in parallel, or in some situations, be entirely omitted. Studies seldom run in isolation, and it is very common for fundamental parameters of the study to change during the study, in response to developing reservoir modelling, technical limitations, economic evaluation and commercial negotiation.

Process Safety in Conceptual Development

The same framework can be used to describe the process safety activities during conceptual development, as described below.

1. Define the Problem

For risk reduction projects, this stage focuses on the reason the opportunity is to be considered. As previously described, this may require focusing on “why” rather than “how”. It is useful to have process safety involved as early as possible in a project, in order to allow the current overall understanding of risk, gained from QRAs, HAZOPs, risk registers, LOPA, bow-ties etc. to inform the problem definition.

A number of the companies we deal with have useful guidance on how to incorporate inherent safety into the early phases of design. These look at value improving processes to generate and improve the quality of the proposed concepts. We have found from our experience that it can be beneficial to frame the problem definition using an inherent safety mind-set, and where appropriate we will use an inherent safety workshop as part of project initiation. These tend to be facilitated multi-disciplinary workshops, where the particulars of the project are reviewed, and the opportunities to remove, prevent, control or mitigate the key risks are identified. Using a variety of disciplines in this meeting provides the benefit of being able to explain the key technical risks to the combined project team, and achieves better alignment and understanding over the project.

We carried out such a session for a novel production facility concept, which was intended as a floating unmanned facility. The facility was unusual in that the production facilities would be located underwater within a buoy, and would be operated remotely from onshore. The meeting considered issues such as vessel movement, informed by the naval architects, remote operation, informed by the C&I engineers, design to contain explosions, informed by the process safety engineers, low gas-oil ratio production strategy, informed by the process engineers, etc. At the end of the session, the key process safety issues had been identified and a common understanding developed; for those items considered high risk or novel, a strategy was developed to consider these during the conceptual phase to reduce the overall risk, while more conventional issues were considered to be manageable during later project phases. The session also ensured as far as possible that no hazards were inadvertently added.

2. Generate Options

Option generation requires a good knowledge of the potential options to address the hazard, and whether these can be applied to the circumstance in question. Typically, process safety and process engineering are very broad disciplines, and conceptual engineering is normally driven by these disciplines.

3. Model Options

Depending on the scale of the project, multiple levels of "modelling" can be carried out from a process safety point of view. For relatively small modifications, it may be appropriate to use any existing risk modelling, QRA, or analysis to inform on the direction and potential magnitude of the risk change. For risk reduction projects, this may be as simple as determining on a risk matrix the current risk, and the likely reduction. For more complex projects, a high level risk model may be constructed.

Atkins has its methodology for carrying out such assessments, and this has been documented previously (ref 3), including updates for environmental threats presented at previous Hazards conferences (ref 4, 5). The "Concept Risk Assessment" tool uses indicative building block assessments of concepts to allow comparison of options and provide guidance as to the optimum risk concept or opportunity.

Atkins recently applied this methodology in the development of a marginal field in the UKCS West of Shetland. At the conceptual stage, 10 separate options were reviewed, from a jacket platform exporting to shore to a variety of subsea tank supporting options. At the conceptual stages, an articulated tower concept was proposed, and this was reviewed using the CRA and advanced as a favoured option from the risk point of view. Further development in the select phase chose this as the preferred option of the shortlisted, as it had the lowest overall risk. This convinced the oil company investors to sanction additional drilling in the area. The results of the drilling exceeded the expectations of the development, and the conceptual stage had to be re-opened to deal with the additional fluids which could potentially justify a different solution. Again, the CRA was used to quickly refine the risk profile for the potential options, and the risk associated with a jacket production solution incorporating the subsea tank was found to be lowest risk, as the articulated tower was no longer feasible due to increased production facilities. Throughout the concept phases, the CRA was used as a key way to differentiate between the options and formed a key model of the system for the project team.

4. Evaluate Technically

In this stage, if evaluation has not been carried out in the previous activities, the process safety team need to consider if there are any inadvertent introductions of new hazards, or unknown increases to existing hazards. A variety of tools can be used for this, from checklists and what-if questions through high-level hazard analysis techniques. It is prudent to draw on industry and company standards at this stage, as they may point to additional hazards that have been codified into the standards based on previous losses.

5. Evaluate Cost/Time/Schedule

For cost, time and schedule, often key process safety issues come from the construction requirements of the project. If a proposal requires risky work processes, such as diving or hot-work, or may cause an extended shutdown, the project would need to consider this in more detail. While ALARP is often expressed as a cost-based expression, it does also include time or trouble, and exposing people to a high level of immediate risk to reduce a lower, chronic risk may not be ALARP.

6. Rank the Options

Option ranking may be done internally in a project, but if a coherent framework for project prioritisation is in place, the ranking may also take this into account. Individual project benefit needs to be expressed and updated in the project prioritisation lists at the end of each project phase.

Successful Application of a Process Safety Mind-set

The goal of process safety is to ensure that hazardous substances, fluids and energy are kept from doing harm to people or the environment. This in turn leads to better business performance with less process upset, recovery from abnormal conditions, or loss of product quality.

Conceptual development can be challenging, in that decisions have to be made on how to proceed based on short timescales and limited information. Dealing with this uncertainty is one of the key behaviours for a conceptual engineer, and, in the process safety context, focus on the potential hazards and the engineering measures in place to prevent them will go a long way towards improving performance.

Units and symbols

bbl = oil field barrel. 1 m^3 = 6.29 bbl.

bbl/d = barrels per day.

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