The Use and Abuse of Feasibility Studies – Has Anything Changed?

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ABSTRACT

In 2007, the authors presented a framework for the conduct of resource project feasibility studies and provided guidance on minimum standards and best practice (Mackenzie and Cusworth, 2007).

This paper will present the authors' observations in relation to feasibility studies undertaken to support investments made during the unprecedented period of resource project capital investment since 2007. It will also provide comments on general trends in the mining industry's approach to project assessment and update recommendations on best practice.

INTRODUCTION

Projects that produce mineral commodities typically involve the development of not only mine and mineral processing facilities, but also the site infrastructure, services and facilities necessary to support remote sites and transport infrastructure to facilitate the delivery of products to customers. These types of projects are typically capital intensive and require considerable time to be delivered.

The rapid growth of emerging economies that commenced in the early 2000s, particularly in East Asia, drove a global surge in demand for mineral commodities. With global mineral commodity supply unable to respond quickly to rising demand, prices for mineral commodities surged to historically high levels (RBA, 2015), triggering a surge in mineral project investments around the world on an unprecedented scale. In Australia alone, private new capital expenditure in the mining industry grew from $14.2 billion in 2005 to $94.5 billion in 2012 at an average annual growth rate of 31 per cent, as illustrated in Figure 1 (ABS, 2015).

This paper will investigate how the industry has performed in the delivery of capital projects during this period of frenetic project development. The first section will look at the industry's historical performance of delivering projects that meet their feasibility study expectations, both in the period leading up to the investment boom and during the boom. The second section will examine the findings of other studies to determine what characteristics are common to projects that both have and have not met their feasibility study expectations. The third section will present case studies of recent projects that have or have not met their feasibility study expectations and explore features that correlate well or poorly with expected project outcomes. Finally, the paper will present recommendations based upon these investigations and observations from the authors' experiences in project definition and delivery.

INDUSTRY TRACK RECORD

In 2007, the authors reviewed a number of papers available at the time and concluded that the industry's track record of delivering against feasibility study expectations was poor. The authors wrote:

In the authors' experience, feasibility studies:

- *are regularly portrayed as being much more comprehensive and accurate than they are*

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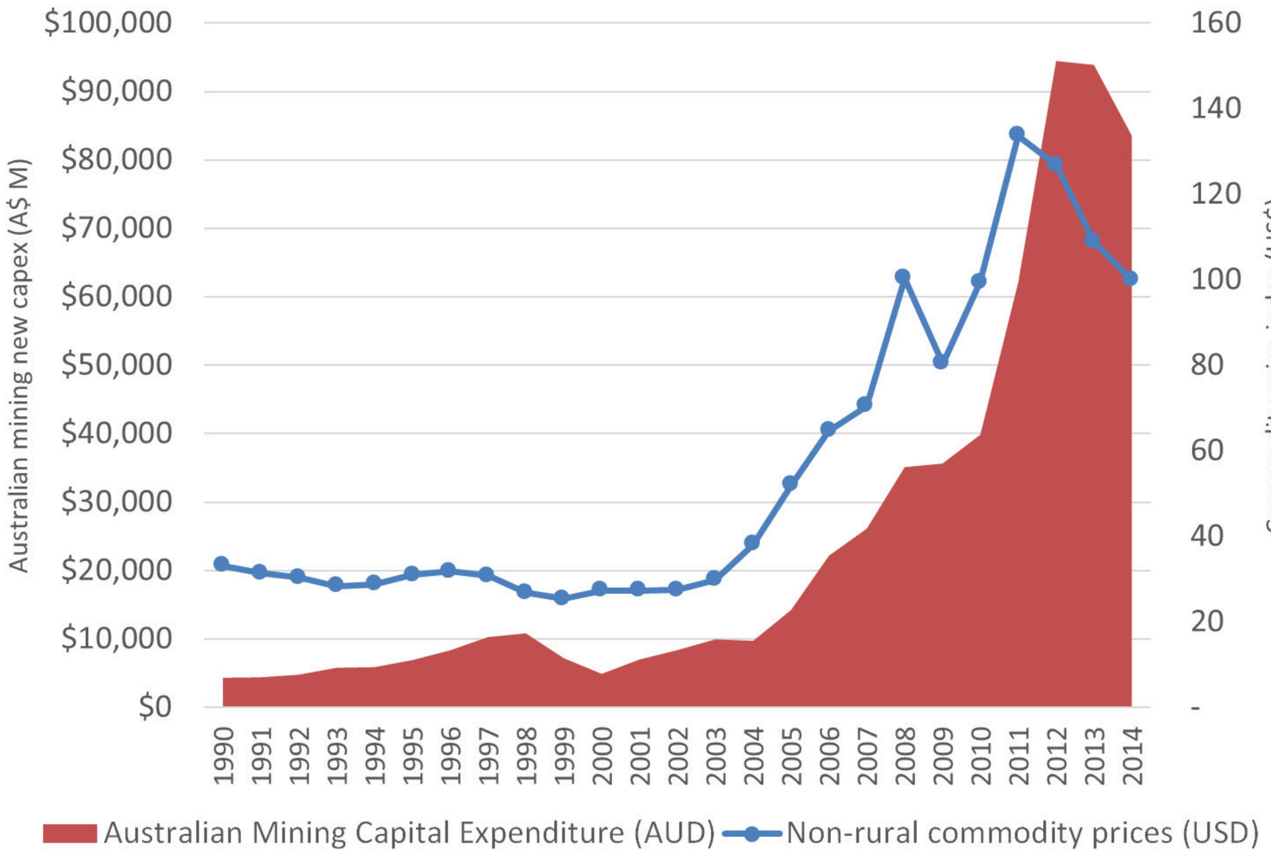

FIG 1 – Commodity price and Australian mining industry investment trends (Australian Bureau of Statistics and Reserve Bank of Australia 2015).

- *are often not fit for their intended purpose*
- *tend to focus on technical issues at the expense of critical business and project delivery issues.*

The poor track record of the industry – which indicates only half of projects meet their feasibility study expectations – demands a better approach to the feasibility study process. (Mackenzie and Cusworth, 2007)

Other authors have studied the industry's record of the delivery of projects against feasibility expectations. Bertisen and Davis (2007) focused on project cost outcomes when reporting on a sample of 63 worldwide mining and smelting projects completed between 1980 and 2001. They determined that feasibility study capital cost estimates had an average overrun of 25 per cent when as-built costs were measured in actual (nominal) dollars and 14 per cent when measured in inflation-adjusted (real) dollars. Bullock (2011) summarised eight different independent studies conducted on 16 to 60 resource projects between 1965 and 2002 and determined that the weighted average cost overrun of all projects studied was 26 per cent.

At the time of writing our 2007 paper, the Australian resources industry was in the early stages of an unprecedented period of capital investment, as illustrated in Figure 1. Given the level of capital expenditure since 2007, the authors hoped that the industry's track record would have improved. As our previous paper concluded that only half of projects were meeting their feasibility study expectations, the performance benchmark for improvement was fairly low.

As we found when researching the 2007 paper, public domain information on project success measures is limited, no doubt due to the commercial sensitivity of capital project outcomes. Nevertheless, this remains an area of significant interest to the industry, and the following is a summary of the findings of some recent studies into the resource industry's track record.

Biery, Hollonds and Young (2009) analysed a sample of completed projects authorised after 2002. Of the projects reviewed, 46 per cent were delivered within ±10 per cent of feasibility study cost expectations and 46 per cent were completed within ±10 per cent of feasibility study schedule expectations, but only 25 per cent were delivered both on time and on budget (within ±10 per cent).

A review by Haubrich (2014) of a database of mining projects built between 1965 and 2013 reported 50 years of persistent capital cost overruns. These were periods of variable average overruns (expressed actual cost as a percentage of feasibility study cost) ranging from a low of around 20 per cent in the 1990s to a high of around 60 per cent since the mid-2000s (as illustrated in Figure 2).

EY (2015) collected data from 108 recent global capital projects in the mining and metals sector and found that 69 per cent of megaprojects were facing cost overruns, with an average overrun of 62 per cent for projects with available data. It also observed that project cost overruns were not universal, with different commodities and different regions exhibiting varying cost overrun percentages (as illustrated in Figure 3). Furthermore, EY reported that only 31 per cent of the projects surveyed delivered in line with their cost, schedule and scope commitments.

IPA (2015) conducted a survey of approximately 30 mining projects from 2006 to 2013 that showed that actual project outcomes for asset operability, cost and schedule expectations were often wildly off target. Production from seven to 12 months after start-up fell short of its target by an average of 20 per cent and costs were ten per cent higher on average than forecast. A vast majority of projects experienced significant cost overruns, and a few had massive underruns. On average, projects experienced schedule slip of nearly 20 per cent, and poor performers' schedules slipped by as much as 80 per cent.

These reviews of project performance do not paint a pretty picture and confirm that the industry has not only failed to improve its performance in the delivery of projects that meet their feasibility study expectations, but has probably got worse over the last decade. It seems that things have changed little since our 2007 paper; if anything, they have changed for the worse.

CHARACTERISTICS OF PROJECTS FAILING TO MEET THEIR FEASIBILITY STUDY EXPECTATIONS

Notwithstanding the different time periods, data sets and approach taken in the studies referred to in the previous section, they provide ample evidence that it is commonplace for resource development projects to not meet their feasibility study expectations – whether this is manifested as cost overrun, schedule slippage, production shortfalls or a combination of all three.

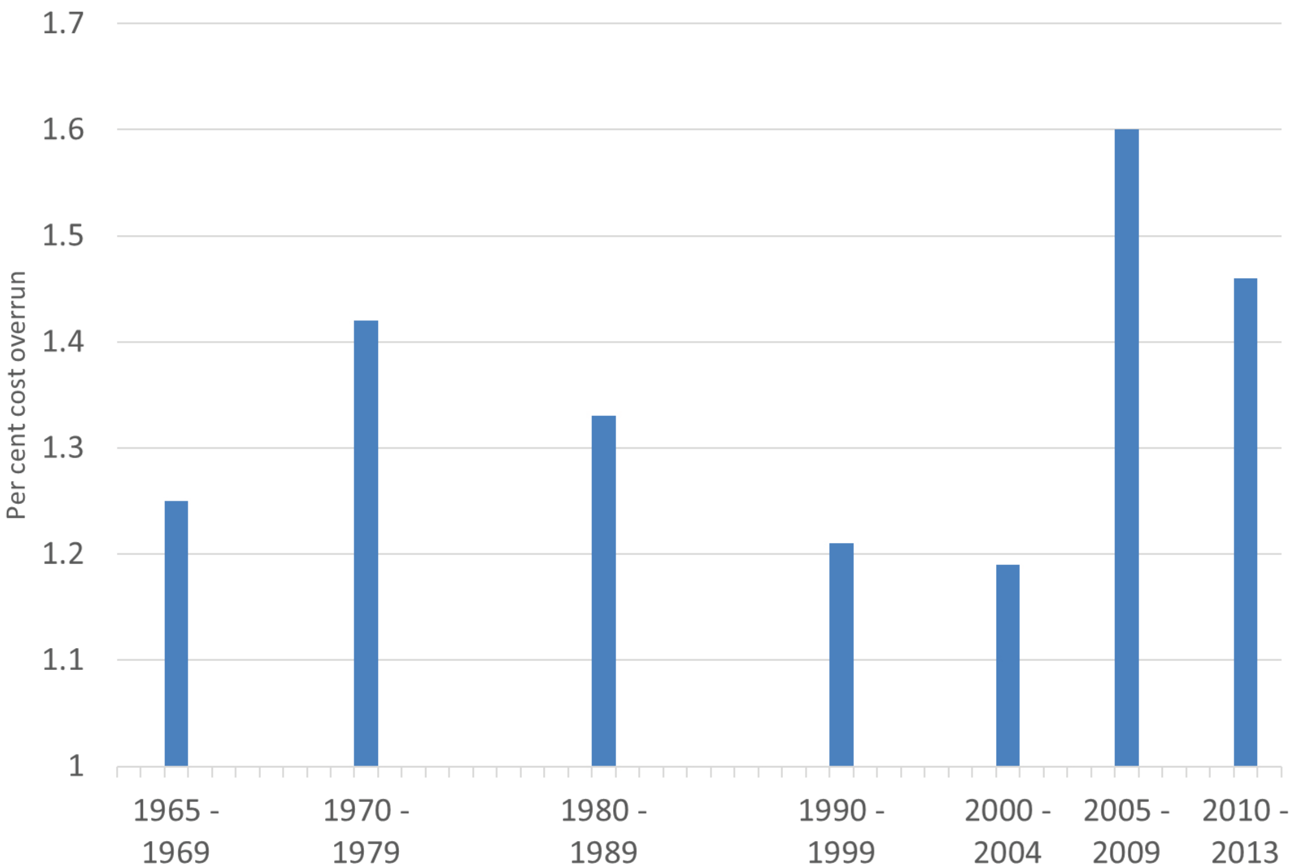

FIG 2 – Mining project cost overrun over time (Haubrich, 2014).

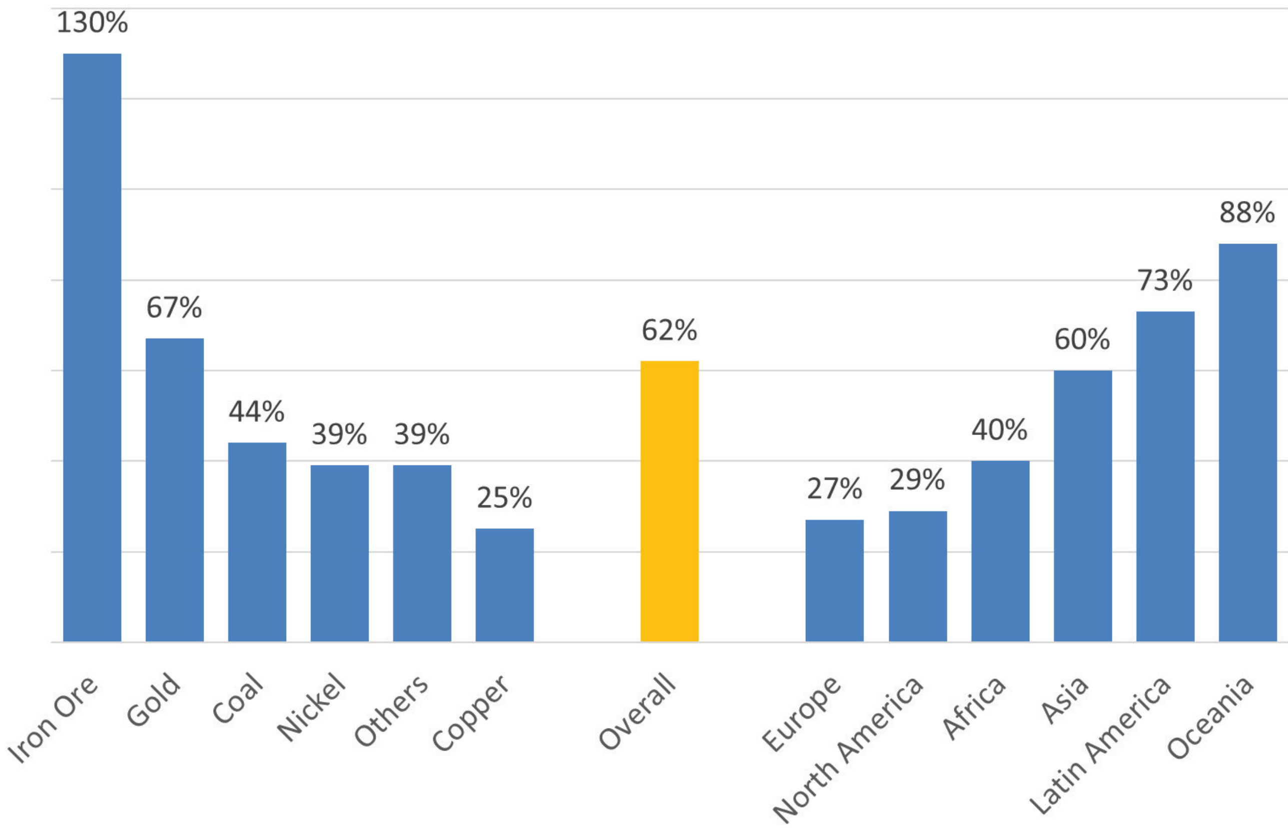

FIG 3 – Average mining project cost overruns by commodity and region (EY, 2015).

But why is this happening? Why is performance not improving? Does the root cause lie with the feasibility study prediction, the execution of the project or both? And are some projects inherently more or less likely to meet their feasibility study expectations? Some of the papers referred to in the previous section explored these questions.

Bertisen and Davis (2007) postulated that the persistent capital cost overruns recorded in the mining industry over many decades are indicative of bias, not merely errors in estimation. Their analysis concluded that there is bias in mining project capital cost estimates that results in as-built capital costs being 25 per cent higher than the estimate in the feasibility study, and they demonstrated that the bias tends to be smaller for larger projects. They also argued that this bias is intentional, with engineering consultants acting rationally in underestimating capital costs. After allowance for this bias, only 54 per cent of projects in their data set fell within the expected ±15 per cent of the feasibility study estimate. They could not demonstrate any statistically significant evidence that the capital cost deviations are larger for small projects, underground mines (where uncertainties around development costs are inherently high) or foreign projects (which have an additional variable to contend with by way of exchange rate exposure).

In 2009, Biery, Hollonds and Young (2009) defined 'predictable' projects to be those that were delivered within ±10 per cent of feasibility study cost and schedule estimates. They concluded that, in general, the level of feasibility study development, or project definition, at authorisation was appreciably lower in poor performing projects than for predictable projects, and that:

- there is very strong evidence that projects with comprehensive and integrated study and project delivery teams and best practical levels of definition in their feasibility studies have more predictable outcomes
- project size is not associated with any more or less schedule slippage, but larger minerals projects appear to have a greater percentage cost increase than smaller projects
- no single region is consistently producing poor projects or regularly executing predictable projects
- complex minerals projects are associated with greater percentage cost increase, but these projects did not have any more or less schedule slippage than smaller projects
- projects that employ one or more new-to-industry processing steps have a greater cost increase than those using conventional processing technology that generally have fewer processing steps.

Bullock (2011) reviewed the literature and lamented the lack of feasibility study standards within the industry, both in nomenclature and effort levels, leading to investment decisions based on insufficiently detailed or accurate studies. He identified numerous common feasibility study problems, such as insufficiently detailed study inputs (for example, resource estimate, process design or cost estimates), incomplete study scope, inaccurate cost estimates, invalid economic assumptions and failure to consider external uncontrollable events (for example, weather, permit delays or activism).

Haubrich (2014) analysed a sample of 50 mines built between 2005 and 2013 and established that many factors given for capex overruns – including poor execution or engineering, poor weather, inflation and currency fluctuations – were not statistically significant. He found that only two factors had a statistically significant association with capital cost overruns:

1. commodity market heat – which is a measure of the direction and rate of change of the relevant commodity price when the project is being built, with periods of sustained rapid price rises correlating with periods of capital cost overruns
2. project quality – which is measured as the net present value (NPV) to capital investment ratio presented in the feasibility study, with lower-quality projects having higher cost overruns.

EY (2015) identified five key categories as the main causes of budget and schedule overruns across their global sample of mining and metals investments. They were: inadequate project management, stakeholder conflicts, resource constraints, regulatory and policy challenges and external business environment factors.

IPA (2015) noted that when compared with other industry sectors (petroleum refining, chemicals and others), resources industry projects experience higher NPV losses and much higher NPV gain/loss variation compared to project feasibility study expectations. It concluded that in the minerals industry, most of the leading performance drivers of mining projects are less defined than in other industries, a lot of fundamental project definition work is not done and, as a consequence, projects are losing value that could be preserved in many instances.

When looking at the characteristics of projects that fail to meet their feasibility study expectations, the aforementioned papers demonstrate that:

- Inherent project factors such as size, location, commodity and scope have little influence on the predictability of project performance; however, complex projects tend to be somewhat less predictable than simple projects and projects that use new or innovative technology are less predictable than projects that use mature technologies.
- External macroeconomic circumstances can have a substantial impact on the delivery of projects as predicted in feasibility studies. Projects developed during periods of high gross demand on project resources (eg qualified people, skilled labour, construction services and plant and equipment) are more likely to suffer project cost overruns and delays.
- Poorly developed feasibility studies tend to produce poor project outcomes.

It would not be unreasonable to conclude that the apparent decline in project predictability seen in recent years is in part due to the unfavourable external macroeconomic circumstances of extraordinary demand for project definition and delivery. However, we believe that projects whose expectations have been set after comprehensive, detailed and integrated feasibility studies and which are then delivered by experienced, integrated teams encompassing all relevant areas of project expertise are able to deliver predictable project outcomes regardless of the inherent project factors or external macroeconomic circumstances. The impact of the uncontrollable changes in external macroeconomic circumstances will be lessened if all other aspects of a project's planning and execution are well controlled.

The next section provides some case studies of recent projects that illustrate these points and the corollary that unless project expectations are established through comprehensive, detailed and integrated feasibility studies, project outcomes will not be predictable.

EXAMPLES OF RECENT PROJECT PERFORMANCE – THE GOOD, THE BAD AND THE UGLY

To illustrate the points outlined in the previous section, we selected a number of projects executed since 2007 and compared the project outcomes with the project cost, schedule and output declared when the projects were given the go-ahead. All information used in this section has been sourced from the public domain, typically regulatory reports, company announcements and press articles.

The projects selected are not a representative sample of projects executed since 2007. Rather, they have been picked to illustrate that during the reference time period, there were projects that did achieve cost, schedule and production results as expected and projects that did not produce anywhere close to the cost, schedule and production results planned for. The diverse nature, size, commodity, location and complexity of the selected projects is presented in Table 1. The performance of the selected projects against feasibility study expectations is presented in Table 2. The status of the project prior to go-ahead being given is presented in Table 3.

TABLE 1
Selected recent projects.

Project	Nature	Location	Commodity	Go-ahead given	Forecast capital (millions)	Forecast completion
RGP5	Brownfield	WA	Iron ore direct shipping ore	November 2008	A$4800	H2 2011
Degrussa	Greenfield	WA	Base metal concentrate	March 2011	A$384	September 2012
Tropicana	Greenfield	WA	Gold	November 2010	A$750	November 2013
Kevitsa	Greenfield	Finland	Base metal concentrate	November 2009	US$400	July 2012
FMG Stage 1	Greenfield	WA	Iron ore direct shipping ore	March 2006	A$2247	January 2008
E&G project	Brownfield	WA	Alumina	May 2008	A$1900	H1 2011
Karara	Greenfield	WA	Magnetite concentrate	October 2007	A$1706	March 2010
Rocklands	Greenfield	Qld	Base metal concentrate	March 2011	A$250	December 2012
Kaunisvaara	Greenfield	Sweden	Magnetite concentrate	January 2011	US$694	March 2013
Minas Rio	Greenfield	Brazil	Hematite concentrate	January 2007	US$3456	December 2009
Sino Iron	Greenfield	WA	Magnetite concentrate	January 2007	US$2470	January 2010

RGP5 – Rapid Growth 5 Project (BHP Billiton Iron Ore); FMG – Fortescue Metals Group; E&G – Efficiency and Growth project (BHP Billiton Worsley Alumina).

TABLE 2
Selected recent project outcomes.

Project	Actual capital (millions)	Actual completion	Cost overrun (%)	Schedule overrun (%)	Performance achieved
RGP5	A$4800	Q3 2011	0	-5	Yes
Degrussa	A$400	September 2012	4	0	Exceeded
Tropicana	A$833	September 2013	11	-6	Exceeded
Kevitsa	US$470	August 2012	18	3	Exceeded
FMG Stage 1	A$2825	May 2008	26	18	Yes but delayed
E&G project	A$2995	Q1 2012	58	28	Yes
Karara	A$3051	January 2013	79	113	No after two years
Rocklands	A$480	Not completed	92	N/A	Not completed
Kaunisvaara	US$1500	December 2013	116	35	Abandoned
Minas Rio	US$8400	October 2014	143	242	Too early
Sino Iron	US$12 000	December 2013	386	230	No after three years

RGP5 – Rapid Growth 5 Project (BHP Billiton Iron Ore); FMG – Fortescue Metals Group; E&G – Efficiency and Growth project (BHP Billiton Worsley Alumina).

TABLE 3
Selected recent project study status.

Project	Category	Three-phase study process	Study scope complete	Scope frozen at go-ahead	Permitted at go-ahead
RGP5	Good	✓	✓	✓	✓
Degrussa	Good	✓	✓	✓	✓
Tropicana	Good	✓	✓	✓	✓
Kevitsa	Not too bad	✓	✓	✓	✓
FMG Stage 1	Not too bad	✓	✓	✗	✗
E&G project	Not so good	✓	✓	✓	✓
Karara	Ugly	✓	✗	✗	✗
Rocklands	Ugly	✗	✗	✗	✗
Kaunisvaara	Ugly	✓	✗	✗	✗
Minas Rio	Ugly	✓	✗	✗	✗
Sino Iron	Ugly	✗	✗	✗	✗

RGP5 – Rapid Growth 5 Project (BHP Billiton Iron Ore); FMG – Fortescue Metals Group; E&G – Efficiency and Growth project (BHP Billiton Worsley Alumina).

The good

Projects that fall within the 'good' category are those that were delivered within ±15 per cent of their stated capital cost and schedule and operate in accordance with expectations. Three diverse projects have been selected to illustrate the notion that good projects can occur regardless of inherent project characteristics.

BHP Billiton Iron Ore's Rapid Growth 5 Project (RG5P) in the Pilbara region of Western Australia is a brownfield project that involved the expansion of existing mine, port, rail and infrastructure facilities. RG5P was given the go-ahead in November 2008 and was reported to have been completed on budget and ahead of schedule in the third quarter of 2011; however, the scope of the project was changed in October 2010 when the project was 79 per cent complete, so it is difficult to ascertain if the scope was altered to deliver within the approved budget as the expansion of the BHP Billiton Pilbara assets is ongoing. Nevertheless, this was a large-scale project requiring multiple working fronts at a time of extreme demand for construction services in the region, and its completion on time and on budget is notable.

Anglogold's Tropicana gold project (Tropicana), located in a remote, undeveloped area 340 km NE of Kalgoorlie, was a greenfield project that involved the development of an open pit mine, a 5.8 Mt/a processing plant and supporting infrastructure. Anglogold assembled an experienced, multidisciplinary team to assess the development of the project, which was first discovered in 2002 and whose initial resource estimate was published in December 2007. Several study phases were conducted, culminating in a bankable feasibility study in which the project scope was frozen, despite additional resources being discovered as the studies progressed. The project go-ahead was given after the receipt of environmental approval in November 2010. The project was delivered slightly ahead of schedule in September 2013, but suffered an 11 per cent cost overrun. However, this was forecast in a January 2013 revision of the budget. Nameplate capacity was achieved within three months of start-up.

Sandfire Resources' Degrussa copper project (Degrussa) is located adjacent to a national highway in a sparsely populated area 800 km NE of Perth and 150 km from the nearest town of Meekatharra. This greenfield project involved the development of open pit and underground mines, a 1.5 Mt/a processing plant and site infrastructure. When the Degrussa orebody was discovered in May 2009, Sandfire Resources was a small exploration company with no experience in project development. An experienced team was assembled to conduct a comprehensive set of studies into the development of the project. A scoping study was completed in February 2010, and the company made a conditional go-ahead decision and placed orders for long lead equipment based upon the strength of findings from a prefeasibility study completed in March 2011. This study confirmed the financial and technical strength of the proposed project. Final approval and debt funding was based upon a definitive feasibility study in which the project scope was frozen, despite additional resources being discovered as the studies progressed. Essentially the same study team transitioned into the management of project execution after the project was permitted and approved for development. The project was delivered on time with a modest four per cent increase in capital cost and successfully passed its debt finance completion test within six months of project completion.

The not too bad

Projects that fall within the 'not too bad' category are those that exceeded their forecast capital cost or schedule by 15–50 per cent but operate in accordance with expectations. Again, the examples provided have very different inherent project characteristics.

First Quantum Minerals' (FQM) Kevitsa Ni-Cu-PGE project (Kevitsa), located north of the Arctic Circle in Finland, is a greenfield project that involved the development of an open pit mine, a 5.2 Mt/a processing plant and infrastructure suitable for severe Arctic conditions. The project was subject to several studies, including prefeasibility and feasibility studies, prior to its acquisition by FQM in June 2008. FQM undertook further drilling and engineering studies on an increased resource base and made the project go-ahead decision in November 2009 after receipt of environmental authorisations in September 2009. The project achieved commercial production in August 2012, which was within one month of forecast. While public information on the actual capital cost incurred is limited, the company reported final costs of US$470 million, including commissioning costs that were not included in the announced capital cost. This was 18 per cent greater than the capital cost announced at project go-ahead, but on a like-for-like basis, the cost overrun is likely to have been less than 15 per cent.

Fortescue Metals Group's (FMG) stage 1 iron ore project was a greenfield project located in the Chichester Range, which is approximately 260 km SE of Port Hedland in the Pilbara region of Western Australia. The project involved the development of iron ore mines, processing facilities, support infrastructure, railways and port facilities, including new berths. The initial capacity of stage 1 was set at 45 Mt/a of direct shipping ore lumps and fines, though the logistics infrastructure was easily scalable and now produces in excess of 150 Mt/a after the establishment of new mines and processing hubs. Following completion of a scoping study in September 2003, the company immediately embarked on a prefeasibility study that investigated a range of development options while exploration continued with great success. Separate feasibility studies were completed for the infrastructure and mine components of the project, which together formed a definitive feasibility study. This formed the basis of a business plan referenced in an offering memorandum used to successfully raise debt in the international debt market. Approvals and land and infrastructure access were a major focus during these studies. FMG benefitted from having effective project management systems in place that allowed for timely reporting of cost and schedule performance trends, which enabled the proactive management of any issues that arose. Despite missing its initially forecast cost and schedule targets by 26 per cent and 18 per cent respectively, the project cost, schedule and scope were well monitored and controlled through the construction period. If not for the unusual occurrence of three tropical cyclones during construction, a one-month delay in the receipt of a final approval and a conscious change in project scope (to incorporate mine infrastructure facilities originally included in the mining contractors scope of services), the project would likely have been delivered within ±15 per cent of feasibility study forecasts.

The not so good

Projects that fall within the 'not so good' category are those that exceeded their forecast capital cost or schedule by more than 50 per cent or which operate at less than 85 per cent of nameplate capacity within 18 months of start-up. Our example is BHP Billiton's Worsley Alumina Efficiency and Growth project (E&G), which was a brownfield expansion of the Worsley refinery located 140 km south of Perth. The E&G project was designed to increase refinery output from 3.5 Mt/a to 4.6 Mt/a. The project entailed expanded open pit mining operations, additional refinery capacity and upgraded port facilities. The complex refining process has been tailored to match the properties of the bauxite feedstock and substantial proprietary processing knowledge subsists with the Worsley technical group. Ultimately, the project was delivered ten months late and 58 per cent over budget, although its performance has been as planned. A revised budget and schedule was announced 12 months prior to actual completion, and in making that announcement, BHP Billiton (2011) noted that:

The ... refinery expansion is being executed within the existing footprint of the facility, making it one of the most complex brownfield projects undertaken. Such complexity has resulted in significantly lower levels of construction progress than previously anticipated, while broader inflationary pressures and the strengthening of the Australian dollar have also contributed to the cost increase.

The ugly

Projects that fall into the 'ugly' category have either a cost or schedule variance in excess of 100 per cent or they actually never reach completion. The following is a selection of notable ugly projects.

Gindalbie Metals' Ansteel JV Karara magnetite project (Karara), located 220 km ESE of Geraldton in the Mid West region of Western Australia, made its first shipment of magnetite in January 2013, 34 months later than originally forecast and 79 per cent, or A$1.3 B, over budget. In addition, it is achieving only 75 per cent of nameplate capacity after 30 months of operation. Although scoping, prefeasibility and bankable feasibility studies were reportedly completed in February 2005, January 2006 and September 2007 respectively (with the project commitment based on the 2007 banked feasibility study findings), delays and material scope changes occurred from the outset. Environmental approvals for the project were not received until two years after project go-ahead. The owners are currently in breach of loan covenants, and the project has been written down to zero value. A 2015 independent expert report (BDO, 2015) notes that:

The Project is currently unable to operate at the production levels originally forecast and as a result has not yet become cash flow positive. … At current iron ore prices, the Project is not economically viable.

Completion of a comprehensive feasibility study for Cudeco Limited's Rocklands copper project (Rocklands), located 12 km NW of Cloncurry in Queensland, has not been reported, and the project was seemingly developed 'on-the-fly'. In April 2011, Cudeco made reference to capital requirements of A$200–250 M to develop the project, which involved a greenfield open pit, a processing plant and infrastructure. Expenditure to June 2015 totalled approximately A$480 M, and progress achieved included substantial open pit development (a 2.2 Mt stockpile has been mined) and substantial process plant construction (electrical and instrumentation was 30 per cent complete as of 30 June 2015). Chinese debt funding was provided as early as September 2013, despite ongoing project scope and process flow sheet changes occurring through 2014 and 2015. The project was halted and Cudeco was suspended from trading on the Australian Securities Exchange (ASX) in June 2015 until further project financing can be secured.

Scoping, prefeasibility and definitive feasibility studies for Northland Resources Limited's Kaunisvaara magnetite project (Kaunisvaara), located 140 km ESE of Kiruna above the Arctic Circle in Sweden, were completed in September 2009, May 2010 and September 2010 respectively; however, the scopes of these studies were incomplete, with, for example, the product logistics being excluded. Project development proceeded on the basis of the definitive feasibility study, and construction commenced in March 2011. Capex was revised upwards to US$765 M in May 2011, and then the process plant output was revised downwards to 4.4 Mt/a and the forecast capex increased to US$807 M in February 2012. Significant additional cash requirements were subsequently identified for working capital, predevelopment, performance bonds and guarantees, requiring several hundred million dollars of additional debt and equity raisings. In late 2012, the need for an additional US$425 M in funding was announced. The first concentrate shipment was dispatched in February 2013, and the project operated intermittently until October 2014. The owner was declared bankrupt in December 2014 after spending more than US$1.5 B to complete just one of two processing lines that only operated at around 80 per cent of design.

The US$2.35 B initial capex estimate for Anglo American's Minas Rio iron ore project (Minas Rio), located 75 km east of Belo Horizonte in Minas Gerais, Brazil, was provided by the project vendor prior to the acquisition of the project by Anglo American in May 2007, when development was already underway. By December 2007, the project cost was revised to US$3.46 B, and there were multiple and frequent revisions to cost and schedule from then on. By December 2008, the first shipment date had slipped to June 2012 and the cost was forecast to be US$3.63 B. Project delays and cost overruns attributed to permitting delays, labour market issues and inflation pressures in Brazil saw the capital cost balloon to US$8.4 B. Since commissioning in October 2014, Anglo American has had to write down a large proportion of its investment in the project. No information can be found as to whether a three-step study process was followed prior to the execution of the project; however, the project outcomes point to a rush to start production.

The rights to develop the Sino Iron magnetite project (Sino Iron), located 80 km SW of Karratha in the Pilbara region of Western Australia, were acquired in 2006 by Citic Pacific with a basic scoping study having been completed. Stated project output was 24 Mt/a of magnetite concentrate, with around 6 Mt/a of this pelletised. When given the go-ahead in January 2007, the project was forecast to require US$2.47 B of capital investment, with first product expected to be shipped in January 2010. However, this project has failed to meet these targets by the widest margin of any resource development project that we are aware of in the last decade. The total investment to mid-2015 is reported to have exceeded US$12 B, the first shipment was almost four years behind schedule and, notwithstanding the almost fourfold increase in capital expenditure to mid-2015, only two of six parallel processing lines had been constructed. The proposed pellet plant has been removed from the project scope. Nineteen months passed between the announcement of the first production of concentrate and the announcement that the project had shipped its one millionth tonne, and it has yet to reach 'commercial production'. Citic Pacific continues to capitalise net operating expenses and has recently recorded a US$2.5 B impairment charge against the project. Operating costs are reported to currently exceed US$90/t.

Comprehensive and detailed feasibility studies have not been reported, and the preliminary nature of the work done prior to project go-ahead is evidenced by statements in an independent technical report appended to the notice of general meeting for the approval of the acquisition of the mining rights in 2006, which included:

> *The geotechnical work carried out to date is insufficient to define the appropriate slope angles for the final mine design.*
>
> *A comprehensive analysis of the hydrogeological setting and the impact on the proposed pit design has not been prepared at this stage.*
>
> *[The independent expert] is not aware of any technical obstacles preventing the current In-Pit Measured Resources being eventually defined as Proved Ore Reserves following such further studies which would be included in a conventional feasibility study.*
>
> *Because of insufficient basic engineering, components of the capital cost estimate (capex) are consistent with a Prefeasibility Study only. The approach taken to address this risk is to use fixed price tenders provided by nominated suppliers for all major aspects of the project engineering.* (Citic Pacific, 2006)

When Citic announced that it had acquired the project in 2006, it noted its intention to '… cooperate with partners of Peoples' Republic of China (PRC) background with expertise in mining …', but in a 2014 press interview, the Citic Chairman was quoted as saying:

> *We don't understand the actual conditions of building large mining projects in Australia. We tried to apply our lessons learnt in China locally and severely underestimated the difficulty of the project.*
>
> *We must negotiate and remove every sacred site within the mining area with the local indigenous tribes. That took us an entire year and we didn't think about that at all during the initial planning stage.* (Cai, 2014)

A three-phased study approach was not adopted for this project, and a sufficiently comprehensive, detailed and integrated feasibility study conducted by suitably qualified and experienced professionals would have enabled recognition of the time and cost to execute this project prior to project go-ahead.

What do these examples illustrate?

These examples illustrate the conclusions drawn earlier, which are summarised in the following:

- Inherent project factors such as size, location, commodity and scope have little influence on the predictability of project performance. The examples cited in this paper are certainly diverse in size, location, commodity and scope. The projects within the 'good' category are diverse, yet the performance against expectations of the two similar greenfield copper projects (Degrussa and Rocklands) could hardly be further apart.
- Complex projects tend to be less predictable than simple projects, and projects that use new or innovative technology are less predictable than those that use mature technologies. In the examples cited in the previous section, of the two brownfield projects involving the expansion of existing facilities (RGP5 and Worsley E&G) undertaken by the same owner (BHP Billiton), the more complex project had a far worse outcome.
- External macroeconomic circumstances can have substantial influence on the delivery of projects as predicted in feasibility studies. Projects developed during periods of high gross demand on project resources (eg qualified people, skilled labour, construction services or plant and equipment) are more likely to suffer project cost overruns and delays. All of the projects cited in this paper were executed during a period of extreme demand for project services, and the owners of some of the projects specifically acknowledged that this was a factor in overruns (Tropicana, Worsley and Minas Rio).
- Poorly developed feasibility studies tend to produce poor project outcomes. All of the projects that went ahead without a comprehensive phased study effort (Karara, Rocklands, Kaunisvaara, Minas Rio and Sino Iron) had ugly outcomes.
- Projects whose expectations have been set after comprehensive, detailed and integrated feasibility studies and that are then delivered by experienced, integrated teams encompassing all relevant areas of project expertise are able to deliver predictable project outcomes regardless of the inherent project factors or external macroeconomic circumstances. Six of the examples in the previous section (RGP5, Degrussa, Tropicana, Kevitsa, FMG Stage 1 and Worsley E&G) completed phased, comprehensive, detailed and integrated feasibility studies prior to commitment, yet, of these, only one (Worsley E&G) had a poor outcome. Three of the remaining projects (Tropicana, Kevitsa and FMG Stage 1) suffered cost increases to varying degrees, but each was clearly identified well in advance and expectations were reset in a timely manner.

Notwithstanding that the examples in this paper were selected to illustrate these points, in reviewing the projects, we found that better outcomes correlated with:

- completion of comprehensive, multistage feasibility studies by experienced teams
- project scope frozen at commitment
- project permits in place at commitment
- effective project controls and monitoring during execution.

Clearly, a good study does not guarantee success – a study is after all only a forecast of what might be and will never be entirely predictable – and the Worsley E&G project outcome illustrates this. Too much study work can lead to unnecessary costs and delays and may not add value, with an example of this being Sandfire's decision to conditionally go ahead with the Degrussa project based on prefeasibility study findings.

In this regard, we restate one of the conclusions from our 2007 paper that it is important to maintain perspective and exercise good judgement during the study process and that it is always better to be approximately right than precisely wrong.

OBSERVATIONS, EXPERIENCES AND RECOMMENDATIONS

In the authors' experience, the current issues adversely impacting the conduct of studies and project execution, and the resultant poor outcomes, can be categorised as:

- a lack of clarity around the guidelines and standards to be achieved during the execution of studies and planning of projects
- a lack of understanding on behalf of project owners and study engineers of the reasons for undertaking certain aspects of the study and project execution processes
- studies and project execution failing to achieve requirements of the guidelines or standards.

These are discussed further in the following sections, together with some recommendations.

Guidelines and standards

As noted previously, the completion of comprehensive, multistage feasibility studies by experienced teams is one of the factors that correlates with project cost and schedule targets being met. In our 2007 paper, we presented a framework for the conduct of feasibility studies and guidance on minimum standards and best practice to provide consistent, fit-for-purpose project evaluations. In our view, good studies should be:

- comprehensive enough to cover all aspects of the proposed business plan by area, activity and phase
- appropriately detailed and assessed in sufficient detail to align with the purpose of the study
- fully integrated to demonstrate internal consistency between study elements.

Waldie, Whyte and Ténière (2015) provide a good summary of best practices and useful guidance for the Canadian regulatory regime applicable to mining disclosure and a comparison between the Toronto Stock Exchange NI 43–101 reporting requirements and the ASX JORC Code (2012) reporting requirements. Both regimes incorporate the notion of multistage feasibility studies by experienced study teams, although terminology and definitions differ somewhat.

In relation to study content, NI 43–101 prescribes the content of a technical report in considerable detail, whereas the JORC Code merely requires a summary of the items listed in Table 1 on an 'if not, why not' basis. The authors believe that there is considerable merit in standardising the content of the reporting of studies along the lines of NI 43–101 to ensure that all aspects of the proposed business plan to develop a project are covered.

However, guidelines as to what is an appropriate level of detail are limited in both NI 43–101 and the JORC Code.

The JORC Code states that a feasibility study must include:

> *… appropriately detailed assessments of applicable Modifying Factors together with any other relevant operational factors and detailed financial analysis that are necessary to demonstrate at the time of reporting that extraction is reasonably justified (economically mineable).* (JORC, 2012)

Some guidance on study scope is provided in Section 4 of Table 1 of the JORC Code, which lists Modifying Factors that need to be considered in Preliminary Feasibility and Feasibility Studies. However, the JORC Code provides little guidance for professionals as to the appropriate level of detail required in a study. Clauses 38, 39 and 40 of the JORC Code, which respectively define the terms Scoping Study, Preliminary Feasibility Study and Feasibility Study, are silent on this issue. Indeed, the statement in Clause 39 that 'a Pre-Feasibility Study is at a lower confidence level than a Feasibility Study' (JORC, 2012) coupled with the statement in Clause 40 that 'the confidence level of the (Feasibility) study will be higher than that of a Pre-Feasibility Study' (JORC, 2012) is not particularly insightful or helpful as to what is an appropriate level of detail.

Although the JORC Code creates an expectation that by reporting an Ore Reserve the net present value (NPV) of a project will have been assessed, guidance on what is it to be considered when determining the NPV is limited. For example, the Code expects reporting of 'the derivation of, or assumptions made, regarding projected capital costs in the study' and 'the methodology used to estimate operating costs' (JORC, 2012), yet provides no guidance on what cash flows are to be included or what accuracy is expected.

The NI 43–101 regime incorporates references to the Canadian Institute of Mining, Metallurgy and Petroleum (CIM) Guidelines; however, guidance as to the expected accuracy of different study types (preliminary economic analysis, preliminary feasibility study and feasibility study) remains elusive. The current CIM Best Practice Guidelines merely states that:

> *The test of economic viability should be well documented as part of the Mineral Reserve estimation process. The requirement for economic viability implies determination of annual cash flows and inclusion of all the parameters that have an economic impact.* (CIM, 2003)

The authors believe that this lack of reference to expected accuracy for different study phases in either the JORC Code or NI 43–101 creates substantial variance in what is reported.

While the AusIMM's *Cost Estimation Handbook* provides some guidance on study content and accuracy, assessment of the accuracy of operating costs appears to be less well defined in comparison with assessing the accuracy of capital costs. In this regard, guidance is also required pursuant to Section 4 of Table 1 of the JORC Code, which states that:

> *Accuracy and confidence discussions should extend to specific discussions of any applied Modifying Factors that may have a material impact on Ore Reserve viability, or for which there are remaining areas of uncertainty at the current study stage.* (JORC, 2012)

In the authors' experience, the assessment of accuracy in studies is fraught; observations include:

- In recent years, Monte Carlo range analyses have consistently resulted in claimed cost accuracy that are in some cases totally unrealistic and generally far narrower than experience demonstrates. Furthermore, contingency allowances continue to be too low at all study phases, leading to project owners' investment decisions being made on the false premise of high accuracy levels, which ultimately result in low levels of contingency.
- There is also the issue that many study contractors and engineers base accuracy and contingency on process plant and infrastructure areas only and don't properly consider overall accuracy and contingency levels that include mining, preproduction, owners costs, funding and start-up costs. Emphasis must be placed on combining these assessments to ensure that the final cost estimate considers the uncertainty around the total estimate of all project costs.
- The feasibility study standards used by many companies typically require escalation to be calculated but not included in the project 'headline' capital costs announced. Sometimes, but not always, the foreign exchange (FX) cost provisions might be included in the announced capital costs. This has resulted in a number of examples of companies not providing for escalation in their project budgets and not hedging or allowing for FX costs. In the opinion of the authors, a formal definition of the issues around escalation and FX and a protocol for their inclusion/exclusion in 'headline' announced capital costs needs to be developed.

Establishing clear guidelines for study accuracy and scope, together with explanations on how to use the guidelines and the rationale for them, will be of benefit to the entire industry.

Lack of understanding of study and project execution requirements

Most, if not all, of the points in this section point to the pressure that owners can be under to produce projects quickly and at the lowest possible cost. A lack of understanding of the time and effort required for study and project development can result in poor to extremely poor project outcomes. Information and education is required for owners' teams to ensure that the concepts and pitfalls of owners' project management are well understood. Our observations include:

- Many owners think that 'prefeasibility study' means 'preliminary feasibility study', implying that it should not cost or take as much time and effort as a feasibility study. However, a prefeasibility study will typically cost more and take longer than a feasibility study. The higher cost and longer time required for prefeasibility study phases relates not to the technical evaluation part of the phase, but to the field investigations, drilling, test work and evaluation of options essential for the prefeasibility study. Many studies managed by owners seek to create schedule improvements by excessively overlapping the steps of investigation, data analysis and evaluation, leading to incomplete analysis and invalid evaluation of incomplete or preliminary data. Feasibility studies should typically commence only after detailed geological and metallurgical investigations are complete.

- The time taken to properly plan for the development of >A$1 B projects or projects involving significant 'off-site' development (eg transport corridors) has proven to be inadequate. The extended effort and time taken to investigate, evaluate and plan appropriately prior to commencing such projects will generally result in a better project outcome. The areas of permitting, field investigations, resource definition, test work, environmental assessment, financing, infrastructure access, government and stakeholder relations and execution planning tend to increase disproportionally as project size increases, offsetting economies of scale that may arise elsewhere.
- Implementation strategies outside the common 'default' case of engineering, procurement and construction management (EPCM) are not well thought through, yet the strategies can significantly impact costs by ±15 per cent and schedules by up to ±25 per cent. Care must be taken to consider all aspects of the execution strategy as costs saved in one area may well be taken up in others. EPCM may be an appropriate default case for the comparison of different project configurations during a prefeasibility study, but for the single project configuration taken into the feasibility study stage, the schedule and cost estimate must reflect the recommended contracting strategy.
- A common area of business failure lies in what, how, when and why is to be done between the end of the feasibility study and the decision to proceed. As a result, Enthalpy has added a new phase to its minimum standards called 'commitment', which falls between the feasibility study and implementation. Owners must be the planner of the commitment phase so that the objectives, costs and time definition are well understood. It is essential that the commitment period allows for environmental approval, funding, project approvals and mobilisation. Not allowing for this commitment time will cause the project to be late from the outset.
- The concept of estimate accuracy is not well understood by owners. The P50 estimate is frequently used as the budget for a project, but the project economics may not have been tested at P80, P85 or P90. Sensitivity analysis is also not properly understood. Single variable sensitivity assessment is of limited value, and there is little to be gained by assessing the NPV/internal rate of return effect of a 10 per cent cost overrun but ignoring the effects of a schedule delay causing the cost overrun. Owners need to understand the combined effects of a cost and schedule overrun on the project economics.
- While independent peer review (IPR) processes and quality of outcomes are improving, they are often devalued when the conclusions of the IPR are not clearly stated in a firm, concise manner. IPRs are also often conducted as a 'tick the box' exercise using preliminary or incomplete information and often have an unreasonably limited scope and duration. It is often unclear or misunderstood who the customer of the IPR is, and the IPR recommendations are rarely described in the final study reports. A best practice guideline for the IPR process could be developed and added to the JORC Code.
- Study effort levels are usually dominated by engineering inputs, which can skew the emphasis of the study to engineering issues rather than project delivery and execution issues. Planning around project delivery in areas such as human resources, commercial strategies, IT systems integration, operational readiness, working capital needs, financing and stakeholder management is often poorly developed.
- Governance of studies and execution is often poorly developed and understood. The time required to obtain critical authorisations, whether from owners or financiers, and the needs of those decision makers, such as independent reviews, are often overlooked in project schedules. Furthermore, the delegation of authority is often structured around monetary value rather than business impact, and seemingly minor design decisions made with limited monetary value can sometimes have greatly magnified impacts on schedule and commercial risk.

Studies and project execution fail to meet standards

Issues around the execution of studies and projects could be relatively easy to overcome by continually educating study and project teams and ensuring that guidelines appropriately emphasise all concepts of project execution. These include:

- Schedules for development programs continue to lack an overarching structure that breaks down activities into field work, data collection and analysis for each study phase or the differing effort levels required during each study phase.

- Field work, data collection and analysis often appear not to be connected to the study work. This is due to organisational gaps between the exploration groups and the study groups of the owners. A benchmarking exercise should be undertaken and industry definitions developed by peer leaders, which should then be considered for publication and adopted as industry standards to ensure that sufficient time is allowed for data collection, data analysis and evaluation during the three-phase study approach.
- The environmental baseline studies, assessments, public inputs and approvals are now so extended that they lie on the project development critical path. As a result, the environmental impact statement process has to start not at the feasibility study stage, but early in the prefeasibility study process. This can artificially constrain the future opportunities to change the project size, configuration and locations because these are key issues that need to be fixed for the public phase of the environmental impact statement process. Benchmarks known within the mining industry need to be published and a process to integrate prefeasibility studies and environmental impact statements developed, so as to de-risk the approval process. We also note that successful (predictable) projects have generally received development approvals or, as a minimum, completed all necessary investigations and consultation work for approvals prior to project go-ahead.
- Most prefeasibility and feasibility study schedules fail to provide a sufficient time contingency period to deal with known unknowns that always happen in studies.
- Prefeasibility studies are often badly planned from the beginning. The plans lack the structures of considering a wide range of capacities, technologies, configurations and locations. All too often, the prefeasibility study declares 'base case' scenarios early in the prefeasibility study phase, which in reality announces that this is the case that the study leader wants to see succeed. A paper on the best practice of the process and approach to developing and assessing prefeasibility study cases should be developed and published to inform study managers.
- There is a lack of understanding of what a work breakdown structure is for and what it must look like. This problem results in scope being lost or not identified, out of balance project areas and, ultimately, operational problems. If the work breakdown structure is not well thought out at the scoping stage and then at the prefeasibility study stage, the problems will continue throughout the life of the project. The Project Management Institute and other project management industry groups need to be involved in this discussion, but the current dialogue is less than encouraging. It is possible that the mining industry could lead the way in ensuring that the development of a work breakdown structure is well considered and understood.
- Prefeasibility and feasibility studies lack strategic and business analysis integration with the technical and project studies. The result is a disconnection between what the engineers think is a best project and the strategic and economic drivers for a good investment. For example, a project prefeasibility study was developed that recommended a go-forward case that was so large that the owner had no chance of ever funding the deal. This situation meant that the owner was seriously disadvantaged in the subsequent commercial aspects of the negotiation of a sale to a large mining company capable of carrying out the investment.
- Prefeasibility and feasibility studies lack the process of 'trend' management of the financial analysis of the project during the study periods, based on regular reruns of the financial models. Business analysis and financial modelling typically come in two-thirds of the way into the study or later to build the financial model. This is too late to provide guidance and support to study teams as to what drives and influences the investment. This issue is partially related to the previous point of ensuring that strategic objectives are met, rather than wasting money producing a proposed case that is wildly off the company's business and economic targets. Such business and economic guidelines must be set as part of the upfront study work plan process.
- Ideally, the feasibility study should not be started until all significant options are resolved. The authors continually see feasibility studies completed with too many 'trade-off studies' and inadequately defined issues to be resolved during the front end of implementation. This leads to uncontrolled change processes destroying the cost and schedule baselines of the project that have been set during the feasibility study

- The referencing of information developed and data collected continues to be done poorly over the life of studies. The authors continually see study teams only start to think about building a data room or collating essential appendices as a feasibility study is nearing completion. This leads to the situation where conclusions made in studies are not able to be tracked back to source investigations and data analysis. The need for careful recording of project decisions and conclusions and their traceability needs to be reinforced.
- The failure to produce a draft project execution plan at the feasibility study stage continues to be a significant weakness in the study process. Generic EPCM contractor descriptions of what might need to be done during implementation are simply not good enough. A project execution plan must be project specific, cover all aspects of the proposed project execution and, in particular, explain what the owner is planning to do – after all, the owner must drive policy down into the project. The project execution plan demonstrates that the plan of how the project is to be brought to fruition has been considered and communicates this plan to the owner's project team and the engineers and contractors. The *Cost Estimation Handbook* guidelines need to be reinforced in this area.
- Another area of feasibility studies that is often inadequately detailed is operational readiness planning. This leads to major shortfalls in estimates for this area of activity and hence creates the potential for unanticipated project cost increases, especially working capital. The establishment of operationally ready enterprise resource planning systems is also often late, resulting in inefficient project ramp-up and expensive temporary solutions being relied upon. The AusIMM *Cost Estimation Handbook* needs to be revised to ensure that sufficient allowances for operational readiness are made in the feasibility study.

CONCLUSION

The last ten years has not seen any major improvement in project outcomes in the mining industry. Instead, a boom period has led to a decline in the successful completion of mining projects. It will only be through diligent work to educate project owners and project teams and the provision of clear guidelines that the industry will improve the success rate of project execution. Work is needed to ensure that the mistakes made in the past are not repeated. We hope that the next ten years of project development will see a more careful and controlled approach that will improve the rate of successful project completion.

In closing, we note the question posed by Bullock that laments the lack of industry standards for feasibility studies:

> *Why has such a tremendous effort been put forth to greatly improve the quality and standards of the resource and reserve classifications, but with little or no effort to improve the detailed definition of that which determines whether or not a resource will move from a resource to a reserve classification?* (Bullock, 2011)

We believe that this paper reinforces the case put by Bullock for the industry as a whole to establish quality standards for the conduct of the three-phase feasibility study project evaluation.

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