AMC CONSULTANTS

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DIGGING DEEPER

WHAT DOES A FEASIBILITY STUDY COST?

Paul Harper

Earlier this year AMC undertook a review of 105 feasibility studies completed worldwide between January 2000 and January 2007. These were final feasibility studies for new mines and expansions prepared by consultants, engineering firms and in-house mining company teams.

There were sixty-nine surface mines and thirty-six underground mines in the study, which was prepared for AMC's internal purposes. Figure 1 shows the relationship between the mining rate (expressed as tonnes of ore per annum) and the project capital cost, adjusted to 2007 Australian dollars. The high outliers in Figure 1 are nickel laterite and iron ore projects with extensive infrastructure requirements. Figure 2 shows the same relationship for underground projects separately for clarity.

The average capital cost of open pit projects can be expressed as $53 million plus $33 million per one million tonnes per annum of ore production and treatment capacity. For underground projects, the relationship is $37 million plus $68 million per one million tonnes per annum of ore production and treatment capacity. As the charts show, there is a wide variation in these costs.

The relationship between project capital cost and the feasibility study cost is shown in Figure 3. Study costs averaged 5.7% of project capital for underground mines and 4.6% for surface mines. The higher study costs, above 10% of capital, tended to be for expansions of smaller projects and were also influenced by the inclusion of the cost of large drilling programmes or trial mining. It proved impossible to normalise the available data for these effects.

As might be expected, the cost of the mining component of a feasibility study (geology, geotechnical, mine design, scheduling and costing) was a low proportion of the total cost of establishing the mining operation, at around 1% of mining department capital cost.

There was a substantial increase in project and study costs during the period considered, particularly after 2004. AMC does not yet have enough data to adjust out this effect, but the relationship between study cost and project capital cost is likely to remain valid.

Figure 1 – All projects

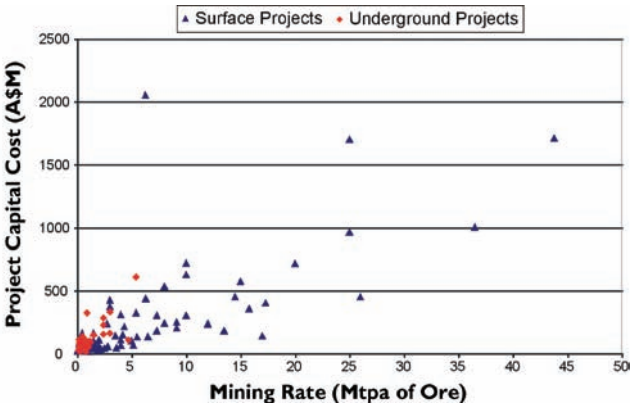


Figure 2 – Underground projects

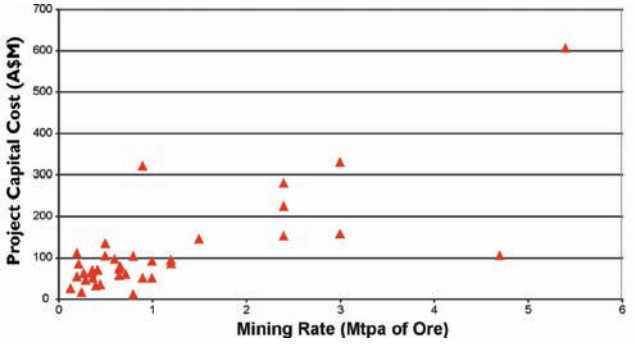
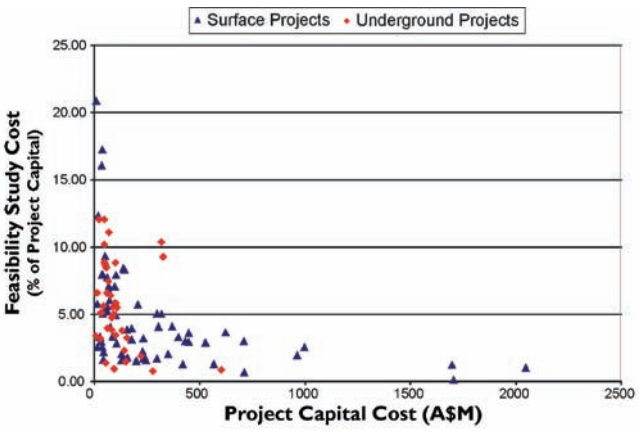


Figure 3 – All projects



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ESTIMATING THE COST OF A LARGE UNDERGROUND EXCAVATION

Peter McCarthy and Tony Weston

Large excavations are required in underground mines for facilities such as crushing stations, loading stations, workshops and pump stations. This note may be of interest to engineers who need to estimate the cost of such a large excavation.

In a Scoping Study (accuracy +/- 30–50%), factored costs of similar facilities, including the excavation costs, are appropriate. Alternatively an excavation cost per cubic metre and a support cost per square metre can be used, together with a factored lump sum for the installed cost of the equipment. Costs should be factored from a site having similar rock conditions.

In a Prefeasibility Study (accuracy +/- 20–25%) a general layout of the facility should be prepared at least in plan view, and a preliminary assessment of ground support requirements made. Sufficient thought should be given to excavation techniques to be able to estimate the volume of rock to be broken by each of hand-held, jumbo or longhole drilling, and the method of rock removal for each. Excavation, loading and haulage costs per cubic metre for each method can then be applied. Ground support costs can be estimated per rockbolt in backs and walls, plus per metre of cable bolt where required. Mesh and shotcrete (or fibrecrete) costs can be estimated per square metre applied, with shotcrete typically at 75mm or 100mm thickness.

If estimating shotcrete costs volumetrically, allow 10–20% rebound losses for wet-mix fibrecrete, with a further 10–20% roughness factor. After allowing these factors and wastage (spillage, left in agitator bowl or dumped) the total shotcrete useage will be 1.8 to 2.5 times that for a theoretical case using the design thickness of shotcrete applied to a design excavation. Overbreak, actual excavation roughness, rework, temporary support and specification of a minimum design shotcrete thickness are some of the other causes besides rebound and wastage. The specification of 50mm minimum thickness can result in an average actual thickness of 75mm, depending on the roughness of the actual excavation. In large excavations there is a greater possibility of overbreak.

Depending on its purpose, the excavation cost may include the cost of a concrete floor. In poor ground, particularly where well-developed structures are present, substantial overbreak may occur, for example around the crusher pit and crushed ore pass below the crusher. This needs to be considered when estimating concrete volumes. Blinding concrete on final excavation floors in a particular area can reduce overbreak

from subsequent adjacent excavations below this level. Blinding concrete helps prevent chamfers (overbreak) being created at the intersection between a horizontal surface (a permanent floor) and a vertical face subsequently excavated adjacent to this permanent floor.

In a Feasibility Study (accuracy +/- 10–25%) a detailed design of the excavation should be prepared showing how the major mechanical components fit into the excavation. Allowance needs to be made also for the installation of the mechanical components including mobile crane access, conveyor cable reels etc. Sufficient geotechnical work, possibly including stress measurement and 3D modelling, should have been done to enable the orientation to be optimised and the permanent ground support to be specified in detail. A Construction Method Statement should be prepared, explaining the method and sequence of excavation, temporary ventilation, how the broken rock will be removed, any need for temporary ground support, and the method of installing permanent ground support.

In many tall excavations a "top down" method is used, allowing cable dowels and permanent back support to be installed prior to taking out the bulk of the chamber. Typical industry practice is to complete mining and support of the chamber before handing it over for civil and mechanical construction. An alternative is an integrated mining and construction schedule, with concrete and steel work constructed at the top of the chamber off a solid rock floor, eliminating the need for extensive scaffolding and working at heights. Careful blasting techniques will then be required for later stages of excavation to prevent damage, but the overall cost and / or duration of the project may be reduced.

Large excavations are now more likely to be made using development jumbos than longhole methods. Access by rubber tyred vehicles allows shotcreting and cablebolting to be safely and efficiently performed. Longhole methods need to take account of more skilled and labour intensive installation of ground support, and the potential for ground movement or relaxation while support is being installed. Mobile cranes, specially constructed ladderways and systems for working at heights may also be necessary. Longhole methods may also result in overbreak in poorer ground, and efforts to reduce overbreak can result in underbreak with associated time consuming survey and minor stripping.

Temporary ground support is likely to be required in one (temporary) wall, while excavating and installing cablebolts in the backs of a large chamber and in subsequent excavation lifts below this level. Good geotechnical knowledge of crusher chambers is required as there is less flexibility in locating crusher chambers, particularly in relation to a block cave or long conveyors. Conveyor transfer points require some thought in scheduling of excavation sequences, particularly where access is required for two or perhaps even three separate excavation lifts. Good QA and survey systems or generous (0.3 to 0.5m) tolerances are required to ensure that steelwork and infrastructure components fit in the completed excavations.

MESSAGE FROM THE MANAGING DIRECTOR

The number of women working in the mining industry is much lower than it should be. They make up only 18% of the mining workforce, compared to 45% in the Australian workforce as a whole. The mining industry recognises this as an important problem, not just because there is a shortage of qualified and experienced people, but because of the cultural and behavioural bias it sets up in the workplace. A balanced gender mix is likely to improve decision-making, interpersonal behaviour and workplace safety. There is also clear evidence that women are better operators of equipment.

At AMC, women make up 25% of our employees, but this is nowhere near good enough. Thirty-two percent of the consulting staff at Graduate and Engineer/Geologist level are women, but this falls to 17% at Senior level and just 2% at Principal level. At the more senior level this low participation is simply a reflection of the very few qualified women available to us in that demographic. However, I am hoping that as participation grows at AMC, a critical mass will begin to attract more.

The consulting business can involve a lot of travel, and it is my observation that women tend to value relationships and family (and damage to them) more highly than males when striking the work/life balance, so they would prefer (all things being equal) a job with less travel. Remote, isolated locations may not appeal or the male-dominated culture may be discouraging. In the past, living and working conditions have been basic but this is changing rapidly as firms compete for the available workers. One practical limitation is the lack of affordable child care provisions, which is still not being addressed by most mining companies, although this should not be a constraint for city-based consulting jobs.

However, for those who value the experience of travel, the mining industry is an excellent choice. There are opportunities to work "in the bush" in exploration or as a team leader and manager in operations. Travel opportunities also extend to international locations and many people working in the industry have gained valuable life and professional experience while working and living overseas. One of our successful policies allows employees to work from home at their discretion, or to work hours that suit their personal needs, so many AMC staff chose to 'offset' the travel they undertake as part of their jobs with time spent working from home.

The mining industry is very technically sophisticated and offers opportunities for anyone drawn to maths, science and engineering. A very interesting statistic is drawn from the 2001 Australian census which shows that 17.3% of people working in the mining sector are university graduates, compared with 9.9% for manufacturing, 7.1% for trade and 6.2% for agriculture. Only the education sector, with 55.8% graduates, is more "intellectually intensive" than mining. Of course, these are percentages; in absolute terms mining employed only 1% of the Australian workforce and 0.8% of graduates in 2001, although this will have grown due to the mining boom.

Mining opens the doors to working with cutting-edge technology, with a lot of money available to develop and apply the latest software methods, automation and robotics. Consultants like AMC, together with major corporations like RioTinto and BHPBilliton, are at the forefront of these developments.

Traditionally, many women have not known about the mining industry, known how or where to start, and have had few role models or mentors. Two of my daughters have chosen a minerals career, and this points to a particular influence on women in mining – they become familiar with the industry through a family connection or have grown up in a mining town. This is also true, I should add, for male participants. All are drawn by the high comparative wages in the industry.

At AMC we will continue to strive for a better gender balance, not because it is "politically correct" but because it makes excellent business sense for us. As this opens up more training and development opportunities for women, then the industry and community also benefit.

Peter McCarthy
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Excavation crews need to understand that large excavations are civil engineering projects and not a mining job such as advancing a decline for truck haulage. A dedicated crew for large excavations may have quality and schedule benefits although initially appearing more expensive. The interface between a mining contractor and infrastructure contractor also needs consideration. Schedule delays on the excavation can result in significant costs to the infrastructure contractor and the principal.

All of the points mentioned have direct or indirect costs, which are probably not all captured in most costing systems. Actual costs are therefore typically higher than those shown in cost reports.

Cost estimation should be based on contractor's tender or at least a firm contractor's schedule of rates based on a detailed scope of work for the

Continued on back page.

PROMOTIONS

Andy Robb

Andy was recently promoted to Regional Manager, UK. Andy's broad technical strengths are managing mining studies, mine production, project and risk management. With more than 30 years experience in the mining industry, he has held many international senior roles and is well experienced in change management.

Martin Staples

Martin recently relocated form AMC's Perth office to the Maidenhead office, this move is part of the growth strategy for AMC (UK). Martin will become a Director of AMC Consultants (UK) Ltd whilst remaining on the board of AMC Consultants Pty Ltd. Martin's primary expertise is in the management of feasibility studies and has recently been managing a number of studies in Russia and Central Asia. Martin's move to the UK will allow him to better serve this region.

Peter Cunningham

Peter was recently promoted to Regional Manager, Perth. Peter's expertise in mine planning, technical evaluations and feasibility studies developed whilst working for major resource companies at operating mines in Broken Hill, in the corporate environment in Melbourne and in an in-house consulting role based in Perth. His exposure covers a wide range of mining methods, mine planning, capital projects and underground materials handling systems and infrastructure. In his new role, Peter will continue to carry out underground and corporate consulting work.

Peter Reynolds

After completing a two year posting in which he established AMC's Maidenhead office in the UK, Peter will return to Australia to establish a new AMC office in Adelaide. Peter's primary expertise is in due diligence reporting for acquisitions and IPOs, management systems, feasibility studies, business improvement strategies, mine operations planning and change management. He has broad experience in most aspects of the mining industry.

INDUSTRY INVOLVEMENT

Congratulations to Pat Stephenson who was runner up (Highly Commended) at the fourth Annual Australian Mining Prospect Awards in the category of Outstanding Contribution to Mining.

DOUGLAS HAY MEDAL

Terry Medhurst of AMC and Kevin Reed (formerly of Ulan Coal Mines) have been awarded the Douglas Hay Medal 2007 for the best paper published in the Institution of Mining and Metallurgy Transactions A, Mining Technology. The award is given based on recommendations received from the Transactions editorial boards and it is not necessarily awarded every year, but to a paper of merit.

The paper's title is *Ground Response Curves for Longwall Support Assessment*. The award was accepted on behalf of the authors by Karen Goh of AMC at the Awards Ceremony in London on Wednesday 24 October, 2007.

Terry's article is available at the AusIMM website.

EMPLOYER OF CHOICE

The success of AMC is a reflection of the professional skills of its employees. Ensuring employee satisfaction, both professionally and personally, is essential to that success and AMC proudly promotes itself as an employer of choice. With the professional skills of its senior consultants, global reach and "home life is important" philosophy, AMC provides an exciting and flexible alternative for mining professionals

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specific project. Alternatively the cost may be built up from first principles using a "notional gang" mining crew with hourly labour and on-costs, together with current itemised costs for drilling equipment and consumables, explosives, loading and haulage, ground support, concrete, ventilation, temporary pumping, maintenance, power supply and supervision.

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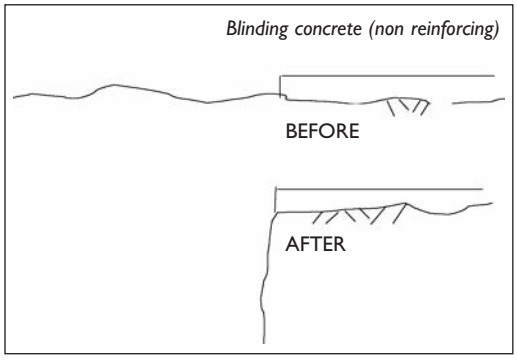

Figure 1 Use of blinding concrete in large excavations

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