现代矿山工程的采矿规划

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1 Abstract 摘要

Hatch is a leader in the development of modern mine planning services and the delivery of mineral industry projects to customers around the world. Hatch, being a "one stop shop" for resource estimation, mine planning, mineral processing design, detailed engineering, procurement and construction management services, is uniquely qualified in modern planning and project delivery methods.

在现代矿山规划服务以及向全球客户实施完成矿产项目方面，Hatch 一直是领先者。作为资源评估，矿山规划，选矿设计，详细工程设计，采购和施工管理等"一条龙式服务"的提供者，Hatch 拥有独特的现代矿山规划和项目实施方法。

The paper presents the case for the integration of studies and project engineering and discusses the contributing factors to project failures, the benefits of the integration of mineral processing, environmental and sustainability issues and the importance of staged studies and engineering services.

本文提供了整合各项研究和项目工程设计的案例，讨论了一些造成项目失败的因素；将选矿、环保和可持续性等问题综合考虑的裨益；以及分期研究和工程设计服务的重要性。

The paper also presents an outline of the methods and techniques used in modern mine planning, and how these planning techniques provide the opportunity to better utilise information to deliver to customers successful mineral projects. The paper discusses recent advances in mine optimisation, mine design, mine scheduling and mine cost estimation.

本文还介绍了现代矿山规划使用的方法和技术，以及这些规划技术如何更好地利用信息为客户成功实施矿产项目提供机会。本文讨论了矿山优化、设计、计划和成本预算等领域最新的发展。

2 Introduction 介绍

The primary objective of a mineral project is to maximize the value of the resources for the stakeholders, typically owners, employees and communities. Because mineral deposits are unique in physical and chemical properties, the description of the deposits, (i.e. the mineral resource estimate) is fundamental to the assessment of economic viability of mineral projects. Resource estimates are based on the collection and testing of samples of the deposit. Because the drilling, sampling and testing programs are expensive and occur early in a mineral projects development cycle, there are economic limitations to the programs and therefore a balance is struck between expenditure and risk.

矿产项目的主要目的是为利益相关者，通常包括业主，雇员和社区，增加资源价值。因为不同的矿床具

有不同的物理化学特性，因此对于矿产项目经济可行性最为重要的是矿床描述(即矿产资源评估)。资源评估基于矿样的采集和试验。由于钻探、取样和试验活动费用较高而且发生在矿产项目开发周期的开始阶段，经济上限制这些活动，因此在费用和风险之间要取得一定的平衡。

The confidence that can be placed in a mineral resource estimate is the most significant issue for investors and engineers working on a mineral project. If the mineral resource is poorly understood and inadequately described, the consequences are usually significant for the process and engineering designs, mineral recoveries, capital and operating cost estimates, revenues, profits and occasionally, the financial stability of the company involved. To protect investors in Australia, the reporting of mineral resources and ore reserves (the latter being the portion of a mineral resource technically and economically viable) is done under a Code of Practice. The Australasian Joint Ore Reserve Committee (JORC) sets out minimum standards, recommendations and guidelines for the public reporting of Resources and Reserves such that investors can form a reliable opinion on mining and exploration projects. At the Code's foundation is an accredited Competent Person. The Competent Person/s is to satisfy themselves that a resource/reserve estimate can be quoted with sufficient confidence, such that a committee of their peers would arrive at a similar conclusion.

对投资者和工作在矿产项目上的工程人员来说，最重要的是矿产资源评估的可信程度。如果对矿产资源的了解不够，说明不足，那么对工艺、工程设计、开采、基建和运营成本预算、收入、利润以及相关公司的财务稳定性将造成重大影响。为了保护澳大利亚的投资者，矿产资源和矿石储量(后者指矿产资源中具有技术和经济可行性的部分)报告必须按照操作守则来编写。澳大利亚矿石储量联合委员会 JORC 为资源和储量公告制定了最低标准，建议和指南使得投资者能够对开采和勘探项目形成可靠的意见。该守则的基石是胜任人员 Competent Person，该类胜任人员确保资源 / 储量评估可以被充分信任地被引用，以至于同行组成的委员会将得出类似的结论。

Once sufficient confidence has been reached in a resource estimate, then from an engineering perspective the design criteria can be developed. Thus the design of the capital assets and the operations become the last activities that can significantly influence the profitability of the mineral project. The design of the mine, processing facility, enabling infrastructure and operation methodology are based on technology and optimised by the intellect of the people on the project team.

一旦对某份资源评估报告有了足够的信任，便可以从工程设计角度来编制设计标准，最后对矿产项目盈利性能够造成重大影响的活动是固定资产的设计和矿山的运营。矿山、选矿设施、启动基础设施和作业方法的设计以技术为基础，靠项目组成员的智慧来优化。

This paper puts the case for better integration of mine planning and project delivery activities.

本文将摆出理由，说明矿山规划和项目实施活动应更好地整合。

3 Mineral Industry Performance – Project Delivery 矿产行业的表现—项目实施

It is difficult to get reliable data on project failures. The Mineral Industry tends to "move on" and does not collect a lot of data on projects that fail. Table 1 summarizes aggregate results of 43 project failures identified over the last decade, in our industry, from a variety of public sources. The definition of a project failure has been defined by Morrow (Morrow and Yarossi, 1994), as being a project that either:

要获得有关项目失败的可靠数据很难。矿产业倾向于"向前走"而不是收集有关项目失败的数据。表 1

总结了过去十年间从公开渠道获得的 43 个失败了的矿业项目。根据 Morrow 和 Yarossi 1994 的定义，失败的项目是指具有下列任一表现的项目：

goes 10% over its capital budget　资本预算超出了 10%以上；

starts up over 3 months late, or　投产时间晚了 3 个月以上；或者

takes more than 12 months to reach 85% capacity　花了 12 个月以上的时间才达到设计能力的 85%

In 1994, Morrow reported that 18% of over 1000 projects sampled in the chemical and metallurgical industries met all 3 criteria. These criteria are extremely hard to achieve in the mining industry. In the case of many major "world class" developments, meeting operating performance criteria is, however, substantially more important than the initial cost or construction schedule.

1994 年，Morrow 报告：在化工和冶金行业内抽取的 1000 项目中 18%符合上述 3 个标准。事实上，在采矿行业要达到上述标准是极其困难的。在许多"世界级"大型项目开发中，满足运行标准要比满足起初的预算费用或施工计划重要得多。

Table 1 – Aggregated Project Failures　失败项目统计

Major Problems/Projects Identified　发现的重大问题 / 项目	43
Capital Value　资本价值	US$21 Billion
Bankruptcies, closures and write-downs　破产，关闭和减值	16
Project Distribution (by number of projects)　项目(数量)分布	
North America　北美	47%
South America　南美	16%
Australasia　澳大利亚	26%
Rest of the World　世界其它地方	11%
Project Capital Costs (by number of projects)　项目基本投资	
Less than US$100 million　低于 1 亿美元	11%
US$100 to $500 million　1 亿到 5 亿美元之间	51%
Over US$500 million　高于 5 亿美元	38%

Key points to recognize in Table 1 are:

表 1 揭示的关键点：

It is not a complete listing of "failures"; it is a sampling of projects that have received substantial press coverage.该表并未列出所有失败项目而仅仅是一些被广泛报道的失败项目。

The projects are skewed heavily towards large projects (over US$100 million), where information on poor project performance is "material" and, therefore, normally publicly available in some form.这些项目主要偏向于大型项目(1 亿美元以上)，关于这些项目表现情况的资料都是实质性的，通常可以从公开渠道获得。

From a corporate perspective, it is possible for one disaster project to effect the financial stability of the proponent and the consultants involved.从公司角度来看，一个灾难性的项目有可能影响到项目支持者和咨询方的财务稳定性。

4 Factors that Contribute to Project Failures 造成项目失败的因素

A summary analysis of the 18% of projects which failed is presented in Table 2.

表 2 对那些 18%的失败项目进行了总结性的分析。

Table 2 - Factors Present and/or Contributing to Project Failure in Table 1.造成表 1 所列项目失败的因素

Fast tracking, poor phasing 赶工，阶段划分不清	70%
No continuity in project team 项目组缺乏连续性	63%
Turn key fixed price projects 固定价格的钥匙工程项目	42%
Major new technology 主要技术为新技术	50%
Front end issues 前端问题 Budget cuts/without scope cut, 工作范围不减而预算削减 Late scope changes, 后期的工作范围变更 Key information ignored (from geology, pilot plants, etc.) 忽视关键信息(地质和试验工厂等提供的信息)	40%

4.1 Fast Tracking, front end issues and poor phasing 赶工，前端问题和阶段划分不清

These failures are a typical result of the desire of owners to fast track projects. Project momentum can carry studies and projects forward beyond the point where they should have been stopped. There is a point where the sunk costs, stakeholder expectations, return on investment, public profile, and continuity of employment for the project team creates a pressure to continue. It is not unusual for significant technical problems to be identified and glossed over or ignored. Six project failures totaling nearly $2 billion in write-downs in Table 1 were the result of this management behaviour.

这些失败因素往往是业主希望"开快车"项目造成的。项目动能使各项研究和项目在它们应该停止的点之前未能停止，而且已花费的成本、利益相关者的期望、投资回报、公众形象和雇用项目组的连续性会产生压力使项目继续往前赶，重大技术问题虽被发现但被掩饰或忽视也就不奇怪了。表 1 中六个失败项目共造成近 20 亿美元的减值就是这种管理行为的结果。

The industry needs optimists to develop mineral projects. This is because without an ability to see beyond the many obstacles many mineral projects would not be developed. The industry also needs independent review to identify significant issues or at worst fatal flaws that an optimist might not recognise. Project phasing provides a break in the pressure to continue and an opportunity for technical review, additional data collection, review of scopes and study budgets.

矿产行业需要乐观者来开发项目，因为如果没有这种透过众多阻碍看未来的能力许多矿产项目将根本不会被开发。这个行业也需要独立审核来发现乐观者可能认识不到的重大问题甚至是致命问题。

4.2 No continuity 项目组缺乏连续性

A lack of continuity in the project team is always a major issue. This typically happens when a pro-

ject is re-bid between phases resulting in two or three separate teams working on a project sequentially before it is completed. The risk of information loss and loss of design intent is very high. Documentation cannot bridge these discontinuities, particularly if the owner team changes as well.

项目组缺乏连续性往往是个主要问题。这种问题往往发生在项目分期招投标上，造成项目竣工前由两三个不同的项目组先后为同一个项目工作。结果是信息和设计意图的丢失风险非常高，而文件记录也无法将这些中断部分连接起来，尤其是当业主队伍也发生了变化。

4.3 Turnkey fixed price 固定价格的钥匙工程

These arrangements are a major risk except with very well defined and demonstrated technologies. It is critical that the technology status is properly understood, where a range of levels of risk and readiness are identified. Turnkey is suitable only for "well proven" technology at similar plant setting and scale technologies. For all other classes, particularly with "fast track" execution, problems can be expected (Hatch et al, 1984). During start-up turnkey contractual structures make cooperation to overcome problems very difficult. Several of the projects in Table 1 were in litigation with the prime contractor while trying to start-up. Substantial delays and costs resulted in several cases. The combination of lump sum turnkey and a major new technology accounted for eleven of the 43 project failures and nearly $5 billion in write offs or significant problems Financiers seem to drive the requirements for turnkey fixed price contracts as a means to manage the financial risks. In fact, this contracting strategy can increase the risks.

除非技术被很好地确定并示范工厂，否则这些安排会构成重大风险。正确理解技术状态很关键，因为这样才能发现风险水平和具备的水准。交钥匙只适用于那些"验证良好"而且设备设置和规模相似的技术上。对于其它模式，尤其是"开快车"执行模式，出现各种问题也是意料之中的(Hatch 等，1984)。在投产试车阶段，交钥匙合同使得合作克服问题变得非常困难。表 1 中的数个项目在试车的时候与总承包商发生诉讼，产生长时间的延误和大量的费用。在失败的 43 个项目中，因同时采用固定总价交钥匙模式和新的重要技术造成的失败占了 11 个，造成了近 50 亿美元的减值或重大问题。金融机构似乎是要求以交钥匙固定价格合同来控制财务风险的驱动力量。事实上，这种发包策略却会提高风险。

To mitigate these risk factors, it is necessary for the owners and owner's agents to convince the financiers of three basic points.

为了减轻这些风险因素，业主及其代理机构有必要在下列三个基本点上说服金融机构：

Project risks should be managed by those with the appropriate expertise, this is normally not the construction contractor.

项目风险应由那些具备经验的专家来管理，施工方往往并非这方面的人选。

The ultimate risk always lies with the facility owner, that of product supply to customers, on time, to specification at the appropriate cost.

以合适的成本向客户按时按质量交付产品的最终风险往往由业主承担。

Turnkey fixed price contracting gives a built-in incentive to the contractor to cut costs to achieve profitability executing the contract, often sacrificing maintainability and future operating costs. This is normally not in the owner's interest.

交钥匙固定价格发包模式促使承包商在履行合同的过程中通过降低成本来盈利，这往往会牺牲可维护

性和未来的营运成本。这往往对业主不利。

4.4 Major new technologies 新的主要技术

Technologies can be summarized (Twigge-Molecey, 2003) as;

技术可归结如下(Twigge-Molecey, 2003)

Well proven technology at similar plant setting and scale

验证良好而且设备设置和规模类似的技术

Well demonstrated technologies that have been soundly integrated at a similar scale

示范良好而且在类似规模上可靠集成的技术

Existing technology adopted to new settings or scale

新设置或新规模下的现有技术

New technology developed to be implemented for the first time

新开发出来首次实施的技术

New technology is present in 50% of the problem projects. While this might be a result of new technologies attracting publicity so are more "exposed" than "routine" projects therefore being over represented in this sample there is a relationship and it should also be noted that other factors are usually present. Of the 22 projects with new technology that failed:

50%的项目问题在於使用了新技术。尽管这有可能是因为新技术吸引公众注意比"常规"项目更容易"曝光"从而使得新技术因素被过分突出,但新技术和项目失败之间存在关系,而且其它因素也应被注意到。在 22 个采用了新技术的失败项目中:

11 (50%) were under turnkey contract arrangements

11 个(50%)项目采用了交钥匙合同模式

11 (50%) were not properly phased

11 个(50%)项目阶段划分不准确

6 (>25%) had no significant test work to guide scale-up

6 个 (>25%)项目无大的试验工作来指导比例放大

5 had pilot plant results ignored or misinterpreted

5 个项目忽视了或误解了试验工厂结果

12 (>50%) had limited or no continuity in the technical team

12 个(>50%)项目存在技术队伍不足或缺乏连续性

Several key issues must be properly addressed around the technology transfer activity. These apply to new projects as well as internal and purchased developments. They are developed in detail (Economist Feb 1999, Peacey) and in summary are:

在技术转让活动中有几个关键问题必须被正确解决。这既适合在新项目上,也适合在内部和购买的项目上。这些问题在《经济学人》(1999 年 2 月,Peacey)有详述,现归纳如下:

Recognizing the ultimate business risk is the owner's,

认识到业主将承担最终的业务风险。

Having an owner's team with the skills to manage the risks, including stakeholder issues,

建立一个具备风险(包括利益相关者问题)管理技能的业主队伍。

Recognizing "guarantees" are ultimately not meaningful except with well proven processes,
认识到"保证书"的最终意义不大，除非采用那些验证良好的工艺。
Project teams must be set up to succeed,
建立项目组，致在成功
Rigorous phasing must be employed,
必须严格划分阶段。
The risk-reward equation for all participants must be equitable and well understood,
所有参与方的风险－回报公式必须公平并且被充分了解。
A project must be accompanied by the appropriate personnel change management process,
必须为项目编制合适的人员变化管理程序
The best possible experienced leader or project manager must be in place.
最好最有经验的领导或项目经理必须就位。
With these criteria in mind and acted upon, the risk of project failure is greatly reduced.
记住这些标准并以此为行动准则，那么项目失败风险就会被大大降低。

Technology development is also an inherently risky business. Recent work by the Washington Institute indicated that even developments demonstrated at significant scale have only a 25% probability of commercial success. More recent examples are presented by Peacey. That said, the methodologies to minimize the risk of implementing a new development are again well known (Twigge-Molecey, 2003; The Economist 1999; Peacey, 2002).

技术开发本质上是一个风险行业。华盛顿学院指出：即使那些在相当规模上示范良好的项目也只有25%的商业成功机会。Preacey 给出了近期发生的更多案例。总之，那些用以降低新项目实施风险的方法已为大家所熟悉(Twigge-Molecey, 2003;《经济学人》1999; Peacey, 2002)。

Because each mineral deposit is unique the resource description, the required technologies and the associated risks are also unique. Therefore an ability to identify the unique issues is a fundamental requirement for successful project development.

由于每个矿床都是独特的，因此资源说明、所需的技术和相关的风险也是独特的。有鉴于此，发现这些独特问题的能力是项目开发取得成功的基本要求。

There are 6 elements of technology for projects:
对於项目来说，有关的 6 个技术要素为：
1. The knowledge of the project team,
项目组的知识
2. The technology developed by service providers (e.g. software companies),
服务供应商(如软件公司)开发的技术
3. The systems and procedures that are available, and
可利用的系统和程序，以及
4. The technology embedded in the capital stock.
股本投资的技术
5. Management and retention of information.

信息管理和保有

6. The ability to identify the unique issues for the project

在项目中发现特殊问题的能力

Only 2 - 3 % of a projects life cycle costs represent:

就项目寿命周期而言，其费用只有 2 - 3 %花在下列工作上：

The research and development 研发

The engineering 工程设计

The project and construction management. 项目和施工管理

Increasing this initial investment to maximize the chances of project success, (which includes achieving capacity on schedule and achieving the projected operating costs), is normally a sound business strategy. A major proviso is that many projects are not robust enough to maintain acceptable NPVs with high upfront costs. These projects have to be scrutinized carefully before proceeding.

通过增加此类初期投资来提高项目成功机会(包括按期达到设计能力以及营运成本符合预测)通常是一个可靠的商业策略。一旦前期费用过高，许多项目便无法维持可以接受的 NPV(净现值)。这些项目在开始之前必须仔细审查。

The key reasons for specific technology development programs failing include:

造成技术开发失败的关键原因包括：

Lack of strategic alignment with the business, resulting in lack of adequate support and resources,

技术与业务之间缺乏战略协调，导致支持和资源不足

Lack of a disciplined, multi-function "stage gating" process (or phasing) during development allowing projects to progress that should not,

开发过程中缺乏规范的、多功能"分级控制"程序，使项目到达到它们不该进入的阶段。

Lack of a corporate champion who will maintain the momentum over the many years required to bring a new technology to successful commercial application and

缺乏长期坚持的龙头企业来负责将新技术带入成功的商业应用。

Not bringing the best possible minds and experience to the program.

没有将最好的想法和经验注入到项目中去。

There are many standard references on R&D portfolio management. Typical is the work of Cooper, (Cooper, 1998). All advocate a rigorous multi-disciplinary stage-gate approach with legal, marketing, construction, operations and safety professionals as part of the technical teams. The one key failing of a rigorous stage gate approach is that it will miss "hidden gems", whose true value only becomes apparent after full implementation, the "Law of unexpected consequences" at work.

有关研发组合管理的参考标准很多，典型的是 Cooper 的文章(Cooper，1998)。所有文章都主张严格的多专业分级控制方法，让法律、营销、施工、营运和安全专业人士加入到技术小组中去。但是严格分级控制方法存在一个关键的缺陷，即会漏掉"隐藏的人才"，只有在全面实施之后这些人才的真正价值才表露出来，即所谓的"意外结果法则"。

Clearly there is nothing new here except a persistent climate of ignoring well-known principles of technology and project management. It is worth noting that an exhaustive study by the US Corps of En-

gineers, during the 80's, concluded from over 1000 projects that the key significant factor to successful projects is a good, experienced project manager. In this context the "good" project manager will insist on proper phasing, scope definition, scope control, team continuity and appropriate contracting strategy. Support by key technical specialists is also critical (Twigge-Molecey, 2003).

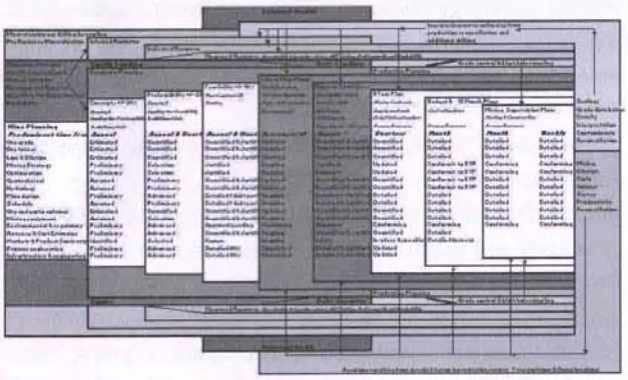
除了对人所众知的技术和项目管理原则忽视这一顽症外，显然本文并没有提及什么新东西。值得注意的是美国工程师团于八十年代从 1000 多个项目中得出的结论：项目成功的关键因素在于优秀的、经验丰富的项目经理。此处所谓"优秀的"项目经理将坚持正确的阶段划分、工作范围定义和控制、队伍连续性以及合适的发包策略。关键技术专家提供的支持也很关键(Twigge-Molecey, 2003)。

5 The Importance of Staged Studies and Engineering Services 分阶段进行研究和工程设计服务的重要性

Mine planning activities continue beyond the project study and development phase. Mine planning activities are a fundamental requirement for the life of the project. The spread of these activities is illustrated in Figure 5.1.

矿山规划活动不仅仅限于项目研究和开发阶段。矿山规划是项目寿命的基本要求。图 5.1 展示了这些规划活动的分布情况。

Figure 5.1 - Life of Project Mine Planning Activities 项目的矿山规划活动



The methodologies for successful project delivery are well known and have been documented and taught for decades. Appropriate project phasing has always been identified as critical to success. (Hatch, 2004; IPIA, 2002; Twigge-Molecey and Dawson, 1999). Project phasing, often termed "front end loading" (FEL), is once again being embraced after a decade of poor project results.

项目成功实施的各种方法为大家所熟知，几十年来一直在被存档和传授。合适的项目阶段划分也已经被认为是成功的关键(Hatch, 2004; IPIA, 2002; Twigge-Molecey and Dawson, 1999)。经历了十多年的项目失败，称为"前期工作"(FEL)的项目阶段划分也正在被接受。

Improper or lack of project phasing is also a major cause of problems. The consequence is that many decisions are made on insufficient information. The outcomes vary from rework in the design offices (the easiest and cheapest changes) to field changes and post-startup changes, many of which can be very expensive or financially catastrophic. Typical of impacts resulting from improper phasing include:

项目阶段划分不正确或缺乏也是造成问题的一个重要原因，使得许多决定是在不充分的信息基础上做出的，后果从设计返工（最容易也是最便宜的变更）到现场变更和投产后的变更不等，很多后果的代价昂贵甚至造成财务灾难。阶段划分不正确通常造成下列影响：

Rework due to late equipment information,

由于设备信息过晚导致返工

Rework due to unexpected permit conditions

由于意料之外的许可条件导致返工

Rework due to the operating team bringing new perspectives late in a project

由于营运小组在项目后期提供新方案导致返工

Redesign due to test work results being introduced late

由于试验结果太晚导致重新设计

Changing geological/mineralogical data affecting plant feeds late in the project.

变化的地质 / 矿物数据影响项目所需的原料

6 Integration of Studies and Project Engineering 各种研究和项目工程设计的整合

The management the operation of a mineral project commonly brings together professional staff trained in many different disciplines. For example a typical management team may consist of geologists, mining engineers, metallurgists, maintenance engineers, project engineers, environmental scientists, IT professionals, mine management and production foremen. These discipline groups may often be further subdivided into exploration geologists, mine geologists, short term mine planning, long term mine planning, primary metallurgists, secondary metallurgists, mechanical engineers, electrical engineers, civil engineers, flora and fauna scientists, operations manager, general manager and so on.

矿产项目的管理和营运往往牵涉许多领域的专业人士，比如典型的管理小组可包括地质学家、采矿工程师、冶金学家、维护工程师、项目工程师、环境科学家、IT 专家、矿山管理人员和生产领班。这些专业组可进一步被分成勘探地质学家、矿山地质学家、矿山短期规划人员、矿山长期规划人员、矿物处理专家、冶金学家、机械工程师、电气工程师、土木工程师、动植物学家、作业经理和总经理等等。

The point is, the management of an operating mineral project consists of many specialists that need to work as an integrated team. Similarly these disciplines are required for the successfully undertake feasibility studies and the engineering to develop a mineral project.

重要的是，一个正在营运的矿产项目的管理团队由许多不同的专家组成，他们应作为一个联合小组来携手工作。开发矿产项目所需的可行性研究和工程设计要取得成功同样需要这些专业。

Some of the techniques used by Hatch to manage the interaction between disciplines are:

Hatch 在专业互动管理方面采用的一些技巧：

Integration of staff with study and operational experience into project teams.

人员整合，将不同领域和操作经验的人员融到项目组中去

Life of mine planning is incorporated into studies and project development plans

项目规划应包含在各项研究和项目开发计划中

Project definition. Project success depends on ensuring a common clarity on project objectives, scope and constraints at the onset of work.

项目定义。项目成功取决于大家从工作一开始就清楚了解项目目标、范围和限制条件。

Project planning. In the planning phase, a common plan for the duration of the project, diagnosing the information to minimise risk and looking for opportunities to improve the implementation process.

项目规划。在规划阶段，执行项目过程中应有一个计划，通过分析信息来降低风险，以实施过程中寻求改进的机会。

Project Implementation. Project planning is a continual process throughout the project to adjust for uncertainties identified at project launch and other event that impact the project. The ability to be innovative and flexible during project delivery is one of Hatch's strengths.

项目实施。项目规划是一个贯穿于整个项目、对项目开始时发现的不确定因素以及影响项目的其它事件进行调整的连续过程，在项目实施过程中的创新和灵活能力是 Hatch 的强项。

Project communications. Effective communication is critical to project success. Effectively communication project details to the entire project team, regardless of their organisation, team role or geographic location.

项目沟通。有效沟通对项目取得成功至关重要。不管他们属于哪个组织、承担何种项目责任以及身处任何地理位置，项目细节应在整个项目组内得到有效沟通。

Sustainable Development practices such as Sustainable Plant Design (SPD). SPD encourages thinking about whole systems that often reveals inefficiencies that can be missed within a narrower perspective. The broader view considers the impact of possible improvements on all disciplines, where combined benefits may outweigh a marginal cost increase in one area. Looking at the life cycle of the plant, equipment and materials ensures that decisions made today will achieve the lowest cost and environmental impact over the full life of the operations. The SPD approach fosters cross-discipline approaches to innovation and forces design and project decisions to be made with all technical, fiscal, environmental and social consequences clearly in mind. To be successful, an integrated approach is essential. The design principles must be considered together to ensure that one principle is not achieved at the expense of others. Similarly, it is critical that the various design discipline groups' work together to maximise benefit across the board. This will ensure that gains made in one area do not cause greater losses elsewhere. When pursued correctly SPD ultimately delivers results for the triple bottom line (economics, society, environment).

可持续发展，比如可持续工厂设计(SPD)。SPD 鼓励人们对整个系统进行考虑从而揭示那些可能因狭隘思想被遗漏的不足之处。开阔的视野意味着要考虑各种可能的改进对所有专业造成的影响，因为综合利益可能会超过单个领域内增加的边际成本。通过考虑工厂的寿命周期，设备和材料能够确保今天所作的决定能够在整个运营寿命产生最低的成本和环境影响。SPD 方法能够培养跨专业创新，迫使设计和项目决策综合考虑技术、财政、环境和社会等各个方面的影响。要想取得成功，一体化模式至关重要。所有设计原则必须一起考虑从而确保不以牺牲某个原则为代价来实现另一个原则。同样重要的是，所有设计专业小组必须携手一起工作来提供整体利益。这将确保某个领域取得的成就不会对另一个领域造成更大的损失。只有方法正确，SPD 最终会实现三合一底线(经济，社会和环境)确定的目标。

Project teams are formed as soon as possible. Dedicated teams focus effort and prevent team members being distracted by other responsibilities.

项目小组应尽快成立，这样他们才能专心致至不为其它任务分心。

Open plan offices encourage open communication an interaction between disciplines.

敞开的办公室鼓励各专业之间的开诚布公的沟通和互动。

Standardised Project Management Systems ensure consistency across all areas and functions in large complex projects.

标准化的项目管理体系能够确保复杂的大型项目在所有领域和职能部门里保持统一。

Hatch's fundamental business structure (Figure 6.1) is focused around delivery of integrated projects. Hatch has many business units that are commodity focused. Each business unit contains technical experts in their field. The Project Delivery Group (PDG) has the objective of supporting all business units in providing the best project development, set-up, quality and delivery to customers. The PDG works with each business unit to ensure the successful transition of planning into practice.

Hatch 的基本业务组织(图 6.1)以综合项目的交付为中心。Hatch 公司内部有许多以不同商品为中心的业务部门，每个业务部门都配备其各自领域内的技术专家。项目实施组(PDG)的目标是通过为客户提供最佳的项目开发、设置、质量和实施来支持所有业务部门。PDG 与各个业务部门合作，确保成功地从规划向实践转化。

Figure 6.1 - Hatch Business Unit Organisation Hatch 业务部门组织



7 Project Delivery Models 项目交付模式

Major projects in the mining and metals industries (value in excess of $500 million) generally adopt a delivery model that separates the execution streams between:

采矿和金属领域内的大型项目(价值超过 5 亿美元)一般采用的交付模式将实施流与以下方面分开：

Long term strategies to enhance the business asset (i.e. sell more product) and

长期战略是保证业务的扩充和资产的增长(比如销售更多产品)和

Shorter term focus on creating the physical facilities that produce the required product

短期目标是(建立能够生产出所需产品的设施)

Applicable delivery models are:适用的实施模式有：

Integrated teams where an EPCM contractor is engaged to supplement capability in the owner's organisation. In this format, the owner takes the lead but the person best qualified from either party fills positions in the project structure. The two functions identified above become less defined as separable ob-

jectives.

联合组模式，通过聘用 EPCM 承包商来补充业主组织的能力。这种模式以业主为主，项目结构中的位置由最胜任的人员来承担而不管他们出自何方。

EPC arrangements, although there are no known contemporary examples.

EPC 模式，尽管目前还没有现成的案例。

Alliance arrangements, such as are used in the gas and oil sector, where project outcomes can be benchmarked and used as the basis for determining performance and assessing rewards. The use of this model in the mining sector is not unknown but results have been inconsistent.

联盟模式，这种模式为油气行业所采用，它通过设定项目结果标杆来确定绩效和奖赏。这一模式在采矿行业内的运用并非不为大家所知晓，但结果却各不相同。

Program management occurs through a matrix structure that integrates 'areas' in one dimension, with 'functions' in the other dimension. Large projects are very complex and are typically divided into areas that become self-contained projects. These are executed to project standards with support from functions in the matrix structure in which:

项目通过矩阵结构来管理，即将“区域”和“职能”为两个不同维度。大型项目非常复杂，往往被分成众多自成一体的区域。这些区域按照项目标准来实施，由矩阵结构中的职能部门提供支持，在该矩阵中：

Area Managers are responsible for delivery of the facilities according to the scope, budget and schedule

区域经理负责项目工作范围、预算和进度计划

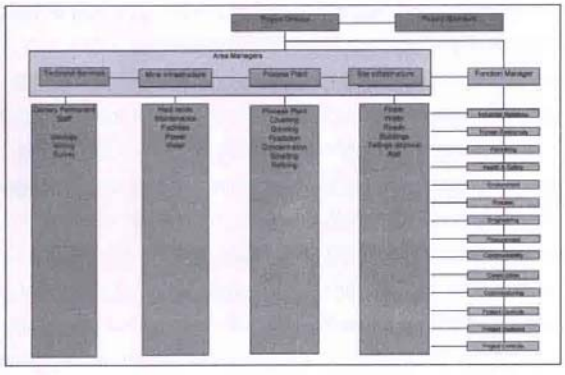
Functional Managers provide services to the Area Managers and maintain consistency of technical and discipline standards across all project areas. They manage resources and focus on systems, practices and quality of deliverables.

职能经理向区域经理提供服务，确保技术和专业标准在所有区域内保持一致。

The matrix model for the project organisation is shown in Figure 7.1. Within this overall structure, the organisation will be developed to meet the needs of each phase of the project.

图 7.1 显示的是项目组织的矩阵模式。在整个结构内，组织的建立是为了满足项目各阶段的需求。

Figure 7.1 - Matrix Program Management Delivery Model 项目交付矩阵管理模式



8 Project Information Management 项目信息管理

The application of appropriate information technology (IT) and information system (IS) can improve how mineral projects function. In developing mineral projects Hatch helps its clients select and implement different IT/IS applications. These applications include:

信息技术和信息系统的合理应用能够改善矿业项目的运行。在开发矿业项目中，Hatch 帮助客户选择并实施各种不同的信息技术 / 信息系统应用，包括：

Production systems 生产系统

Mine planning and operation management systems 矿山规划和营运管理系统

Process control and automation systems 工艺控制和自动化系统

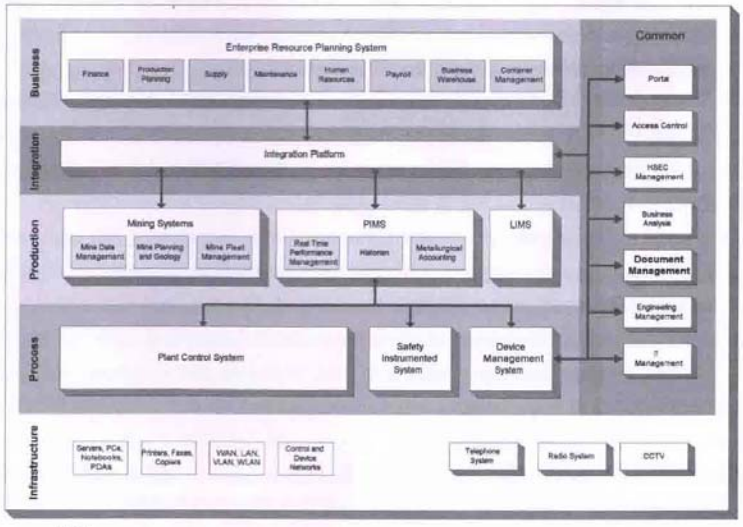
Business systems 业务系统

Advanced control systems 高级控制系统

Integration of many individual IT/IS components into a coherent and intelligent system is a powerful means by which information can be collected, stored, presented and disseminated throughout an organisation. Individual systems can become islands of information. By collecting data from a number of sources, information can flow to appropriate decision makers within an organisation. All this builds business intelligence and allows informed decisions to be made.

把多个单一信息技术 / 信息系统的某些成分相结合成为一个统一的智能系统是通过某一组织收集、储存、显示和分散信息的一种有效方法。单个系统可以成为信息群。通过各种来源收集数据的方法，信息可以在一个组织内到达相关决策者。

Figure 8.1 -Information Management Example 信息管理实例



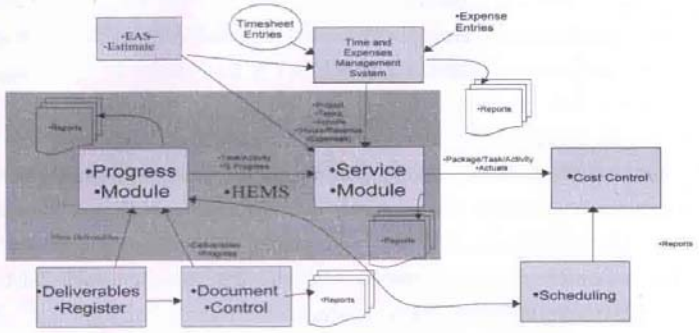
Hatch ©

8.1 Engineering Management System 工程设计管理系统

To track project costs, deliverables and progress, Hatch has developed a proprietary database application called HEMS (Hatch Engineering Management System).

为了追踪项目成本、交付内容和进度，Hatch 自主开发了一种数据库应用系统，即 HEMS (Hatch 工程设计管理系统)。

Figure 8.2 - HEMS System Hatch 工程设计管理系统



The HEMS system is divided into two modules, HEMS Service and HEMS progress. The service module captures timesheet and expense entries to provide up to date reports on project effort and expenditure. It provides a tool to measure activity progress in terms of 'Earned vs. Spent', manage scope changes in relation to the stored Original budget (Hours and Costs) and report on both. The primary objective of this module is to report actual hours, costs and physical percent progress of engineering effort. These values can be used to generate various reports and charts.

HEMS 系统分为两个模块，HEMS 服务和 HEMS 过程。 服务模块包括工作时间表和项目花费，提供项目状况和费用的数据报告。它是一种在"收入 vs 支出"时间方面衡量各项活动进度，管理与原预算(人工时和成本)相关的工作范围变动的工具，并进行以上两种报告。此模块的首要目的是报告实际人工时、成本和工程进度实际百分比，使用这些数据可以制作各种报告和图表。

The HEMS progress module provides an integrated solution to engineering management and document control. It is a tool to measure progress and track deliverables. The document control function also serves to track the status of vendor documentation and reviews. The progress measurement system uses milestones attached to each deliverable and report progress. Progress is credited on the achievement of milestones according to predefined rules relating to document type and milestone definition. The system can be optionally linked to a document control system to enable automatic update of actual milestone data.

HEMS 过程模块提供工程管理和文件控制的完整处理方法。它是一种衡量进度和追踪可交付的工具。文件控制功能也可以用来追踪供应商文档状态和复查。进度衡量系统使用里程标标示每一个可交付和进度报告。根据预先定义的文件类型规定和里程标定义，进度通过所取得的里程标来确定。该系统也可以选择连接到至一文件控制系统，使得实际里程标数据能够自动更新。

9 Methods and Techniques used in Modern Mine Planning 现代矿山规划的方法和技术

For resource projects to realise their potential a successful mine plan needs to be developed and realised. The process of unlocking the potential of a mineral resource begins with mine planning. There are a number of techniques that deliver mine plans that make the best use of the available resource. These methods and techniques are discussed below.

为了挖掘资源项目的潜能，必须成功地开发和实施矿山规划。矿物资源潜能的挖掘过程开始于矿山规划。有很多种实施矿山规划的技术，以最大化利用可用资源。

9.1 Strategic Mine Planning 矿山战略规划

Strategic mine planning is the activity that determines the basis for a mine plan and an initial estimate of project economics. It is at this stage that a number of 'what-if' questions can be answered. Some of these questions can be:

矿山战略规划确定了矿山规划的基本原理和项目经济的初步评估。正是在此阶段，可以回答很多"如果这样就会那样"的问题，例如，

Should we build a bigger plant? 要不要建造一个更大的工厂？

When should we go underground? 什么时候开始地下开采？

What is the project payback? 项目回报是多少？

What is the mining rate? 开采率是多少？

How will the mine look? 矿山的将会是什么样子？

Can we make a profit? 能不能赢利？

There are a number of commercial software packages available that will allow the user to run a number of scenarios relatively quickly. The economic portion of a resource model is almost universally determined by applying the Lerch-Grossman algorithm. Recently mine planners have been able to add a number of tools to answer strategic questions. These include the Whittle multi-mine module, which enables many mining areas to be optimised individually, but be scheduled together.

有好多种商业软件包允许用户较快运行各种方案。资源模块的经济部分几乎普遍应用 Lerch-Grossman 运算法则而决定。近期矿山规划者已经添加了很多解决战略性问题的工具。其中包括 Whittle 多矿山模块，它使得很多采矿区域能够个别优化但却共同规划。

Traditionally the phasing of open pit cutbacks has been left to an engineer's discretion, supplemented by knowledge of nested pit shells. Recently BHP Billiton (Stone et al, 2004) has developed a new mine planning optimisation tool called Blasor. Blasor (sometimes known as Phasor) software brings the optimisation of the mining schedule and cutback selection together in the one environment. The software aggregates blocks according to grade bins and spatial arrangement while respecting pit slope constraints. Once the aggregation is complete an initial global optimisation is done to identify the best extraction sequence that fulfils the mining, processing, market and slope constraints. If required, the mine planner modifies any impractical mining features generated by the initial optimisation. The final phase involves scheduling the modified sequence on a bench-by-bench basis to produce the final mine schedule.

露天矿开采阶段的划分一般由工程师决定，通过基於嵌套井壳知识来补充。最近必和必拓公司 (Stone 等, 2004) 开发出了一套新的矿山规划优化工具，名为 Blasor。Blasor（有时也称为 Phasor）软件在同一环境

下优化开采计划和开采方案。该软件根据品位和空间布置同时考虑矿井坡度限制将各采区整合起来。一旦整合完毕便进行初步优化以便确定最佳开采顺序以满足开采、选矿、市场和坡度限制条件。如果需要，由矿山规划者修改初步优化造成的不切实际之处。最后阶段包括在标杆基础上对修改后的顺序安排最终的开采计划。

Much of the work on optimisation techniques has focussed on open pit mining. The nature of the surface mining problem is easier to solve. The area of underground optimisation is less well developed. Underground optimisation has more dimensions, the direction of mining, development sequence and backfilling are some of the variables that need to be considered to find an optimal solution.

优化技术的很多工作都集中在露天矿的开采。表面采矿问题的本质更易于解决，地下开采的优化就差一些。地下优化涉及更多维度，开采方向、开发顺序和回填都是优化方案需要考虑的一些变量。

Hatch has developed an underground optimisation technique. This brings together a number of tools to optimise underground mine layout and scheduling (Carter, Lee and Baarsma, 2004). It includes selecting the economic minable envelope, developing an optimal decline path by accounting for both development and operating cost and developing a production schedule. The technique begins by building a cost model for the resource and then applying the Datamine MRO optimiser to select stoping areas. Geotechnical and mining width issues govern the dimensions of the stope. Once the stoping areas have been identified, a decline access solution is developed by choosing the path that minimises capital and operating costs. The decline path accounts for gradient and curvature requirements, such that a practical solution is developed. The scheduling solution tests a number of different schedules such that the sequence that produces the best value is identified.

Hatch 已经开发了一项地下优化技术，共同使用多种工具优化地下矿山的布局和规划 (Carter, Lee 和 Baarsma, 2004)。它包括选择经济性的可开采覆盖层，开发和操作成本，最佳斜坡路经，和生产规划。该技术首先建立一个资源的成本模型，然后应用 Datamine MRO 优化器选择采矿区域。地质条件和矿山宽度控制了采矿的维数。一旦采矿区域确认后，选择最小化资本费用和操作成本的进入坡度途径。坡度路径解释坡度和弧度要求，这样形成一种实际方法。规划方法对一系列不同规划进行测试，以确认最佳生产值的顺序。

9.2 Mine Design 矿山设计

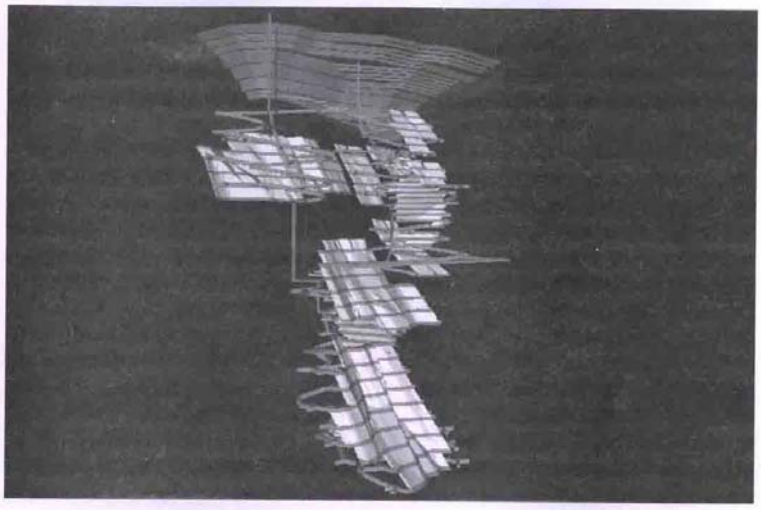
Good mine designs provides the link between what is theoretical and what is practical. Current mine design tools provide the user with better visualisation and understanding of the ore body than ever before. A range of software packages allow the user to build up detailed plans and sections as well as three dimensional images of a mine design. Intersection of the mine design with the resource block model enables the ready reporting of basic statistics such as strip ratio, tonnes per vertical metre, tonnes and grade by level or bench as well as minable reserves. The combination of wire framing and computer graphics allows the planner to understand and visualise the mine plan to show primary ventilation systems, materials handling arrangements, stope layouts, pillar designs and planned development relative to existing infrastructure.

好的矿山设计提供理论和实际之间的连接。目前的矿山设计工具给用户提供了最好的矿体观察和理解。一系列的软件包都允许用户建立矿山设计的详细平面图、剖面图和三维立体图。矿体设计的网络图和资源块模型能及时报告基本数据，例如带条比率、垂直每米吨数，基准的吨位和级别，以及可开采储量。电线框

架和计算机图表的结合使得规划者能够理解和可视矿山规划，显示最初通风系统、物料处理计划、采矿布置图、立柱设计和现有基础设施的发展计划。

Figure 0.1 - 3D Mine Design Using Datamine Studio

利用 Datamine Studio 软件开发的矿山三维设计

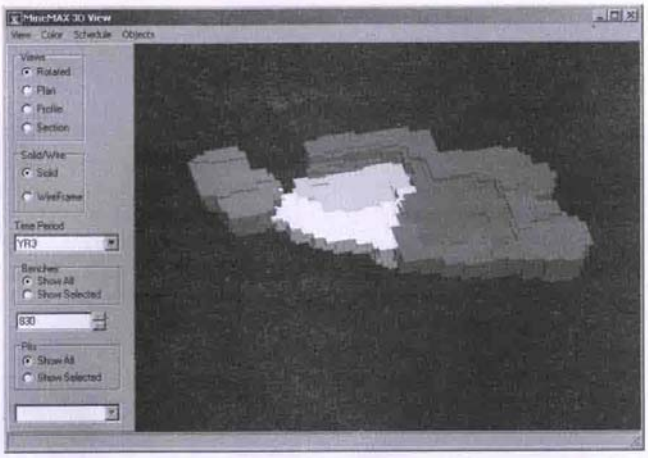


9.3 Mine Scheduling 矿山计划

Developing a realistic and achievable mining schedule forms the basis of cash flow modelling and mining equipment requirements. A number of software packages currently exist that use heuristic or mixed integer linear programming (MILP) to produce schedules that meet a number of practical mining constraints. While manual scheduling generally produces a feasible schedule there is little way of knowing if it can be improved. Using computer-based algorithms, the required time to produce a schedule is much reduced, so that many alternative schedules can be investigated and the best schedule produced. Most of these packages enable the meeting of several targets, such as blending targets, while meeting constraints, such as pit slope angles. These packages allow the user to view a three dimensional progression of mining; this enables the scheduler to check a logical progression is being produced. These packages include XPAC Autoscheduler, MineMax scheduler and NPV scheduler.

开发实用的矿山计划是现金流模型和采矿设备要求的基础。现在有很多软件包使用启发性或混合整数线性规划模型制作的计划满足实际采矿的限制条件。一般手工制作的可行性计划修改的可能性较小。使用计算机进行运算，可以大大节省制作计划的时间，因此可以研究出许多其它方案，从而得出最佳计划。这些软件包的大部分当满足限制条件时，例如矿井坡的角度，同时达到数个目标，例如混合目标。 这些如软件包向用户提供一个三维的采矿进程，这样就能够检查此采矿过程是否合逻辑。这些软件包包括 XPAC Autoscheduler，MineMax scheduler 和 NPV scheduler。

Figure 0.2 - Mine Schedule Progression 矿山计划进程



Underground development sequencing has benefited from the integrating Gant chart based scheduling with computer graphic windows (eg iGant). This allows activity or resource based schedules to be quickly checked. Precedence between activities can be generated and resources assigned to activities. Development can be set to maximise individual heading development while restricting total development.

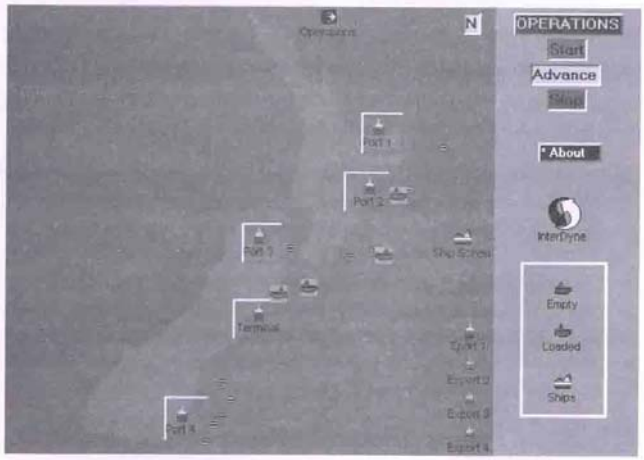
地下开发的顺序受益于计算机图表窗口(例如 iGant)制作的整体 Gant 图。它使得各项活动计划或资源计划能够很快得到检查。各个活动的先后次序也由此产生，资源被分配于各项活动中。可以在控制整体开发的同时最大化单个方向开发。

9.4 Simulation 模拟

Simulation of mining processes and systems can be an invaluable tool for designing mine layouts and plan operational logistics. Mining projects typically require large capital outlays to bring them into production. By using simulation techniques systems can be designed which have a high probability of achieving required outputs. Typically, discrete event simulation can model material handling systems and logistics. Simulation allows bottlenecks to be identified, solutions to be evaluated and train/truck fleet sizes to be determined. Linear programming can be a successful strategy in cost reduction by aiding the integration of operations. Assessing production networks, developing a model and applying linear programming techniques can identify inefficiencies and reduce costs.

采矿过程和系统的模拟是对矿山布置的设计和物流及保障系统的计划是一种无价的工具。通常采矿项目投入生产需要大笔的基建投资，运用模拟可以设计技术系统，使得最大可能达到要求产量。一般情况下离散事件模拟可以仿真物料运输系统和物流系统。 模拟能够识别瓶颈问题、评估解决办法和确定火车 / 卡车队的规模。线性规划模型借助联合作业在战略方面可以成功节省费用。评估生产网络、开发一个模型并运用线性规划模型技术可以辨认低效率和节省费用。

Figure 0.3 - Dynamic Simulation Graphical Environment 动态模拟图形环境



Similarly computer simulation of underground mine ventilation systems can assist in ventilation planning. To provide acceptable environmental conditions underground systematic planning of ventilation, refrigeration and cooling systems is essential. Several tools exist that enable the ventilation engineer to perform ventilation network analysis, heat load analysis and undertake refrigeration and cooling system studies.

同样，地下通风系统的计算机模拟有助于通风规划。通风、冷藏和制冷系统的地下系统规划是提供可接受环境条件的要点。通风工程师可以使用几种工具完成通风网络分析、热负荷分析和进行冷藏和冷却系统研究。

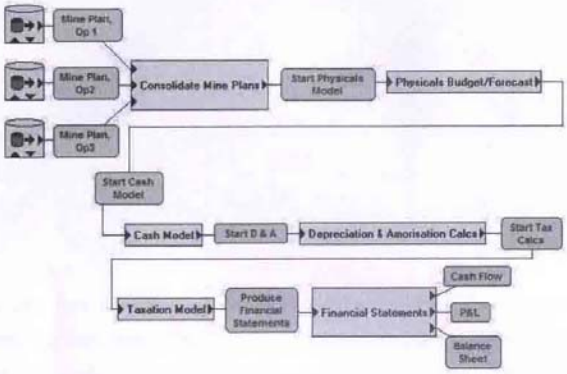
9.5 Cost Estimation and Financial Modelling 费用预算和财务模型

Capital and operating costs can be estimated from a number of sources. Existing operations have their own database of costs, new operations require estimates to be made. The estimates can be drawn from known costs at similar operations or built up from first principals. Once the mine schedule has been established manpower and equipment lists can be built up based on the scale of operation required. Establishing usage and quantities of mine consumables such as fuel, lubricant, tyres, explosives and drilling equipment needs to be undertaken. Purpose built software exists for estimating fuel usage and equipment productivities for mining equipment. Products are available that provide a template to rapidly build up mining cost estimates based on equipment databases and project particulars. These tools take much of the legwork out of cost estimation and allow more time for analysis. Software packages such as APEX, XERAS and XEMPLEX enable the user to link the production schedule to cost information and generate sophisticated financial models. Once the financial model has been built cash flows can be discounted to determine the net present value (NPV) of a project.

资本费用和营运成本可从多个方面来进行评估。旧矿山有自己的成本数据库，而新矿山需要进行预算。

可以根据类似矿山的现有成本或基本原理来进行预算。一旦矿山规划建立，人力和设备清单就建立在所需经营规模的基础上。矿山消耗品如燃料、润滑油、轮胎、炸药、钻探设备的用法和数量需要进行说明和计算。有专门设立的软件，用来评估燃料用法和采矿设备生产力，同时也提供建立在设备数据库和项目细节基础上的快速建立采矿成本评估模板的产品。这些工具减少了成本评估中的很多外勤工作，腾出了更都分析时间。软件包例如 APEX,XERAS,和 XEMPLEX 都使得用户能够连接生产计划和成本信息，从而产生更详细的财务模型。一旦财务模型建立，可以提前考虑现金流动并确定项目的净现值。

Figure 0.4 - Xemplex Financial Modeling Graphical Environment　Xemplex 财务模型图形环境



Source www.xemplex.com

9.6 Risk Assessment 风险评估

Understanding the risks in resource projects enables to project owners to develop strategies to control significant downside risks and to generate opportunities from upside risk. Typically mineral projects are most sensitive to geological risk, commodity price and metallurgical recovery. Traditionally sensitivity analysis is conducted to try and understand the size of these risks. More recently, assessment of projects using real options and stochastic simulation techniques are available.

了解资源项目的风险使得 项目业主能够开发战略，以控制重要下滑风险和制造上升风险的机会。通常矿产项目对地质风险、商品价格和冶金回收率都是最敏感的。一般敏感性分析用来考查和了解这些风险的大小。最近人们已经掌握了使用实质选择权和随机模拟技术的项目评估。

Conditional simulation is one way of trying to quantify the uncertainty that exists in mineral resource estimates. While estimation strives for accuracy simulation strives for realism (http://www.ai-geostats.org). By drawing random values from a probability distribution conditional simulation tries to honour the underlying variability within a deposit. Conditional simulation can give a spread of resource estimates from which a best case, worst case and expected case can be generated. Assessing the project against these cases can help determine the robustness of the project. Conditional simulation can also be a practical tool for making decisions regarding bench heights and the size of selective mining units (Glaken, Noppe and Titley, 2000).

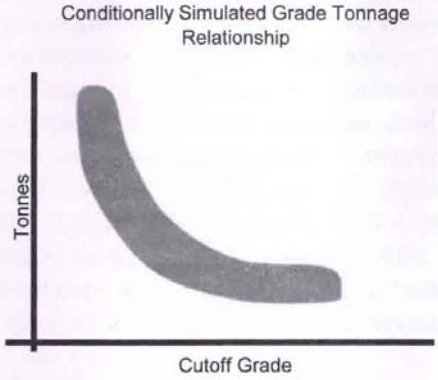
条件模拟是现有矿产资源评估中的一种对不确定尝试定量的方法。评估力求精确，模拟力求真实(http:

//www.ai-geostats.org)。通过从机率分配中获取的随机数据，条件模拟尽力在一个存储内考虑潜在可变性。条件模以也可以提供一系列的资源评估，从中可以产生最优案例、最差案例和期望案例。根据这些案例评估项目可以帮助确定项目的活力。条件模拟也可能是确定基准高度和选择性采矿群体大小的一种实用工具。

Assessing project risk to commodity price can benefit from statistical forecasting techniques. Instead of using one universal metal price, future metal prices and confidence intervals can be generated based on past prices. Logically, the confidence of price estimates is less the further into the future you go. Similar to conditional simulation, a spread of scenarios can be generated to aid in assessing the price risk.

从项目风险到商品价格都可以借助统计预测技术来评估。未来的金属价格和可靠区间可以在过去价格的基础上产生，而不是使用统一的金属价格。理论上，价格评估的可靠性比矿山将来发展的可靠性小。与条件模拟相似，考查一系列方案有助于评估价格风险。

Figure 0.5 - Conditional Simulation and Grade Tonnage Relationships 条件模拟和吨位－品位关系



Real options theory is about flexibility and keeping options open to exploit situations that arise due to variability or uncertainty. Real options can be discussed qualitatively or quantitatively. The qualitative judgement is about building a strategy that can respond to volatility. Andarko Petroleum Corp used real options to outbid other companies for the Tanzanite oil field. Andarko paid more because the range of potential reserves was so large. The vice-president for exploration, Michael D. Cochran said, "Most people looked at it and just saw the minimum case"(Coy, 1999). The quantitative side makes use of different mathematical models to try and price how much the investor should pay to keep their options open. If a strategy were selected to exploit the fluctuations in commodity prices than the value of the strategy would depend on the current price, how widely the commodity price fluctuates and the time frame of interest. While the theory of real options has been around for some time it has not yet become a standard way of valuing a project. While the mathematics of a NPV analysis are readily applied and understood, the techniques of real options are less user friendly. As the technique becomes more widely used and the knowledge base increases it will probably become more common.

所谓真实方案理论就是指灵活性和保证各种方案能够充分利用各种因变化性或不确定性产生的情况。对真实方案进行的讨论既可以定性也可以定量。所谓定性判断是指建立一种能够对变化做出反应的战略。在 Tanzanite 油田竞标中，Andarko 石油公司利用真实方案一举成功。由于潜在储量范围巨大，Andarko 公司支付了更多的钱。负责勘探的副总裁 Michael D Cochran 说"多数人都看过，但只注意到了最小储量(Coy, 1999)"。定量判断则利用不同的数学模型来确定投资者应出多少钱才能使得方案得以实施。利用商品价格波动的战略取决于当前价格、商品价格波动范围以及相关的时间框架。尽管真实方案理论已经存在了一段时间，但它仍没有成为项目估价的标准方法。NPV 分析数学很容易运用和理解，而真实方案技术对用户却不那么"友好"。随着该项技术的使用越来越广其知识基础也在扩大，真实方案理论将有可能变成更加普遍。

10 Conclusion 总结

Much of what has been put forward in this paper is modern only in terms of its relevance to current mineral project development. Much has been learnt about how projects fail and how to deliver successful mineral projects. Unfortunately organisations have very poor memories. Whole industries have no memory at all. While the potential for project failure will always exist, applying appropriate systems and project management techniques can mitigate the risk. The integration of people and systems to share knowledge and build on experience provides a strong foundation to successfully plan modern mineral projects. The range of tools and techniques to create good designs and assess project strategies continues to develop. There are many reasons why projects fail, but by taking advantage of new developments and implementing appropriate techniques poor planning need not be one of them.

本论文中大部分内容观点仅仅只是相对于现有矿业项目的发展而言的。在项目如何失败和如何实施成功的矿业项目方面收益很多。不幸的是各种矿产组织的记忆力很差，整个行业更是一点记忆力也没有。虽然项目失败的可能总是存在，但采用正确的系统和项目管理技术可以降低风险。人机结合共用知识、分享经验为成功规划现代矿产项目奠定了坚实的基础。创作良好设计和评估项目战略的工具与技术范围将会更广阔的发展。虽然项目失败的原因是多方面的，但是借助新的规划和实施正确的技术可以避免不当规划，从而使项目成功。

11 Acknowledgments 感谢

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