



# Justification techniques for computer integrated mining

by S. Dessureault\*

## Synopsis

Computer Integrated Mining (CIMG) is a process of using computer networks to transform islands of enabling technologies into a highly interconnected mining system. CIMG involves the integration of advanced technologies at various levels in the mine business to achieve higher flexibility, better quality of processes and control, and improved profitability. Justifying the benefits of CIMG are difficult as many of the advantages are derived from improved flexibility, quality, and control. Justification is based on the evaluation of the benefits to be gained, compared to the required capital investment. Management tools used in mining are currently inadequate in assessing the value of advanced technology whose benefits are primarily qualitative. A key aspect of successful implementation is management acceptance, which has to be won through the capability to justify the technology's financial costs and the true value of all of its benefits.

The manufacturing industry faced similar justification difficulties when adopting advanced technology in factories. A significant amount of funding and research was invested in developing management strategies and approaches to justification. Many of the problems that faced the transformation of the manufacturing industry in the late Eighties and early Nineties are now facing mining. The solutions derived for manufacturing may help mining in its transition to an increased reliance on integration technology. Reviewing the industrial history of computer integrated manufacturing identifies several tools and strategic frameworks that can be adapted for mining.

Keywords: Computer integrated mining, justification techniques, CIM, information technology.

## Introduction

Computer Integrated Mining (CIMG) is a process of using computers and communications networks to transform islands of enabling technologies into a highly interconnected mining system. CIMG involves the integration of advanced technologies at various levels in the mine business to achieve higher flexibility, better quality, process outcomes and control, and higher profits. This is achieved by connecting all business functions together such as design, implementation, and management. These business functions are connected using information technology (IT). Other business

sectors have accomplished, to varying degrees, the integration of their business functions and processes through the adoption of IT.

One of the most successful is the manufacturing industry that originated the use of the acronym CIM, as Computer Integrated Manufacturing (the similarity of the acronyms necessitates the use of the acronym CIMG to specifically identify the computer integrated mining version of the CIM). The manufacturing industry had undergone a fundamental change in the adoption of CIM. The technology allowed a significant increase in quality, product customization, and integration with other business units. Manufacturing changed on account of market factors that demanded improved quality, flexibility, and precision.

Mining is also undergoing significant market challenges such as international competition, reaching the technical limits of economies of scale, and continued declining commodity prices. As with manufacturing, the health of the mining industry may be dependent on new methods of cost saving, flexibility, and productivity improvements.

The origins of CIM are in the US defense initiatives during the cold war that required new manufacturing capabilities to produce the increasingly complex machines, thereby gaining technical superiority in the arms race. The department of defense sponsored initiatives that focused on the development of tools to design strategies, management systems, and computer system architectures necessary to design, build, and maintain complex machines. These deliverables were seen as necessary infrastructure to revolutionize the aeronautics and manufacturing industry.

As the necessity to evolve manufacturing in the private sector due to market factors

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began to emerge, factory managers encountered another problem: justifying the political and financial expense of purchasing technology and implementing new business paradigms that are required to take advantage of CIM. Management changes and the purchase of technology were difficult to justify economically as the tools traditionally used to calculate the value of a project were unable to directly account for the increased quality, flexibility, and opportunities enabled by CIM. Alternative justification tools were introduced that complemented the limited capabilities of traditional methods.

This paper explores the industrial development of CIM to identify the strategies necessary to evolve the mining industry to take advantage of the opportunities IT enables as integrating technology. As was determined in the CIM experience, these categories of technology would require new justification methodologies so that managers can rationalize the acquisition and integration of the technologies.

These new integrative technologies require both financial investment and commitments to change. However, justifying the benefits of CIM are difficult as many of the advantages are derived from improved flexibility, quality, and control. Justification is based on the evaluation of the benefits to be gained, compared to the required capital investment. Management tools used in mining are currently inappropriate when assessing the value of these types of benefits as they focus on the direct economic outcomes of a particular decision. A review of the justification tools developed for CIM and how they can be applied to CIMG will enable managers to identify appraisal approaches for use in a justification package. Strategy and thoroughness in justifying CIMG are the focus of this discussion.

### Industrial history of Computer Integrated Manufacturing.

The concept of CIM was formulated by Dr Joseph Harrington in 1973. CIM focuses on a strategy of integrating manufacturing facilities and systems in an enterprise through computers or, more recently, computer networks. The department of defense (DOD) was a central figure in the development and application of CIM. In 1975 an Air Force Computer Aided Manufacturing (AFCAM) group was formed to provide improved manufacturing technology. From this group, the Integrated Computer Aided Manufacturing (ICAM) initiative was formed to develop strategies for applying advanced manufacturing technology. Also in 1975, the Society of Manufacturing engineers created the Computer and Automated System Association (CASA/SME) as an educational and research association to spearhead the concept of CIMF to the public. One of their key developments was the CIM enterprise wheel, which represents CIM as an enterprise-wide concept. The wheel emphasizes that CIM acts as an integrator of islands of automation. In 1992 the CASA/SME revised the concept of the CIM enterprise wheel from an internal focus to an external view that includes the customer<sup>1</sup>. This new view reflects the importance of the product consumer popularized in the development of management tools such as reengineering concepts.

Substantial effort and funding were committed in the development of the CIM strategy, personified by 'The Wheel,'

and in the creation of tools used to implement CIM strategies. Modelling formalisms are an example of the tools developed to help implement CIM. For example, the ICAM definition (IDEF) modelling methods were developed in the US to model business functions (IDEF0), information models (IDEF1), and dynamics models (IDEF2). Defense budgets and manufacturing corporations are capable of funding strategic initiatives from inception to implementation, so the issue of financial justification was not encountered at this stage. In the current climate, the mining industry does not have similar funding levels; however, a similar strategic initiative may be developed based on the experiences and conclusions of the manufacturing industry.

Implementing CIM was a required stipulation for many defense contracts; therefore, some sectors of the manufacturing industry did not have to financially justify the technological and business changes required to adopt integration. However, as CIM began to be applied in the public sector, managers struggled with the inability of traditional tools to account for the 'soft' benefits for which CIM was intended<sup>2</sup>. The benefits of CIM to the defense industry were observed but traditional economic tools, such as payback method, showed that the technologies could not measure up to the hurdle rates. New justification methods, such as the Analytical Hierarchy Process (AHP), real options pricing, and simulation began to be used to provide a more thorough evaluation of investments in CIM. These new justification tools addressed the traditional tools' inability to include the qualitative benefits of CIM such as increased flexibility.

The strategic reasons for adopting CIM are not always applicable to CIMG. For example, the ability to easily produce highly variable products in a mass-production environment (for example, manufacturing cars to the customer's exact specification) is not necessarily advantageous in mining. However, some advantages to CIM can be shared with CIMG. An example of the benefits commonly attributed to CIM include<sup>3,4</sup>:

- Flexibility in product, volume, and inventory
- Improved productivity and quality
- Improved interface between design and manufacturing
- Reduction in both direct and indirect labour especially in functional units such as engineering, middle management, administration, and operations support (ordering, receiving, etc...)
- High quality designs from increased engineering-operations technical communication
- Better enforcement of standardization and material utilization
- Common databases eliminating redundant data storage
- Reduction in inspection time and inspectors
- Competitive advantage over competitors.

Some of these advantages are not applicable to mining. For example, inspecting the final product is not frequently undertaken by mining operations. However, several additional advantages that can be achieved in CIMG can include:

- Reduced maintenance delays and costs (through improved planning and communication)
- Improved safety (by keeping better records of safety statistics and tracking the safety violations of employees).

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## Justification of CIM

Justification of CIM is a key component of the strategic planning and implementation of CIM. Many authors suggest that justification of CIM requires both qualitative/concept and quantitative/analytical approaches<sup>5</sup>. For example, Meredith and Suresh suggested three categories of approaches: economic, analytical, and strategic as seen in Figure 1<sup>6</sup>.

Various authors<sup>2,6</sup> have discussed how new manufacturing technologies vary from stand-alone equipment to full CIM systems. This variation in complexity can vary from stand-alone automated equipment including robots and numerically controlled (NC) machine tools to fully automated and networked enterprises. Less integrated manufacturing technology acquisitions are typically designed to replace worn-out or obsolete equipment. Highly integrated manufacturing technology can be linked with the design, planning, materials handling, manufacturing, and support systems through computer control.

The mining industry is fairly familiar with economic and risk analysis methods of evaluation. For example, justifying the acquisition of a new haul truck can be undertaken using economic tools. However, more involved, less technical tools are needed to justify technologies that integrate processes. An example of an integrating technology can be the software package that links engineering with operations by seamlessly communicating engineering design specifications to operators; the technology then helps those operators comply with the design through visual feedback on computer screens. An example of this type of technology is Caterpillar's CAES system that allows an engineer in an office to 'drag-and-drop' designs, such as a grade outline, to an icon that represents a piece of equipment on site, such as a shovel<sup>7</sup>. The technology can then aid the operator in that shovel to

comply with the plan through a screen that can identify where the operator is digging through graphics on a screen in the shovel's cab. These integrated technologies are now being widely accepted and the full range of their true costs and benefits (both qualitative and quantitative) can be determined through case studies. However, this level of integration is not as extensive as the CIM factories. A classification scheme to segregate levels of integration would benefit appraisers when applying the many justification approaches available.

Dessureault *et al.*<sup>8</sup> evaluated the use of the various justification approaches seen in Figure 1, in appraising advanced mining technology. The approaches that were applicable to mining were organized into three categories, labelled one to three, as seen in Figure 2. A similar diagram was developed by Meredith and Suresh<sup>6</sup> to facilitate the selection of appropriate justification tools, given the level of integration of the technology under evaluation. The figure reflects the tendency of a technology's benefits to be increasingly qualitative and challenging to quantify as its degree of integrating the business functions also increases. Figure 2 aids the evaluator to choose appropriate justification approaches by dropping a line from the intended level on the top X-axis downward to the diagonal line, then across horizontally to the left Y-axis. The methods above this point are most appropriate to the level of complexity of the technology, while those below are too involved for the evaluation. Those closest to the horizontal line are the most appropriate, while those higher are still useful. For example, consider a manager appraising a technology that falls in the level 2 category: methods such as scoring models, options pricing, and activity based costing (ABC) may be most appropriate, while the economic methods remain useful.

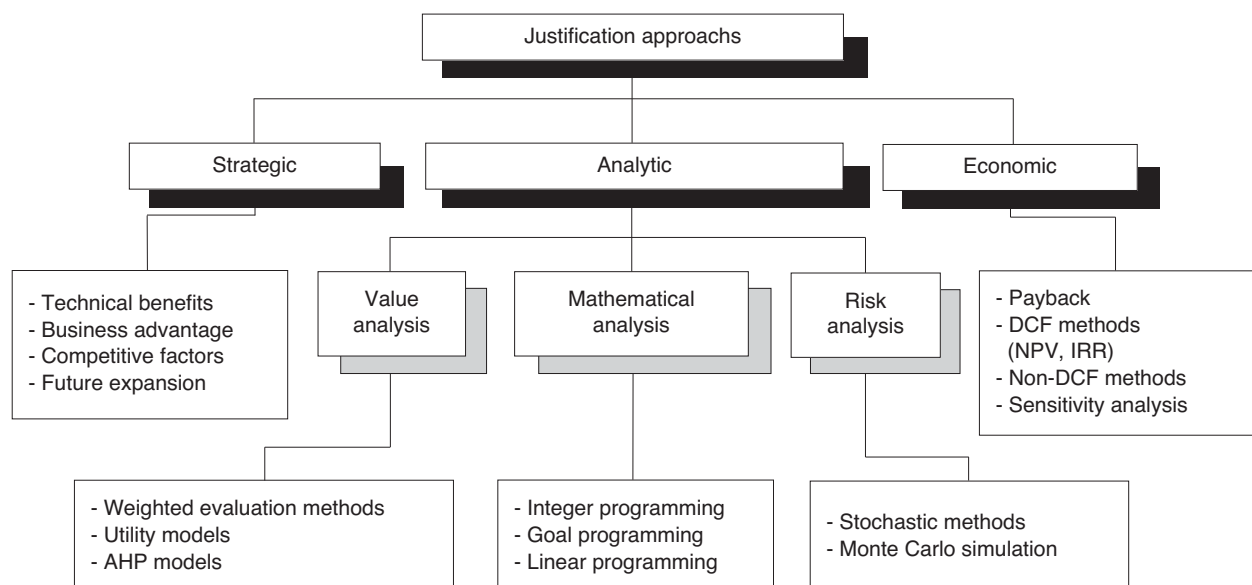


Figure 1—Categorization of justification approaches<sup>6</sup>

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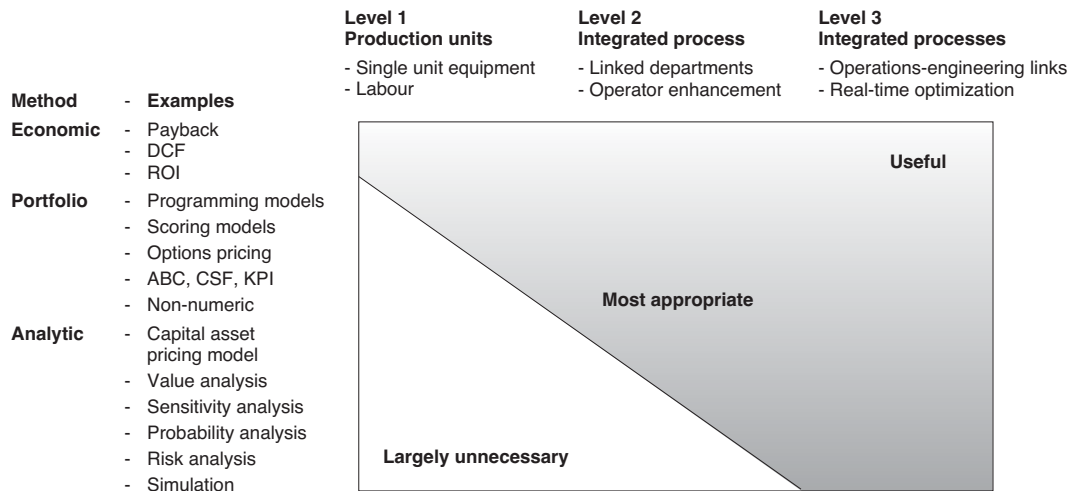


Figure 2—Justification approach selection diagram

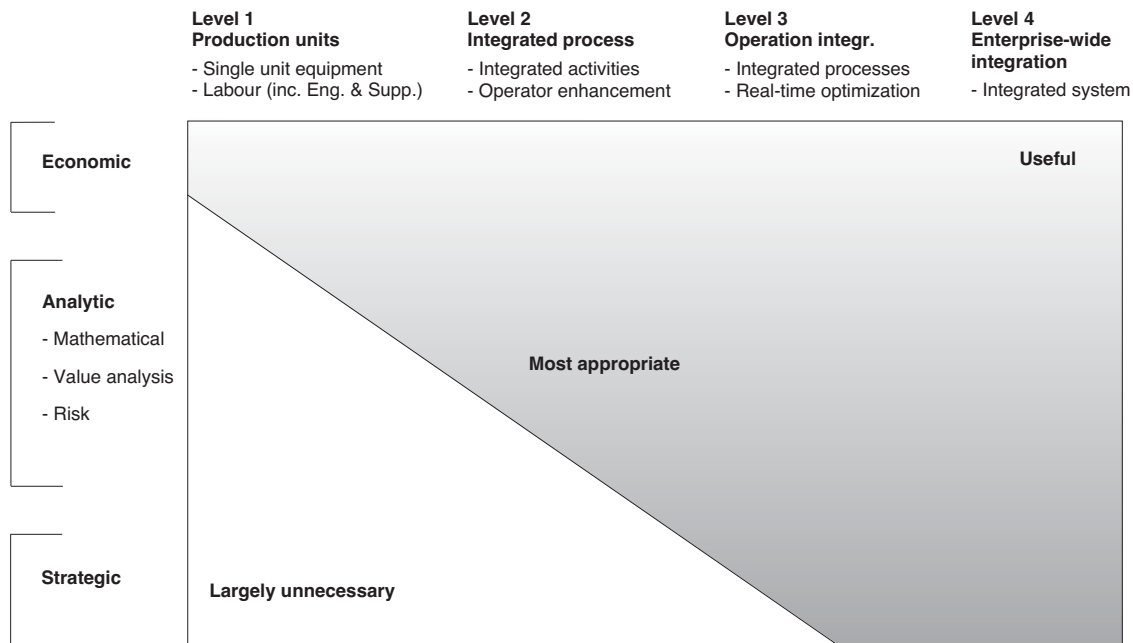


Figure 3—Updated justification approach selection diagram

IT suppliers such as Gemcom, SAP, MINCOM, OSISoft, and JD Edwards are now offering software packages that increase the degree of integration between mining processes to a state where several business functions are integrated providing significantly more information sharing and comparison. These technologies allow the collection of several types of information such as production statistics, costs, and targets. This information can be accessed by the various levels of management and automatically formatted for those particular managers. Higher-level managers would view highly aggregated information from which to make better strategic decisions while lower-level managers and engineers would access raw production statistics to make tactical informed decisions and planning.

Enterprise Resource Planning (ERP) tools have been

available for several years, however, true integration, where planning, inventory, maintenance, geological, and management software packages all share a common data source within an integrated management framework, are only beginning to emerge<sup>9</sup>. These changes are enterprise wide and would result in not only technology changes also in but work and management changes. Hence, a much stronger focus on strategic justification would be required as the benefits of enterprise-wide technology (CIM) are increasingly difficult to assess using exclusively economic or analytic approaches. A fourth level can be added to Figure 2, reflecting the new technology options and subsequent justification challenges available to mining executives. Figure 3 is an updated version of Figure 2, reflecting the recent availability or technological advances leading to CIM.



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The strategic justification approaches are less technical compared with the other approaches as they focus on the qualitative attributes. These attributes may include business strategies, competitive advantage, and long-term vision of the company. As with other justification approaches, strategic methods cannot be used in isolation from the other methods of appraisal<sup>10,11</sup>. Other approaches must be included in an 'evaluation package' as these types of investments are sizeable and long-term financial commitments.

### Evaluation Package

Nagalingam and Lin<sup>12</sup> developed a Decision Support System for Computer Integrated Manufacturing (DSSCIM) as a spreadsheet based multi-attribute decision tool that can facilitate the evaluation of several CIM alternatives. The method allows the option to use several types of justification approaches to evaluate a particular CIM then integrates the values. The method is represented by a flowchart in which several stages of evaluation are followed to measure both qualitative and quantitative benefits and subsequently optimize the CIM initiative. The system is optimized by determining the individual values that each intended sub-system provides. Development or adoption of existing evaluation packages would prove beneficial for mining managers contemplating implementation of CIMG and requiring justification to shareholders.

### Conclusion

Descriptive analyses of industrial history can identify stages of evolution in technology and tools that aided the transition between levels of innovation. Insight into potential challenges faced by mining operations can be recognized in analyzing the challenges encountered during the evolution of technology in manufacturing. In the past decades, factories have evolved from top-down-orientated management and isolated islands of technology to a more informed and integrated system. Mining is experiencing market challenges in industrialized nations (particularly in North America) necessitating a re-examination of any potential cost saving mechanism including CIMG. Mine managers may be able to avoid the delays or ill-advised implementations of integrating computer technology by learning from the experiences of manufacturing and applying the tools designed to facilitate change.

There are also significant advantages in adapting the tools and procedures developed by others. The justification tools and categorization of technology can be adapted for use

in a mining context. The vast resources used to develop the strategy and tools to plan and implement CIM are not available to the mining industry; however, the industry may have the political and economic resourcefulness to adapt CIM tools and strategies to suit mining operations. Strategic planning is required to design and implement successful and long-term CIM changes. Evaluation packages, such as DSSCIM, or familiarity with the various justification tools would greatly benefit mine managers in developing and justifying the new technology available through CIM.

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## Geoinside—winner of the Innovation Award for Outstanding achievements at the *Mining Journal* World Congress, London\*

Geoinside received the *Mining Journal* Innovation Award for Outstanding Achievements on 3 December 2003. The prize was handed over at the gala dinner of the Mining Journal World Congress, Mines and Money, in London. Over 550 delegates, including the major players in the mining industry and finance, participated in the congress. The congress aimed at bringing the global mining community to the capital of mining finance, London. It was an excellent platform for major and junior mining companies seeking financial opportunities, expert opinion on the current state of the industry, and forecasts.

The winners were selected by a jury consisting of representatives of the World Bank, a university, an independent consultant, and *Mining Journal*. Geoinside received the innovation award for its innovative and long term approach to establishing an Internet marketplace for trading minerals and metals. Geoinside was among the following 5 nominees in its group: HydroZinc, mine-to-metal process (Teck Cominco); Phelps Dodge, copper concentrate leaching (Bagdad plant); Platinum Plus, diesel catalyst; Titan24, high-definition resistivity data (Quantec Geoscience Ltd); and WebGF, mill simulation (CSIRO Australia).

Further awards went to:

- ◆ *Country Award*: Armenia
- ◆ *Deal of the Year Award*: Norilsk acquisition of Stillwater
- ◆ *Exploration Project Award*: Alto Chicama project, Barrick Gold
- ◆ *Sustainable Development Award*: Rio Tinto campaign
- ◆ *Communication Award*: Xstrata
- ◆ *Life-Time Achievement Award*: Sir Robert Wilson, Rio Tinto.
- ◆ *Special Award*: Jim Ainsworth, former Anglo American and Warrior International.

More information is available under [www.minesandmoney.com](http://www.minesandmoney.com) and *Mining Journal*, December 5, 2003. Further award reports will be published in *Mining Journal*.

At the end of 2003, the Geoinside Marketplace has changed to [www.Geo.net](http://www.Geo.net). Geoinside GmbH will be renamed Geo.net Commodities GmbH accordingly. The Marketplace is by far the most comprehensive online forum currently available, especially for industrial minerals, including offers, inquiries, detailed specifications, and prices. The aim of the Marketplace is to generate new business and trade opportunities. Geoinside (Geo.net) assists the mining industry to increase the export of mineral products and the manufacturing industry to substitute currently used products or to build up alternative sources. Geoinside (Geo.net) also gives small and medium scale companies in less developed countries the chance to gain market access to industrial countries, and is an example of the successful integration of old and new economies.

The Marketplace is updated daily. It currently has more than 1 000 professional members, over 700 offers and inquiries, and about 100 visits per day. Launched in 2000, it had its breakthrough in 2003. The actual trade is offline. Geoinside (Geo.net) evaluates the incoming offers and inquiries, starts intense communication with the potential trade partners, and advises them. The offers are checked for their detailed chemical and technical specifications for various industrial applications, prices and delivery terms. The inquiries are discussed extensively with the buyers. Offers and inquiries are then presented anonymously on the Marketplace to protect a buyer's and seller's interests.

Services include distribution of mineral commodities, market studies, valuation reports, quality assurance, freight, finance, and evaluation of mining and processing. The Marketplace also includes invitations for tenders for geo-related projects in the German market.

Geo.net Commodities currently forms a holding company to establish an oil fund for the investment in oilfields in Kazakhstan.

More information under [www.Geo.net](http://www.Geo.net). ◆

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