University of Southern Queensland

Faculty of Engineering and Surveying

# Literature Review of Advanced Research and Innovation in the Mining Industry.

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# Abstract

Technology Transfer is defined as, a purposive, conscious effort to move technical devices, materials, methods, and/or information from the point of discovery or development to new users. The aim of this project was to apply this process to the Australian Mining Industry. This was accomplished by firstly investigating the technologies used in the Mining Industry and developing methods by which technologies can be transferred to other industrial fields. And secondly through the identification of industries that are unrelated to the mining industry, develop transfer methods that allow the adaptation and development of technologies of these industries into the mining industry.

The main focus of this project was to research Technology Transfer methodologies within the Australian Mining industry and report on the methodologies used. This was accomplished through the review of advanced literature which focused on Technology Transfer and issues affecting Technology Transfer. The main issues to come from this were the level of the Government support and involvement within the promotion of research and development of technologies that are capable of transfer. Technologies relating to the transfer process were also researched to establish transfer types and methodologies that are currently employed by the Mining Industry. The results form these technologies were used to form the boundaries for a Technological Dissemination Model. This model is the start of creating a successful transfer process for technologies within the Mining Industry as well as other industries.

Due to this fact, future work will need to be carried out to complete the Technological Dissemination Model. Some of the future work will include the development of the model within the framework of the Mining Industry and the application of the completed model to a transfer of technology. It is hoped that the information presented in this report will add to the Technology Transfer knowledge base and even be converted into an Industry Technology Roadmap in which future needs are identified and a series of potential future directions are defined for the project.

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# ENG4111 Research Project Part 1 & ENG4112 Research Project Part 2

## Limitations of Use

# Certification

I certify that the ideas, designs and experimental work, results and analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

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# Glossary of Terms

| | |
|---|---|
| ACIP | Advisory Council on Intellectual Property |
| ABARE | Australian Bureau of Agricultural and Resource Economics |
| AMIRA | AMIRA International Ltd (formerly Australian Mining industry research Association) |
| CFD | Computational Fluid Mechanics |
| COMET | Commercializing Emerging Technologies |
| CRC | Cooperative Research Centre |
| CSIRO | Commonwealth Scientific and Industry Research Organisation |
| DNRM | Department of Natural Resources and Mines |
| GFRO | Government Funded Research Organisation |
| IP | Intellectual Property |
| LNG | Liquefied Natural Gas |
| LPG | Liquefied Petroleum Gas |
| MCA | Minerals Council of Australia |
| MTSAA | Mining Technology Service Action Agenda |
| MTS | Mining Technology Service |
| R&D | Research and Development |
| SET | Science, Engineering and Technology |
| SME | Small to Medium Sized Enterprise |
| TSC | Technology Selection Criteria |
| TT | Technology Transfer |

# 1. Introduction

The method of applying an existing technology to solve a problem is not a new process. It has existed for many hundreds of years and is the basis for today's modern engineering. Sometimes this process is termed Technology Transfer or Technological Dissemination, though, no matter what this process is called, the outcome is still the same. Technology Transfer is defined as, a purposive, conscious effort to move technical devices, materials, methods, and/or information from the point of discovery or development to new users.

The aim of this project is to apply this process to the Australian Mining Industry. This project will accomplish this by firstly investigating the technology used in the mining industry and develop methods by which technologies can be transferred to other industrial fields. And secondly through the identification of industries that are unrelated to the mining industry, develop transfer methods that allow the adaptation and development of technologies of these industries into the mining industry. Through identification and interchange of this knowledge, it is hoped that a broader awareness and acceptance is gained and applied to all industries through the benefit of transferred technologies.

It is an aim of this literature review to find such examples of Technology Transfer and document their successes. To do this, technologies that are in use, technologies that are being implemented and technologies that are in the design stage will be researched. By researching technologies that are in these three different design stages, it is hoped that a clear understanding of what makes Technology Transfer (TT) successful and the processes needed to for TT to become viable in industry are identified. Having gained an understanding of TT and what is required from industry, manufacturers and designers, a hypothesis of further technological research and diffusion will be formed to promote areas of future research.

As with all projects, there must be an underlying reason for spending so much time on research, design and testing. This project is no different. The purpose of this literature review is to try to offer some benefit to the mining industry. One such way that the Mining Industry can benefit from transfer of technology is through cost saving. Cost saving is important to all industries. The desire to keep operating costs down and increase profits is essential to maintain the industry for the future. The implementation of new innovations and technologies such as monitoring equipment or harder materials can lower life cycle costs, increase asset utilization and the productivity of the equipment. The benefits that new technologies will have will hopefully cause a lead on effect to all areas within the Mining Industry.

Sustainability is another area that development and transfer of new technologies can affect. Up until recently, most of Australia's mineral deposits were inaccessible until the implementation of new technologies that were capable of accessing them were implemented. This newly found access to the economic demonstrated resources in Australia has increased our domestic production and export share of the international market. With the advancement of new technologies comes the ability to harness more of the seemingly inaccessible resources creating longevity within the erratic industry that is mining.

Another area is competitiveness. With new technologies comes the promise of new advantages. Advantages in the dominance of local or international markets, the technology to acquire better and bigger contracts, or the hiring and retention of the 'best' talent are just a few examples that the transfer of technologies can have on competitiveness. Indeed there are immeasurable benefits that can come with new technological innovations and dissemination. The benefits listed above are only examples of why this literature review is being completed. Indeed they *are* underlying factors and may well be found to be the resulting force behind this literature review but, it is hoped that the purpose of this review is ultimately to educate and make aware the new technological innovations that are being developed and methods that are most suitable for their transfer.

# 2. Mining Background

## 2.1. The MTS Sector

The Australian Mining Technology Services Sector (MTS) has existed since the foundation of the minerals industry in Australia. The development of innovative technologies to maximise returns from mineral exploration, extraction and processing has been an integral, but essentially unacknowledged part of the minerals industry. In addition to the support the MTS sector provides to the minerals industry, many of its products also have significant applications in other industries.

The MTS sector focuses on technology based businesses that service the mining sector which includes mineral exploration, mining and basic mineral processing activities (ibid, 2002). This definition includes products that incorporate other scientific, technical or engineering based technologies and services that provide expertise within these technology areas on a fee or contract basis. The ABARE survey places MTS businesses into six broad industry categories:

- Exploration and other mining services;
- MTS machinery and equipment manufacturing (including scientific, electronic and other machinery and equipment except heavy machinery and equipment);
- Construction services (e.g. mine site preparation);
- Scientific research services (including services undertaken in public research organisations);
- Technical services (surveying, consultant engineering and other technical services); and
- Computer services (data processing, information storage and retrieval, computer maintenance and computer consultancy services).

The total desire of the listed industry categories is to retrieve Australia's mineral resources, which include bauxite, thermal coal, metallurgical coal, copper, gold, iron ore, lead, mineral sands, manganese ore, nickel, silver, uranium, zinc, rare earth elements, and platinum group elements. The MTS sector does not include the exploration, extraction and processing of gas and oil as the responsibility of these resources falls under the Australian Constitution which ensures that the development of petroleum resources is shared between the Commonwealth Government and State and Territory Governments. Ownership of petroleum resources is reserved to the Crown and all rights are held by the Government of the State or Territory in which they occur. Australia’s oil and gas resources include crude oil and condensate, liquefied natural gas (LNG) and liquefied petroleum gas (LPG).

## 2.2. Exploration and Production

Exploration is the key to supporting a competitive mining industry. A competitive mining industry is a prerequisite for growth in high-value minerals processing and technological service industries in Australia.

As proof of Australia’s competitiveness within the global market, stronger levels of exploration investment were seen in 2005/06 due to continuous levels of global demand for minerals. This is seen through the $1,240 million spent on minerals exploration in Australia, with 37 per cent of this on ‘new deposits’, and 63 per cent on ‘existing deposits’ (ABARE 2006). To sustain such growth and contribution to national economic performance in the medium and longer terms depends on new resources being discovered and developed for production at rates sufficient to meet demand.

The predicted outlook for production of the bulk commodities (i.e. all types of coal and iron ore for 2006/2007) was expected to increase approximately 9 per cent on average, base metal production (copper, nickel etc) was expected to increase by approximately 10 per cent on average, and aluminum and alumina production is expected to increase (MCA, 2006). These predictions were reflected in the returning figures which saw an increase relative to 2004/05 in iron ore, coal copper lead, zinc, gold and uranium within mine production. Within smelting and refining production there was an increase in alumina and aluminum.

There was increased activity within the oil and gas industry, specifically, exploration and development drilling in both on and off shore drilling. Exact detail of this increased activity is not readily available, though comparisons have been made to the industry results for the 2004/05 period.

## 2.3.Exports

Despite this high rate of production and export, exploration activity has led to an increase in Australia’s Economic Demonstrated Resources for most commodities. For this reason, Australia is the largest exporter of alumina, black coal, iron ore, lead, and zinc; it is the second largest exporter of uranium.

The largest percent of Australia’s energy resources are exported to Japan and Korea and the largest percent of other mineral resources is supplied to China and Japan. According to ABARE, 2006/07, exports rose significantly, by around 18 per cent to $108,100 million, particularly as a result of very strong demand and subsequent higher prices caused by limited supply. These exports accounted for approximately 40% of Australia's total goods and services exports.

## 2.4.Financial

Net profit (in dollar terms) increased for the minerals industry rose by 74 per cent to $11,771 million – its highest level since records were kept from 1977/78. This is due to the current resources boom experienced by Australia that is being driven by a global demand for mineral resources.

The same can be said for the oil and gas industry. Oil prices set new records and the industry maintained a historically high level of activity in 2006. This is presumably due to the arrival of Enfield NW shelf production resulting in Australia’s positive production for the 2006/07 period. This may lead onto an overall net profit for 2007.

## 2.5. Employment

The Australian Mining Industry directly employs 127 500 and indirectly 200 000 workers nationally (MCA, 2007). This is a 19 percent increase on direct and indirect employment from previous year's figures across all areas of employment. The resulting total labor costs of this increase (i.e. gross wages and salaries, payroll tax, workers' compensation, fringe benefits tax, contract costs and superannuation) rose by 14 per cent to $5,996 million (MCA, 2007).

## 2.6. Research and Development

Australia has been a leader in mining research and development, investing large amounts of capital to develop new technologies and processes to strengthen its competitiveness. In 1999–2000, the Australian minerals and energy sector spent $273 million on research and development (DNRM, 2002). Australian mining companies are leaders in the area of technology development—both of advanced mining equipment and systems, and in the areas of mining software and management systems. The Minerals Council of Australia has estimated that 60% of all computer software used in world mining comes from Australia (DNRM, 2002). In addition, exports of Australian mining-related intellectual property totaled over $1000 million in 1999–2000.

The growth of the industry through R&D can be seen in today's figures on gross profit within the mining industry and the amount of Australia's available EDR. Government support is instrumental in the promotion of R&D through its schemes and initiatives (ref. section 1.8) and allow for the dissemination of Australian innovations throughout the global market.

## 2.7. Mining Projects

In the six months ended October 2006, there were 21 mining and minerals processing projects 'completed' at a combined value of $3,399 million, 48 projects at the 'advanced' stage with an estimated combined capital expenditure value of $18,387 million, and approximately 150 projects at the 'less advanced' stage with a collective value of approximately $56,716 million (MCR, 2006). This clearly shows the effects of the current boom of activity experienced in the Mining Industry.

## 2.8. Government Support

The Australian, State and Northern Territory governments continued to support the sector with programs designed to help reduce the inherent risk in exploration. The government's schemes to enhance and increase the amount of R&D being conducted in Australia include,

- Smart Exploration Initiative
- Smart Mining – Future Prosperity
- R&D Start
- R&D Tax Concession
- Commercial Ready Program
- COMET Program
- The Innovation Patent
- Industry access to Government Funded Research Organisations (GFROs)
- Cooperative Research Centers (CRCs)

The exact details of selected initiatives vital to the success and continuing growth of the Australian Mining Industry will be discussed in greater detail with in section 3.3.1, Government R&D Support.

## 2.9. Cooperative Research Centers

The Cooperative Research Centre (CRC) is a collaboration mechanism between industry, academia and government. The objective of the Program is to enhance the benefits to Australian industry through the development of sustained, user-driven, cooperative public-private research centres that achieve high levels of outcomes in adoption and ccommercialisation.

The Programme is an Australian Government funded initiative. It boosts world-class research with the aim of turning Australia's scientific innovations into successful new products, services and technologies, making our industries more efficient, productive and competitive. The CRC Program model has been tried and tested over the past 16 years and copied in a number of other countries, including Chile and Austria.

The main CRC for mining is CRC Mining Australia. Within this CRC there are a number of initiatives aimed at a sustainable and competitive Mining Industry. Some of these include,

- CRC for Mining Technology and Equipment
- CRC for Coal in Sustainable Development
- CRC for Predictive Mineral Discovery
- CRC for Alloy and Solidification Technology
- CRC for Hydrometallurgy
- Queensland Centre for Advanced Technologies (QCAT)
- Sustainable Minerals Institute

Since its inception, Technology Transfer has increased through the collaboration with Cooperative Research centers. It has achieved this by the CRCs acting as primary facilitators of technology transfer. The benefits provided to Technology Transfer through this connection have allowed for the expansion and uptake of technologies within various industries.

# 3. Technology Transfer Background

## 3.1. Innovation and Technology Transfer

Innovation is the process in which the results of research and development (R&D) are taken into the marketplace. Innovation is more than discovery and engineering design, it is the process by which new knowledge is generated and applied to physical and intellectual operations of society. The physical occurrence of innovation in industry is often referred to as Technology Transfer (TT).

Technology Transfer has been defined by Mongavero and Shane (1982) as the use of knowledge. Through this explanation, it can be said that TT is the use of knowledge that has been applied to any situation or invention. It is important to understand that while the knowledge may have been understood, it does not mean the knowledge has been transferred, unless, that knowledge is applied or used. However, if the resulting innovation does not meet the expectation of the designer or user, then it is still considered that TT has occurred.

There are two modes through which TT can occur. Firstly is self initiation. This style of initiation relies on the motivation and desire of the user to gain the adequate knowledge to use and diffuse the technology throughout the community. For example, the ability to play computer games is an informal form of self initiation through which multiple sources of information are used. This mode of initiation is often too slow with random outcomes that don't meet the expectations of designers and R&D companies. That is why a second transfer mode is utilized. Deliberate initiation is used to bypass the gradual diffusion and arbitrary outcomes of technologies into the commercial industry. This can be seen through government agency adopting policies regarding water saving innovations or energy generation through renewable energies.

Innovations capable of TT can be separated into two categories; these are, 'soft' and 'hard'. Technologies that are defined as 'hard' include items that are physical objects such as machines and equipment. Technologies that are defined as 'soft' are more intangible in nature and include mining procedures and development processes. In general, there has been a greater industry and academic consideration towards the implementation of 'hard' technologies. This could be because the value of 'hard' technologies is easier to accept where as placing an initial value on an intangible process is difficult and can only be judged over an extended period of time. Other dimensions affecting the implementation of soft technologies have been set out by Bessant and Francis (2005), which include,

- The requirement of soft technologies to be lived rather than acquired,
- The inherent ambiguity of out comes,
- The stylistic options and technology implementation paths that are available for implementation, and finally,
- The extent to which the transferring party has a hard or soft ‘product’.

Therefore it can be said that the development of new mining technologies precedes changes in mining methods (Nantel 1996). This is the case for the implementation of ‘hard’ and ‘soft’ technologies. The invention of a ‘hard’ technology such as larger capacity mineral extraction equipment brings the procedures and methods of utilizing the innovation that are described as ‘soft’. As with the implementation of all technologies there are associated difficulties that must be overcome to achieve a suitable foundation for the growth and development of innovations.

## 3.2. Why should Technology be transferred?

Technology is transferred in the hope of ‘gain’. In the mining industry, it is the strength of the mineral resources that is the gain. Through this desire, some of the risks associated with the transfer of new technologies are alleviated. In the mining industry, R&D management combined with TT by the Mining Technology Services (MTS) has enhanced the exploration accuracy, production and processing efficiency, engineering ability, occupational health and safety conditions, environmental and mine sustainability and improved business and financial operations. The gains listed above are the results of TT within one industry. Similarly the transfer of technologies from the MTS sector is impacting on other industries that are unrelated to mining.

Through coordinated research, a broad based foundation of scientific outcomes is achieved. This is seen through a diverse range of unrelated industries such as pharmaceuticals, film and printing. Technology will continue to be transferred as there are ever increasing desires by companies and individuals to gain an advantage within their industry.

## 3.3. Issues affecting Technology Transfer

Analysis of the Australian MTS industry has indicated that key to a company's ability to innovate successful are (ABARE, 2002):

- Government support through the R&D incentives and programs,
- Improved rates of commercialization and technology transfer,
- Access to financial support for R&D and technology transfer,
- Improved levels of IP retention and protection,
- The ability to attract staff with specialist skills, and
- Access to public research organizations.

### 3.3.1. Government R&D Support

There are a range of schemes and initiative designed to enhance and increase the amount of R&D being conducted in Australia. Some of these that are vital to the success and continuing growth of the Australian Mining Industry include,

- R&D Tax Concession
- R&D Start
- Commercial Ready Program
- COMET Program
- The Innovation Patent

The R&D Tax Concession is a broad based, non industry specific initiative that allows each company to control the direction of its R&D. The Tax Concession is part of the company tax system and the benefit is claimed through the annual company tax return. The R&D Tax Concession program was independently evaluated in mid-2003. The evaluation found that the R&D Tax Concession is an appropriate policy instrument and is effective in encouraging additional business investment in R&D. Other key findings of the evaluation are (Government Industry Website):

- The main focus of R&D is on developing new and better products, and reducing costs through process improvements;
- On average, firms expect that their R&D is highly novel or develops a platform technology that might spur innovations in other industries or applications;
- About 30% of firms who responded to the survey indicated that their R&D built on R&D developments in other industries, and about a third of firms obtained access to R&D by buying the IP; and
- On average, firms expect that a typical year's R&D will contribute substantially to sales and profits five years after it is conducted.

The R&D Start program was established to support innovation. This program is merit-based and designed to assist Australian industry undertake R&D and its commercialization through a range of grants and loans. The main economic impacts of the R&D Start Program are:

  - development of a new or better product, service or process;
  - development of technology to reduce respondents' costs;
  - increased intellectual property; and
  - increased opportunity to engage in new ventures for collaboration.

Commercial Ready is a competitive grant program supporting innovation and its commercialisation. It aims to stimulate greater innovation and productivity growth in the private sector by grants to small and medium-sized businesses (SMEs). A wide range of project activities can be supported, extending from initial research and development (R&D), through proof of concept, to early-stage commercialisation activities.

The program is divided into two elements depending on the size of the grant, large grants for innovation projects of up to three years duration and small grants for projects of up to eighteen months duration. The Commercial Ready program provides competitive grants to small and medium enterprises to undertake R&D, proof-of-concept, early stage commercialisation activities.

The Commercializing Emerging Technologies (COMET) program provide small start up firms with a support package covering training, IP strategy and working prototypes. Participants in the COMET Program are companies who are in the early stages or are close to having a product, process or service to commercialise, but who experience barriers to commercialisation. The activities and services supported by the COMET program are designed to assist companies to overcome these barriers.

The innovation Patent was implemented after the Advisory Council on Industrial Property (ACIP) identified a demand for industrial property rights for those incremental or lower level inventions that would not be sufficiently inventive to qualify for standard patent protection. The innovation patent is a secondary tier system that provides better access to industrial property rights for local industry and help to foster indigenous invention and innovative activities.

The innovation patent provides an exclusive right for lower level inventions. This additional patenting system covers technologies that are not covered by the petty patent which does not meet the consumer's needs because it has an inventive threshold similar to that of a standard patent. The innovation patent should encourage Australian businesses, particularly SMEs, to develop their incremental inventions and market them in Australia. Increased use of the system will also increase the amount of technological information available to businesses, as the invention covered by each application is published.

### 3.3.2. Rates of Commercialization and Technology Transfer

Present rates of commercialization of Australian innovations by Australian companies are lower than ideal, which results in a loss of commercial opportunities both here and abroad. The reigning economic environment has caused a trend towards short-term, operational focused off the shelf style technology that leaves little opportunity for onsite development. This style of environment favors cost reductions as a mechanism to deliver financial outcomes at the expense of new technology. This has resulted in the decrease of qualified technical staff that are capable of acting as 'champions' for a new technology which in turn limits the uptake and acceptance of new innovations.

### 3.3.3. Financial Support for R&D

One of the challenges facing the MTS sector is increasing pressure in terms of funding and in particular, access to venture capital. Access to financial markets and investment capital is a major factor in the ability of the MTS sector to develop and commercialise technology. It also impacts on the ability of companies to refine business strategies and structures. Raising the financial community's awareness of the work of the MTS sector and emphasizing its highly technical nature is essential to improving the ability of the MTS sector to attract finance.

A recommendation by the MTSAA, 2003 report: Strategic Leaders Group Report to Government is: To implement actions to raise the profile of the MTS sector with the financial community and to assist the sector to become more knowledgeable about investor options. This will be accomplished through the collaboration of industry with governments to develop initiatives to raise the profile of the MTS sector in the financial community, and increasing companies' knowledge and skills in, securing capital and government support schemes for commercialization.

### 3.3.4. Intellectual Property Protection

*Intellectual property represents the property of a person's mind or intellect. Types of intellectual property include patents, trade marks, designs, confidential/trade secrets, copyright, or circuit layout rights*. – IP Toolbox, 2001

Many Australian MTS companies may not be fully realising their competitive advantage because of inadequate utilisation of Intellectual Property (IP) protection mechanisms. In the drive to become more productive and to maintain competitive advantage, it is important that the sector understands its IP protection options, and works more effectively to fully exploit the value of IP from the MTS sector.

Reoccurring problems with the limitations of IP consist of the self monitoring of the way patented technology is used after ownership is confirmed, and the amount of detail present in the information available through patents. Nevertheless, IP Protection is vital for promoting innovation because ideas or expensive to produce but cheap to reproduce (TT and R&D Coordination Work Group, 2003).

It is a recommendation of MTSAA in their Strategic Leaders Group Report To Government that, action is taken to raise the level of awareness and understanding of intellectual property, to assist in exploiting the wealth of innovation within the Australian MTS sector, ensuring global recognition of innovative Australian MTS products and services. Action outcomes form this paper includes the collaboration with IP Australia to achieve:

- Assist in the development of intellectual property best practice management strategies for MTS firms; and
- Develop sector specific seminars on intellectual property which not only specify how MTS firms identify and protect intellectual property but explain in detail the various ways that intellectual property can be exploited (e.g., manufacturing, licensing, assignment and franchising).

### 3.3.5. Specialist Staff

Through the current economic environment that has led to short-term operational focused technology, there has been a decrease in qualified technical staff that are willing to undertake onsite development of new innovations and research limiting the uptake and acceptance of non-industry specific transferable technologies. There has also been a decrease of science, engineering and technology (SET) students in Australia's universities. These two aspects are anticipated to lead to a skills shortage in the near future.

All three SET discipline areas are necessary for innovation in the sector: science is the new discovery; technology is the process and machinery to put it into production; and engineering is the design work that makes it happen (Institute of Engineers Australia, 2001). The challenge is to raise the profile of the MTS sector, and promote the minerals industry as an attractive career option at primary, secondary and tertiary education levels.

The Mining Technology Services Action Agenda Education and Training Working Group have explored these issues and released recommendations in their Industry Issues Paper (2001). These recommendations are:

- Develop a mechanism to identify and address skills gaps.
- Increase the attractiveness of SET courses to secondary and tertiary students to provide the MTS industry with a greater pool of skilled Australian graduates.
- Increase industry awareness and uptake of the accreditation courses offered by the NMITAB and investigate the possibility for increasing the number of nationally accredited courses relevant to the MTS sector.
- Develop a mechanism to address the impediments facing private SME education and training providers in the MTS sector.
- To allow access to appropriately skilled international personnel to fill short to medium term shortages in the MTS sector.
- Enhance to image of the MTS sector to target high caliber people.
- Increase industry awareness of the benefits of providing a diverse, positive and open learning and development culture.

### 3.3.6. Access to Research Organisations

Collaboration with Government Funded Research Organizations (GFROs) and access to preliminary research conducted by GFROs is one such way in which a stable, enthusiastic and competitive foundation for innovative technology transfer will be established.

The Commonwealth Scientific and Industry Research Organisation (CSIRO) is one such GFRO that includes Mining Technology Services (MTS) to its portfolio of collaborative research aimed at increasing the competitiveness of the mineral resources sector in the global marketplace. The CSIRO’s R&D portfolio covers a variety of MTS sector products including, exploration, extraction, processing, mine site rehabilitation and safety. The contributions made by CSIRO increase the research capability of the mining industry and form alliances with MTS companies, universities and other GFROs.

Another concern considered to be allied with the access of public research organizations is the collaboration between mining companies and the primary buyers of MTS products. At the forefront of this collaboration is AMIRA International. AMIRA International is an independent association of minerals companies created to develop broker and facilitate collaborative research projects. AMIRA operates by developing and managing jointly funded research projects on a fee for service basis on behalf of members and companies.

# 4. Technology Transfer Modes

There are two modes through which TT can occur. The first is self initiation. This mode of transfer presents the technology to the user without assisting the user with its application, for example, an oral presentation or report. This is more commonly known as knowledge transfer and is generally termed ‘passive’ transfer. The use of passive transfer is more of a natural progression of the technology from one industry to another that relies on individuals who have some familiarity with the technology.

The second mode is ‘active’ transfer. In this mode the transferring activity goes beyond mere interpretation of the transmitted data and advises the potential user on how to apply the technology, or demonstrates the relevance of the technology to the perceived need. This can be through workshop demonstrations, onsite development or structured lessons designed to familiarize the potential user with the technology. The active mode of transfer is not solely reliant on individuals for its transfer as such but benefits from the involvement of industry partnerships.

The use of the active and passive modes of transfer is situational and depends upon a number of factors for the success of each mode, for example, the industry that the technology comes from, the type of technology that the innovation represents and the market that the developer is trying to sell the innovation in. Within Technology Transfer there are many aspects that make for a successful transfer. Each aspect has to be analysed and carefully considered to ensure that no process within the transfer is unexplored.

## 4.1. The Passive Mode

The passive mode is illustrated in Figure 1. Knowledge that falls into this category includes, how-to guides, manuals and cookbooks. From these information sources, many activities can be accomplished without any further input from the developer of the technology. This mode of TT presumes an elementary familiarity with the subject material and a level of competence in reproducing the information. This skill comes from practice under instruction and is termed by Mogavero and Shane (1982) as a technology transfer agent.

The passive transfer agent is heavily reliant upon this technology transfer agent that is more likely seen as the understanding, experience and level of skill of the individual. The results of this type of transfer are by no means the best examples of Technology Transfer and their success stories are rarely ever heard. This is mainly due to the fact that this mode of transfer is purely for the benefit of the individuals involved. The process of passive transfer involves the transferee searching for existing technologies, the results of which are limited in number and sophistication. Next is the resulting transfer which can only be described as basic at best despite the resourcefulness of the individual. The effort exerted to transfer the technologies in this mode of transfer far out ways the resulting transferred technology that can only satisfy a small niche market of equally skilled individuals.

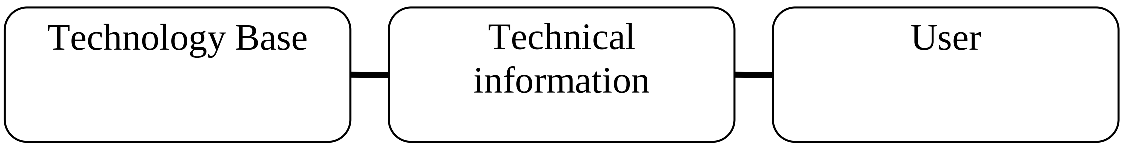


**Figure 1. Technology Transfer - The Passive Mode**

## 4.2. The Semi-Active Mode

In the semi-active transfer mode (Figure 2), there has been a move from self education and retrieval to a middle ground which includes the technology transfer agent that assists the user. The technology transfer agent in the case of the semi-active transfer mode has not gone beyond the role of a communicator that allows the user to remove unnecessary and irrelevant information to complete successfully their activity. An example of this may be a supervisor that assists the user in understanding the basic functions of the technology but allows the user to add to their already existing knowledge to properly use the technology.

The technology transfer agent is still passive and relies upon the skill of the user to complete the transfer process, however, the addition of an external information source, in this case, the transfer agent is a valuable addition towards the completion of the process. While the transfer process is still for the benefit of the individual who is completing the transfer, the success is greatly increased and somewhat more sophisticated when compare to the passive mode of transfer. The example of the supervisor is a good description of the technology transfer agent as it demonstrates that there is a strong base of knowledge and experience in the transfer agent itself but the level of assistance is minimal and only augments the user's abilities.

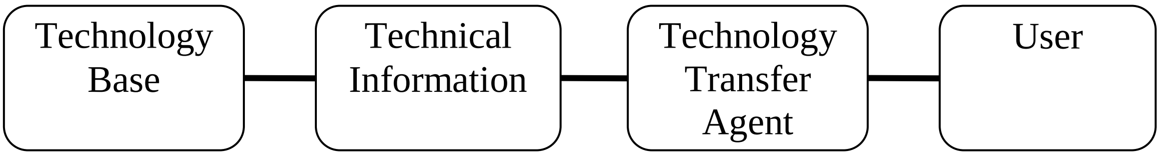


**Figure 2. Technology Transfer – The Semi-Active Mode**

## 4.3. The Active Mode

When the technology transfer agent has an active part in the application of technology, the next mode of transfer is said to have occurred. The active mode of technology transfer carries the process through to an actual demonstration as shown by figure 2.3. The technology transfer agent is no longer merely feeding information to the user and is an important role in this mode. This form of technology communication recognizes that words alone may not sufficiently communicate what is being transferred. In this case the technology transfer agent may be an entrepreneur or manufacturer who has a clear understanding of what it takes to complete a successful transfer of technology and satisfy the needs of the user. The active mode is the general, commonly occurring way in which technology is transferred.

Within the active mode of transfer there is a greater sense of purpose behind the transfer, there is no longer the benefits solely for the individual but a push to increase the number of people and processes that can benefic from the transfer of the technology. It is mainly the champion or the entrepreneur who acts as the technology transfer agent. While both the champion and the entrepreneur have different roles in the transfer process, they are equally enthusiastic and determined to see the completion of the project. This mode of transfer is the most common method for transferring technologies and by far the most successful of the three modes of transfer. Active transfers are generally large scale and carry industry backing and partnerships which want to see guaranteed results.

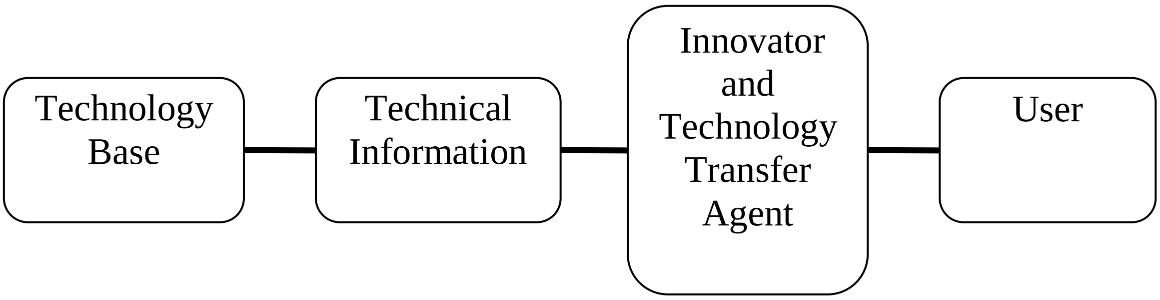


**Figure 3. Technology Transfer - The Active Mode**

# 5. Types of Technology Transfer

There are three recognized types of Technology Transfer. These are, transfer within the private sector, transfer in the public sector and transfer between the two sectors. Within each transfer type used by the different sectors there are subtle difference that have evolved over time to suit the requirements of the sectors, industries, individuals and problems to ensure that every transfer is successful. Each transfer type is unique and offers different ways to solve the transfer problems which results in different transfer outcomes.

## 5.1. Technology Transfer Within the Private Sector

In the private sector, problem solving is done in the hope of profit. This internal application of technology is the most common type of TT. Problems are identified and solved by an exchange of goods and services, ensuring that the perceived needs of the problem are met by the solution. This type of problem solving follows the Engineering Design Model with problems being recognized by customer requests, technical surveys or research and development people. This type of transfer is best described as active as it has the benefits of industry backing and partnerships to support the technology transfer process.

Within the private sector it is often a ‘pull’ that is associated with the solution of a problem, i.e. here is a perceived problem, what technologies are available to solve it. Often, it is the individuals involved with the project that will search for existing technologies to fulfill the user’s needs. However with transfers within the private sector it is more often the company’s involvement with research organizations and partnerships that fulfills the technology requirements for the project. Technologies that have been developed and transferred through this process are often strong, reliable and easily reproducible technologies.

Another transfer type that is seen in the private sector is the ‘push’ of technology, i.e. here is a technology, what problems exist that can be solved by its application. This is the inverse of the pull transfer type and is seen less than its counterpart within the private sector. The distinct differences between the two methods of transfer come down to the technologies ability to be transferred. While the benefits of some technologies are easy to see and easily applied to various situations, the benefits of other technologies are not so easy to apply. Both the push and pull methods are viable options for technology transfer within the private sector, however it is the pull of technology that the private sector favors. Whatever the type of transfer, the success of TT within the private sector is ultimately reliant upon the openness of companies to explore the worthiness and application of new technologies.

## 5.2. Technology Transfer Within the Public Sector

In the public sector problem solving is done to provide a service. These services are provided by, but not limited to, state and federal government organisations such as departments of fire, transport, education, police, environmental protection, and transportation. In direct contrast to the private sector, the public sector has less structured mechanisms and is rarely organized or funded to participate in the transfer of technology. Nevertheless, some amount of Technology Transfer still occurs within the public sector even if it is on a smaller scale when compared to transfer within the private sector.

The public sectors' ability to make technologies mainstream is limited at best thereby minimizing widespread use of the successful applications of technologies for the benefits of the communities and taxpayers in their respective areas. This is a key factor in the transfer within the public sector as it demonstrates the level of commitment and enthusiasm necessary from the parties involved to complete a transfer of technology. It also highlights the technology and the resulting products' need to demonstrate the ability of technology to solve the problem as well as a working model of the technology.

## 5.3. Technology Transfer Form the Public to the Private Sector

The transfer of technology from civil agencies is based on the desire to promote the welfare of individuals within industry and communities. Within the transfer process of technologies from the public to the private sector there are regulatory functions designed to monitor and give feedback on the current state of technologies within the Technology Transfer process. This is to ensure that a standard of quality is maintained during the transfer but also because these technologies have been designed publicly and then transferred into the private sector. Research organisations in this situation often move their technologies into the marketplace through a transfer process simulating a ‘push’ method. This push method is an attempt to find problems that require a solution and fit a technology to answer the problem

The push of technologies that have been developed within the public then transferred into the private sector is a common occurrence that is often seen in the context of Technology Transfer. It is quite common to see the transfer of technologies between these two sectors and partnerships between public and private organizations to develop technologies which bring together public and private knowledge and skills. The most prominent of the civil agencies that transfer technology to private industry are Department of Agriculture, Department of Mining and The Department of Defense.

Examples of technologies within these departments include the tried and tested person-to-person approach of the agriculture industry. This is seen through their trials and research into improved varieties and species of wheat, and sugarcane. The mining industry is another good example of Technology Transfer. By developing and transferring technology that has made the operation of open and closed cut mines safer for all who work in them. These types of transfers demonstrate the strength of the transfer method between the public and private sectors.

# 6. Literature Review

This aim of this project is to investigate the technology used in the mining industry and to suggest other industrial fields which could benefit from its use, as well as identify non industry related technology and suggest its further adaptation and innovation in the mining industry. To accomplish this, an initial literature review was conducted that focused on those technologies that were in the design stage, being implemented and had been in service for a number of years. Through this research some interesting but common opinions on fields of research arose. For the purpose of this appreciation, these research opinions will be known as 'findings', and they can be categorized into:

- Technology needs to be introduced earlier to promote awareness and acceptance.
- Technology transfer is a result of trade agreements with developing countries.
- IP protection is essential for securing new technologies.
- Technology Roadmaps are promising approaches to the application of new technologies into industries.

## 6.1. Initial Criterion

For this literature review, research was focused on technology that is used in the mining industry whether it was an innovation from within the industry itself or one of its related fields. It also focused on innovations from industries other than mining and its related fields. The purpose of this was to distinguish between and report on technologies that were specifically designed for a particular purpose/industry and technology that has been transferred from one industry to another.

Similar industries to mining were defined as mineral exploration, mineral processing and mining and mineral tools and technology. Industries that were defined as unrelated include but not limited to, computer modeling simulation software, health and safety, civil engineering, material handling and the environment. The areas that will be covered in the literature review will be varied and diverse due to the fact that coordinated research often focuses on broad based scientific disciplines. This means that while a technology has been researched to solve a specific problem the resulting technology

may be transferred to many other applications. It is an aim of this literature review to find such TT and document their successes.
Another of the aims for this literature review is to find what new technologies are currently being used, what is being implemented and what is in the design stage. Ideally, for this to occur, the geographical coverage would not be limited to Australia. However to limit the scope of the technology and to make the research relevant to a local market and industry the scope of this review shall be restricted to Australia. Though, exported innovations will be included within this review.

Another limiting factor for this report will be the time in which these innovations are to be taken from. The year from which technological innovations are to be included from will be limited to no later than 2002. The reason for this is to find and deliver the most recent, cutting edge technology while still allowing for some innovations that have encountered difficulties in the implementation stage.

**Finding 1: The Awareness and Acceptance of New Innovations**

It can be said that Australia's current attitude towards innovation is more focused on short-term, operational focused, off-the-shelf style technology that leaves little or no room for the trial of a new technology or innovations. It can also be said that Australia is slow to realize the benefits of a new technology developed on its shores and only recognizes a technology after it has achieved success overseas. While raising awareness of specific technologies has always been an issue for the inventor, few have done more than the Australian Government to promote technologies and innovations. The literature in this finding mainly consisted of Government Action Agendas and reports. These reports focused on Government Programs that are specifically designed to expose new technologies and raise the level of awareness of the industry.

There is a lot of research on technologies and innovations that are going unnoticed, in particular, research by Small to Medium Enterprises (SMEs), universities and public research enterprises. The problem is not the technologies, but the knowledge by the institutions on how to properly market their technologies. Initiatives to assist with the uptake of new innovations by the Australian Government include COMET, R&D Start and CRC Programs. These initiatives assist innovators by giving advice, skills and knowledge to plan their path to commercialization. These initiatives foster innovation by promoting long-term strategic links and collaborations between researchers, industry and government, turning Australia's scientific innovations into commercial successes.

While having a path that innovators can follow to commercialization is good, it is only one of the factors needed to allow for complete market coverage. Another factor is sponsorship or grants. Sponsorship of a product assists with research of an innovation to seek additional capital for their project and establish strategic partnerships to take their innovation to market. Commercial Ready and AusIndustry's Innovation Fund are examples of programs aimed at sponsoring innovations. These are venture capital based programs that assist with the development of new technologies with early stage venture capital investing. The Department of Industry and Tourism's 2005 study on SMEs receiving innovation grants confirmed that there were improved rates of commercialization due to firms or financiers invest in Australian SMEs that have developed an innovative product with strong market potential. Thus, in turn, attracting foreign investment or the interest of an international company which according to current opinions is regarded as a sign of success.

**Finding 2: Trade Agreements with Developing Countries Promotes Technology Transfer**

Technology Transfer is defined as the transfer of knowledge relating to scientific and technological developments. These developments are not necessarily new, but include the use of already existing technology to new uses or even to nations, areas or users where the particular technology has not been previously known or utilized. This type of technology transfer is common in third world countries and occurs through the integration and recombination of small bits of information obtained from diverse sources and put to new uses. The most surprising aspect of this form of transfer is that it relies heavily on people as opposed to agencies and government initiatives.

There are selections of these transfers that occur many times over in a variety of different countries. Some of these are, the reuse of waste materials for buildings, efficient crops and farming methods, bio gas harvesting methods and other health and industrial practices. Mogavero and Shane (1982) discuss several opinions and observations of this particular type of technology transfer which have important bearings on any attempt to organize the transfer of technology to developing countries. From these discussions, a list of important factors that needed to be included in the transfer processes was established. Such process would include:

- Screening of technologies for relevance and appropriateness,
- Modifying the technology to suit local conditions, including social, political and cultural,
- Implementing the project in physical terms.

The factors listed above would no doubt assist with the transfer of technologies and innovations. By relating the technology to the specific demographic and taking the technology though to a physical working model, the acceptance of technologies within developing countries would increase greatly. The above factors could also be included in the engineering design model to fully encapsulate and define a new working model for this type of transfer.

**Finding 3: IP Protection is Essential for Securing New Technologies**

All of the literature reviewed for the initial survey listed IP protection as one of the key processes that can assist with the sustainability of the Australian MTS sector. The retention of research and technologies by all Australian industries and in particular SMEs is a key factor in the success of the MTS sector and its related fields.

The retention of innovations and technical data is critical for any industry however, it is even more important for the mining industry due to its high volume of technologies that are developed within its minerals exploration, extraction and processing service industries. With the high number of exported technologies being researched and developed within Australia, it is important to actively maintain ownership of technologies, even intangible or ‘softer’ innovations. The Working Group on Managing Intellectual Property (2000) found that alack of understanding by Australian firms, particularly by SMEs, about the value of intangible assets within their businesses. The lack of strategies for measuring, managing, protecting and commercializing intangible assets were considered impediments to innovation and denied them the ability to reach their economic potential.

It is only through education and continual assessment of individual companies technologies that an understanding of the real value of technologies, whether they are tangible discoveries like machinery and equipment or softer technologies like services and processes. IP Australia (2005) suggests that intellectual property is a business asset, and an integral part of the business process. It is as important to commercial success as business strategies, marketing and financial planning. Many smart businesses identify and value their IP, listing it with other assets on their company balance sheet.

IP protection is an issue for all industries that deal with high volumes of designs and processes. Through better management of processes to ensure the ownership of innovations for secured periods of time and education as to the importance of IP protection for all technologies, it is hoped that there will be security for Australian innovations creating a broader range technologies for the mining industry to trial and develop.

**Finding 4: Suggested Approaches to Technology Transfer**

While no two technologies are the same, the way to commercialization for technologies is never the same. A commercialization method that worked extremely well for a particular technology may give limited results when applied to another technology. From the literature reviewed, there were a variety of ways to successfully implement technologies into the mainstream market, from the tried and tested ways of transfer of technology, to a more natural, uninitiated progression. Whichever method is used, each success paves the way for future uptake of new innovations ensuring further diffusion of technology.

The tried and tested method starts with the Engineering Design Model. That is, recognition of a need, engineering the design, search for existing technology, concept to a working model, fabrication and demonstration of a working model. Other techniques for the commercialization of the actual innovation commence after this process, however Mogavero and Shane (1982) suggest steps of successful TT that occur within the Engineering Design Model. The inclusion of a champion is one of the first steps suggested by Mogavero and Shane and secondly is the selection an entrepreneur.

The role of the champion within the context of the project is to motivate, keep the project heading forward and more importantly, make the necessary adjustments to make certain the project moves forward in the right direction. The champion must be enthusiastic about the project not to mention have some familiarity of the technologies involved. This is why the selection of a champion is different for each technology. Each project's needs are different and the champion must be chosen to meet the specific needs of the project. The addition of a champion to the design process is a valuable addition to the project's resources. The champion may also act as a team leader or consultant for the project.

While satisfying a need does not guarantee use of the product, the addition of an entrepreneur is a step towards a rectifying this problem. While it is the champion who brings the technology to the marketplace, it is the entrepreneur who makes the most significant contribution by taking the technology *into* the market place. The entrepreneur brings people, money, production facilities and knowledge together to create a commercial entity that did not exist before. As the champion if tailored specifically to the technology, so is the entrepreneur is tailored to the desired market. The motivation behind the entrepreneur is the hope of gain, while the motivation behind the champion is a combination of social and professional satisfaction.

Another approach to commercialization is Technology Roadmapping (TR). Technology Roadmapping is a combined initiative of the Australian Government and Industry to develop methods to successfully transfer research and innovations within a specific industry. It is an industry-led planning process to identify future products, services and technology's needs to evaluate and select the technology alternatives to meet them. Technology Roadmapping is industry specific commercialisation process that involves partnerships between research organizations and industry and on-site development. Technologies that are involved in this type of process rely upon the previous successful implementation of technologies for its own success.

The results of the technologies for this literature survey were mainly concerned with successful TT. While successful technology transfers are a valuable resource that allow for the analysis of the process and continual iterative processes to further the TT process, unsuccessful transfers are also a valuable tool. They define tolerances and boundaries within the transfer process that allows for a greater understanding of methods for transferring specific technologies. While every technology has its ups and downs within the transfer process, there were no drastic and complete failures that could be found to compare results with.

## 6.2. Secondary Literature Review

From the initial literature review that was orientated around the awareness, protection, modes and types of Technology Transfer, there were ideas within these topics that provided some insight into the nature of successful technology transfer. A secondary literature review was then conducted to explore these factors that assist with TT. While no findings were derived from this research, a list of successful technology transfer factors was determined. It was anticipated that findings from this proposed research would be able to contribute to the body of knowledge in firstly, identifying key areas of the mining industry and factors that make TT successful, and in turn, develop an interactive exchange method for successful technological dissemination.

### 6.2.1. Secondary Criterion

The factors that were determined by the secondary literature review form part of the Technology Selection Criteria (TSC) for this project.  The TSC is a scale rated method for determining the viability of technologies that were selected from the initial criterion which determined the scope of this project. Further detail on the TSC can be read in section 9, Technology Selection Criteria. The main factors that form TSC include:

- Success of the technology in the market place.
- The ability of the technology to meet developer and consumer needs.
- The ability/success of the technology to be transferred.
- The relevance of the industry.

**Factor 1: Success of the technology in the market place.**

The success of a technology within a specific market place is difficult to judge. There are many factors that need to be considered before a realistic assessment can be made. For instance, is there a need for the technology? Does this specific technology meet consumer and or developer needs? Is the market flooded with similar products? What market will selling the innovation?

The answers to these questions are difficult to gauge, especially through a review of literature on what the innovations do and how they are revolutionizing the mining industry. The only real way to determine the success in the market place is through the creators and respective industries that these technologies represent. It is the opinions of the people who have worked with the project that is the real and only way that the success of a technology in the market place can be gauged.

**Factor 2: The ability of the technology to meet developer and consumer needs.**

The ability of the technology to meet developer and consumer needs is also a factor that determines the success of the technology in the marketplace. This is because this factor is important in measuring the technology's marketplace success and is the foundation for its ability to be transferred. The significance of this factor is that while a technology is developed to solve a problem or make a process easier, the way in which the innovation achieves the end result is always under the consumer's scrutiny. For the technology to meet the consumers and developers needs, firstly there must be a product that achieves a result and secondly, there must be an underlying familiarity with the technology or an easy learning process if the consumer is going to consider the products use.

A starting point in this factor is the commitment and analysis of the users needs. There must be a firm statement of need, followed by clearly stated boundaries for acceptable solutions. The user must also be committed to remain actively associated within the development and even the transfer if the project is to be successful. Through this user and developer relationship an innovation that satisfies both consumer and developer needs can be developed. However, this process occurs more when a company is developing a product for a customer with a specific problem as opposed to the development and transfer of a product to the general consumer market.

**Factor 3: The ability/success of the technology to be transferred.**

This factor relies on the technology itself for the success of the transfer. Innovations that reduce the users working time, rely on fewer inputs by the user and offer more functions than other products will be more successful in the marketplace despite the transfer process used. The successes of technologies in this category pave the way for newer versions of the technology creating a niche user market in which consumers will actively seek out technologies that build upon tried and tested technologies.

**Factor 4: The relevance of the industry.**

This factor takes into account the industry that the technology is being transferred to and from as an aspect for the success of technology transfer. For this project, the relevance of the industry was a consideration for the selection of the final technologies due to availability of technologies that were being researched. The research concluded that technologies that were transferred between similar industries have the most success where as technologies that are transferred between dissimilar industries are seen to have more difficulties. However, this is not always the case.

Technologies that are transferred between similar technologies are somewhat generic in nature with software, procedures or processes classified into this category. While it is sometimes the technologies themselves that afford this ease of transfer through their basis in a broad base of technological research, it is also the backing of the industry that supports these technologies and pushes them into the spotlight. With transfers between dissimilar industries, the difficulties experienced include the lack of knowledge about the technology and the unwillingness of the consumer to try a different product. There are a range of technologies that fall into this category and often rely upon spokespersons to convince others of the technology's worth.

# 7. Technology Transfer Example

The following is an example of technology transfer. It details how a technology was developed and transferred to solve a problem given the modes, types and methods of transfer from the literature reviewed. This transfer process follows Flotation Optimisation Methodology which was developed by a government funded research organisation, the CSIRO. Flotation Optimisation Methodology is a relatively new technology which the CSIRO has developed and adapted to more easily separate arsenic from copper ore, promising significant potential economic and environmental benefits.

The transfer of technology exists in this process through the development of the technology to solve a problem within the private sector. This is seen through the development of a computational fluid dynamics model that determines the effect of cell design and operation conditions on flotation performance. The CSIRO's researchers have developed the first CFD model that determines the effect of cell design and operating conditions on flotation performance. The CFD model calculates the effect of cell design and operating conditions on hydrodynamics of the slurry, bubble distribution and bubble size. It achieves this through design features that affect the flotation process. These features are (CSIRO, 2006),

- impeller and stator design The CFD model calculates the effect of cell design and operating conditions on hydrodynamics of the slurry, bubble distribution, bubble size and tank geometry
- operating variables including;
- slurry concentration
- aeration rate
- Impeller speed.

This information is then used to determine bubble-particle attachment rate and flotation cell performance factors. This means that the model has more mechanisms allowing for more prediction of the actual results than other models of flotation. The model was developed as part of AMIRA projects P780 and P780A. Project 780A is a research collaboration between AMIRA and CSIRO which builds on the successful results of the computational fluid dynamics and experimental work carried out by CSIRO. The new models being developed will dramatically increase the understanding of flotation cell hydrodynamics, potentially allowing the sponsoring companies to achieve large savings in operating and capital costs.

The benefits include the detailed hydrodynamics provided by the CFD model which is useful for understanding batch flotation test results and for the design and operation of larger flotation cells. Applying computational fluid dynamics (CFD) technology to the flotation process has the potential to identify design and operational modifications which could result in significant improvements in:

- Copper recovery
- Energy consumption
- Capital utilisation.

The flotation model has recently been used to optimise the level of turbulence required for bubble-particle attachments in slimes and coarse particle flotation. Applying CFD technology to flotation processes allows researchers to identify potential process improvements for the treatment of various ores including nickel and copper. The flotation process developed by the CSIRO can more easily separate arsenic from copper ore, promising significant potential economic and environmental benefits.

The problem is that arsenic occurs at varying levels in some copper ore bodies, and is a significant environmental hazard in the copper smelting process when emissions are released into the atmosphere. The arsenic in the ore is contained in copper-arsenic sulphide minerals, such as enargite and tennantite. This is important to the Australian mining industry because Australia ranks fourth in the world as a copper producer, with six per cent of world production, after Chile (35 per cent), the US (ten per cent) and Indonesia (eight per cent), (CSIRO, 2006). In Australia, mining companies delivering copper concentrates containing high levels of arsenic to smelters are subject to substantial penalties, making some copper ore deposits economically unviable.

CSIRO researchers have discovered that variations to the chemical flotation process widely used at mine sites to produce copper concentrates enable a much easier separation of arsenic from the copper ore. Early removal of arsenic avoids dispersing such toxic elements through downstream processing of concentrate. The standard flotation process involves copper ore being ground and made into a slurry, which is mixed with various chemicals. By pumping oxygen through the mix, the copper concentrate rises to the top and is then scraped off. CSIRO’s development involves using electrochemical processes during flotation. By studying individual copper minerals’ flotation behavior, including the copper-arsenic minerals, the CSIRO team has identified several electrochemical windows in which it is possible to selectively float copper-arsenic minerals from other copper minerals.

This produces a much purer form of copper concentrate, with low arsenic content, that can be supplied to smelters. The process involves some changes to existing chemicals used in the separation process. It also involves possible changes to the flotation gas, such as the use of nitrogen instead of oxygen. This method is a cheap solution to a problem that uses an already existing technology to create a solution. If a company already had a flotation process, then this wouldn’t be that difficult to implement within the existing system.

Flotation Optimisation Methodology developed by the CSIRO in conjunction with AMIRA fulfils the requirements of technology transfer by firstly being a public to private transfer. This is seen through the nature of the research organisation and the intended user of the developed product. Secondly is the type of transfer. This is counted as an active transfer due to the sponsors funding the project. The sponsors of the project were Anglo Platinum; Outokumpu Technology Pty Ltd; Rio Tinto Limited and WMC Resources Ltd.

Other factors from the research that indicate the success of this transfer of technology include access to GFRO by companies, partnerships in developing technologies and the overseas market potential of the technology. High arsenic levels in copper concentrates are not a unique problem to Australia, which means the technology, has global potential. The level of arsenic varies on the copper deposit and there are other places around the world which have similar problems.

# 8. Methodology

Due to the nature of the project there were a few guidelines that were created to assist with the sorting of the vast amount of literature that was researched. These guidelines were the boundaries for the various methodologies employed within the project. Through the searching of information and technologies the methodologies were continually revised with the gain of new information. Detailed in the following chapter are the final revisions of the methodologies employed in this project.

## 8.1. Related Industries

As described in the literature review, section 6.1 similar industries to mining were defined as mineral exploration, mineral processing, mining and mineral tools and technology. These areas were the main focus for the related industries and were apart of the scope and initial criterion for the selection of technologies. While these boundaries are quite broad, they encompass a large amount of the current technologies. Some of the areas of research that fell within the boundaries included:

- Communications Systems and Equipment
- Control and Automation Systems
- Crushers, Breakers and Grinding Mills
- Drilling and Blasting
- Hydraulics and Electromechanical Equipment
- Mine Data and Resource Management Software
- Power Supply, Engines, Transmission and Drives
- Pumps, Compressors, Valves and Actuators
- Survey Systems and Equipment
- Tunneling Systems and Equipment

These are only a few of the areas of research that were discovered through the research for the project but by no means do they exclusively represent the mining industry as a whole. The initial boundaries of exploration, processing, tools and technologies were chosen as related technologies because of their ability and actual likelihood to be transferred between similar industries. This comes back to the aims of the project which was to find technologies that are used in the mining industry whether it was an innovation from within the industry itself or one of its related fields. This means that for a technology to fit into the related category, it has to be transferred within an industry or be transferred from within the boundaries that have been outlined. Therefore it is essential to define the related industries so that technologies of this nature can be found, assessed and reported upon.

Another reason these specific research areas were chosen as boundaries for the related industries, was because of the findings from the initial literature review, more specifically the modes and types of Technology Transfer. From these findings it was determined that there were certain technologies within Technology Transfer that were more susceptible to specific situations than other technologies. These were active transfer, transfers within the private sector and to a lesser extent transfers from the public to private sectors. These situations promote the transfer of technologies to other fields that have been defined as ‘related’ more so than to any other factor. Through these assisting factors and the aims of the project the research and defining of related technologies was guided to the listed outcomes for related technologies.

## 8.2. Unrelated industries

Industries that were defined as unrelated were defined as, but not limited to, computer modeling simulation software, health and safety, civil engineering, material handling and the environment. While some of the areas that are listed for the initial literature review could be considered closely related to the mining industry, they were simply a starting point so that research could be conducted. Throughout the research an understanding of the types of technologies and transfers that occur was recognised and a new set of boundaries was established. These areas were chosen due to the possibility and the technologies likelihood of being transferred. Some areas of research that came from the new set of boundaries include:

- Abrasion Resistant Materials
- Chemicals and Reagents
- Flotation, Agglomeration and Filtering

- Steel, Special Metals, Plastics and Welding
- Workshop Equipment, Consumables and Lubricants

Once again, these are only a few of the areas of research that were discovered through the research for the project but by no means do they exclusively represent the mining industry as a whole. The choosing of unrelated industries comes back to the aims of the project which was to find innovations from industries other than mining and its related fields. The purpose of this was to distinguish between and report on technologies that were specifically designed for a particular purpose/industry and technology that has been transferred from one industry to another. This was done through an initial, brief set of boundaries to define and gain an understanding for these unrelated industries, then through a definite set of boundaries which resulted in the technologies included in this dissertation.

The new boundaries were established through the initial literature criterion and research into available technologies. The scope of the new boundaries included the modes and types of transfer as seen in sections 4 and 5 of this report. As with the factors that effect the related industries, these specific situations which promote the transfer of technologies between unrelated industries include the passive and semi active modes of transfer and the transfer within the public sector. As well as setting the boundaries for the selection of technologies, the factors affecting the boundary conditions acted as a guide in the searching and selecting of technologies. By knowing the situations behind transfers between unrelated industries the fields of research were shortened allowing for another important aspect to be considered.

This important factor in defining the new boundaries for the selection of technologies was the relevance of the technology and the industry. While it is great to have examples of technology transfer from industries that are completely unrelated to the mining industry, the relevance to the overall project in reporting on these technologies was taken into consideration. Industries of this nature include:

- Medical / Pharmaceutical
- Film Industry.
- Printing
- Fashion.

While there are relevant examples of technology transfer within the Medical / Pharmaceutical and printing industries, finding definite examples was a difficult task. The fact that these technologies had been transferred was an exciting prospect as it would add an interesting perspective on the Technology Transfer Model, however, in regards to the overall scope of the project, industries such as fashion and the like, would be insignificant and irrelevant to the project. Therefore the relevance of the industry was carefully considered when the technology and industry was compared to that of the mining industry and its related fields.

## 8.3. Criterion for selecting final technologies

Since this project is a literature review, the findings presented in this project will be purely from the reviewed literature. It can also be said that the literature findings from the initial and secondary review and in conjunction with definitions on the industries and technology transfer, also the methods used to search and select the technologies all have a position that may affect the final outcome of this project. The effect that these factors will have on the project will include the information that is presented in this report and on the selection of the final technologies. The result of these factors will be subtle and while not ultimately effecting the project in an adverse way, the inclusion or exclusion of an information source or technology may position the report one way or another.

While a literature review is a reliable way to find out about the factors effecting technology transfer and ways that technology is transferred, it is somewhat lacking in the ability to answer the questions for the final selection of technologies. To fully understand the factors that are listed as a criterion for the selection of the final technologies, section 6.2.1, it is necessary to gain the opinions of the creators and respective industries that these technologies represent. It is only through the opinions of the people who have worked with the project that the success of a technology in the market place can be gauged.

To gain these opinions a survey was designed and sent to a variety of industries involved within the mining industry, more specifically CRC Mining Australia and to the developers of the final selected technologies. It was hoped that this survey would reveal some insight into the thought and industry opinions on technology transfer and offer another level of real experience when the technologies were selected and judged. The results and nature of the survey will be discussed later in section 8.7.

## 8.4. Literature Sources

During the literature review and technology search there were a lot of different information sources that were utilized. Each source of information had its benefits for specific parts of the project. Initially hard copy trade magazines at USQ's library were used. This was a good starting point to gain an understanding and an awareness of the types of information and technologies that could be contained in this dissertation. A library search was also conducted at this point in time to assess the library's depth of information and built a glossary of terms that would define the projects scope and aims for later database searches. Once the review of the hard copy magazines was complete, continuing online copies were used. The online copies of the trade magazines were not as detailed as the hard copies and only contained a few articles per issue. This proved to be ineffective so an online information search into the glossary of terms was attempted.

The search into the glossary of predefined terms lead to some interesting books located at The University of Queensland and James Cook University. The catalogue of each library was then searched with inter-library loans in mind. While there was a lot of information within the libraries of each library on the Mining Industry, there was limited information on the actual transfer of technologies found during the literature searches. At this stage the online databases, available through the USQ's library website, were used to perform greater detailed searches into the glossary of terms and technologies that fulfilled the selection criteria. Having a great deal of information on technology transfer, the finding and sorting of technologies for this project began.

A variety of sources was noted during the initial search and then was reused for the finding of technologies. These include the hard copy and online trade magazines, e-journals and the various databases. These sources proved valuable in providing technologies for selection however, there were some specific areas that were difficult to find technologies to exemplify. To find these technologies a search of patents was utilised. The search of technologies using this method was a difficult undertaking that took vast amounts of time resulting with limited success.

## 8.5. Research methods

The majority of the information gathered for this report is focused on the Australian Mining Industry. This includes the technologies that were selected to represent the industry. Though, it is not the technologies that are the ultimate goal of this project. The main focus of this project is to report on the technology transfer methods and their success within the Australian mining industry using technologies to exemplify the modes, types and methods used in the transfer process. Having said that, there were certain types of technology transfer modes that were difficult to exemplify through the selection of technologies. Technologies from the Mining Industry that had been transferred to other industries were one such example of this.

It is understandable that there is a lot of secrecy surrounding the development of new innovations. Withholding technologies until legal rights to technologies and patents are secured is essential for the companies that develop the innovations and for the industry. Due to this, the information available on desired technologies which did show promising technology transfer methods was limited at best. This information was restricted in the ways the technology achieved its end results, but did show some hints of the processes involved in the transfer and promised some hope in the methods to come from this. If future work is conducted on this project it is hoped that through better research methods the full process used to transfer the technologies is obtained.

Another problem encountered during the research of innovations was the inclusion of oil and gas technologies examples, as well as the lack of the technology transfer types, modes, methods of this sector. The exclusion of information from this sector was not intentional but simply due to the lack of information found during the research stage of this project. This is because the MTS sector does not include the exploration, extraction and processing of gas and oil. The responsibility of these resources falls under the, Australian Constitution which ensures that the development of petroleum resources is shared between the Commonwealth Government and State and Territory Governments.

To obtain information relating to this sector a better research method would have to be employed in the future.

## 8.6. Survey

The survey used in this project was an attempt to assess the technological needs of the Australian Mining Companies as well as gather information on government support and research organisations, IP Protection and Technology Transfer within the Australian Public and Private Mining Sectors. It was hoped that the use of an industry survey would assist in the gathering of industry opinions on a broad range of topics to assist with the selection of technologies through the technology selection criterion. It was also anticipated that the survey would add to the quality of content contained in this report by adding to area of information that needed industry opinions and backing technologies to make strong arguments for the successful transfer of technologies.

The scope of the questionnaire was aimed at a select number of companies. The reasons behind this include the timing of the survey and willingness of companies to complete the survey. The survey was only developed after some consideration was given to the means by which the final technologies would be chosen and since this project is mainly focused on the findings from the literature review, it is secondary to the overall project. The ways in which the technologies were chosen up to the development of the survey relied upon the technology being rated against a list of factors that were determined to be critical for successful technology transfer. With industry opinions it was hoped to have better insight into how the selected technologies met this criterion. One limitation of the survey was the limited time needed to develop, critique and implement a successful and thorough outcome.

The other reason as to why the survey was sent to a limited amount of companies was the willingness of the individual to complete the survey. This factor was critical in the development and success of the survey. Most of the topics included in the questionnaire were orientated around a management level of understanding and knowledge of the company’s involvement with the associated topics. So the possibility of getting people of this nature to complete the survey was optimistic at its very least. That is why a limited number of companies who were involved with the topics in the survey were chosen. By surveying companies who had the experience with the associated topics it was hoped to receive clear industry knowledge that would help with the project and selection of technologies. While this was considered a good approach at the time, the sending of the survey to a limited number of companies could have a double sided effect. If most of the companies that the survey was sent to responded to the survey than a reasonable amount of information could be derived and reported on, however, if only a few companies responded than the results would not be able to positively add to the project. Companies that were sent the survey and the reasons why are detailed in the following table.

| Company | Reason for Including Company |
|---|---|
| Peabody Pacific Pty. Ltd. | Peabody Pacific is one of Australia's largest mining companies; it is also the world's largest private sector coal company. It was hoped that a range of innovative technologies would be gained by surveying Peabody. |
| Anglo Coal Australia Pty Ltd | Anglo Coal was surveyed due to its involvement with CRC Mining Australia. A perspective on a company's involvement with a CRC was anticipated from the survey. |
| Theiss | Theiss is an integrated engineering and services provider. Theiss was surveyed for its perspective on development and protection of 'softer' technologies. |
| New Hope Coal Australia | New Hope Coal was surveyed for its locality of its open and closed mines. Issues effecting local industry was hoped to be gained from surveying New Hope Coal. |
| Komatsu Australia | Komatsu Australia was surveyed due to its involvement with CRC Mining Australia and due to the range of technologies developed by Komatsu that were found during the research stage. |
| JK Tech | JK Tech was surveyed for its involvement with government support and sponsorship. A perspective on the government support facilities as hoped to be gained by surveying JK Tech. |
| RME | By sending a survey to RME it has hoped to gain an understanding of a local company's involvement and understanding of the range of topics covered in the survey. |

**Table 1. Selected companies for the survey.**

There were many aspects that go into making a successful questionnaire that ensures the user will want to complete the questionnaire and that appropriate answers are gained through the use of the questionnaire. The intended audience was the first step. Careful consideration was taken to ensure that an appropriate audience was chosen. An audience that knew about the topics listed in the survey and had some knowledge to offer towards the technology transfer model was essential if appropriate responses were to be received. That is why an interesting survey with well researched questions and a flawless presentation that will entice the respondent is required.

The nest step in making the questionnaire was the selection of topics to include. As well as the opinions as to the technology selection criteria, a few topics were chosen to get an industry perspective and gauge the industry's use of these services. The first topic was government support. The inclusion of government support in the survey was a necessary inclusion because the amount of literature researched that indicated it as a key factor in technology transfer. The question in the survey on government support included the use of support programs, access to public research organisations, involvement with CRC programs and an evaluation of the government support by the respondent.

The next topic included was Intellectual Property Protection. The aim of questions in this section was focused on the patenting of technologies, the technology that was patented, the method of the patenting process and an evaluation on IP Protection. IP protection and the securing of assets was also listed as an important factor in the technology transfer process so the attitudes of Australian companies and individuals of management level were significant to the assessment of IP within the technology transfer process. The views of the respondent to all of the topics in the survey are of considerable weighting due the position held within the respective companies. The survey was aimed at upper management due to the nature of the topics and questions included and was hoped to be a valuable resource in gauging industry trends towards certain services and processes.

Technology innovation, technology transfer and the technology transfer process were the next sections that were included in the questionnaire. These sections focused on the technologies employed at the respondents companies that were most relevant to the mining industry, the use of transferred technologies and the transfer of technologies by the company, and the processes used to transfer the technology. The purpose of this section was to gain an understanding on the types of technologies used in the respective industries and acquire a feel for the amount of technologies that are being transferred within the sectors and chosen companies. The last topic included in the questionnaire was technology road mapping. Technology road mapping is a combined initiative of the Australian Government and industry to develop methods to successfully transfer research and innovation within a specific industry. The Mining Industry has a Technology Roadmap called, The Mining Technology Roadmap for CRC Mining Technical Advisory Panel. It covers methods to commercialise technologies for large and small to medium enterprises and a rage of services and support processes to assist with the commercialisation of technologies. While it does not cover technology transfer process, methods and procedures could be developed from the information set out in this report.

The last step in making the questionnaire was the level of open-endedness of each question. Within each section it was important to position the question correctly. The questions were positioned in accordance to their level of importance and the intended responses that were desired from the questionnaire. This means that for certain questions a scale rating system was used, while for other questions short responses were required. The balance of open-endedness of each question was discussed with my supervisor to ensure that appropriate guidance was supplied for each question and relevant answers were gained from the respondent's answers.

## 8.7. Survey Results

The success of the survey was limited at best. There was limited number of response received for the survey and result received were too general with most sections lacking answers. The tabulation of the results has been omitted for these reasons. Causes for the poor performance of the survey have been defined and include,

- Time frame of survey,
- Methods used to circulate the survey,
- Number of surveys circulated, and
- Companies selected to complete the survey.

The time frame for the survey was 4 weeks. This was set to coincide with the presentation seminar so that results could be tabulated and used in the presentation. It was estimate that this was adequate time for the completion of the survey however it cannot be said if this was a factor in the poor performance of the survey. It is believed that the main factor that affected the survey was the methods used to circulate the survey. The survey was circulated to the chosen companies with no definite person to complete survey in mind. To ensure that a questionnaire is completed or at least to give it the best chance, the questionnaire must be personalised with a specific individual and even company in mind. Also there must be contact with the intended respondent to ensure the willingness to complete the survey or if not respondent is initially found there must be follow up to see if there is a willing applicant to complete the survey.

Improvements can be made in regards to the companies selected to complete the survey. While the style of company selected was good i.e. involved with CRCs, research organisations and government support, the number of companies and a broader selection would be necessary for future work. The limited number of surveys sent out was a factor in the success of the survey. While a limited number of surveys was sent out due to time constraints, the reality is that the more surveys sent out means the possibility of more surveys filled out and received. There are many improvements that can be made in regards to the survey and the ways that it was circulated and the amount of time given to complete the survey. Nevertheless, the survey was a valid attempt to gain a sampling of opinions by individuals of management level experiences within the Australian Mining Industry.

# 9. Technology Selection

Within the literature presented in this report, there has been a variety of factors listed that help to improve the transfer of technologies. These factors have been taken from an assortment of reports, technology transfer methods and from the technologies themselves. Within this chapter a hypothesis for a model will be discussed which combines all of these factors together to create a Technological Dissemination Model. This model will build upon previous examples and suggest more additions that may be includes in future models.

## 9.1. Technology Roadmaps

A Technology Road map is a practical planning and communication tool where future needs are identified and a series of potential future directions are defined for the project. The interaction of a Technology Roadmap within the context of a project places a strategic rather than tactical emphasis on the interaction of individuals, companies and resources that are available to complete the project. The use of a Technology Roadmap is beneficial to the project however, like all project plans it needs to be updated regularly to reflect changes in business environment and new emerging and enabling technologies. By doing this, alternative paths to avoid delays in the completion of the project are identified and can easily be avoided. Technology Roadmaps offer a range of benefits. These include (RMDSTEM, 2006),

- A practical strategic planning and communication tool,
- The ability to balance short term needs with long term vision,
- Align individuals within the project and highlights critical issues and competencies.

The inclusion of a Technology Road map within a project offers another level of planning and resource management that can assist with the completion of a project. This is achieved through the benefits listed above. The nature of any two roadmaps is never the same as each is tailored to meet the specific need of the industry and project.

As seen in the following figure there are a broad range of categories as to how Technology Roadmaps are classified.

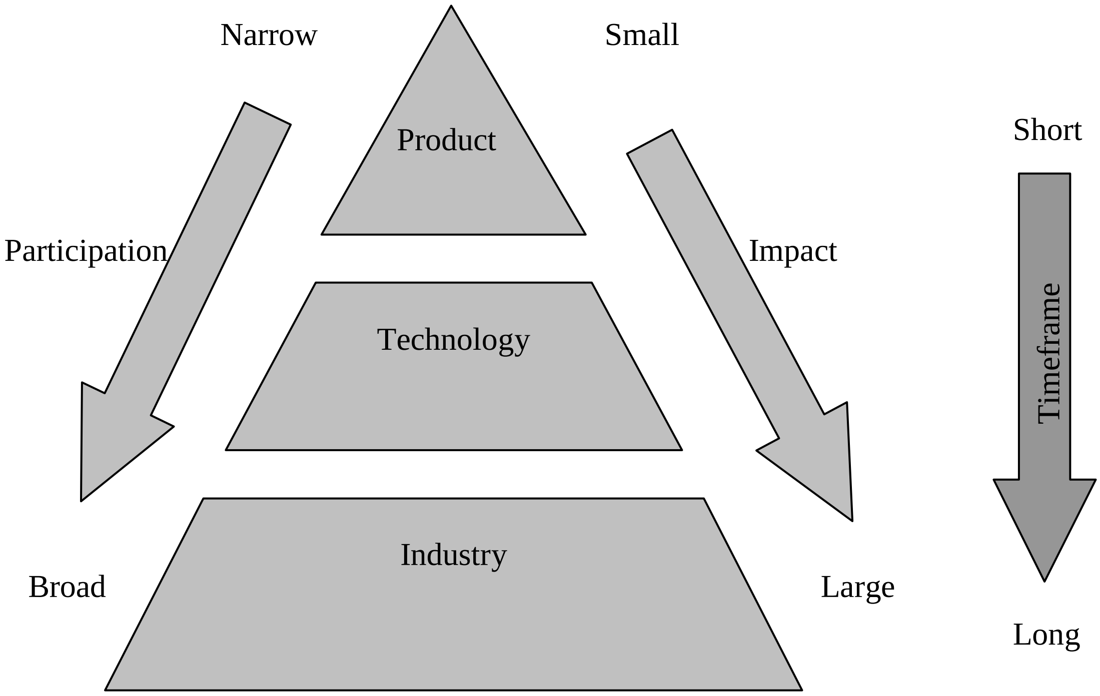


**Figure 4 Types of Technology Roadmaps**

Figure 4 details ways that technologies are classified (AMIRA, 2001). Technology road maps that focus on a product are quantified as narrow in the levels of participation required by individuals within the project and have a small impact on the project. The average time for the completion of projects is short. Projects of this kind are passive in nature and are normally self initiated transfers of technologies for the benefit of the user. The use of a powerful tool such as a Technology Roadmap at this level is considered a misuse of resources. That is not to say that transfers of this level would not benefit from the uses of such a tool, but rather that a simpler planning tool is generally enough to complete the project.

Technology Roadmaps that focus on industries are broad in the levels of participation and have a large impact on the outcomes of the project. The average time for the completion of projects is considerable. The use of a planning tool at this level is essential and a roadmap is possibly only one of the current tools available that is capable of successfully accomplishing the task. Transfers and development of technologies at this level are highly active with the full backing of industry sponsorship and partnerships which want to see the successful completion of the project. Transfers within the private sector and transfers form the public sector to the private sector fall under this category of guided, large scale transfers. A typical industry Technology Roadmap can be seen in the following figure (AMIRA, 2001).

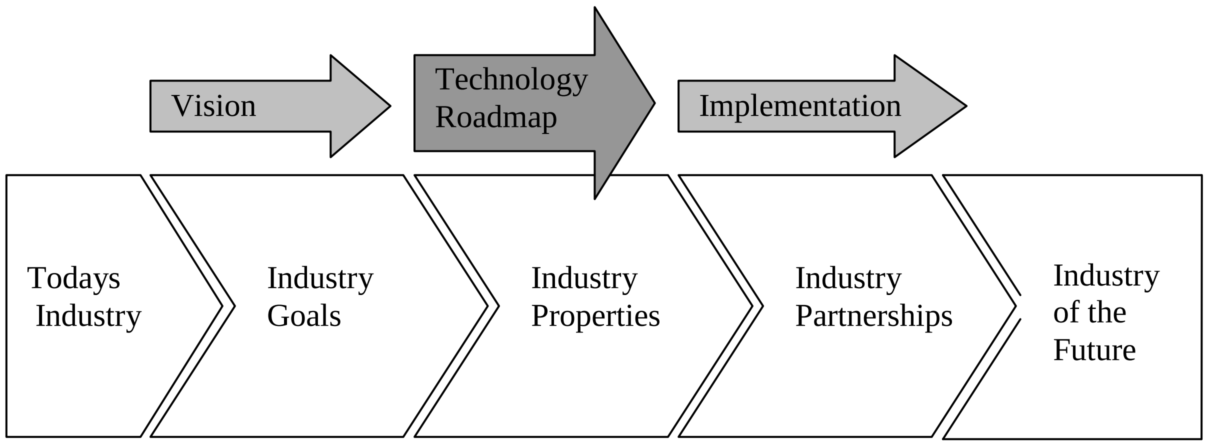


**Figure 5 Industry Technology Roadmap**

The above figure is a diagrammatic explanation as to the ways that Technology Roadmaps assist with achieving goals when implemented into a project. Firstly it starts with the vision or the desired outcomes of the project. This leads onto the Technology Roadmap which ties in the industry's goals, the properties of the industry and any partnerships that are required to complete the project. The Technology Roadmap is then implemented which brings today's industries, standards, manufacturing abilities and processes into the perceived future industry capabilities. The industry of the future will rely on the advanced techniques, processes and tools such as the Technology Roadmap to streamline projects, cut down on the use of company's available resources and increase productivity. By implementing advanced planning processes that allow for greater product development and technology transfer within industries of today, the leap towards industries of the future will be decreased.

## 9.2.Methods to Problem Solving

Technology Roadmaps are strategic rather than tactical which places an emphasis on the ways that are used to accomplish the results required by the roadmap. To do this there are a range of different methods employed within the implementation of a Technology

Roadmaps that ensure that the roadmap is tailored to meet the requirement of the project. The first of these methods is Incremental Roadmapping. Incremental Roadmapping is based on idea driven problem solving. This is the realization and creation of the original idea of the project and then gradual building up of resources, processes and sponsorship to achieve the end result. The gradual building up is seen as a stepping action which builds upon the work that has already been completed for the project. Incremental Roadmappping requires the previous step to be completed before the next stage on the project can start. It also relies heavily upon the success of each step and is only seen as a sum of its parts.

The second method is Visionary Roadmapping. Visionary Roadmapping is based on the desired outcomes for the project. In this method the gathering of resources, processes and sponsorship to complete the project are only gathered after the end results are recognized. The necessary factors that are needed to complete the project can be overlooked in this process due to the main focus being on the end results. Generally, projects of this nature fall apart due to these oversights.

There are different results gained through the use of each method. The use of idea driven problem solving is seen as a ‘forward’ approach. In this approach that is driven by the availability of ideas, the solutions are pushed forward, but the results are not necessarily lead in the right direction. In the objective driven problem solving method the vision is set and the ideas are developed to achieve the vision. This leads to under estimation in the requirements needed to complete the project and the final results are difficulty to achieve. In reality both methods are required, the bottom-up approach to understand where the capability will lead and the top-down to lead in the right direction. These two methods can be seen in figure 6.

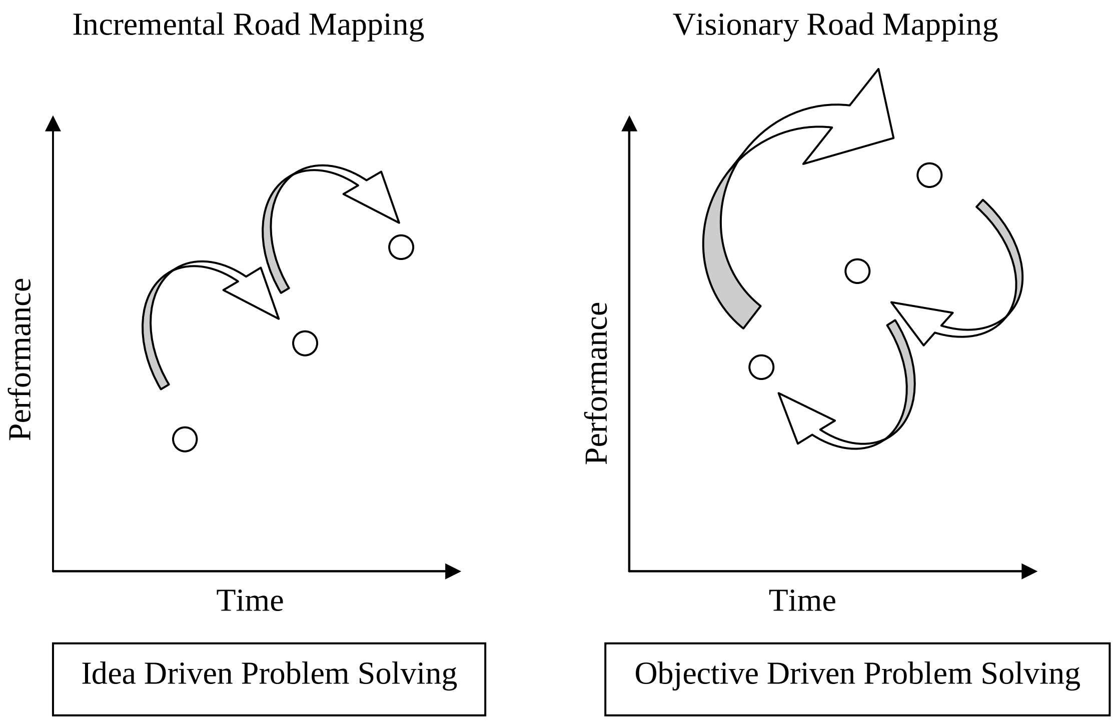


**Figure 6 Approaches to Problem Solving**

## 9.3.Methods to Technology Transfer

While there are methods within Technology Roadmaps that assist with the solving of the problem, there are also methods that assist with the transfer of technologies. These methods are orientated around successful Technology Transfer factors which help with the implementation of the roadmap and the completion of the project. There are two methods that fall within the context of this category and each has proven themselves to be reliable in transfer factors. The first method is problem based Technology Transfer

Problem based Technology Transfer is the process of applying innovations and processes to solve a problem. As previously stated these technologies do not necessarily have to come from within the mining industry but can be transferred from any industry as long as there is a potential to meet the requirements of the project.

As seen in figure 7, the process follows the Engineering Design Model. This is the recognition of a need, the search for technologies, the transfer and development of the technology to the final solution that suits the requirements of the project. There is a difference between the Engineering Design Model and the application of this processes to solve the problem based transfer of technologies. This difference is that there is a definite iterative loop within this process that allows for constant revision and refinement of the technology, transfer, development and solution. This iterative process is the reason for the success of this method as it is a constantly evolving process that continuously strives to better itself.

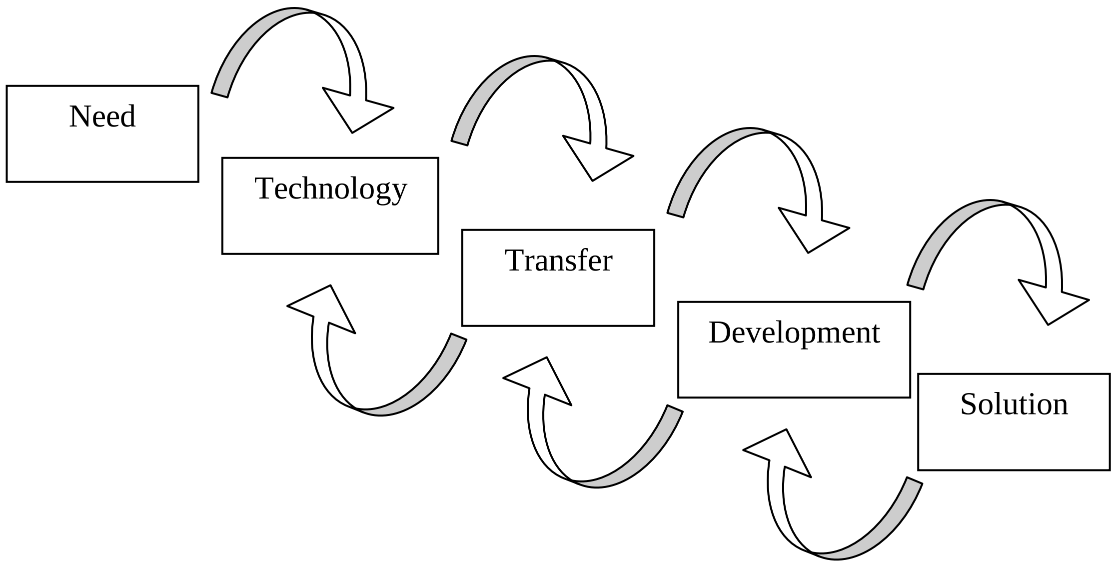


**Figure 7 Problem based Technology Transfer**

Market based transfer is the other method for solving the implementation of Technology Roadmaps. This method relies on the marketable aspects of the technology to achieve this. Within this method it is the success of the technology that is the most circumstantial factor in the success of the process. This is due to the current trend for off the shelf technologies which leaves little room for error when applying this method. Within the model seen in figure 8, there is a back and forth action between the market and factors which include, the global  and domestic industries, the rate of technology change, the relevant standards, the cost of the technology and the complexity of the product / technology. These factors show the alterations that are necessary to make the technology suit the market. It is through theses alterations that are prepared from market analyses that ensure that this method has the most chance of success.

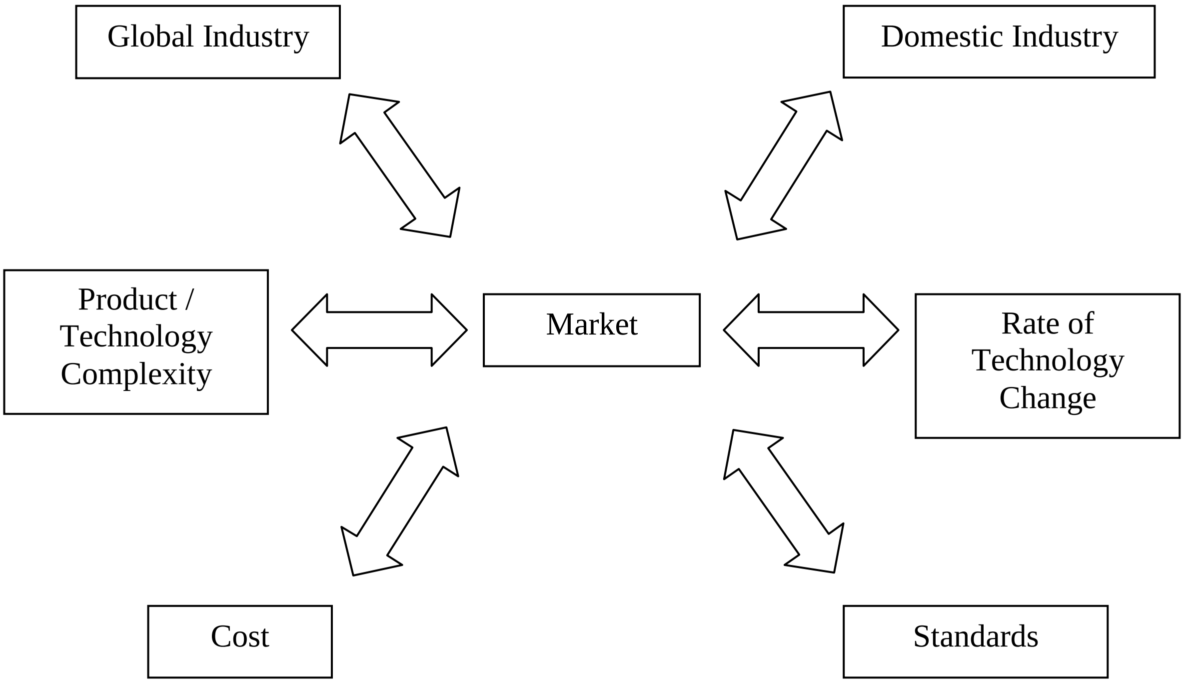


**Figure 8 Market Based Transfer**

The use of the two different problem based Technology Transfer agents to solve the implementation of the Technology Roadmap achieve the same results i.e. successfully apply the Technology Roadmap to the projects process with the use of the technology as the basis for both methods. The problem based Technology Transfer method achieves its results through the development and iterations of a technology while the market based method achieves its results from the commercial side of the technology. In reality both methods are required, by focusing on the development of the technology and how this relates to the market then a transfer of technology that is strong in both aspects is achieved.

## 9.4.Successful Factors for a Dissemination Model

There are a numerous factors that assist with the development and transfer of technologies. These factors have been gathered throughout the various stages of this project with the intention of applying them to a Technological Dissemination Model for the Mining Industry. Through identification and interchange of this knowledge, it is hoped that a broader awareness and acceptance is gained and applied to all industries through the benefit of transferred technologies. The factors identified though the research of this project are,

Commitment by user

- User statement of need
- Clearly stated and understood boundaries of acceptable solutions
- Commitment by the user to remain actively associated during and after development

Definition of the Process

- Include the right people
- Begin to build partnerships
- Design a manageable process –Technology Roadmaps

Definition of the Product

- Clearly define goals
- Link activities
- Define the roles of key individuals
- Set performance standards

The factors listed above are definitive of an interactive process to optimise the transfer process. The importance of the commitment of the user is the base point on which the entire project can be built. Without the interaction of the user (the user may also be a customer for which the product is developed), there would be no need for the transfer of technologies to begin with. The definition of the process is an active step in the planning stage of the project which ensures that there are appropriate resources available to complete the project. This initial planning process is essential for the overall success of the project and can incorporate a Technology Roadmap. The last of the factors is the definition of the product. This factor ties into the commitment by the user and the definition of the process. The resulting product is the main reason for the transfer and is the basis for many of the considerations within the two previous factors.

It is the combination all of these factors that ensures the successful transfer of technologies and in reality all the listed factors are needed for a competent transfer model. This is the basis for the Technological Dissemination Model. The combination of the factors listed above to create a working hypothesis for the transfer model. This includes the use of the different problem solving methods employed through the use of a Technology Roadmap and the factors to improve the transfer of technologies. The use of each of these significant methods and process will compliment the other to create a superior process for the transfer of technologies in the Mining Industry.

## 9.5.Criteria for Transfer from the Mining Industry

In addition to the factors listed for the transfer model, there are specific factors which promote the transfer of technology from the Mining Industry to other industries. These industries can be either related or unrelated to the Mining Industry. Onsite development is the first factor. Onsite development of innovations is essential to promote awareness of innovations, gain better transfer processes from active interaction with the transferred technologies. Through this method an understanding of the requirements from the technology and the industry are realised to form a better bond between the two.

The second factor is that success depends on problem or market based Technology Transfer. The reason for this is these two approaches have already proven themselves to be reliable in transfer factors in the context of Technology Transfer so the application of these methods is not new to the technology transfer process. The transfer process for this type ofTransfer is the push of technologies away from the industry that relies on the individuals to transfer the technologies. In this case it is the skill of the individual that is the transfer agent. Therefore this type of transfer is seen as passive with most of the technologies transferred coming from the development within research organisations. These technologies have the potential to meet the needs of multiple industries and are transferred easily. Sponsorship for the transfer of technologies in this method is important as is affords an additional sense of worthiness to the project.

## 9.6.Criteria for Transfer to the Mining Industry

Factors that influence the transfer of technologies into the Mining Industry include the use of the idea and objective driven modes of problem solving. These forms of problem solving provide the means for gathering technologies that have the potential for application in the Mining Industry. It is through the use of both methods that a balanced approach is gained, the bottom-up approach to understand where the capability will lead and the top-down to lead in the right direction. Once again, onsite development of innovations is essential to promote awareness of innovations, gain better transfer processes from active interaction with the transferred technologies.

Within this transfer type it is the pull of technologies that provides the solution to the project. Transfers of this type are performed by private companies who actively transfer technologies for the benefits of the stakeholders in the project. Partnerships are an important commodity in this type of transfer which provide the means and push to achieve marketable and transferable technologies.

# 10. Selection of Technologies

Within this chapter a selection of the researched technologies will be presented. These technologies were selected for their characteristics that fulfil the initial criterion and the technology selection criterion. The technologies presented in this section also display qualities from the factors listed for the successful Technology Transfer. The technologies will be categorised in the following manner,

- Technology used in the mining industry from other industries.
- Technologies used in other industries from the mining industry.
- Own selection of possible crossover technologies.

## 10.1. Mining Industry Technologies

The innovations in this section are representative of technologies that have been transferred to the Mining Industry from other industries. Both technologies are software which were designed to enhance the performance of a mining process. This encompasses and emphasises the development of 'softer' technologies within discussed transfer methods. The first technology is Computational Fluid Dynamics. This technology was mentioned in section 7, The Technology Transfer Example. This technology calculates the effect of cell design and operation conditions on Flotation Performance. More detail on the technology can be found in section 7.

This innovation was chosen to represent a technology selection that was transferred to the mining industry by firstly, meeting a development requirement specific to this transfer type. This development requirement was the way in which the technology was developed. The interaction of public and private organisations was the basis for this transfer and has been discussed within this report and listed as a factor for this type of transfer. The second reason this technology was chosen was for the active way in which this technology was selected. This was through a GFRO in conjunction with private sponsorship.

The second innovation selected to represent this category is the IOR Meter. The IOR Meter was designed by J W Bennett, S Askraba and P Mackenzie in 2005 This technology is a new method to characterise black shales in mining operations. The IOR Meter measures the intrinsic oxidation rate (IOR) of samples of broken rock by circulating air through a sample and monitoring the oxygen concentration over time. The intrinsic oxidation rate is given by the rate at which oxygen is consumed per unit mass of sample, in units of kg (oxygen) kg-1(sample) s-1 (J W Bennett, S Askraba and P Mackenzie, 2005). Up to eight samples can be measured simultaneously and the turn-around time can be less than 12 hours.

The reason this technology was chosen was the introduction of new technology, which built upon the previous oxidation method to help solve a problem within this process. This is a vital part of Technology Transfer. The searching and application of existing technologies to improve existing processes and technologies

## 10.2. Other industry Technologies

The technologies selected in this section are Cemented Paste Backfill and Barricade Bricks. These technologies were selected for this category because they are representative of technologies that have been transferred to other industries. The transfer is not of the technologies themselves but of the processes and ideas that come from the innovations. It is the reuse of mining by-products and lesser-valued products to make products that are capable of improving mining processes. This is seen through the use of such materials in roads, landscaping and as additives and fillers in concrete and plastics.

Paste fill is the newest form of backfill material in the industry available to domestic and international mines and is made from full mill tailings. Tailings are combined with a small portion of binder and water to make paste. It is deposited into the voids created by mining which are referred to as stopes. The empty voids are approximated as vertical rectangular prisms, with plan dimensions of 15–40 m and heights of 100 m or more. Backfilling of mined stopes provide an increased level of local and regional stability to the ore body, as well as providing a suitable and economic dump of mining related waste. Paste is a relatively new technology in the mining industry.

Barricade bricks are fundamental to the safe operation of a mining site. Past failures have lead to loss of life and reduced mine efficiency or even shut down. Within the mining industry there is the need to backfill the pits and tunnels that are created during the ore extraction operation. The backfill confers two important functions; (i) the backfill material itself is a lesser-valued product of the mining operation and, therefore, there is a need to conveniently and efficiently dispose of it, and (ii) a stable backfilled mine site acts as a solid platform so that neighbouring mining operations can be maintained in a safe manner (Grice 2001). When the mine is being filled, the horizontal drives at various sublevels are blocked by a retaining wall structure made of the barricade bricks.

The use of waste materials in processes that do not require premium materials is a promising development which has been taken up in many industries. The technologies chosen to represent this category are by no means the most cutting edge innovations that have come from the Mining Industry as there is a great amount of secrecy for developed innovations. However it is through these lower level technology transfers that are mainly seen from the Mining Industry.

## 10.3. Own Selection of Technologies

During the searching of technologies that was conducted for this project, there were technologies found which had the potential for transfer but were transferred from the industry in which they were developed. The first of these technologies is the Universal Joint – Thompson Coupling. The Thompson Coupling, displays the strength of a universal joint with all the attributes of true constant velocity promises to revolutionize drivelines in everything from motor vehicles and mining equipment to heavy machinery and industrial roller-mills (Australian Mining, 2005). The benefit of the Thompson Coupling is that it can handle significant loads while at a constant velocity and have an angle of 15-20 degrees applied to the system. The application of this universal joint is not limited to any particular industry and has the potential to be applied to the automotive and agricultural industries and many industrial applications. This technology has been developed by an industry described by the criteria within this dissertation as an unrelated industry. Due to the versatility of the joint its application to numerous mining processes would prove beneficial.

The other technology discovered was the Dash 8 Excavator featuring ECOT 3 Technology. The Dash 8 Excavator was developed by Komatsu and incorporates Komatsu's ecot3 (ecology and economy technology Tier 3) approach, combining electronic control, hydraulic and engine technology, with all machine components designed and manufactured by Komatsu to work together as an integrated whole (Australian Mining, 2007). The reason this technology was selected was for its innovative and transferable technologies that combine to create the tier 3 system. This technology which has been developed for the Mining Industry has the ability to be transferred to many other industries offering the benefits of low-emission engines and improved fuel consumption.

The information presented in section 9 of this report, Technology Selection, was derived from the technologies listed within this chapter. The finding of the technologies were important for this project, however it was the methods on how the technologies were developed, transferred and marketed that was foremost in the scope of the project. These technologies were instrumental in creating the Technology Selection Criteria and allowed the information which was gathered in the information search and literature reviews to be applied to the transfer model.

# 11. Conclusion

The development of innovative technologies to maximise returns from mineral exploration, extraction and processing has been an integral, but essentially unacknowledged part of the minerals industry. Australia has been a leader in mining research and development, investing large amounts of capital to develop new technologies and processes to strengthen its competitiveness. A competitive mining industry is a prerequisite for growth in high-value minerals processing and technological service industries in Australia. To sustain such growth and contribution to national economic performance in the medium and longer terms depends on new resources being discovered and developed for production at rates sufficient to meet demand. This is where the transfer of technologies comes in.

Technology is transferred in the hope of ‘gain’. In the mining industry, it is the strength of the mineral resources that is the gain. Through this desire, some of the risks associated with the transfer of new technologies are alleviated. In the mining industry, R&D management combined with TT by the Mining Technology Services has enhanced the exploration accuracy, production and processing efficiency, engineering ability, occupational health and safety conditions, environmental and mine sustainability and improved business and financial operations.

There are numerous factors that assist with the development and transfer of technologies. These factors were gathered throughout the various stages of this project with the intention of applying them to a Technological Dissemination Model for the Mining Industry. This model is the start of creating a successful transfer process for technologies within the Mining Industry as well as other industries. Through identification and interchange of this knowledge, it is hoped that a broader awareness and acceptance is gained and applied to all industries through the benefit of transferred technologies.

## 11.1. Achievement of Objectives

The method of applying an existing technology to solve a problem is not a new process. It has existed for many hundreds of years and is the basis for today's modern engineering. Sometimes this process is termed Technology Transfer or Technological Dissemination, though, no matter what this process is called, the definition is still the same. Technology Transfer is defined as, a purposive, conscious effort to move technical devices, materials, methods, and/or information from the point of discovery or development to new users.

The aim of this project was to apply this process to the Australian Mining Industry. This project was an attempt to accomplishing this by firstly investigating the technology used in the mining industry and developing methods by which technologies can be transferred to other industrial fields. And secondly through the identification of industries that are unrelated to the mining industry, develop transfer methods that allow the adaptation and development of technologies of these industries into the mining industry.

The aims of this project were to be completed through the advanced review of available literature. Initially there were specific objectives that were discussed with the projects supervisor that would form boundaries which would guide the outcomes for the project. Though, due to the sources of literature used and the methods used to find the technologies the literature findings lead to the information contained within this report. This also includes the selection of technologies.

The unforeseen change in the direction of the project came in the initial literature review which mainly focused on government support. This was not a bad direction as it is relevant to the current issues affecting the Australian Mining Industry. There was always a desire to achieve a Technological Dissemination Model with the selection of technologies to highlight the transfer types and methods used in the transfer. This was achieved with the information gathered in the initial literature review and lead to the outcomes in the Technological Dissemination model. With different initial results a different model may have been achieved.

The selection of the technologies that represent the specific categories could also have been improved. While the technologies that were selected were good examples of Technology Transfer in all of its forms, the extent of the technologies available was a consideration. By linking future research with the Australian Mining industry technologies which show an increased proficiency in the transfer methodologies would be obtained and a more accurate and detailed transfer model would be gained.

The results from these technologies were used to form the boundaries for a Technological Dissemination Model. The ideas presented are a suggested approach to achieving a successful transfer of technology. This model is the start of creating a successful transfer process for technologies within the Mining Industry as well as other industries. Due to this fact, future work will need to be carried out to complete the Technological Dissemination Model. Some of the future work will include the development of the model within the framework of the Mining Industry and the application of the completed model to a transfer of technology. It is hoped that the information presented in this report will add to the Technology Transfer knowledge base and even be converted into an Industry Technology Roadmap in which future needs are identified and a series of potential future directions are defined for the project.

# 12. Future Work

If this project was to be continued, there are a few aspects within the searching methods and methodologies that could be improved to ensure that better results were achieved. The first aspect would be the inclusion of oil and gas resources and technologies. Due to the nature of the searching methods there weren't any technologies from within this sector or discussion papers on issues affecting the oil and gas industry. The majority of the research focused on the MTS sector which does not include the exploration, extraction and processing of gas and oil as ownership of petroleum resources is reserved by the Crown and all rights are held by the Government of the State or Territory in which they occur. If future work on this project was conducted then there would definitely have to be inclusions of technologies and reports from this sector.

To achieve the required results and include technologies form the oil and gas sector the use of better defined boundaries for the literature review and technology search would be a must. Also direct contact with an oil and or gas company could be accomplished to produce beneficial results. This could be in the form of a case study. A case study on a specific industry or technology would be a beneficial inclusion to the future work. This would allow for an insight to the challenges and problems associated with the industry as well as problem associated with developing a technology to an appropriate Australian standard. The inclusion of the company's involvement with partnerships and government sponsorship would also be an interesting inclusion.

The case study is a valuable tool and would not be limited to oil and gas technologies and companies. The case study could be used for mining technologies as well. It could also be possible to include multiple case studies that follow technologies from the development stage to the implementation stage and compare the different technologies and methods used to transfer the technologies form one industry to another.

The survey is another aspect that would need to be improved if future work was to be undertaken on this project. Improvements include firstly, allowing more time to research, compile, distribute and receive completed surveys. As explained in section 8.6 and 8.7, the survey was a late addition in trying to gain industry opinions on a broad range of topics so there was limited time to send and receive the completed surveys. It was also unclear as to how difficult a survey was to research, compile and distribute.

Due to this more time was needed to correctly make the survey which meant that there was less time to distribute the survey. For future work, if a survey was included in the research methods, more time would need to be assigned to the successful completion of the survey.

Secondly, the questionnaire would need definite individuals and company representatives to complete the survey. This would ensure that the survey has the best chances for success. If initially there is no clear individual to complete the survey within a company that was essential to survey then follow up actions should be taken to ensure there is an individual to complete the survey. This improvement also includes the greater number of surveys sent out into the mining community. As explained in table 1, the surveys were sent to specific companies specific reasons. These reasons were:

- Range of innovative ‘harder’ technologies
- Perspective on a company’s involvement with a CRC was anticipated from the survey
- Perspective on development and protection of ‘softer’ technologies.
- Perspective on issues effecting local industries
- Perspective on the government support facilities
- Local company’s involvement and understanding of the range of topics covered in the survey
-

The reason that companies were sent surveys was with the intent on receiving specific results and because of the late timing of the survey. By sending a greater number of surveys in the future work a better understanding on the issues affecting the industry and methods used to transfer technologies would be gained. Also, instead of trying to force the results of the survey by sending the surveys to specific companies with the intent of receiving specific results, a more natural set of results that could possible reveal different trends would be gained.

The last two aspects that could be improved with the project are more additions than anything else. These are access to the Mining Industry’s Technology Roadmap and a site visit. The industry has achieved a set of methods to successfully develop technologies within its sectors. While not explicitly detailing ways to transfer these technologies methods could be derived form the process detailed within the roadmap. The Technology Roadmap details include (RMDSTEM Limited, 2006):

- A practical planning and communication tool where future needs are identified and a series of possible paths defined.
- Strategic emphasis rather than tactical.
- Needs to be updated regularly to reflect changes in business environment and new emerging and enabling technologies
- Alternative paths where they are identified should be shown.

The Technology Roadmap was not obtained during this project as the road map as it is part of the CRC's confidential strategic planning documents. The acquisition of the CRC Mining Technology Roadmap for future work would be advantageous to the selection of technologies and Technological Dissemination Model.

The site visit would be an appealing addition to the project for future work. It would allow for a greater understanding of the everyday processes and procedures in dealing with the mining industry and the development of technologies. A site visit was planned for this project though finding a company that was involved with many of the topics in this report was difficult to find within the local area. Permission by access site workshops and processing plants due to confidentiality was also a consideration that could not be ignored when applying for a site visit. If future work was to be undertaken then a site visit must be considered to gain some appreciation of the industry that the company represents.

# Appendix A - Project Specification

University of Southern Queensland

FACULTY OF ENGINEERING AND SURVEYING

**ENG4111/4112 Research Project**
**PROJECT SPECIFICATION**

FOR: Peter Booshand

TOPIC: Literature review of advanced research and innovation in the mining industry.

SUPERVISOR: Steven Goh

SPONSORHSIP: USQ

PROJECT AIM: This project seeks to investigate the technology used in the mining industry, identify non industry related technology and suggest further adaptation and innovation in the mining industry.

PROGRAMME: (**Issue a, 21 March 2007**)

1. Research the background information relating to the mining industry and other areas of potential interest.
2. Set the topic in context in terms of scope, purpose and related/relevant disciplines.
3. Look at relevant information sources for literature review.
4. Obtain current/relevant information and conduct literature review.
5. Organize and position the information.
6. Analyze information to suggest areas of further research and considerations; i.e. Costs and sustainability.
7. Write the literature review.

AGREED (student) (supervisor) ______________________________ ______________________________

Date: / / 2007 Date: / / 2007

Co-examiner:____________________________

# Appendix B – Mining Survey

University of Southern Queensland
Faculty of Engineering and Surveying

# Advanced Research and Innovation in the Mining Industry Questionnaire

This questionnaire is designed to assess the technological needs of Australian Mining Companies as well as gather information on Government support and Research Organisations, IP Protection and Technology Transfer within the Australian Public and Private Mining Sectors.

By completing this questionnaire a copy of the results and findings in the form of my Dissertation can be obtained after the after the final submission date -1 November 2007.

| Please complete this questionnaire and return by Friday, 21 September. |
|---|

| Company Information |
|---|
| Name: |
| Industry: |
| Location: |
| What the company does: |
| **Respondent's Contact Information** |
| Name: |
| Position held within company: |
| Phone: |
| E-mail: |
| **Questioner's Contact Information** |
| Peter Booshand |
| Po Box 142 Crows Nest QLD 4355 |
| Mobile: 0418 720 435 |
| E-mail: booshandp@Hotmail.com |
| Fax: 07 4631 2526 (USQ), ATTENTION Steven Goh |
| **Government Support** |
| Is your company aware of Government Support |

| |
|---|
| Does your company use Government support programs? (tick as appropriate) |
| R&D Tax Concession |
| R&D Start |
| COMET |
| Smart Exploration |
| Smart Mining - Future Prosperity Program |
| Other |
| Has your company accessed Public Research Organisations? (tick as appropriate) |
| ABARE |
| AMIRA |
| AusIndustry |
| CSIRO |
| CRC Programs |
| Other |
| Is your company involved in a Cooperative Research Centre Sector? (tick as appropriate) |
| Manufacturing Technology |
| Information and Communication Technology |
| Mining and Energy |
| Agriculture and Rural-based Manufacturing |
| Environment |
| Medical Science and Technology |
| What program are you involved in within the CRC Sector, in particular CRC Mining Australia? |
| What are your company's opinions on Government Support and Research Organisations? |
| **Intellectual Property Protection** |
| |

| |
|---|
| What was the technology / innovation? |
| What does the technology / innovation do? |
| What did the patenting process involve? |
| What are your opinions on the patenting process? |
| **Technological Innovation** |
| What technologies are employed by your company? List 3 technologies most relevant to mining operations. |
| Electrical and Mechanical |
| Technical services and procedures |

| |
|---|
| Computer Sciences |
| Other |
| **Technology Transfer** |
| Do you use a technology that has been transferred from another industry? Would you rate this transfer as a success or as a failure? |
| How did you find out about this technology / innovation? |
| Have you transferred a technology to another industry? |
| **Technology Transfer Process** |
| If you have transferred technologies to other industries what process did you use? Would you rate this transfer as a success or as a failure? |

What were the outcomes of this transfer?

## Technology Roadmapping

Technology Roadmapping is a combined initiative of the Australian Government and Industry to develop methods to successfully transfer research and innovations within a specific industry.

Has your company used a Technology Roadmap?

Who designed the Technology Roadmap and what was the process involved?

Has your company created a Technology Roadmap for any of its products or services?

| |
|---|
| What was the process of the Technology Roadmap? |
| What are your opinions on Technology Roadmaps? |

## Technology Selection and Grading

For this section of the questionnaire a rating of 1 to 5 is required as to the importance of the following factors for successful Technology Transfer.
Important=5, Less important =1

| | |
|---|---|
| The technology that is being transferred. | |
| The ability of the technology to be transferred. | |
| The usability of the original technology. | |
| The usability of the transferred technology. | |
| The ability of the technology to meet development needs. | |
| The ability of the technology to meet industry needs. | |
| The industry that the technology is being transferred from. | |
| The industry that the technology is being transferred to. | |
| The success of the technology within the Australian marketplace. | |
| The success of the technology within the international marketplace. | |

## Notes:

Please feel free to make any comments or suggestions about any topic raised in this questionnaire or about the questionnaire itself.

# Appendix C – Technology Reference Sheet

| Name | Technology | Category | Industry | Company | Transferred | Success Rating | | Abstract |
|---|---|---|---|---|---|---|---|---|
| CFD Flotation Process | Computational Fluid Dynamics | Soft, Active, Public to Private | GFRO | CSIRO | Arsenic Separation from Copper | Meets all criteria and rated high on TSC. Used for Transfer Model. | Represents *to* mining technology | CSIRO researchers have developed the first CFD model that determines the effect of cell design and operating conditions on flotation performance. The CFD model calculates the effect of cell design and operating conditions on hydrodynamics of the slurry, bubble distribution and bubble size. |
| IOR Meter | Intrinsic Oxidation Rate Measurement Device | Soft and Hard, Semi-Active, Private | Iron Ore Mine | J W Bennett, S Askraba and P Mackenzie | Redevelopement of existing process | Meets all criteria and rated high on TSC. Used for Transfer Model. | Represents *to* mining technology | The new characterisation technique offers the prospect of improving the ability to identify and predict the behaviour of reactive black shales and to differentiate more precisely between different materials. Mine planning, operations, safety and environment all stand to benefit from the success of further trials of the technique. |
| Barricade Bricks | Mine Safety | Hard, Semi-Active, Private | Hydraulic Mine Fill | C. C. Berndt, K. J. Rankine, N. Sivakugan | Use of waste materials | Meets all criteria and rated high on TSC. Used for Transfer Model. | Represents *from* mining technology | Barricade bricks are fundamental to the safe operation of a mining site. The fundamental material property that determines the operational characteristics of barricade bricks is their permeability, which must be tailored to suit the operational environment of the mine. |
| Cemented Paste Backfill | Thickened Tailings | Hard, Semi-Active, Private | Mining | R. M. Rankine, N. Sivakugan | Use of waste materials | Meets all criteria and rated high on TSC. Used for Transfer Model. | Represents *from* mining technology | Paste fill is the newest form of backfill material in the spectrum available to international mines and is made from full mill tailings. Backfilling of mined stopes provide an increased level of local and regional stability to the ore body, as well as providing a suitable and economic dump of mining related waste. |
| ECOT3 (ecology and economy technology Tier 3) | Combined electronic control, hydraulic and engine technology. | Hard and Soft, Semi-Active, Private | Construction and Mining Equipment | KOMATSU | benefits of low-emission engines and improved fuel consumption | Meets all criteria and rated high on TSC. Used for Transfer Model. | Represents own technology selection | The new excavators incorporate Komatsu's ecot3 (ecology and economy technology Tier 3) approach combining electronic control, hydraulic and engine technology, with all machine components designed andmanufactured by Komatsu to work together as an integrated whole |
| Thompson Constant Velocity Coupling | Universal Joint | Hard, Active, Private | Coupling Design and Manufacture | Thopmson Couplings Limited | Potential in transfer to many industrial applications | Meets all criteria and rated high on TSC. Used for Transfer Model. | Represents own technology selection | The coupling, displaying the strength of a universal joint with all the attributes of true constant velocity promises to revolutionize drivelines in everything from motor vehicles and mining equipment to heavy machinery and industrial roller-mills. |

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