Information Technology Systems: Studying Software Applications and the Business Value Chain in Mining

Paulo F. T. Sachs
Post Graduation Program, Mining and Petroleum Department
Polytechnic Engineering School, University of Sao Paulo – psachs@usp.br
Director, Gemcom Latin America – +55 31 3492 1040 – psachs@gemcom.com.br

Eduardo C. Damasceno
Professor, Mining and Petroleum Department
Polytechnic Engineering School, University of Sao Paulo – ecdamas@usp.br

ABSTRACT

ERP systems have been widely implemented nowadays in several industries. However, ERP was originally designed to fit former MRP and MRP II users, and most of the ERP research has been focused on discrete manufacturing . On the other hand, process industries – and mining in particular – present many peculiar characteristics, which are difficult to comply with ERP systems standard functionalities. Again, very limited research has been developed covering enterprise management systems in mining.

The objective of this paper is to identify, through an exploratory study that includes a case study methodology, how ERP systems manage the functional areas of the mining industry, and how they fit into the mineral value chain IT requirements. A secondary objective is to identify the gaps between ERP's functional capabilities and the mining industry business requirements, to identify potential solutions and to point out the perceived benefits they can generate to the companies.

RESÚMEN

Hoy en día, los sistemas ERP han sido ampliamente implementados en diferentes industrias. Sin embargo, como los sistemas EPR originalmente fueron diseñados para satisfacer usuarios de MPR y MPR II, diversas investigaciónes fueron orientadas a la área de manufactura discreta. Por otro lado, los procesos industriales – y la minería en particular - presenta muchas peculiaridades, las cuales son difíciles de ajustar con las funcionalidades estándar de los ERP. Nuevamente, investigaciones muy limitadas han sido desarrolladas para cubrir los sistemas de administración empresarial en minería.

El objetivo de este trabajo es identificar, a través de un estudio exploratorio que incluye metodología de estudio de casos, como los sistemas ERP administran las diferentes áreas de la industria minera, como ellos se insertan en los requerimientos de TI de la cadena de valor, y los beneficios principales que generan. Un segundo objetivo es identificar los espacios entre las capacidades funcionales de los sistemas EPR y los requerimientos de la industria minera, identificar soluciones potenciales, y señalar los beneficios perceptibles que estos pueden brindar a las compañías.

1. INTRODUCTION

First initiatives to implement ERP (Enterprise Resource Planning) in Mining happened globally in the early 90s. Like in many other industry segments, legacy systems – mostly old fashioned and mainframe based – had their life abbreviated by the year 2000 bug, and were replaced at the end of the decade by commercial ERP systems.

In all these cases, the objectives, results and benefits expected and obtained are questionable, considering that mining presents many peculiar characteristics, difficult to comply with ERP systems standard functionalities.

This paper explores the business characteristics that differentiate mining from other industry segments, and presents an exploratory study of the ERP situation in the Brazilian mining industry.

2. ERP SYSTEMS

According to Hicks and Stecke (1995), Enterprise Resource Planning, or ERP, is a term first used by the Gartner Group. It is not a revolutionary conceptual breakthrough, a major technological advance, nor a truly new idea: instead, it's a useful paradigm, essentially concerned with making sure that a firm's manufacturing decisions are made taking into account their impact on the supply chain, both upstream and downstream. Besides, production decisions are affected by and affect all other major areas in the business, including engineering, accounting, and marketing. In order to make better decisions, one needs to take into account all these important interactions within the business.

Davenport (1998) describes ERP systems as commercial packages promising seamless integration of all information flowing through a company – financial and accounting, human resources, supply chain, and customer. The systems imposes its own logic on a company's strategy, organization, and culture: it pushes toward full integration when a certain degree of segregation might be desired, and it pushes toward generic processes even when customized processes may be a source of competitive advantage. The central database, at the heart of the ERP system, draws data from and feeds data into applications supporting diverse company functions and departments. This single database architecture streamlines dramatically the flow of information throughout the whole business.

Langenwalter (2000) describes the evolution history of ERP, as a third generation of systems that started in the late 60s with MRP (Material Requirement Planning), then superseded in the 70s by MRP II (Manufacturing Resources Planning) which integrated material planning, purchasing of production material, accounting and the plant floor.

Ptak and Schragenheim (2000) point out that ERP is not just MRP II with a new name or running in a client-server architecture: ERP is the next logical sophistication level in the evolution of IT tools, bringing new integrated functions to the resource planning capabilities.

Zwicker and Souza (2003) defined ERP as integrated information systems, available as commercial software packages, with the purpose to support most operations of an industrial organization. These packages present some characteristics that differentiate them from legacy systems and other software packages, such as:

- They are commercial software packages;
- They bring incorporated business processes models, so called best practices;
- They are integrated information systems, using a single corporate database;
- Provide extensive functional scope;
- Require specific adjustment procedures to be properly used by one given organization.

Most ERP packages are broken down in modules – sometimes even commercialized and implemented individually – that handle several functional areas, or departments. However, these modules interact as the business processes require information exchange among different departments. These interactions, performed in real time and using information stored in a single database, result in what is possibly the main benefit of the whole system: the integration and availability of consolidated, non redundant data throughout the whole organization (Exhibit 1).

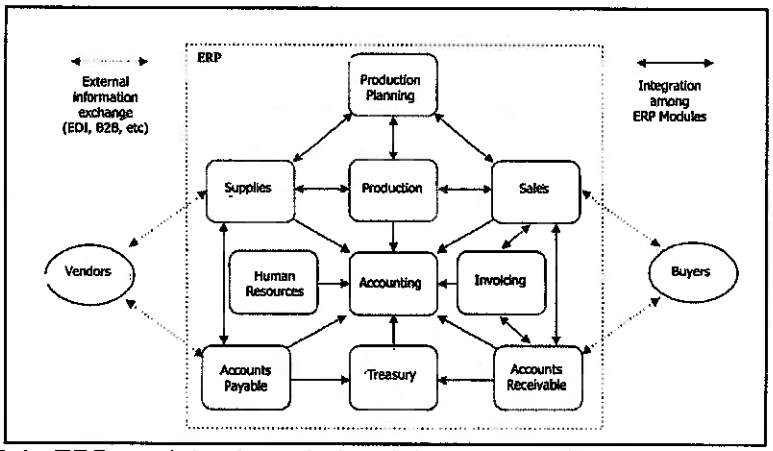

Exhibit 1: Main ERP modules in an industrial enterprise (Zwicker and Souza, 2003)

3. MINING INDUSTRY CHARACTERISTICS

Mining is part of the so called Process industry, that comprises about half of the manufacturers worldwide (Ptak and Schragenheim, 2000). In order to achieve the best return on assets – considering it's a capital intensive business – and lower production costs, mine equipment and plants normally run 24 hours a day, 7 days a week. Therefore, the main focus for any ERP in this industry should be keeping the heavy equipment and plants running, through effective capacity and maintenance management. Thus, avoiding idle time by accurate production scheduling, and avoiding unexpected breakdowns by scheduling preventive and predictive maintenance tasks, are crucial aspects for the business performance.

A unique mining industry characteristic, intrinsic of its own nature, is the fact that the main raw material – the ore –originates from an internal source, the mine. Despite the development and high technology deployed in geologic modeling and geostatistics systems, estimated ore quality parameters – such as mineralogy, assays, granulometry – will always carry a level of uncertainty and an estimation error, and will only be better known after exploitation, already in the production process.

Ptak and Schragenheim (2000) present the concept of "Plant A" and "Plant V" industries:

A "Plant A", or a standard discrete manufacturing plant (Exhibit 2), employs traditional MRP planning and scheduling logic. The components of the bill of materials, their characteristics, and the timing required for assembly are perfectly determined and broken down from the production plan or, ultimately, from the sales plan or orders.

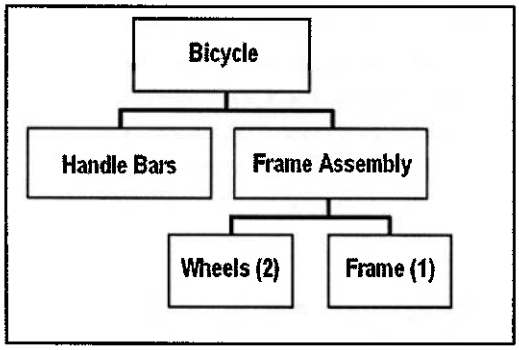

Exhibit 2: Bill of Material – Manufacturing (adapted from Heizer and Render, 2001)

In a "Plant V", or a mining-metallurgy complex (Exhibit 3), MRP planning and scheduling logic does not fit. This plant takes one or a few raw materials to produce one or a few final products. Sometimes, co-products and by-products are just unmanageable consequences of the main products. The uncertainties in the

production process require the existence of buffers, normally stockpiles of intermediate and final products.

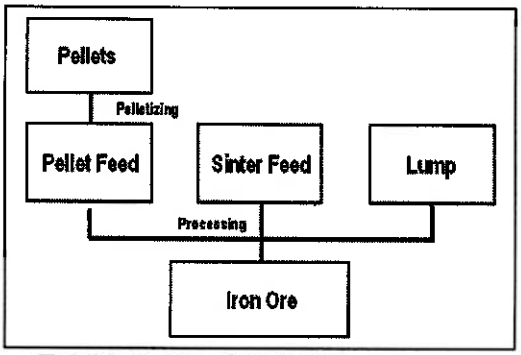

Exhibit 3: Bill of Material – Mining

Even if process industries have always been a challenge for traditional MRP systems, some of the segments – such as pharmaceutical, chemical, food and beverage, etc. – could be served by standard or specialized MRP systems, reasonably suited to manage batch or simple continuous flow plants. However, as previously exposed in this chapter, MRP systems simply do not adhere to the mining industry production flow requirements.

Since ERP can be considered as an evolution of MRP and MRP II systems (Hicks and Stecke, 1995; Langenwalter, 2000; Ptak and Schragenheim, 2000; Laurindo and Pessoa, 2001), with a strong emphasis on production and production planning and scheduling, it is possible to understand the reason why it is difficult to effectively use an ERP system in the most important processes of the mining business, that are related to the production chain.

4. ERP SYSTEMS AND THE MINING VALUE CHAIN

Porter and Millar (1985) state that IT is changing the way companies operate, affecting the entire process by which companies create their products and do their business. Furthermore, it's reshaping the way companies deliver products, services and information to their customers, therefore creating value for their buyers.

An important concept to highlight the role of IT in business is the "value chain", that divides the company's activities into the technologically and economically activities it performs to do business.

A company's value chain is a system of interdependent activities connected by linkages. These linkages exist when the way in which one activity is performed affects the cost of effectiveness of other activities in the value chain (Exhibit 4).

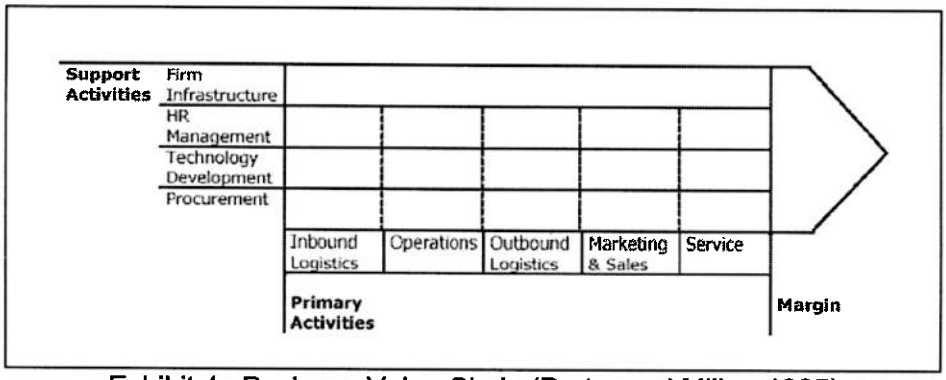

Exhibit 4 –Business Value Chain (Porter and Millar, 1985)

Primary activities are those involved in the production, or the creation of the final product, its marketing, sale and delivery to a customer, and its after sale support and servicing. Support activities provide the inputs and infrastructure that allow the primary activities to take place.

In the mining industry case, it's proposed for the primary activities the following adaptation and further detail of the value chain (Exhibit 5):

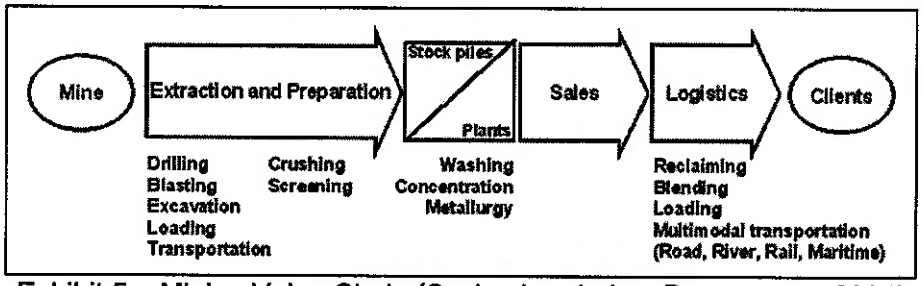

Exhibit 5 – Mining Value Chain (Sachs, Laurindo e Damasceno, 2004)

The main peculiarity of the Mining Value Chain, compared to the generic value chain proposed by Porter and Millar (1985), is that Inbound Logistics is mostly performed through ore extraction unit operations, and its subsequent preparation to feed the plants that follow. The reason why is that, as already seen, the ore is the main raw material in a mining enterprise, although fuel, explosives, chemicals, parts, lubricants, etc. are also part of the inbound logistics.

In theory, as ERP promises seamless integration of all the information flowing through a company – financial and accounting, human resources, supply chain, and customer (Davenport, 1998), these systems should manage and integrate all these activities within the value chain. This affirmative will be investigated in the case study.

5. RESEARCH METHODOLOGY

The key research question related to the aims of this paper is: how extensively can an ERP system be deployed and used in a mining enterprise, considering the industry's characteristics, requirements and limitations, *vis-à-vis* its business value chain? An exploratory qualitative case study approach was adopted (Yin, 1994). Questionnaires and personal interviews were used to collect data. Secondary data were obtained in publications and academic work.

5.1 EXPLORATORY STUDY

Initially, a questionnaire – assuring full confidentiality and anonymity for the respondents – was sent to CIO or equivalent level of eight representative Brazilian mining companies, with questions in the following subjects:

- ERP Information: Modules implemented
- Mining or Strategic Systems and Integration to ERP: Which mining specific or strategic systems were kept, and if and how they were integrated or interfaced with the ERP system.
- ERP Benefits: 23 closed questions were asked based on the work of Poston and Grabsky (2000), Souza, (2000); Zwicker and Souza, (2003), and also in information collected in the preparatory interviews. The respondent should rank with points the potentially obtained benefit, with the following criteria:
  (0) Not verified
  (1) Somehow verified
  (2) Significantly verified

5.2 EXPLORATORY STUDY RESULTS

From the universe of eight mining companies, two are still implementing ERP packages and so did not qualify. Five out of the six remaining ones replied on time and were considered in the final results tabulation.

5.2.1 Implemented Modules

TABLE 1 - ERP Modules Implemented

FREQUENCY	MODULE
100%	Finance
100%	Materials / Supplies
80%	Human Resources
60%	Maintenance

No respondents use production or production planning ERP modules.

5.2.2 Mining or Strategic Systems and Integration to ERP

Most of the respondents decided to keep using dedicated systems for their geology and mine planning, production and sales needs, normally not integrated nor interfaced with the ERP.

5.2.3 Benefits

The perceived benefits were ranked by frequency, calculating the sum of all grades for each benefit, divided by the maximum possible points (Table 4).

TABLE 2 - Benefits

RANKING	FREQUENCY	BENEFIT
1	100%	Productivity improvement
2	90%	Single and consistent database, less errors
3	90%	Data re-entry elimination or reduction
4	90%	Financial close cycle reduction
5	80%	Inter-departmental cooperation improvement
6	80%	Easy and immediate access to information
7	70%	More time spent in departmental core activities
8	70%	Re-work reduction
9	60%	Better business processes implemented
10	50%	Overall productivity improvement
11	50%	Internal processes flexibility improvement
12	50%	Procurement cost reduction
13	40%	Supplier relationship improvement
14	40%	Personnel reduction
15	40%	Overtime reduction
16	40%	Inventory reduction
17	30%	Equipment and Plants productivity improvement
18	30%	Business key performance indicators improvement
19	20%	Profit increase
20	20%	Image in the marketplace improvement
21	20%	Material loss reduction
22	20%	Maintenance cost reduction
23	10%	Customer satisfaction improvement

5.3 CASE STUDY

Considering that two respondents developed in-house production and shipping systems, integrated with the ERP, it was decided to proceed with the case study methodology, in order to better understand the business value chain, and the information flow interconnecting the systems within the value chain.

An interview with the CIO of these two companies was scheduled and performed, having the main following questions in mind:

- How systems – either ERP or internally developed or package systems – cover the activities of the business value chain?
- Why ERP modules were not implemented to manage Production and Production Planning activities, and why the Company decided to keep the legacy system to manage these activities?
- How is the level of integration and the information flow among all these systems?
- How is the Company satisfied with the ERP implementation? Why?

5.4 CASE STUDY RESULTS

5.4.1 Alpha Mines

ERP package comprises the following modules and departments managed: inventory, procurement, maintenance, accounts payable and receivable, treasury, fixed assets, accounting, budgeting, and human resources.

The so-called Production, Sales and Quality Management System, totally in-house developed, handles production (tonnage and quality by product), inventory (tonnage and quality of each product in the stock piles along the mining and transportation chain), shipping and simple "what if" shipping simulation, quality monitoring, sales and customer complaints. The system also provides some basic KPI's, such as productivity, budget/actual, equipment failure, etc.

Mining Engineering packages involve typical applications, such as geological modeling, mapping, geostatistics, reserves calculation, mine planning, rock mechanics, environmental management and truck dispatching.

When Alpha Mines evaluated ERP packages, they did not find any vendor with the required features to handle properly their planning, operations and outbound

logistics requirements. Although some of these vendors claimed they had the right solution, they were not able to prove, clearly demonstrate or to convince the project team about these features.

As the Alpha Mines project team decided that their integrated legacy systems were far superior than any vendor in operations, outbound logistics, sales and services functionalities, they decided to keep it. That decision was clearly not taken to keep in-house developed strategic systems against commercial ones, but just as a matter of technical comparison, reliability and price-performance.

Sales and after sale services were not high priority areas regarding the new systems, due to the limited number of customers (less than a hundred), and the specific invoicing needs – containing both legal and technical mandatory information – for export and for the internal market.

Just after the ERP implementation, the project team faced what should be a natural resistance from the users, that were satisfied with the former legacy system and complained about difficulties and procedure changes of the new ERP package. When maturity level was reached, however, benefits of the up-to-date systems architecture and better practices started to flourish. Special recognition was given to the following benefits: easy and immediate access to information; single and consistent database, with less errors; more time spent in departmental core activities; and productivity improvement.

Externally, it was verified a significant improvement in the procurement practices and in the relationship with suppliers: special focus was put on vendors systematic evaluation, with the goal to reduce the number of vendors and to keep only the ones matching minimum quality requirements. Long term contracts with selected vendors increased productivity and end user satisfaction, while at the same reduced overall costs and delivery time. As the ERP system was not deployed in Sales or Customer Services, there was no impact in customer relationship.

All the applications have a significant level of integration, thorough on-line or batch APIs. Applications running in a lower hierarchical level feed data to applications in higher levels. Limited data is brought from top to lower tiers. Exhibit 6 illustrated how all the systems, in different hierarchical levels, intercommunicate.

Alpha Mines has recently performed a benchmarking study, involving other mining companies and also similar enterprises from other industry segments. The result of the question to top executive level regarding their satisfaction with ERP systems showed only neutral to moderate satisfaction. The justification given was that the impact of ERP system on business performance and results was minimal. Benefits achieved affected much more punctually tasks performed at department level, than the business itself.

5.4.2 Beta Mines

ERP package comprises the following modules and departments managed: inventory, procurement, accounts payable and receivable, treasury, fixed assets, accounting, budgeting, and human resources.

The so-called production and sales system manages production, quality, sales and customer services.
A maintenance system was in-house developed and integrated with the ERP.

Mining engineering packages involve typical applications, such as geological modeling, mapping, geostatistics, reserves calculation, mine planning and environmental management.

Beta Mines decided – just the opposite of Alpha Mines – to develop their production and sales systems, considered strategic for the business. The company believe that no external vendor would fit their own requirements and needs.

The CIO considers that after implementing these systems the IT area became strategically important to the company, because the ERP and in-house systems manage sales, enable the clients to check sales order status through the web and update orders. Beta Mines can also visualize the whole production chain flow.

5.6 RESEARCH CONCLUSIONS

It's clear that a standard ERP package cannot be considered a real enterprise system for a mining company: it's lack of functionality to fit the industry's requirements can be perceived since none of the studied mining companies used ERP modules in production, production planning, outbound logistics or sales, or the business primary activities (Porter and Millar, 1985). If the system does not manage the primary activities, much more business related, it will not result in significant benefits for the whole business.

On the other hand, ERP systems fit very well the secondary or support activities, such as finance, supplies, maintenance and materials – mostly, non-productive – and human resources. This observation matches with Laurindo and Mesquita (2000) statement that many ERP implementations involve only administrative modules, and not production ones. If in manufacturing the production specific functionality is usually provided by a MRP II package, this study did not identify a standard or predominant package or module that suits specifically the mining industry.

It was also clear in the studied case that the ERP covered mostly the support activities, with the exception of a minor participation in inbound logistics, as it

manages all external supplies. The production, sales and quality management system – considered internally as a MES (Manufacturing Execution System) – performs partially this function without the classic approach of bringing down a long or medium term plan from the ERP or the MPR II, and then managing and scheduling the activities at the plant floor to match the plan (Langenwalter, 2000). The mining engineering systems, despite their importance to properly mine the right product, at the right time and on budget, are not integrated with any system within the value chain.

For better visualization, it's presented a representation of the IT systems within the value chain (Exhibit 6):

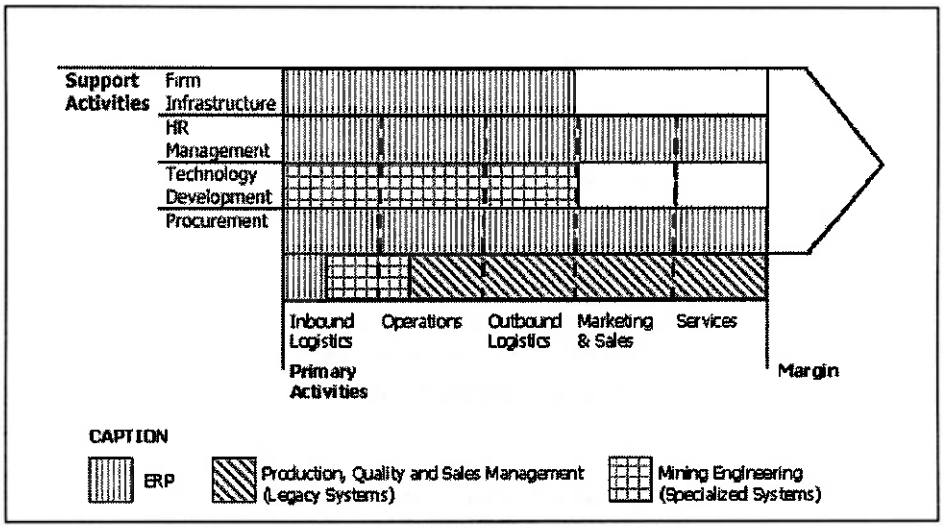

Exhibit 6 – Business Value Chain System Coverage

The most significant benefits mentioned – considering the ones in the first quartile, or: productivity improvement; single and consistent database, less errors; data re-entry elimination or reduction; financial close cycle reduction; inter-departmental cooperation improvement; and easy and immediate access to information – appear to be very aligned with the ERP architecture (integrated application modules running on single data base) and the incorporated best practices, as mentioned in the literature (Correa et al. 1997; Davenport, 1998; Zwicker and Souza, 2003).

6. PROPOSED SOLUTION

One solution provider identified to fill this gap between ERP corporate systems and dedicated mining systems is Gemcom Software, a global company headquartered in Vancouver, Canada. Gemcom develops IT mine solutions, such as: exploration; mine design; strategic planning; mine planning and scheduling; pit optimization; sequencing; and mine production management systems.

Gemcom's MPMS (Mine Production Management System) is a fully-integrated production information management solution that delivers all the production information required to supervise, manage and make business decisions. MPMS integrates data across mine and plant operations. allowing users to track material movements, process flows and stockpile balances through an event-based management system.

6.1 HISTORY

The MPMS concept date back to 1992, when Western Mining Corporation, one of Australia's largest diversified mining companies, assembled a team of professionals to design, develop and implement a common production management solution. Some of the key goals driving the system development were: a.) to produce a technology that would ensure data integrity between its production and commercial systems, and b.) to develop a system that would allow for a common set of standard terms and definitions to be used across an entire work group.

In 1998, Western Mining Corporation (WMC) handed these business operations over to Alpha West, one of Australia's leading software development companies. Growing from WMC's successful implementation of the system – called ProdTrak – and the mining industry interest that had been created, Alpha West continued to invest in the product's future by fully commercializing it, and by securing additional sales to several mining companies in Australia and overseas.

In 2002, Gemcom Software International purchased all of the rights to ProdTrak, making it a wholly-owned technology of the company. Today, best practices from both Gemcom and third-party organizations continue to be incorporated into ProdTrak, and it is now a leading technical system used to effectively manage information for exploration, mining (open pit and underground), processing activities.

6.2 SOLUTION DESCRIPTION

Nader et. al. (2004) state that MPMS components are specifically designed to deal with the complexities of recording, tracking, reconciling and planning the complete mining, processing and dispatching of ore and waste. The system is capable of integration with Distributed Control Systems (DCS) and other SCADA systems, LIMS, Fleet Management, ERP and other third party technical and commercial systems. It supports Business Intelligence and corporate reporting tools to develop Standard KPI reports. KPI's can have drill down capabilities to permit rapid identification of cause and effect.

A better representation of MPMS's scope and integration is presented at Exhibit 7:

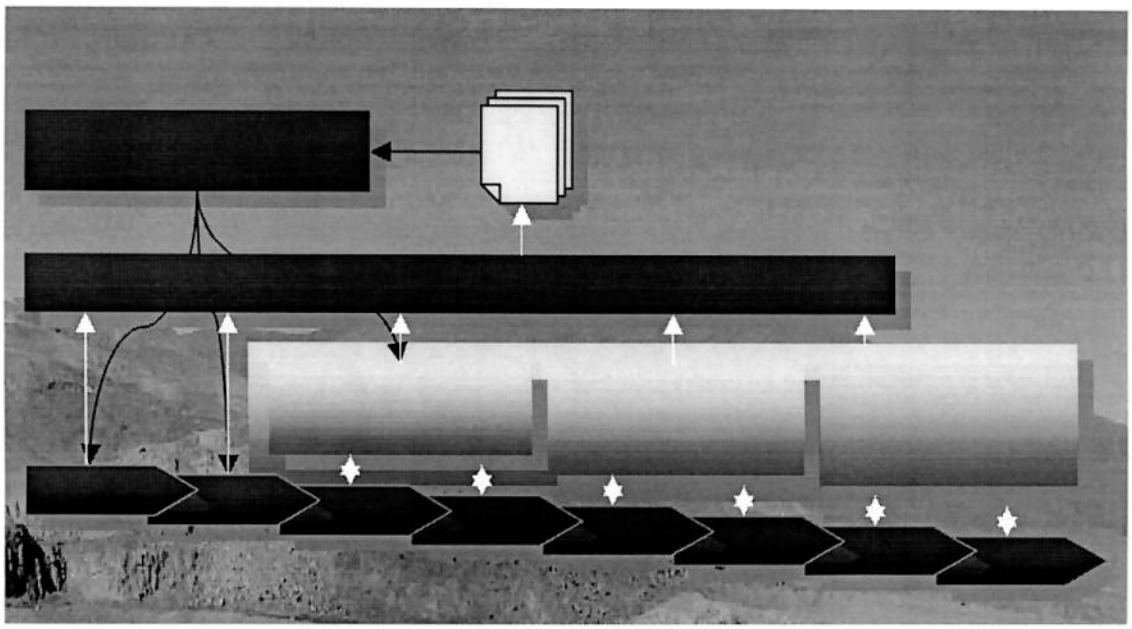

Exhibit 7 – MPMS Concept. Source: Nader, Triginer e Ejtemai (2004)

6.3 SOLUTION CASE STUDY

Keating (2003) describes the case study of ProdTrak - a key component of the MPMS concept - implementation at Iluka Resources, an international mining and processing group, employing 1500 people and generating around US$ 600 million a year in revenue.

The Company has mineral production and processing operations in Australia and the United States. Iluka's main business activities are: mining and processing titanium minerals used mostly for paint pigments and other protective coatings; mining and processing zircon for use in ceramics and refractories; a coal-mining joint venture; and extensive mineral exploration in Australia, the United States and other countries.

6.3.1 The Implementation Project

Following the 1998 merger between RGC Limited and Westralian Sands the new company, Iluka Resources, found itself with multiple corporate applications and production systems. Each tool relied heavily on dedicated individuals to manage production and material movements, and each system had overlapping functionality and stored duplicate data.

Iluka management endorsed a project to implement a production information management system to establish:

- one commercial package with a reasonable fit to existing systems functionality;
- business units working from a common data repository of operational data, providing ready access to management information;
- standardized processes and management of operational data across regions; and
- integration of key operational systems (Process Control, Laboratory, etc).

The project commenced in June 1999, and in January 2000 Southwest operations went live. The Midwest implementation began in December 1999, and mining activities and concentrators were completed in May 2000. Mineral separation and the synthetic rutile plant were completed in June and in September 2000, respectively.

6.3.2 Implementation Benefits

Keating (2003) states that, in accordance with the aims of the project, Iluka's operations now use one commercial package for tracking material movements and production reporting. Data is centralized into two regional databases and is formally managed and backed up. Detailed historical information for Southwest mine sites and mineral separation plants which previously was not kept in electronic format is now available for trending and analysis.

Efficiency gains were achieved in the Southwest laboratory by eliminating the need for operators to type results into spreadsheets for distribution to mining and processing staff. Also, the number of full-time production statistics staff was reduced in both regions.

Standardized practices have been introduced supporting month-end met accounting and reconciliation processes and, although in some cases this process takes longer than the before ProdTrak was introduced, each site is working from the same set of data thereby maintaining data integrity and accuracy. Progressive improvement of the overall month-end process over the last year is mainly due to business improvements related to the responsibility and timing of associated activities (survey, bin dips, laboratory samples, etc).

The ability to automatically maintain weighted average grades in stockpiles has allowed enhanced stockpile management at certain areas. More stockpiles, in-

plant bins and quality elements are tracked than were in previous systems, providing additional information for grade control.

At an enterprise level, Iluka found itself well positioned when SAP (accounting; maintenance; supply; HR and payroll; sales and distribution; and production planning modules) was implemented by having ProdTrak in place. Configuration documents from the ProdTrak implementation were of significant value when configuring the SAP PP (Production Planning) module.

Keating (2003) lists the following major benefits of implementing Gemcom's ProdTrak:

- the consolidation of production information into two regional data repositories reducing data duplication and increasing data integrity;
- the ability to track material movements and associated quality characteristics from mining operations through to processing plants and customer sales;
- efficiency gains through advanced level of data acquisition through the ProdTrak Electronic Data Capture (EDC) module;
- the introduction of standard operational and data management processes;
- well documented process and material flows, and measurement points; and
- reduced IT cost and support effort to maintain multiple systems with overlapping functionality.

7. CONCLUSIONS

Information Technology is not a competitive advantage *per se*, and it's unlikely that companies improved there strategic position or got business benefits from the simple usage of IT.

However, IT can result in competitive advantages and in business benefits if it's employed properly, in its fundamental role of supporting effectively key business processes, and therefore contributing directly to improve the company's results.

ERP systems in Mining represent mostly a back-office solution, focusing on support activities and resulting in administrative processes efficiency, but not in business effectiveness (Sachs et al. 2004).

Specifically in the mining industry, the implementation of a solution such as MPMS can be a way to effectively deploy IT in the business processes of the mining value chain, or in the primary activities of the business value chain.

ACRONYM LIST

API – *Application Program Interface*

BI – *Business Intelligence*

CIO – *Chief Information Officer, IT Director*

DCS – *Distributed Control Systems*

EDC – *Electronic Data Capture*

ERP – *Enterprise Resource Planning*

IT – *Information Technology*

KPI – *Key Performance Indicators*

LIMS – *Laboratory Information Management System*

MPMS – *Mine Production Management System*

MRP – *Material Requirement Planning*

MRP II – *Manufacturing Resources Planning*

SCADA – *Supervisory Control and Data Acquisition*

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